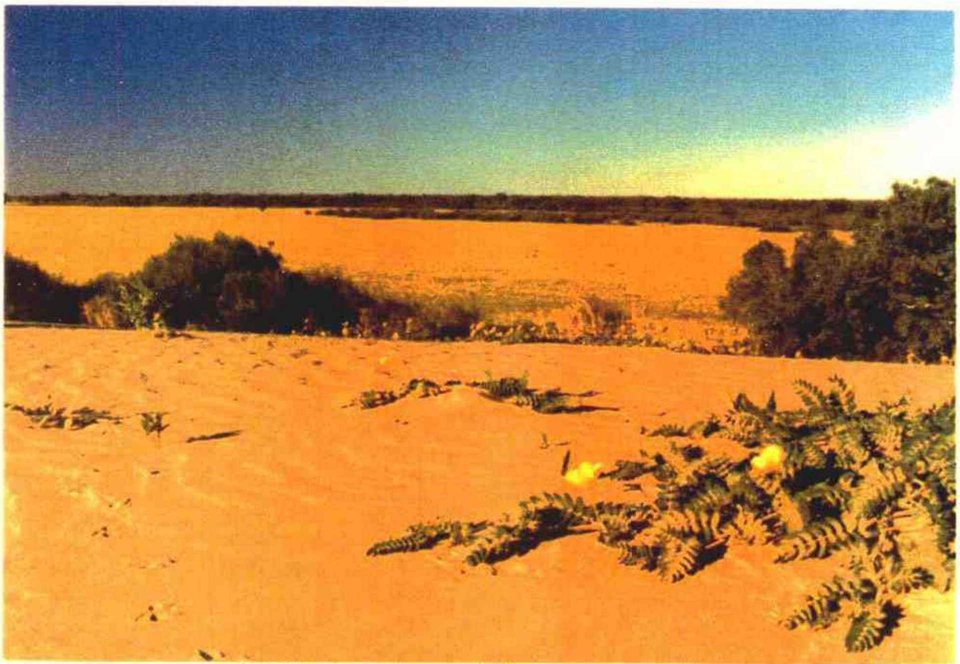
THE COONGIE LAKES STUDY



Emu Flat (Tribulus hystrix) Jake Gillen

Julian Reid and Jake Gillen

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Report on the biological survey of the Coongie Lakes primarly funded by

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Consultancy report to the Department of Environment and Planning.
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Preface

The Coongie Lakes Natural History Study was instigated by a generous donation of $55 000 from Dick Smith's Australian Geographic Pty Ltd through the National Parks Foundation of South Australia (Inc.) to the South Australian Department of Environment and Planning.

This report is the product of a field programme spanning 11 months from November 1986 to October 1987, in which 70 people were actively and voluntarily involved, in addition to the seven listed authors, and so the collaborative nature of the project can be readily appreciated. It is hoped that the presentation of material is simple enough to allow a broad readership. Research at Coongie is continuing, and results will be published in scientific outlets at a later stage.

The future management of the Coongie Lakes (and of Innamincka Station as a whole) is a politically sensitive issue. The views on management of the region expressed in this report are the views of the authors and consultants, and **not** those of the Department of Environment and Planning. Management recommendations have been made, as required by the consultancy's project brief, on the basis of the needs of the region's natural features, particularly those of biological conservation significance.

In addition to the $55 000 from Australian Geographic Pty Ltd and the extensive support provided by D.E.P., funds were kindly made available by:

SANTOS
ANPWS - States Assistance Scheme
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Mrs Begg (through her daughter Mrs Barbara Hardy)

While a list of acknowledgements is presented later, the opportunity is taken here to express appreciation for the support extended by the Department of Environment and Planning in providing an office and departmental services. In particular, the assistance of staff and management of the Community Information Service, National Parks and Wildlife Service and Conservation Programmes Division in Adelaide is acknowledged, while NPWS staff at Leigh Creek, SANTOS and allied personnel in the Moomba region and the storekeepers at Innamincka were equally helpful in the field.

Valued support and guidance through the year were given by officers within the Risk Management Department of SANTOS, by various conservation bodies, and by members of the project's Steering Committee.

The Steering Committee was composed of:

Dr Sue Barker, NPWS (Chair)
Dr Chris Nance, CIS (Executive Officer)
Mr Colin Harris, DEP
Mr Gary Drewien, DEP
Mrs Barbara Hardy, NPFSA
Mr Reg Nelson, SADME
Mr Oleg Morozow, SANTOS
Mr Mike Stone, Delhi Petroleum

Finally, multiple copies of the report were produced by SANTOS Ltd.

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Figures, appendices (apart from 2.1) and those tables not incorporated in the text are included at the end of each chapter on unnumbered pages.

In addition to the authors listed above, the following consultants were involved with the project:

Ashley Sparrow - vegetation sampling design and analyses;
Colleen O'Malley - plant taxonomy, collection of quantitative vegetation data and preparation of field herbarium;
David Peake-Jones - terrestrial and aquatic sampling, performing arts;
Penny Paton - literature review of selected topics (Appendix 2.1).

Acknowledgements

People who have helped with the project are too numerous to mention individually, but to them all our gratitude is extended.

Individuals who have made an invaluable contribution to the project include, in addition to the authors and consultants listed on the previous page, Oleg Morozow, Chris Nance, Sue Barker, Barbara Hardy, Graham Armstrong, Catherine Kemper, Colin Harris, Julie Sandercock, Charles Toohey, Steve Tunstill, Gary Drewien, Mike Steel, Andrew Gassner, Kelvin Sims, Brian Smithson, Lena Lapinski, Peter Bird, Bernie Johnson, Lee Heard, Jeff Foulkes, Art Ingrham, Tim Day, Peter and Deb Canty, Louise Mitchell, Bob and Annette Gillen, Ross and Muriel Reid, Jon and Joan Shannon, Mary Gordon, Kath Shurcliffe, Tony Robinson, Julia Haska, Bruce Leaver, Nicholas Newland, Ashley Fuller, Andrew Black, Meg Robertson, John Rolls, Richard Thackway, Rick Sautter, Ian May, Peter Schwerdtfeger, Mike Tyler, Margaret Davies, Shane Parker, Wolfgang Zeidler, Jan Forrestt, John Glover, Tony Reid, Keith Jones, Keith Walker, Russ Shiel, George Ganf, Fay Gale, Joy Wundersitz, Roger Luebbers, Tom Power, Bob Mossel, Gary Richardson, Aleeta Smith, Nicky Durell, Emily Cant, Brian Gepp, Neville Forde, Chris Miller and John Conty.

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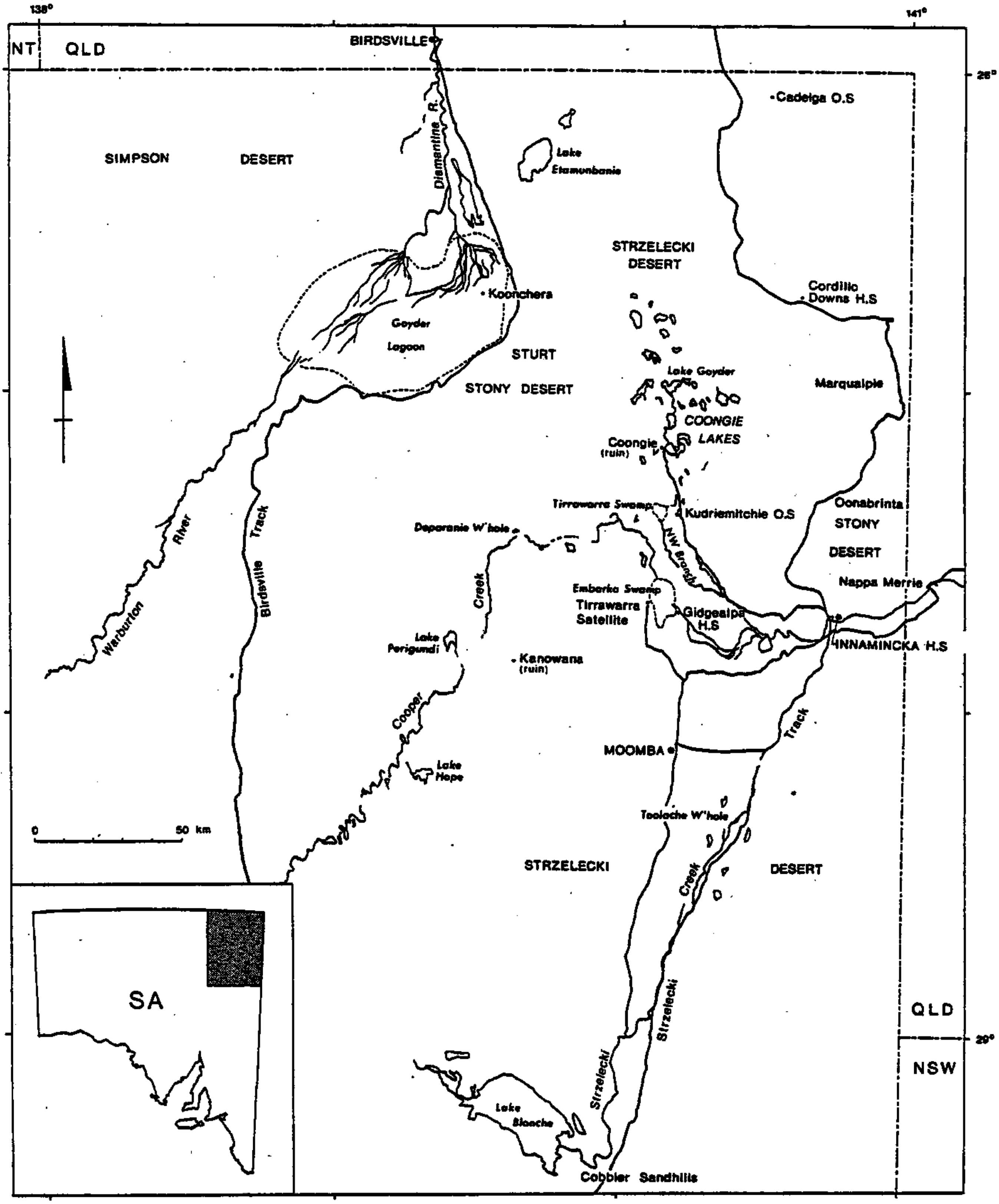
Valuable discussions were held with Mike Fleming, Graham Griffin, Dave Gibson, Dave Paton, Mike Cappo, Nadia McLaren and David Wiltshire at the beginning of the study.

For typing and word processing assistance, we are indebted to Lois Hisco, Karen Lomman, Kathryn Corbett and Doris Worcester.



<u>Figure 1.1</u> THE FAR NORTH EAST OF SOUTH AUSTRALIA

1. INTRODUCTION

Julian Reid

The Coongie Lakes are located in the Far North East of South Australia, some 900 km north of Adelaide and 85 km north-west of Innamincka. Five or six lakes fill regularly as a result of flows along the North-West Branch of the Cooper Creek, and they are Coongie, Marroocoolcannie, Marroocutchanie, Toontoowaranie and Goyder (or Coolangirie, with Marradibbadibba immediately to its east). Browne Creek links Coongie and Toontoowaranie to the north, while further north, Ellar Creek links Goyder with Toontoowaranie. A number of other lakes and channels within the district receive water occasionally in times of big or prolonged flows (i.e. floods) along the Cooper, and together with the main lakes and channels, comprise the Coongie Lakes system. Figure 1.1 shows the location of the Coongie Lakes District within the wider Cooper Creek and Far North East regions. It will be observed that the Strzelecki Creek, which is a distributory of the Cooper, exits at Innamincka, while the Main or South-West Branch or Channel diverges from the North-West Branch c 20 km west of Innamincka, on its long passage towards Lake Eyre, its eventual if infrequently reached destination. Figure 1.2 illustrates some of the complexity of the lake and channel system within the Coongie Lakes District, and depicts the features referred to above.

The Cooper Creek country in the vicinity of Innamincka and Coongie was occupied by members of the Jauraworka (to the north) and Jandruwanta tribes for at least several thousand years (Dr E. Williams pers. comm.), and seemingly in excess of thirteen thousand years (Wasson 1983). European contact was made with these people and the region in 1845 when Captain Charles Sturt's expedition passed through the Cooper country. Sturt traversed the lakes district, and while in the vicinity of Lake Goyder, one of his party, John McDouall Stuart, earned the distinction of collecting the first specimen of the enigmatic Night Parrot, an endangered species about which very little is known to this day (Burbidge and Jenkins 1984).

The most notable and ill-fated pioneering expedition to the Cooper was that of Burke and Wills in 1860-61. Three members of the expedition eventually died along the Cooper, having successfully returned from the north Australian coastline. They endured extreme deprivation and at one stage were besieged by hordes of the long-haired or plague rat (a native rat, which although generally rare, can undergo rapid and huge population explosions when conditions are appropriate).

Several relief and rescue parties were organized in 1861 and 1862, and soon afterwards, the first settlers arrived in the region (the Lower Cooper) with their herds of goats, sheep, cattle and horses (Mollenmans et al. 1984). By the early 1870's virtually all the land, including that along the Upper Cooper around Innamincka and Coongie, had been occupied, and pastoralism has remained the most extensive land-use in the region to this day. Sheep which were initially carried at staggeringly high levels have since given away completely to cattle. The Strzelecki Track was opened as a major droving route to get stock to southern markets in these early days of pastoralism, while camel trains became an important mode of transport of goods into and out of the region before the advent of trucks.

Cattle were removed from the region in the early 1980's, as part of the Australia wide campaign to rid the nation's herds of brucellosis and bovine tuberculosis. The Coongie Paddock of Innamincka Station has remained free of stock, while most of the country in the wider region was quickly restocked with disease free herds.

The feral rabbit naturally colonized the region from the south and the east in about 1890 (Badman 1988), and its numbers quickly grew to pest proportions, with a dramatic lowering of the land's stock carrying capacity. It has remained a major pest in the region, despite myxomatosis having exerted some control since its introduction in the 1950's, and numbers in the Coongie district in particular have historically been very high (although fluctuating widely).

Gas and oil exploration began in the 1950's, and activity was intensified in the following decade, with production beginning in the late 60's. Most production has been concentrated around Moomba (north to Embarka Swamp) although signs of exploration are evident over virtually all of the extensive Cooper Basin (see Fig. 1.3). The production of gas and oil from the Basin is considered vital (by the authorities) for South Australia's economy and for the State's energy requirements. In the Coongie Lakes District, exploration has spanned 15 years, with the most recent seismic work carried out in 1985 (SADME pers. comm.). A grid-like network of tracks through the district is the legacy of these activities.

Wetland habitats in the Coongie Lakes District are recognized as having considerable biological conservation significance. Their significance was not widely appreciated until 1975, when the Nature Conservation Society of South Australia conducted a biological survey of the Far North East (see Foale 1982). Mollenmans et al. (1984) and L.A.B. (1986) have since expounded the district's natural values and reiterated the need for adequate protection. Coongie's significance has been formally recognized in recent years at the national (National Estate Listing in 1980) and international (RAMSAR Convention on wetlands of international importance for waterfowl; listed in 1987) levels, and the boundaries of the areas concerned are delimited in Figure 1.4. Currently the Australian Heritage Commission is preparing a submission proposing an extension to the boundaries of the National Estate Listing, so that all the wetlands associated with the Upper Cooper in South Australia are included. Regrettably such listings confer limited protection.

The district has other values worthy of preservation, apart from its wetlands e.g. terrestrial biota, archaeological and historical sites, and natural and aesthetic qualities such as wilderness, beauty and isolation. These same features and its central location (in the Australian context) have made the area very popular with holidaying Australians seeking a "roughing it", bush camping experience. The level of tourism in the Innamincka region has increased dramatically over the last decade, and this trend will only continue or escalate as the area's undoubted natural and historical attractions are even more widely publicised. Numerous items in the press and popular magazines and several television documentaries about the Innamincka - Coongie region have appeared in recent years. A significant but undocumented proportion of visitors to Innamincka has historically visited the Coongie Lakes, and as the lakes receive increasingly more publicity, this proportion is rapidly increasing (Mike Steel pers. comm.).

Tourism, in its present uncontrolled state, is undeniably causing problems, the most pressing of which relates to archaeological sites. The findings of Luebbers (1988) and Williams (1987 - unpublished reports submitted to DEP) should be consulted for a description of the vandalism (often unwitting) which is occurring at these sites.

At the instigation of Dick Smith, Australian Geographic Pty Ltd assembled a party of scientists and other experts at Innamincka in May 1986 for a two week expedition. An account of the expedition's findings was recently published in Australian Geographic (No. 5, 1987) and a television documentary entitled "The Secret Oasis" also resulted. In both accounts, the beauty of the region and its diverse wealth of life were highlighted. However the expedition members were equally mindful of the gravity of the growing environmental problems, and they were particularly disturbed by the lack of formal protection or conservation status accorded to the Coongie Lakes. Dick Smith was so concerned that he was moved to donate $55 000 to the National Parks Foundation of South Australia, thereby initiating a 12 month research project under the control and direction of the South Australian Department of Environment and Planning. SANTOS pledged their support for the project and offered to make substantial contributions logistically, while Kidman Pastoral Company approved research being undertaken on their Innamincka lease. This report documents the activities and findings of the Coongie Lakes Study, which received help from innumerable sources- individuals and bodies, from the public and private sector.

1.1 Aims and Study Direction

The primary aim, as specified in the project brief (App. 1.1), was to undertake a survey of the natural history of the Coongie Lakes system, in particular seeking to:

1. identify and document seasonal changes to the flora and fauna
2. identify and document the impact on the natural environment of human activities such as mining, tourism, grazing and hunting
3. recommend management strategies.

Particular attention was to be paid to documenting:

- the number and variety of birds, mammals, reptiles, invertebrates and aquatic fauna
- the flora of the region
- human impact on flora and fauna.

Further guidelines directed that the study should:

- trace the changes that occur to flora and fauna with the seasons and the weather
- highlight the diversity and richness of life to be found there
- identify some of the life cycles of lesser known animals
- document animals and plants distinctive to the region
- determine the extent of human impact on the area.

Within this framework of a both very broad and conversely quite specific set of project aims, it was decided to define more clearly the goals of the study on the basis of

(i) resources available to the survey team (materials/equipment, relevant biological/technical expertise, and time), and
(ii) programmes of field research which would yield and maximise valuable information, given the constraints of time.

For instance with respect to the three goals contained within the primary aim, it was deemed appropriate to invest more of the project's time and resources in the realization of the first and third of these rather than the second. Field programmes were devised to enable the quantitative documentation of patterns in distribution and abundance of plants and animals, and to allow changes in these patterns through time and space to be determined. In comparison, the impacts of human activities on the environment were to be studied and documented in a generally qualitative manner with a consequently smaller input of resources. Documentation of these impacts in a strictly quantitative manner would have entailed the use of manipulative experiments (with appropriate replication and controls) requiring time and resources beyond the project's limits. Nevertheless considerable effort was to be expended in the quantitative documentation of tourist activity in the region, partly because tourism was perceived to be having the most immediately detrimental impact upon natural values.

Because previous biological studies in the region (e.g. Waite 1917, ERPG 1980, Foale 1982, Mollenmans et al. 1984, L.A.B. 1986) have focused on the terrestrial environment, little of the biological wealth of the wetlands has been documented; yet undoubtedly it is the range of aquatic habitats associated with the Cooper Creek which make the area unique and so important biologically. Therefore it was decided to pursue the identification of aquatic invertebrates (e.g. crustaceans, molluscs, insects) and non-vascular plants, while largely restricting the terrestrial studies to vertebrates and vascular plants. Furthermore it was considered vital that an understanding of the Cooper's local and regional hydrology be gained. Only the deepest waterholes along the Cooper Creek can be regarded as permanent. The remaining, diverse array of wetland habitats are temporary to varying degrees, which has a crucial bearing on the types of organisms and the strategies that they adopt to cope with this impermanence (see Hynes 1970). As well it is a feature of river systems that energy and matter (and therefore impact) transfers are both strongly directional and potentially rapid. Consequently it is probable that the North-West Branch's terminal wetlands are highly sensitive to up-stream as well as in situ effects resulting from unsound developments and accidents. Accordingly hydrological changes or the release of pollutants anywhere upstream of the Coongie Lakes can be expected to have a detrimental impact on them (although the closer the source of pollution, the greater will be its impact, whereas an altered hydrological regime will have more general and extensive effects). Minimizing the risks associated with developments in the region is dependent upon a thorough understanding of the hydrology.

Midway through the study, the Minister for Environment and Planning announced the State Government's intention of securing Innamincka Station as a "regional reserve" to be administered by the National Parks and Wildlife Service. The regional reserve concept embraces the principle of multiple land-uses over the area concerned, such that economic developments (in this case, mainly hydrocarbon production, stock grazing and tourism) can be pursued together with conservation strategies. The announcement and ensuing political activity necessitated a review of the study's aims and direction. However, field programmes were not altered radically, in that the Coongie Lakes District remained the focus of endeavour; yet opportunities were subsequently taken to conduct limited fieldwork in other parts of Innamincka Station, while it also became necessary to make management recommendations in light of the regional reserve plans.

1.2 Geology and Landforms

The surficial geology of the Coongie Lakes District is of Quaternary age (i.e. geologically recent - last two million years), and consists of three units (SADME Geology 1:250 000 map sheets):

- dunefield (Qrs)
- floodplain (Qra)
- claypan and saltlake (Qrl).

In the wider region a broken gibber and boulder duricrust unit (Qrt) of greater antiquity has been recognized as a mappable unit (Mollenmans et al. 1984). This unit is represented by the flat gibber plains to the north-west of Coongie and by the dissected stony tablelands/residuals to the north of Innamincka.

The region's petroleum resources are located in the Cooper and overlying Eromanga Basins (of Permian to Jurassic age) at depths of 1 400 to 3 300 meters. Major coal deposits are also present but they are not economically retrievable, because of their depth. The aquifers of the Great Artesian Basin lie at the top of the hydrocarbon bearing sequences, while shallow aquifers which bear saline (and some fresh) water are also widespread in the region.

Around Coongie, an exploration programme involving relatively intensive geoseismic testing and the drilling of several wells has been undertaken. It is indicated (McLaren et al. 1986) that the wells were dry, but detailed information from this programme is not publicly available. Certainly intensive production of gas and oil occurs immediately to the south and south-west of the district (centred on Tirrawarra Satellite - see Fig. 1.3), while a field to the east of Coongie is currently under development. The life of fields is generally expected to be 30 years or less.

The Coongie Lakes District is dominated by floodplain and dunefield features, and a wide variety of landscapes are present in the area due largely to the complexities and variability of the Cooper Creek's hydrological patterns. The range of features (or land-units) that occur in the wider and adjacent regions have been described in previous publications, although unfortunately a variety of schemes has been adopted to classify land-units on a hierarchial basis (e.g. see Dawson and Boyland 1974, Laut et al. 1977, Graetz et al. 1982, Purdie 1984, Mollenmans et al. 1984, and L.A.B. 1986). The landforms and land-units represented in the Coongie district have been described by Mollenmans et al. (1984) and L.A.B. (1986) in a general manner, and by Laut et al. (1977) very generally (larger scale again). Currently DEP is preparing a detailed map and inventory of the district's central floodplain units (but not of the adjacent dunefields) which is to be published shortly. This treatment recognizes 20 distinct units, referred to as "terrain-vegetation" land-units (R. Barratt pers. comm.), but other units would undoubtedly be recognized if the exercise was extended to the dunefield and peripheral floodplain environments in the district.

A review of the land systems approach to classifying the region's natural resources is presented in Vol. 2. Purdie's (1984) approach has been adopted for the purpose of this report and seven land zones are designated for the Cooper Creek region. They are dunefield, fringing dunefield, sandplain, floodplain, gibber plain, dissected residual/stony tableland (after Purdie 1984), and uncoordinated drainage dunefield (Mollenmans et al. 1984). Around the termini of the Strzelecki Creek and Cooper's Main Branch (Cobbler's Sandhills and Tirari Desert respectively), an eighth and distinctive land zone is probably identifiable, but because of these areas' distance from Coongie, will not be considered further. Within the Coongie Lakes District, dunefield, fringing dunefield and floodplain are the land zones represented, although the (perhaps tenuous) distinction between dunefield and fringing dunefield is not pronounced, a view echoed by D. Gibson (pers. comm.) for the Simpson Desert.

Within the Coongie Lakes District, a vast array of landforms could be recognized, but a basic distinction can be made between floodplain and dunefield features. Moreover many repeating patterns can be detected, and these will be described briefly along with some of the land-forming processes which have biological pertinence.

1.2.1 Floodplains

Figure 1.4 clearly shows the placement of dunefields (seen as blocks of dunes) and floodplain in the Coongie area. At times of exceptionally high water levels in the Cooper, all the floodplain features south of the solid line which encloses Lakes Goyder and Marroopootanie are inundated by floodwaters. Many of the interdune corridors within the district also receive Cooper floodwaters in such an event, and water extends far to the east and west beyond the bounds of the district depicted in Figure 1.2. However there is a barrier to the north of Lake Goyder (represented by the solid line in Fig. 1.4) consisting of a tall sandhill complex (P. Schwerdtfeger unpub. data, E. Williams pers. comm.) which prevents water from entering the string of lakes to the north and north-east of Goyder. These lakes (e.g. Salt Lake and Lake Deception) fill rarely as a result of run-off from the Cordillo Downs stony tablelands to the north-east after intense rain. This hydrological distinction has a profound biological consequence; even though the lakes to the north of Goyder may have similar flooding frequencies to the outer lakes of the Coongie system (e.g. Lakes Sir Richard and Lady Blanche), the biotas which they support are predictably very different. Fish would not be expected to ever occur in the northern lakes, yet would certainly colonize all of the Coongie system. This would have a significant bearing on invertebrate and waterbird composition and dynamics, for instance.

Most flow events along the Cooper Creek do not result in the inundation of the entire floodplain, and generally the peripheral lakes, such as Apachirie, Apanburra, Warra Warreenie, Mundooroounie and Talinnie are dry. Then they take the form of salt pans (Talinnie) or bare clay pans (Apanburra), but most often as ephemerally vegetated lake beds (Apachirie, Mundooroounie) with heavy, deeply cracking clay soils. The peripheral channels, such as Hamilton Creek, Apanburra Channel, Walkooanie Channel, and the outlet from Apachirie, often contain water in the deeper reaches (from previous flows of the Cooper as well as from local rainstorms) and are lined with coolibahs.

The most significant floodplain features environmentally are the more permanent water bodies - the main channels of the Cooper Creek and Lakes Coongie, Marroocoolcannie, Marroocutchanie, Toontoowaranie and Goyder. The most sizeable stands of timber in the district fringe these channels and lakes, and the biological importance of the red gum woodland in particular, which lines the Kudriemitchie and Tirrawarra Waterholes, will be elaborated upon in later sections. Equally significant is Tirrawarra Swamp - large, densely vegetated, and highly channellised (braided). The waterholes are usually between 1.5 and 4 meters deep (moderate flows), while the lakes fill to the depth of c 2.2 meters, before spilling over their margins. None of the features are considered to be strictly permanent, although the deepest reaches of Kudriemitchie and Tirrawarra Waterholes would very rarely dry out completely. These more permanent waters are especially important for wildlife under drought conditions (the norm and not the exception), but the predictably higher productivity of the more ephemeral lakes and pans in the district should not be overlooked (e.g. Chrome 1986).

As well as the obvious drainage features described above, several other landforms are recognized, which together comprise what is generally considered to be the "floodplain" of a river system, and which Mollenmans et al. (1984) refer to as a "flood-out" land-unit. These landforms intergrade considerably and often gradually, but consistent patterns are usually discernible.

Of these floodplain features, floodouts and backwaters are recognized as being subject to the most frequent inundation. Backwaters are minor, short channels attached to the main channel of the Cooper (or Browne and Ellar Creeks), which regularly receive water as the level in the Cooper rises. They also act as tributaries and are major entry points for water from the floodplain when heavy rains fall locally. Floodouts are not obviously channellised, and are broad, flat expanses onto which water spills from channels or lake margins. They can be (more or less) terminal as in Emu Flat (to the west of the mouth of Browne Creek and a normally dry extension of Lake Toontoowaranie) or have a regular and well defined outlet (i.e. channellised at both ends of the feature). In the wider region, Embarka Swamp (Main Branch, Cooper Creek) and Goyders Lagoon (Diamantina River) can be regarded as floodout features on a large scale, and such features although not obvious within the Coongie district are commonplace along the South Australian sections of the Cooper Creek generally, where the main channel(s) loses its definition for varying distances before reappearing downstream. Floodout lake margins are characteristic of the northern shorelines. Lignum, tangled poverty-bush and river couch are vegetation types typically associated with floodout features in the district, whereas backwaters are generally lined with lignum, coolibahs and tall wattles.

Numerous low lying pans of various sizes, but generally quite small, occur on the floodplain, which can be regarded as either claypans (bare or with low herbage) or small ephemeral swamps (with taller vegetation such as swamp cane-grass). When filled, they represent a distinctive aquatic habitat. A wide range of plant communities occupy these shallow pans.

Less frequently inundated parts of the floodplain can be divided into:

plain - flat clayey surfaces without an obvious sandy veneer;

sandy plain - flat, basically clayey surfaces with a sandy veneer (complete or patchy covering of sandy alluvium);

sandy rise - gently sloping, accumulated heaps of pale sand, frequently occurring at the northern margins of lakes and other major floodplain features;

low transverse or irregularly aligned dunes - (groups of) generally small, pale dunes (or mounds of sand) found to the north and west of the major floodplain features;

low, pale longitudinal dunes - with a strong NNW-SSE trend (and which are probably an actual component of the fringing dunefield land zone), generally to the west of the district's major floodplains.

Extensive intergradation occurs between these five recognized land-units (and between the last three units and dunefield features proper). These five units are occupied by a variety of plant communities, which are usually not specific to any one unit.

Other landforms typical of the floodplain can be identified, for example, lake foreshore, channel bank, island, sand bar, and secondary channel (minor channel adjacent to the main channel which flows when levels are sufficiently high). The names are self-explanatory, and such features will be referred to in the report without further elaboration here.

1.2.2 Dunefields

Dunefields are recognized in the Coongie Lakes District as blocks of (generally) longitudinal dunes (see Fig. 1.5). The colour of the dunes ranges from near white to rich orange, although "dull orange" describes the majority of the district's dunes (or orange-brown as described by Wasson 1983, who attributed specific colours and colour codes to various portions of the Strzelecki and Simpson Deserts). It has been suggested (Twidale 1982) that the intensity of the colour of the sand deepens with age, as a consequence of weathering of clay particles in the sand (e.g. oxidation of iron and magnesium). Certainly the palest sand dunes are found closest to their presumed sources of supply - the recently deposited alluvia associated with the major floodplain features. As remarked before, these pale alluvial deposits are a distinctive feature of the northern and north-western margins of the lakes in the district, and frequently these deposits take the form of dunes, which may be transverse, irregularly aligned, or longitudinal and aligned with the main dunefield systems.

Twidale (1982) gives a classical account of dune formation in the region, stating that short longitudinal prongs extend downwind from the alluvial mounds, and then gradually extend to form part of the regional dunefield, and that the gradation of colour from white to red (speaking of the truly red dunes of the Simpson Desert in this case) can be seen as part of this sequence. This description assumes a gradual, more or less continuous process of dune formation, which Wasson (1983) disagrees with, and certainly classical sequences of the Twidale type are not evidenced in the Coongie district. The pale dune aggregations do not grade into the well defined blocks of more richly coloured dunes, suggesting that a punctuated process of dune formation has occurred.

Wasson (1983) describes several different processes, which have operated to create the different coloured dunefields within the Strzelecki and Simpson Deserts. He concluded that the most recent major dune-forming period in the Cooper Creek region extended from 23 000 to 12 000 years before present, and that these pale dunes are composed of muddy alluvium of fluvial origin (the river system then that equates to the modern Cooper Creek).

Dunefields consist basically of dunes and interdunes. The majority of dunes in the Coongie district are longitudinal and are aligned 10-20^{o} west of north, which is the direction of dune travel. Where the dunes are of the well defined, orange form (of early Pleistocene age), the east slope is steeper than the west and the crests are generally unstable; their average height, although less than 10 meters, does not preclude the occasional dune from being much taller than this (to approximately 30m). Dunes are short by Simpson Desert standards (see Purdie 1984), being usually less than 10km long. Forking is relatively frequent (always downwind) as are interconnecting "saddles" of sand between adjacent dunes. Numerous (semi)circular claypans - bare or vegetated - are formed between pairs of such interconnections, while less well defined depressions are a common feature along the long regular interdune corridors. Interdune flats generally have heavy (predominantly clay) soils, which hold water for several weeks after heavy local storms. The accumulation of sand in some or the presence of a sandy veneer in other parts ensures a highly variable expression of plant communities within the interdune environment. There are many similarities between these environments and those undifferentiated parts of the floodplain which are not regularly inundated by Cooper Creek floodwaters.

Other distinctive features include the occasional long slope to dunes, generally where a dune abuts a broad floodplain (or interdune) feature, and eroding clay aprons on the lower slopes of some dunes, which are often characterised by a sparse cover of low Gunniopsis quadrifida shrubland. Open stands of umbrella wattle are prominent on dune slopes, while the crests of all but the smallest dunes in the regular dunefields are characterised by a sparse sandhill cane-grass hummock grassland. In those restricted parts of the dunefields with the deepest coloured sands, spinifex communities occur on the slopes and raised sandy interdune areas; although of limited distribution within the district, these communities are biologically significant.

The smaller, white or pale coloured dunes on or adjacent to the floodplain (the fringing dunefield land zone) can be longitudinal, transverse or irregularly aligned. They are assumed to be of Holocene or very late Pleistocene age (last 20 000 years), and they support largely different plant communities to those of the orange (and presumed older) dunes, being dominated by ephemerals or short-lived perennials, such as wild tobacco, rattle pod, velute saltbush and buckbush (or rolypoly). The desert cynanchum (a perennial species) and cattle bush are most commonly found on paler dunes adjacent to water bodies, in particular, or the floodplain generally. Grazing pressure, as well as nature of substrate and age of dune, may have caused the observed differences in vegetation between the two dune types.

Finally, another striking feature of the dunefields is their position relative to the lakes and as revealed in Figure 1.5. It will be observed that the blocks of well formed dunes frequently make direct contact with the lakes around their southern and eastern shores i.e. large, orange dunes advance right to the shoreline. As a consequence, at times of high water levels, water from the lakes floods out along the interdune corridors as sou-sou-easterly extensions to the lakes. In contrast, around the northern and north-western margins, water tends to spill out as a continuous sheet. It has been reported that dunes in this region migrate downwind (to the nor-nor-west in this case), even though the last major dune forming period occurred at least 13 000 years ago (Wasson 1983). It would be interesting to know if the dunes have travelled a significant distance in the subsequent period, and also if the arrangement of floodplain features has altered greatly over the same period, and if so, what the nature and direction of the change is (e.g. gradual silting up of the shallow lake basins, or a steady migration of the lakes in a particular direction, or the incision of/divergence from former river channels). Wasson (undated) refers to floodplain features (e.g. scroll bars), which he has dated as late Pleistocene, and which are no longer hydrologically active, and so it seems likely that the currently active channels and lakes are not static features.

1.3 **Climate and Hydrology**

1.3.1 Climatology

The climate of the Cooper Creek Environmental Association 8.4.4 (after Laut *et al*. 1977) has been comprehensively described by and illustrated in Mollenmans *et al*. (1984). Although no historical data have been gathered specifically in the Coongie district, observations made at Birdsville, Moomba, Innamincka and Cordillo Downs (and as reviewed by Mollenmans *et al*. 1984) are considered to give a reliable guide, in general, to meteorological conditions experienced at Coongie.

Climatically, the Coongie Lakes region is located in the arid/semi-arid core of the Australian continent. Median annual rainfall is of the order of 100-150mm (Fig. 1.6) with rainfall variability being among the highest in Australia (Kotwicki 1986). Such extremes can be seen in both the spatial and temporal nature of recorded rainfall. In January 1974, rainfall observations closest to the Coongie system indicated spatial extremes ranging from 696mm at Innamincka, 319mm at Cordillo Downs and 439mm at Moomba. In January 1917, the spatial patterning was 190mm at Kanowana Station, 23mm at Cordillo Downs and 40mm at Innamincka Station, while in November 1920 the patterning was 66mm at Kanowana Station, 140mm at Cordillo Downs and 73mm at Innamincka Station. Patchy rainfall can have striking biological consequences, manifest as localized areas of frantic activity in an otherwise subdued desert landscape. After intense, local rains, invertebrate populations increase in response to rapid plant growth, and then rapid population build-ups of vertebrates may occur through immigration and breeding. Many desert animals have evolved nomadic tendencies and rapid breeding cycles to be able to take advantage of such events (e.g. Schmidt-Nielsen 1965 and Watts and Aslin 1981).

The major sources of rainfall in the region are primarily of tropical origin, in the form of tropical incursions, rain depressions and thunderstorms (Allan 1985). Therefore, more heavy falls are likely to occur in late summer, than at other times of year, and this trend is reflected in the following figures - mean monthly totals for Cordillo Downs, Birdsville and Innamincka are 26-30mm in January and February, and 6-7mm in August and September. On time scales of years, there is a strong association between rainfall over the eastern half of Australia with the El Nino Southern Oscillation (ENSO) phenomenon. Major floodings of Lake Eyre which result from widespread rainfall episodes over the Lake Eyre drainage basin, including the Coongie Lakes District, have been shown to be a manifestation of anti-ENSO (opposite to ENSO) conditions and strong monsoonal incursions (Allan 1985). During such periods, the eastern half of the continent also experiences above average winter-spring rainfall. Interestingly, such influences appear to vary substantially in the longer term, with indications of wetter periods in the 1820s, 1860-70s, 1890s, 1910s, 1950s and 1970s, and drier periods in the 1840-60s and the 1930-40s (Allan 1987, 1988).

Despite heavy rainfall events and wetter periods in the historical record, high evaporative losses in the region account for the general aridity experienced. Mean annual evaporation from Class A Pan data in northeastern South Australia exceeds 3 600mm (Kotwicki 1986 and see Fig. 1.7), with mean annual evaporation at Moomba being 3 610mm. Seasonally, Moomba evaporation varies from a peak of 510-20mm in summer to a low of 120-25mm in winter. As a result, evaporative losses are at least an order of magnitude larger than rainfall (Table 1.1 and Fig. 1.6). As an approximation for water bodies in this region, Kotwicki (1986) indicates that a factor of 0.6-0.7 times the pan evaporation can be used as an estimate of "real" evaporative losses. Thus water bodies such as those at Coongie could lose as much as 2166-2527mm (i.e. c. 2.2-2.5m) of water in one year through evaporation.

Table 1.1

Monthly Mean Evaporation at Moomba (Class A Pan)

Months	J	F	M	A	M	J	J	A	S	O	N	D
(mm)	510	380	380	240	165	120	125	210	235	345	380	520

Temperatures are extreme in the summer - the mean monthly maximum for December, January and February at Moomba is 38-39°C, with daily maxima frequently exceeding 40°C (e.g. Mollenmans et al. 1984), while the mean monthly minima over summer are 22-24°C. July is usually the coldest month in the region, when Moomba has a mean minimum of c 6°C, and sub-zero conditions are occasionally experienced each winter. The July mean monthly maximum for Moomba is c 19°C.

The prevailing regional winds hail from the south or sou-sou-east (Mollenmans et al. 1984), and the period from September to December in particular, can be extremely windy as pointed out by Badman (1988), who also refers to the desiccating effects of the strong hot northerlies in summer.

1.3.2 Hydrology

Hydrologically, the Coongie Lakes system is situated in the Lake Eyre basin, the largest inland drainage basin in Australia (see Fig. 1.6). This drainage system covers an area one seventh the size of the Australian continent and overlies much of the Great Artesian Basin. A myriad of tributaries feeds the Cooper Creek, Diamantina and Georgina River systems, carrying major flows to the basin terminus at Lake Eyre. The Coongie Lakes are located on the Cooper Creek's North-West Branch, which leaves the Main Branch some 30km downstream of Innamincka, and carries floodwaters in a north-westerly direction to Tirrawarra Swamp and then the lakes. According to Ogilvie (1947), the Coongie Lakes are the more regular terminus for Cooper Creek floodwaters. Only in major flooding events do waters extend any distance down the Main Branch to Lake Eyre, with the expansive Embarka Swamp being a major block point to flow along this branch in most years (and see Badman 1988 for a detailed account of recorded flow events along the Main Branch).

The Coongie Lakes system consists of a chain of three southern lakes, Coongie, Marroocoolcannie and Marroocutchanie, which are linked together and fed by the North-West Branch, and two northern lakes, Toontoowaranie and Goyder, which are fed by interconnecting creeks (Browne and Ellar respectively) when the southern lakes fill and overflow (Fig. 1.2).

Precise measurements of the water budget of the Coongie Lakes system are not yet possible, as both hydrological and meteorological observation networks in the north east of South Australia are poor. In fact the only stream gauging station in the Lake Eyre basin in South Australia is to be found at Innamincka (Callyamurra Waterhole - see Plate 5). Rainfall observations are also sparse, with the closest operational stations to Coongie now being at Cordillo Downs, Innamincka and Moomba. Thus estimates of terms in the water budget of the Coongie Lakes system must rely on one stream gauge upstream at Innamincka, three rainfall stations some 100 odd kilometers away, a Class A Pan at Moomba and sparse groundwater information.

Ideally a stream gauge on each of the branches shortly downstream of the disjunction and one closer to each of their termini (i.e. four in all), as well as accurate measures of evaporation and rainfall at Coongie are required to make precise estimates relating to a water budget for and hence seepage losses from the system. At the broader scale, Graetz (1980), using LANDSAT imagery, the available, limited data from established stream gauging stations, and rainfall figures from critical locations within the Cooper, Diamantina and Georgina "Channel Country" system, attempted (with only limited success) to model the system's hydrology (with a predictive component being a major aim of the study).

1.4 Previous Biological Research

Biological studies within the Cooper Creek region of South Australia have focused on vascular plants and vertebrate animals, so that the occurrence of the vast majority of species within these groups (i.e. flowering plants, fish, frogs, reptiles, mammals and birds) has been established. This does not mean that further exciting and important biological discoveries will not be made, and indeed given the time available to the study, it was hoped at the outset that there would be such finds.

Although extremely valuable, early biological observations pertaining to the Upper Cooper (S.A.) are patchy and too sketchy to allow more than superficial comparison with results derived from recent, generally integrated surveys. Consequently it will never be known with certainty, just how many species of plants and animals have been lost from the region, as a result of the ravages inflicted upon the country since European occupation (due to pastoral mismanagement and the introduction of exotic plants and animals - particularly cats, foxes and rabbits), because the precise composition of the original flora and fauna can never be established. ERPG (1980) have compiled a list of mammals that may have formerly inhabited the region, while James (1982) has documented those species actually known to have occurred in the wider North East region.

Apart from a sporadic series of bird observations made by L.R. Reese in the 1920s and 30s, very few biological observations in the Coongie district had been documented prior to the 1970s. Major biological surveys by the Nature Conservation Society (in 1975) and National Parks and Wildlife Service (1983), as well as a number of fieldtrips, having specific goals, conducted in recent years have added greatly to knowledge of the district's biota.

The two surveys referred to above covered a much wider region than the Coongie Lakes District, and the published survey results (Foale 1982 and Mollenmans et al. 1984), in addition to containing timely reviews of the historical record, have generated comprehensive species lists for the vascular flora and vertebrate fauna of the Far North East of South Australia.

The studies which have contributed most to the accumulation of this knowledge are listed below within the major biotic groups.

Plants: Tate (1889), Black (1917), Cleland et al. (1925), Jessop (1982), and Mollenmans (in Mollenmans et al. 1984).

Fish: Glover and Sim (1978), Glover (1979).

Frogs: Tyler (1978), Thompson (in Mollenmans *et al*. 1984).

Reptiles: ERPG (1980), Turner (1982), Thompson (in Mollenmans *et al*. 1984).

Mammals: Finlayson (1933 *et sequitur*), Watts and Aslin (1974), Forrest (1982), James (1982), Thompson (in Mollenmans *et al*. 1984).

Birds: White (1917), Cleland (1925), Reese (1924 *et sequitur*), Cox and Pedler 1977), Parker (1980), Cox (1982), Reid (in Mollenmans *et al*. 1984), May (in L.A.B. 1986), Badman (1988).

Vegetation patterns, as opposed to plant lists with distributional notes, have been described by Lewis (1982 and in ERPG 1980) and Mollenmans (in Mollenmans *et al*. 1984), and broadly treated in L.A.B. (1986).

Of the region's aquatic macroinvertebrates and micro-organisms (plants and animals) very little has been published, with the few studies focusing on distinctive environments atypical of the Cooper, such as mound springs (De Decker 1979 and Mitchell 1985) and Lake Eyre (Williams and Kokkin in press). Identifications arising from cursory inspection of material collected along the Upper Cooper by M.B. Thompson in 1983 are presented in Mollenmans *et al*. (1984).

For comparative purposes, mention is made of recent surveys and/or reviews covering adjacent regions. Gibson and Cole (1987) have recently documented the results of their faunal survey of the northern Simpson Desert, while Purdie (1984) has compiled a comprehensive list of plants occurring in the entire Simpson Desert. Vegetation patterns in the Simpson Desert have been described by Fatchen and Barker (1979a,b) and Buckley (1979, 1981, 1982a,b), while the Simpson Desert Draft Management Plan contains much useful (as well as some misleading) information.

To the east, Dawson and Boyland (1974) studied the plants and vegetation patterns represented in the adjacent, extreme south-west of Queensland, and their report was used as a model for the more biologically oriented NPWS survey of the Cooper Creek Environmental

Association 8.4.4 (Mollenmans *et al*. 1984). The consultants' report has been of enormous value to the present study, and in particular, the efforts of the senior author, to produce an accurate review of the taxonomy, distribution and status of the numerous plants collected in the Cooper region (in excess of 550 species at that stage) deserve wider recognition. However, several errors are contained in that report, in the plant and animal sections e.g. Badman (1988) in his exhaustive treatment of birds of the Lower and Middle Cooper has identified a few errors made by Reid (in Mollenmans *et al*. 1984). One highly significant error of identification which appears in the report, and which has subsequently been repeated (e.g. L.A.B. 1986) needs pointing out. Thompson reported the collection of a single specimen of the rare plains rat *Pseudomys australis*. This specimen was reidentified at the South Australian Museum (C. Kemper, pers. comm.) as Forrest's Mouse *Leggadina forresti*, which although rare in this State (Kemper 1985), is not threatened as is the plains rat. This species of "rat" an inhabitant of gibber plains, has not been reported anywhere in Australia since 1974 (Corbett *et al*. 1975).

COONGIE LAKES DISTRICT

SOUTH AUSTRALIA

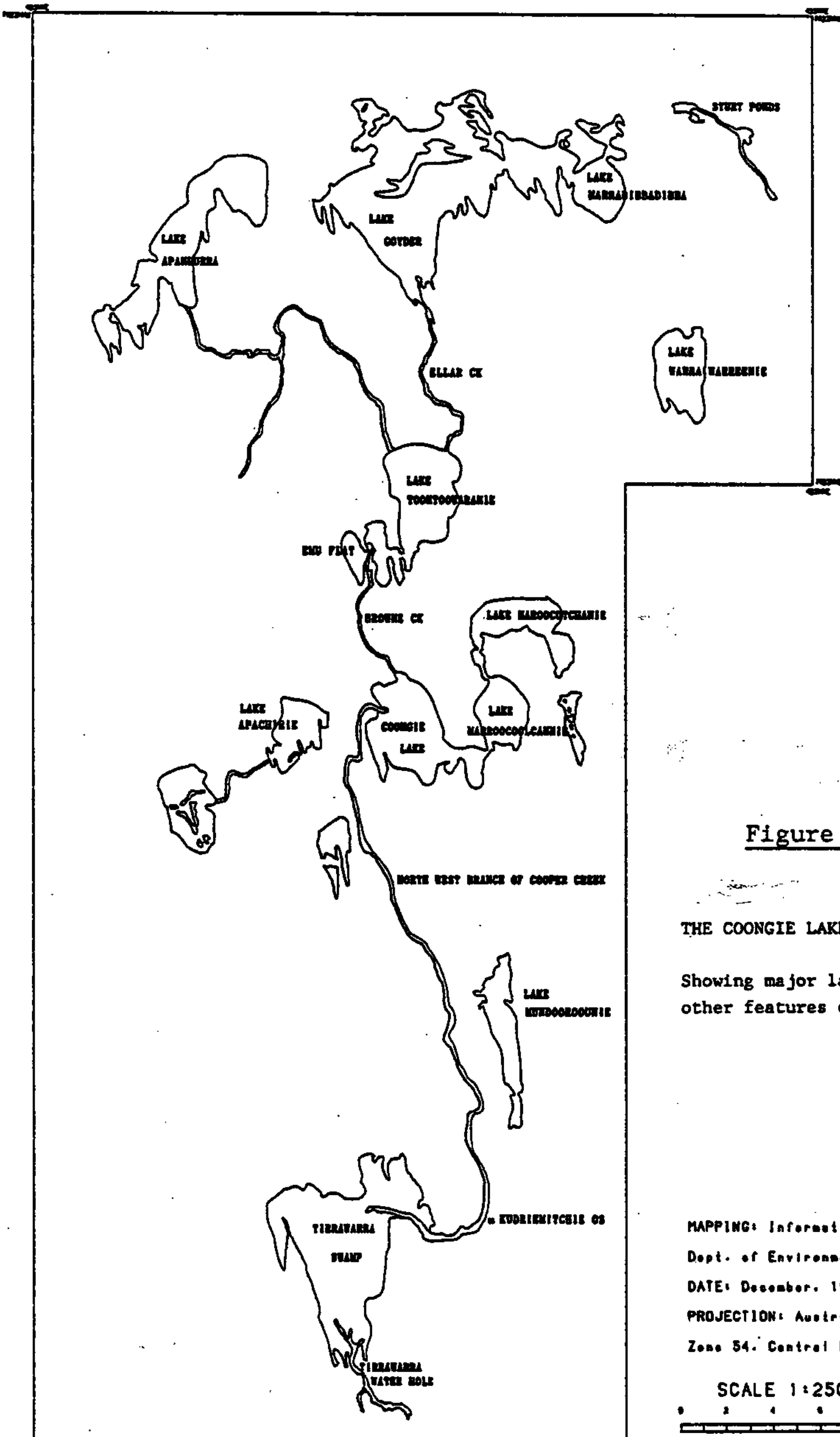


Figure 1.2

THE COONGIE LAKES DISTRICT

Showing major lakes, channels and other features of the district.

MAPPING: Information Systems Branch.
Dept. of Environment & Planning.
DATE: December, 1987.
PROJECTION: Australian Map Grid.
Zone 54. Central Meridian 141 degrees E.

SCALE 1:250 000

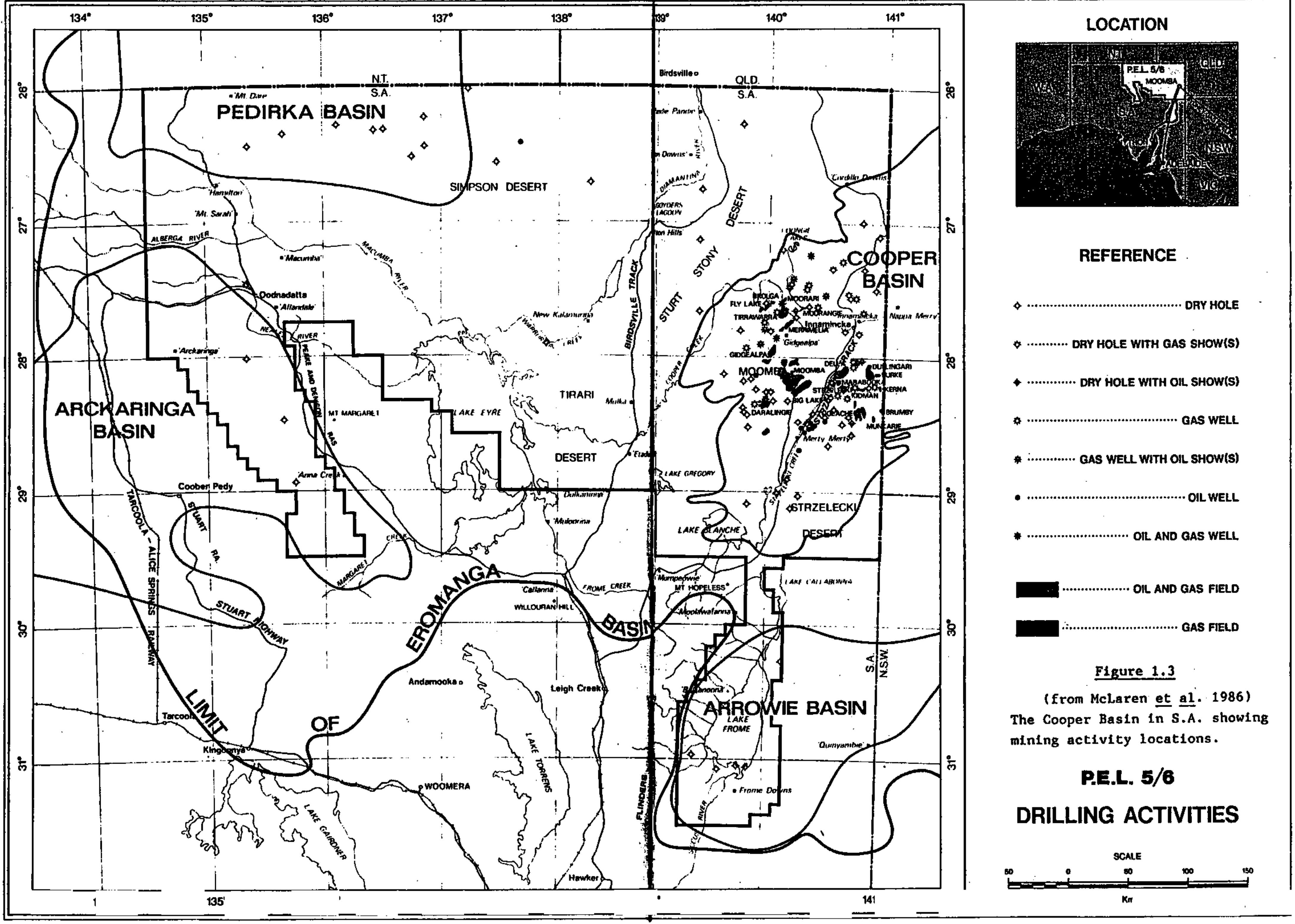


Figure 1.3

(from McLaren et al. 1986)
The Cooper Basin in S.A. showing mining activity locations.

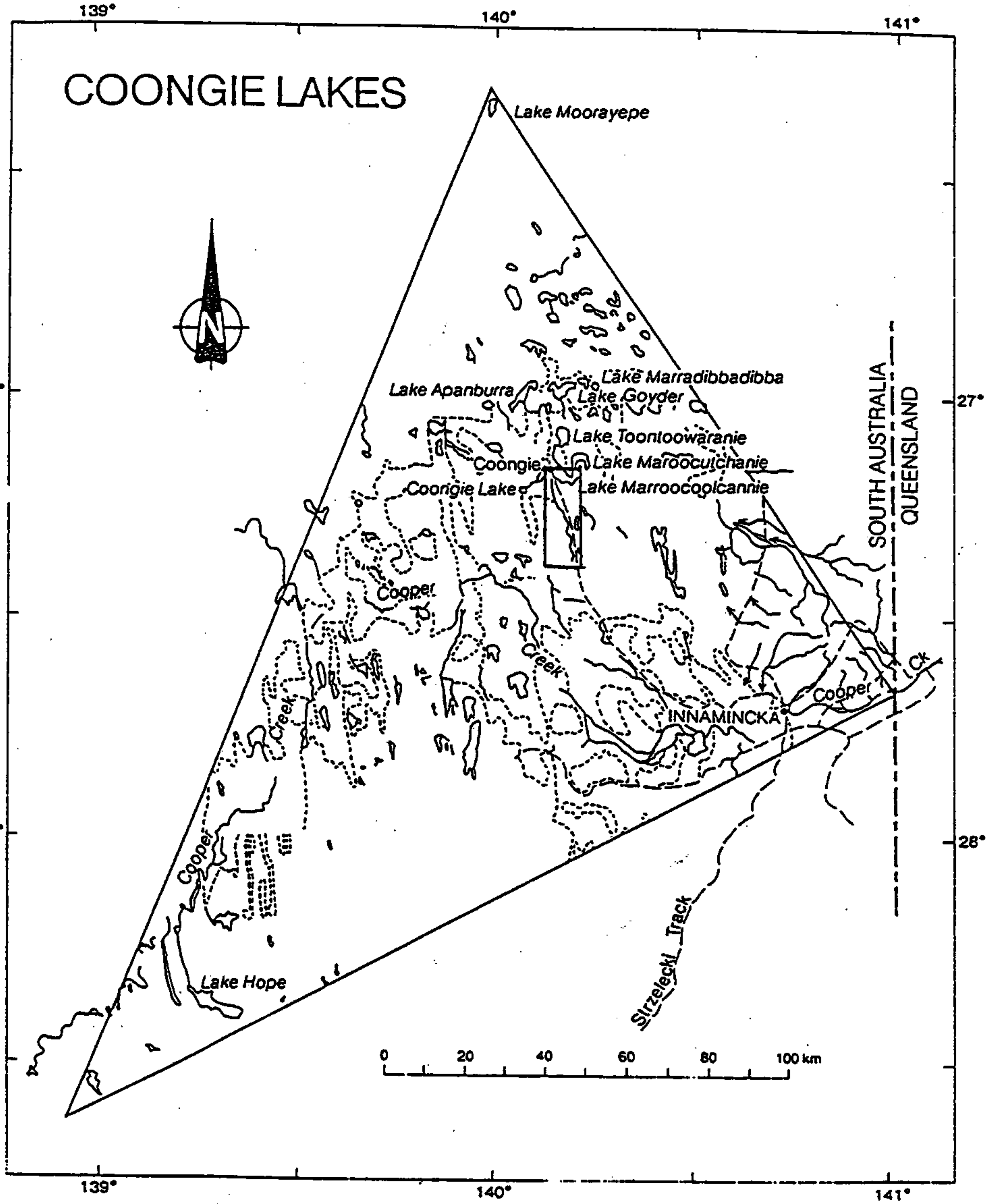
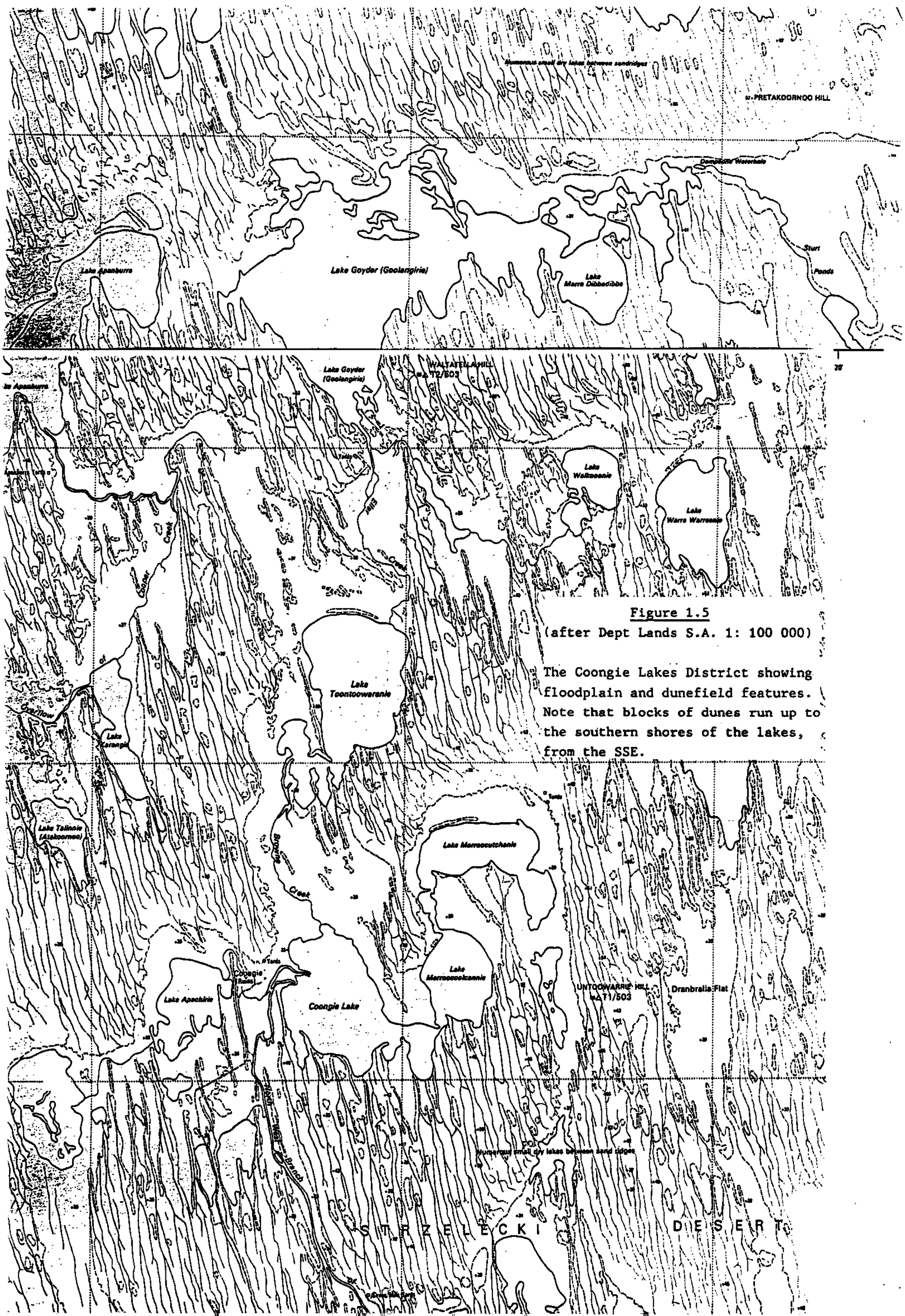


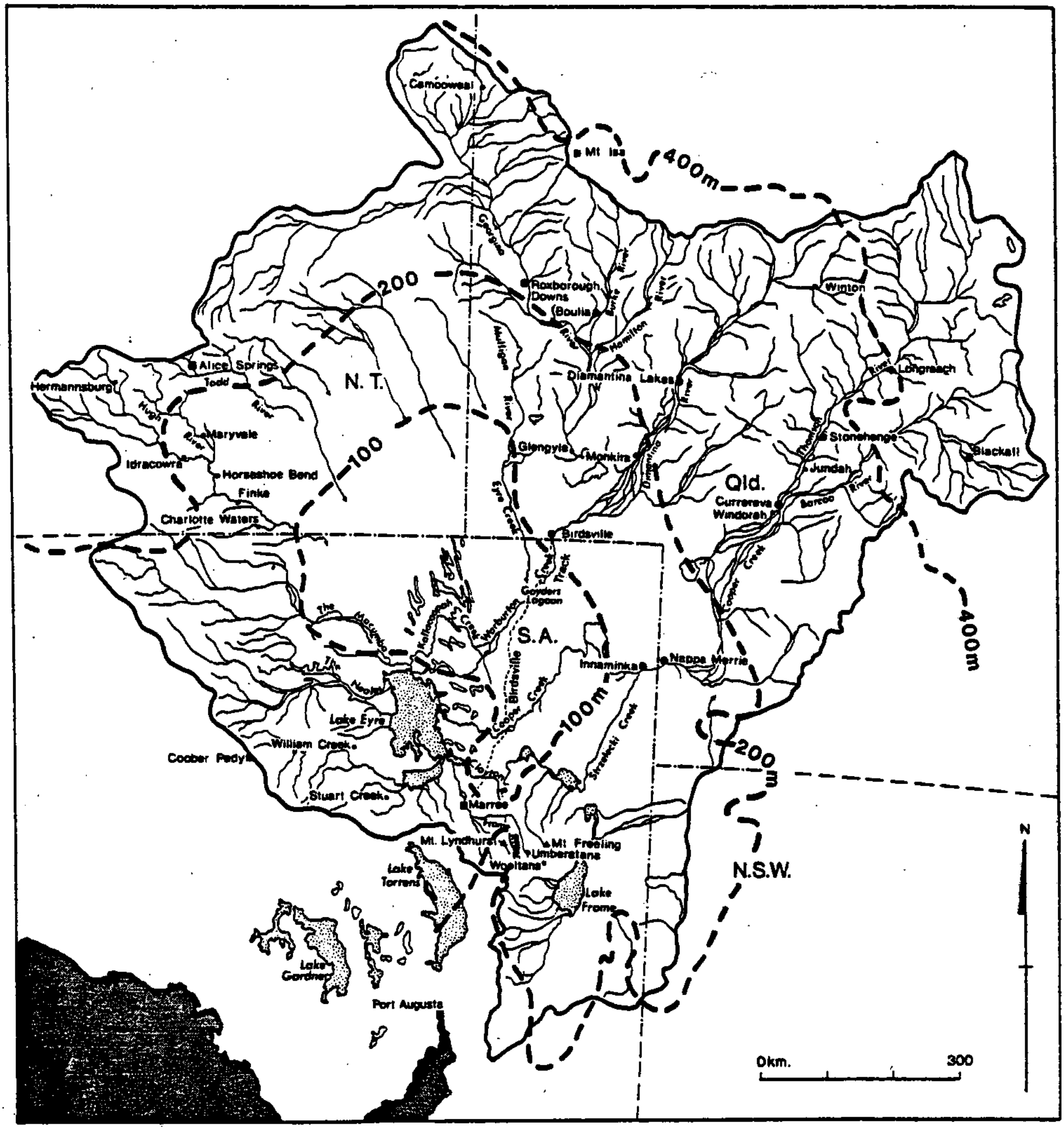
Figure 1.4

Map of the Coongie Lakes Region showing area listed under Ramsar Convention as a wetlands area of international importance (large triangle) and the smaller area listed under the National Estate.



<u>Figure 1.5</u>
(after Dept Lands S.A. 1: 100 000)

The Coongie Lakes District showing floodplain and dunefield features. Note that blocks of dunes run up to the southern shores of the lakes, from the SSE.

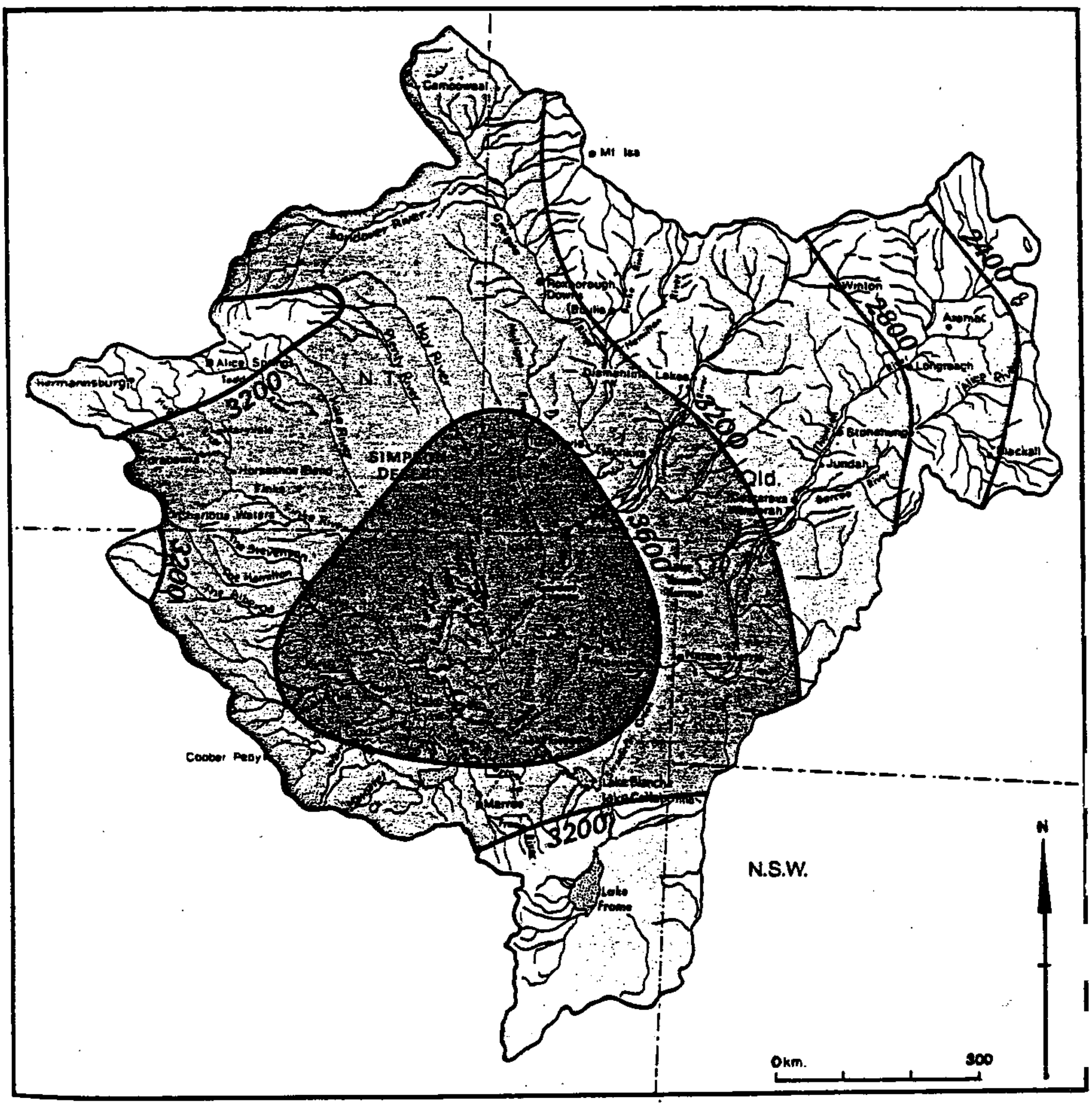


<u>Figure 1.6</u> (after Kotwicki 1986)

The Lake Eyre Drainage Basin showing median annual rainfall isohyets (mm).

Figure 1.7 (after Kotwicki 1986)

Mean annual evaporation (mm) for the Lake Eyre Basin



App. 1.1 Coongie Lakes Survey Project Brief

The survey is being sponsored by Australian Geographic Pty Ltd, the Department of Environment and Planning, the South Australian National Parks Foundation and SANTOS.

1. Aim

To undertake a survey of the natural history of the Coongie Lakes system of South Australia. The study would seek to

- identify and document seasonal changes to the flora and fauna,
- identify and document the impact on the natural environment of human activities such as mining, tourism, grazing and hunting,
- recommend management strategies.

2. Focus of Study

The survey will focus upon

- the number and variety of birds, mammals, reptiles, invertebrates and aquatic fauna, (although it is not expected that each of these will be given equal attention).
- the flora of the region
- human impact on flora and fauna.

In examining the natural history of the systems it is proposed that the survey should

- trace the changes that occur to flora and fauna with the seasons and the weather,
- highlight the diversity and richness of life to be found there
- identify some of the life cycles of lesser-known animals
- document animals and plants distinctive to the region
- determine the extent of human impact on the area.

The person undertaking the survey will be required to compile a report detailing his/her findings and recommending management strategies.

2. FIELD PROGRAMME & CONDITIONS

Julian Reid

A brief account is given of the activities undertaken over the survey period, the environmental conditions that prevailed leading up to and during the survey period, and the gross responses by the biota of the Coongie Lakes District to these conditions.

Field Programme and Activities

Two full months (September and November 1986) spent in Adelaide, were required to order equipment, devise a sampling strategy, and make preparations for 10 months' residence in the remote Coongie Lakes setting.

A two week reconnaissance of the district was undertaken in early November for several purposes:

- familiarization with the district's features, and to ascertain vehicle accessibility within the district along tracks and seismic lines;

- assessment of range of major landform and associated broad vegetation types within the district;

- selection of 30 permanent terrestrial sampling sites, representative (with replication) of the dominant landform/vegetation types;

- familiarization with the district's flora, and initiation of detailed record of bird numbers, habitat preferences and activities;

- initiation of lines of contact with SANTOS staff at Moomba and Tirrawarra and Innamincka towns- and station- people.

Figure 2.1 shows the location of the 30 permanent sampling sites, 1-15 E (eastern sites) and 1-15 W (western sites), and most of the tracks and seismic lines within the district. In November, passage by vehicle, between the east and west sides of the district was relatively easy and rapid, using the Kudriemitchie or Browne Creek crossings. However, for most of the survey period, these crossings were unnegotiable, and subsequently the full day trip via Innamincka, Moomba and Tirrawarra was undertaken to cross sides.

A two week expedition, involving 15 (mainly volunteer) personnel, was conducted in early December, to initiate the terrestrial and aquatic sampling programmes. Due to torrential rains early in the trip preventing access to the western side of the district, only half of the pitfall lines (14 of the 15 eastern sites) could be established. Similarly aquatic sampling could not be conducted in the two northern lakes as planned.

Because the December rains prevented establishment of all the sites, a second "volunteer" party was assembled for two weeks in late January 1988. Pitfall lines at the 15 western sites were inserted, and the vegetation transects initiated, while aquatic sampling was repeated at some of the December sites and performed at new sites accessible on the western side. A heavy rainstorm prevented access to Lake Goyder.

This marked the end of the establishment phase, and repeated assessment of sites was conducted thereafter at approximately six weekly intervals for the terrestrial sites and two monthly intervals for the aquatic fauna programme. Ten to 12 days were devoted to each sampling event (terrestrial and aquatic), which therefore accounted for most of the resident biologists' (Julian Reid and Jake Gillen) time spent in the field (to mid September 1987). During this repeated assessment phase, J. Reid was responsible for studies of the terrestrial fauna (and waterbird counts), J. Gillen for vegetation/floristic studies, and Jim Puckridge made four further two-week visits to complete the aquatic faunal programme.

The repeated site assessments were conducted at the times shown below:

Terrestrial Sampling 2 (first repeat)	: late February/early March.
Aquatic Fauna 3	: late March.
Terrestrial Sampling 3	: mid April.
Aquatic Fauna 4	: late May/early June.
Terrestrial Sampling 4	: mid June.

Terrestrial Sampling 5	: mid July.
Aquatic Fauna 5	: late July/early August.
Terrestrial Sampling 6	: late August/early September.
Aquatic Fauna 6	: late September/early October.

Despite these assessments being the major thrust of the study, a number of other programmes of research were pursued, which included limnological sampling of the district's water bodies, hydrological measurements (flow rates) along the North-West Branch, Browne Creek and Ellar Creek, the collection of quantitative vegetation data at 110 randomly located sites within the district, opportunistic collections of plants in the wider region, and faunal survey in the wider region and in other parts of the Coongie district. As well, progress reports had to be prepared in advance of the bi-monthly meetings with the project's Steering Committee (held in Adelaide in late February, April and June, and on site in early September). Generally one or two weeks was spent in Adelaide every two months immediately prior to and for these meetings, for the purposes of R&R, preparation of progress reports, ordering of supplies and equipment and reacquaintance with buraeucratic procedures.

Six progress reports were completed in all; they contain some information of an anecdotal nature not presented formally in this report. Copies are located within D.E.P. A great deal of information was collected in the course of the study, and not all of it has been incorporated into the report. Much of the outstanding data will be submitted to D.E.P. (as Volume II) in due course.

Jacqueline Gillen organized and conducted (with the assistance of eight voluntary personnel) and intensive visitor survey (partly funded by project monies) in the Innamincka - Coongie region during the July school vacation. She collected additional data at other times during the study period, and in addition to her chapter in this report, she has prepared a detailed report of her findings and recommendations (submitted with this report to D.E.P.).

Hydrological and meteorological observations (partly funded by project monies) were made by Robert Allan and Peter Schwerdtfeger respectively (Flinders University), and some of their results are presented in Chapter 3.

A literature review (App. 2.1) of selected topics, relating mainly to impacts of tourism, recreation and mining in aquatic and arid environments, was prepared by Penny Paton as part of this study.

Conditions Preceding and During Survey Period

In addition to the regular seasonal and diurnal (cyclic) environmental patterns (e.g. temperature, daylength) that have a bearing on biological patterns expressed within the district, the two most critical and irregular influences on the district's biota are rainfall (or lack of it) and flow/flood events along the Cooper. Fire, of enormous importance in sclerophyllous (temperate mallee, woodland and forest) and northern (tropical and sub-tropical) environments over much of Australia (including the northern half of the arid zone), does not exert much influence within the Cooper Creek region. Although large-scale fires occurred in the mid 1970's in the Strzelecki Desert sand-dunes, as a response to the exceptional rainfall experienced in 1974-75 (ERPG 1980), and evidence of a much earlier fire along the banks of the Cooper Ck in the Coongie district (large, dead, hollowed out and still charred trunks of river red gums) was observed during this study, fire is considered to be a very infrequent event.

Rainfall prior to and during the survey period was above average, with large and therefore biologically significant falls experienced within the region in May, June, July, October, November, December 1986, and January, February and June 1987. Within the survey period (November 1986 - October 1987) the general trend was wet conditions initially (to February), and subsequently drier, especially from July to October. Rainfall was often spatially patchy, as can be seen by comparing figures for different rainfall stations within the region (Table 2.1) e.g. in May 1986, Moomba recorded 3mm and Innamincka HS 41mm, in November thunderstorm activity yielded 28mm at Innamincka HS but no rain at Coongie or Cordillo Downs, while in December an estimated 80+mm fell at Coongie, 122mm was recorded at Cordillo Downs, 6mm at Moomba and none at Innamincka. Spatial patchiness is a characteristic of rainfall patterns in deserts and has profound biological consequences (e.g. nomadism in birds - Schodde 1982). The two meteorological stations at Coongie were located only five km apart and a similar distance separates Innamincka HS and Store, yet the discrepancy in rainfall figures observed between these pairs of stations in some months reveals just how small scale the rainfall patterns can be. Rainfall is not always patchy, however, and comparable amounts of rain fell at these localities (and in the wider region generally) in February and May (refer to Table 2.1).

Table 2.1

Rainfall figures for selected months at seven recording stations between May 1986 and June 1987

Station	Rainfall (mm)									
	5/86	6/86	7/86	10/86	11/86	12/86	1/87	2/87	5/87	6/87
*Moomba	3	3	81	31	16	6	7	108	9	43
*Innamincka HS	41	27	94	25	28	0	23	153	12	23
**Inna. Town	24	40	78	32	21	18	26	147	12	25
Coongie dune	-	-	-	-	0	80+	9	88	12	57
Coongie shore	-	-	-	-	0	80+	18	129	7	54
*Cordillo	0	0	92	19	0	122	32	117	-	-
*Birdsville	0	5	108	47	15	8	33	75	7	35

* Data courtesy of Bureau of Meteorology (Adelaide and Brisbane Offices)
** Data courtesy of Mike Steel, Innamincka

Rainfall was observed to cause immediate responses in the area's biota. Heavy summer rains initiated a deafening chorus by frogs within several hours, signifying an immediate capacity to breed in the temporary pools which became the focus for their activity. Within a few days these same pools were teeming with invertebrate life such as the shield shrimp. The mat-forming plant Dentella pulvinata, previously unnoticed or appearing lifeless, rapidly became green and soon flowered. A Peaceful Dove was observed collecting twigs within hours of a light shower in February, and several times over the course of the study, heavy rains were considered to be responsible for the initiation of significant breeding events by terrestrial birds. During the torrential downpour experienced at Coongie in December, an estimated several hundred tortoises appeared on the surface of the Cooper and quietly floated downstream past the campsite with their neck and heads exposed to the rain; the Cooper flowed for about a day in response to this localized rainstorm, and a few days later after the flow ceased, many tortoises were observed heading back upstream - over the rest of the year they were rarely seen above water for extended periods in the manner described above.

Following heavy rains (at any time of the year), the majority of ducks deserted the Coongie Lakes system, presumably to inhabit the newly created temporary waters to harvest the rich invertebrate life and perhaps for some to breed as well. They would retreat to the lakes over the ensuing month as these ephemeral pools and swamps dried. By this time ephemeral plant life had bloomed, and it was fascinating to watch and document the changing composition of these ephemeral floras over the year in response to successive rain events. Another interesting facet of the ephemerals' response to rain was the asynchrony observed in different districts within the region; for example, the autumn-winter species (e.g. Phlegmatospermum spp and Senecio gregorii) appeared and bloomed in the Moomba district about a month before they did in the Coongie district. After the heavy summer rains at Coongie (230+mm in December-February), an explosion of herbivorous insects (e.g. Lepidopteran larvae) occurred to take advantage of the prolific vegetation growth, and within a few weeks of their appearance, the leaves of particularly favoured plants such as Boerhavia spp and Trianthema triquetra had been virtually stripped. Over this period, the qualitative judgement was made that insect herbivory greatly exceeded the effects of rabbits.

The main rabbit breeding event occurred in late winter - early spring, when their population increased dramatically, at a time when the country could least cope with the subsequent onslaught. Virtually no rain had fallen since June, and with the ephemeral flora in an advanced state of decline, perennial plants must have received a hammering in the ensuing spring-summer period. Myxomatosis was observed to be fairly prevalent only over the humid summer period, and it was interesting to observe an increase in percentage of myxoma infected rabbits in the week following the heavy December rains.

The Cooper Creek flowed intermittently during the survey period. Not flowing in November and December, by which time the level of Coongie Lake had dropped to half full (c 1m deep) and Toontoowaranie to a quarter full (with Goyder nearly empty by February), a small regional flow commenced early in the New Year (at Innamincka) in response to the heavy December rains upstream. This pulse reached Coongie in the middle of January, but lasted for a month only. In fact it stopped flowing at about the time of the torrential February rains, which initiated an immediate and large flow event at Innamincka (almost 4m over the causeway - A. Gassner pers. comm.). This pulse reached Coongie about one week later, while a large amount of water flowed down the Main Branch to reach and fill Embarka Swamp (but did not proceed any further downstream than this). An interesting piece of local knowledge (M. Steel pers. comm.) relates to the height of water over the causeway at Innamincka and the passage of water down the Main and North-West Branches - when the Cooper is flowing, all the water feeds into the North-West Branch and thence towards Coongie while the level of water remains less than a meter over the causeway, while above this height water flows down both branches. A much greater flood is required before water enters the Strzelecki Creek from the Cooper at Innamincka. Almost immediately, waterbirds began breeding at Coongie, an upstream migration of catfish and other species took place, and thousands of pelican left the lakes district (a hundred or more appeared at Innamincka to feast upon the numerous migrating fish struggling to cross the causeway there - M. Steel pers. comm.).

Soon the level of Coongie Lake rose sufficiently for water to spill over into Browne Creek and thus feed into Lake Toontoowaranie, and several weeks later, Toontoowaranie filled and Ellar Creek commenced flowing to replenish Lake Goyder's depleted and saline stocks with fresh water. It then took several months for the much larger Lake Goyder to fill and spill over into Lake Marradibbadibba to the east.

The Cooper stopped flowing for the year in October, although it had stopped flowing briefly in the intervening period in June (and again in July), before recommencing in late June after the heavy June rains. Duckweed (Azolla) was observed to cover the entire surface of the channel in these periods of no or little flow.

Other Observations

As well as automatically recording rainfall, the two meteorological stations established at Coongie recorded temperature, relative humidity and wind speed and direction. The stations were sited deliberately in different environments, but reasonably close to each other. One was located close to Coongie Lake adjacent to the Cooper channel and the other was placed in the dunefields five km to the west.

Two interesting patterns emerged, which show these contrasting environments to experience different meteorological conditions. Over the summer period, the diurnal range in temperature differed by as much as three degrees Celcius, with the dune station consistently recording higher daily maxima and lower nightly minima than the lakeside station. As well the lakeside station consistently recorded a higher relative humidity (frequently as much as 20% higher) than the dune station. This "maritime", ameliorating influence of the lake may have a significant bearing on biological patterns expressed in the district, and it is likely that under the (almost closed) riparian red gum canopy, such microclimatic influences may be even more marked, allowing a suite of plant and invertebrate species, relatively intolerant of desiccating conditions, to occur within this environment.

Another meteorological pattern commonly observed was for windy conditions to prevail during the day with the wind dropping away at dusk and still conditions prevailing at night. This cycle was repeated for days at a time.

Some interesting diurnal patterns were expressed by plants (as well as the more obvious nocturnal vs diurnal behaviour displayed by various animal groups) e.g. the large, yellow flowers of Tribulus hystrix (see frontispiece) closed at night, opening again the next morning, to loosely track the path of the sun (from the north-east to the north-west) over the course of the day. The showy yellow flowers of Senecio gregorii also tracked the path of the sun each day. The white, delicately fragrant flowers of Nicotiana velutina appeared to only release the perfume on dusk, presumably to attract specific nocturnally active pollinators. These and other intriguing facets of the natural environment in the Coongie district would certainly bear further study.

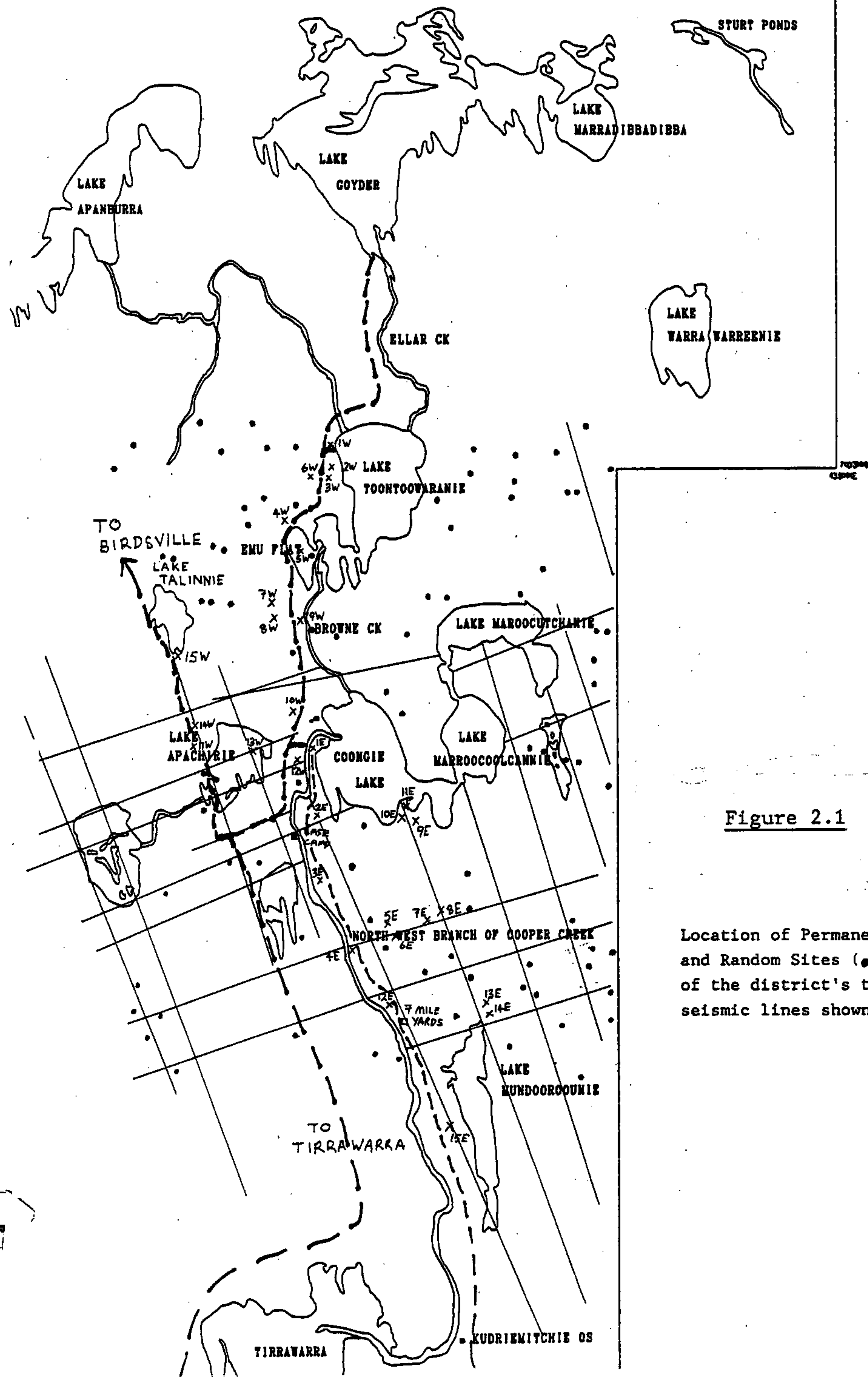


Figure 2.1

Location of Permanent Sites (X) and Random Sites (•) with some of the district's tracks and seismic lines shown.

3. METEOROLOGY AND HYDROLOGY

Robert Allan

3.1 Aims and Significance

The Coongie Lakes system consists of a core of five interconnected lakes that are fed by the North-West Branch of Coopers Creek. The most 'regularly' filled are the chain of three southern lakes, Coongie, Marroocoolcannie and Marroocutchanie, which together cover an area of some 25km^2. If these southern lakes are filled, any additional flood waters can find their way, via Browne Creek, to Lake Toontoowaranie an area of 13.3km^2, and if floods are 'sufficiently large' via Ellar Creek to Lake Goyder, an area of some 39km^2 (43.9km^2 if one includes Lake Marradibbadibba).

To manage this system effectively, there is a need for accurate measurements and long term monitoring of the water budget of the region. Some preliminary steps in this direction were made as part of this study. As well as assessing data from instruments deployed during 1987, an attempt was made to assemble all of the available historical and contemporary material relating to water in the Coongie Lakes system. Results of both of these aspects are presented in this section.

3.2 Data and Methods

To obtain some understanding of the hydrology and meteorology of the Coongie Lakes region during the 1987 study period, a range of instruments and measurements was required. Two battery-powered meteorological stations and a portable current meter were provided by the Flinders Institute for Atmospheric and Marine Sciences (FIAMS). In addition, members of the study team and other consultants made measurements of lake and channel depths, surface water temperature, water temperatures with depth and conductivity both at set locations and on various traverses of the lakes.

During May, the FIAMS meteorological aircraft undertook a series of flights over the lakes system to measure a number of atmospheric parameters. During July 1987, this consultant visited the Coongie Lakes region to undertake a bathymetric survey of Coongie Lake.

The remote weather stations contain sensors to measure and record air temperature, relative humidity, rainfall, wind direction and wind speed. The two stations were deployed near the North-West Branch of the Cooper, some two kms from its outlet into Coongie Lake and some five kms away in the sandhills respectively (Fig. 3.1). These locations were chosen to provide information relevant to both ecological/biological interests and hydro-climatological studies. The collected data will ultimately be used to produce a record of changing weather conditions during the study period, as a 'ground truthing' for some of the FIAMS aircraft observations taken during May, and together with Coongie Lake surface water temperatures, for the derivation of evaporation rates.

The portable current meter was used at three channel locations where the cross-sectional area of the channel had been measured. These sites were on the North-West Branch upstream from its outlet into Coongie, and on Browne and Ellar Creeks (Fig. 3.1). Current meter measurements of flow on a number of days together with the known cross-sectional area of the channel at each site allowed the calculation of the water volume/day passing each location. Such data were then comparable with stream gaugings upstream at the Callyamurra Waterhole near Innamincka (Fig. 3.2), and permitted the first quantitative estimate of the response time of the Coongie Lakes to flood pulses leaving Innamincka.

Bathymetric measurements of Coongie Lake provided the first survey of the depth structure of a lake in this system. Such information was vital for accurate estimates of the volume of Coongie Lake. It was also used as an analogue for the likely bathymetry of the other major lakes in the system so as to improve calculations of the system's water budget, as an analogue for the likely bathymetry of the other major lakes in the system and, in conjunction with contemporary aerial and ground photography, as a means of obtaining an estimate of past water volumes in the lakes.

The combination of these data sources provided the basis for an estimation of the water budget of the Coongie Lakes system in 1987. However, it was obvious that additional data of both contemporary and historical nature were required if a more meaningful understanding of the response of the system to flood and drought conditions was to be obtained. To these ends, an effort was made to collect and collate: historical references to floods/drought on Coopers Creek and in the Coongie region, Queensland stream gaugings at Currareva that extend back to 1939/40, aerial photographs, and general photographs of the Coongie system and LANDSAT remotely sensed imagery.

3.3 Findings

Results of observations and surveys during 1987 provided varying information on the Coongie Lakes system.

3.3.1 Hydrological Results in 1987

a. Coongie Lake

Data collected from Coongie Lake of relevance to this section of the report included a series of lake level measurements, current meterings and flow estimates in the North-West Branch of Coopers Creek, and a bathymetric survey of the lake in July 1987.

The bathymetric survey results from 44 lake soundings are shown in Fig. 3.3. They indicate that the lake had a maximum depth of some 1.85m in mid July. The depth contours also suggest a fan shaped outflow of sediments from the North-West Branch.

As a result, the lake bed has 'gentle' gradients, giving the lake a saucer-shaped bottom profile. Volume and area changes with depth are shown in Fig. 3.4. These follow the shape of similar types of profiles deduced for Lake Eyre in Kotwicki (1986), and can be used to estimate the area/volume changes during drying and filling phases. They show that a full Coongie Lake (approximately 2m deep at the centre) would hold approximately 0.02Tl (0.02km^3) of water. These curves can also be used to provide an estimate of the amount of evaporation that would be needed to dry out Coongie Lake in the absence of flow in the North-West Branch or rainfall replenishing the lake. Given a mean annual pan evaporation at Moomba of 3600mm, a correction to estimate 'actual' evaporation from a lake body (0.7 times the pan evaporation) and no new water entering the lake, a previously full Coongie Lake would dry up entirely in about 7-9 months, depending on the time of year.

Lake level pegs provided some information on Coongie's water levels during the early parts of the year, with more detailed analyses made possible by using Fig. 3.4 in conjunction with lake depths taken during limnological studies. However, the response of Coongie Lake to hydrological influences must be seen, where possible, in the context of the broader lakes system.

b. The Coopers Creek - Coongie Lakes System

In looking at the total lakes system, the sparsity of observations necessitates some assumptions. Principally they are that all of the lakes in the system have similar bathymetric structure (this is suggested by various depth soundings made in 1987), and that because of wind mixing and lake overturning, they all have similar winter temperature structures.

i) Stream gaugings, levels and volumes

The response of the lakes system to flooding and drying events in 1987 is shown in Fig. 3.5. This diagram also includes the daily stream gaugings at Innamincka, the closest station upstream. Current meterings and flow estimates in the North-West Branch of the Cooper, and in Browne and Ellar Creeks are contrasted with the Innamincka values. Additional information is provided by lake and channel pegs and estimates of water volumes in Lake Coongie and Lake Toontoowaranie.

During 1987, a number of flooding events were recorded in the Innamincka stream gauge record. However, three of these events are particularly interesting in light of the current metering results from the North-West Branch. The events are marked A, B and C, with A and B being small and large sharp pulses in mid-late February, respectively, and C a smooth 'wave-like' pulse peaking in late April. Only pulse C in late April can readily be related to North-West Branch current metering values. Coongie responses to pulses A and B can only be made in conjunction with flow measurements estimated by timing a float (an orange) over a 50m distance of the North-West Branch. The results of this comparison are treated as being very approximate, and are further complicated by the small number of channel data points available. Nevertheless, some measure of the response of the Coongie Lakes system to upstream flood pulses of sharp and more wave-like nature can be suggested.

In February, pulse A at Innamincka appears to take some five days to reach Coongie Lake. The time lag in regard to pulse B is more uncertain because of the poor distribution of flow measurements, but is likely to have been of a similar duration. In April, pulse C is not as sharp and thus produces a slower response time (water volume is distributed over a longer time period and not as one sharp event) of the order of 10-13 days. However, the most revealing aspect comes from a comparison of the Coongie Lake volume response to the two types of pulses. The Coongie Lake volume response to A and B is less in relative magnitude than is the response to C. In other words, Coongie receives something like 80% of the volume of pulse C but less than 30% of B. Such a variable response would appear to be a direct result of the different frequency and amplitude of the pulses. Only as a result of pulses A and B is water known to have travelled down the Main Branch of the Cooper. In regard to pulse C, all of the water appears to have been channelled down the North-West Branch to the Coongie system.

The response of the lakes system beyond Coongie Lake itself also involves a series of lags. This is suggested by a comparison of the timing of the peak flow on the North-West Branch and flows in Browne and Ellar Creeks. Of the two, the Ellar Creek response is more clearly defined, being of the order of 20 days after the North-West Branch peaked. Sills on both Browne and Ellar Creeks are likely to be a major cause for lags in the system. However, the small number of flow observations precludes detailed analysis of this situation. Nevertheless, one apparent point of interest is that following the February flood pulses, flow in Ellar Creek lagged about 25 days behind Browne Creek.

A combination of water levels in the North-West Branch and Coongie Lake, and volumes in Coongie and Toontoowaranie support much of the current metering and flow observations. Once again, there appear to be lags in the system. In this case, they involve lake volumes and water flow regimes in the feeder channels. The highest Coongie Lake stand and the peak flow in the North-West Branch of the Cooper appear to vary by approximately seven days. As the flow in the North-West Branch diminishes, Coongie Lake water volumes appear to fall rapidly. This is most likely due to a combination of losses due to evaporation and outflows from Coongie to Marroocoolcannie, Marroocutchanie and Toontoowaranie.

Water volumes in Toontoowaranie seem to be of a similar magnitude to Coongie. This is not surprising given that the two lakes are of similar area (Toontoowaranie = 13.3km^2 and Coongie = 12 km^2) and, from observations made in 1987, of similar depth. The few measurements in Fig. 3.5 show Coongie volumes being higher than those in Lake Toontoowaranie until the arrival of pulse C and flow through Browne Creek to raise water levels in Toontoowaranie. As suggested earlier, the 1987 water volumes in the Coongie system appear to have received a significant amount of their input from pulse C. By late May, following pulse C, Coongie, Marroocoolcannie, Marroocutchanie and Toontoowaranie had reached depths of between 2-2.2m and were full. From other observations during the study, Lake Goyder would appear to have filled between June and late August.

ii) Lake water temperatures

The seasonal temperature structure in the lakes system follows the general theory of holomixis, in which greater wind stirring and less solar radiative input to the lakes in the winter months results in well mixed lakes with isothermal temperature structures. During summer, this effect diminishes under higher incoming solar radiation conditions and a stratified water column develops. Such structural changes can be seen in Figs 3.6, 3.7 & 3.8. In these diagrams, Coongie, Marroocoolcannie and Marroocutchanie all show a trend in water temperature structure from a more stratified water column in summer to a near isothermal structure by winter. It is this fact that has been used to make generalized lake surface water temperature assumptions for some of the salinity calculations during June and July, when few water temperature readings accompany a scattered number of lake conductivity measurements.

iii) Salinity patterns

A number of conductivity measurements were made in the Coongie Lakes system during 1987. These data were sufficient for four profiles of the conductivity of the surface waters in the lakes to be made. Using known and estimated surface water temperatures at each conductivity measurement site, it was possible to obtain values of lake salinity distributions. The salinity patterns deduced for 31/3/87, 15-17/5/87, 8-10/6/87 and 2-4/7/87 over most of the major lakes in the system are shown in Figs 3.9 - 12.

In general, the salinity distributions in these figures show the effect on the lake system of the major water pulses during 1987. This can be seen most clearly by comparing Figs 3.9 and 3.10. Between the 31/3 and the 15-17/5, the influence of pulse C in Fig. 3.10 is clearly evident. This is true particularly for Lakes

Marroocoolcannie and Toontoowaranie, where salinities fall from greater than 0.2^{o}/oo to between 0.1–0.2^{o}/oo as fresh waters from pulse C pass through the system. From 15–17/5 to the 8–10/6, salinity values are generally on the rise throughout the lake system. By this time, parts of Coongie Lake have reached 0.15–0.2^{o}/oo, while Lakes Marroocoolcannie and Marroocutchanie are up to 0.3–0.4^{o}/oo and 0.5–0.6^{o}/oo respectively. Lakes Toontoowaranie and Goyder do not show as large a change, with parts of Toontoowaranie now above 0.15^{o}/oo and the southern area of Goyder above 0.5^{o}/oo. By the 2–4/7, a new pulse of water (see Fig. 3.12) has entered the system with Coongie Lake salinity values less than 0.16^{o}/oo Lake Marroocoolcannie between 0.2–0.25^{o}/oo and Lake Marroocutchanie back to 0.4–0.44^{o}/oo. Lake Toontoowaranie is marginally less saline, with probably the same situation in Lake Goyder (there is only one salinity value for Goyder at this time). It may also be that the major influence of the July-August pulse may not have reached either of these northern lakes.

3.3.2 Meteorological Results in 1987

A great deal of data was collected by the remote weather stations during the 1987 field-work phase. At the time of compiling this report, only a fraction of these data has been analysed.

Coongie Lake Environment - Evaporation Rates

Probably the most useful observations for an understanding of the evaporation component of the water budget of the Coongie Lakes system are wind speed and direction, humidity and temperature. Together these parameters should provide a measure of evaporation rates from the Coongie Lake environs without recourse to extrapolations from Moomba pan evaporation values. However, it must be remembered that Coongie values are only available on a handful of days when water temperatures from the lake surface were taken. Furthermore, the exposure of the near-Coongie weather station is questionable under a number of wind and temperature conditions. Certainly, the fetch of the wind before it reaches the weather station is only representative of lake conditions when the flow is from the east-south-east. In addition, an examination of the remote station temperature sensor response under high temperature conditions suggests that it may read as much 10-14°C too high in summer conditions. As a result, Coongie Lake evaporation rates were deduced using Moomba maximum temperatures in summer rather than Coongie values. By late March, this was found to be unnecessary as maximum temperature values at both locations were similar.

The results of Coongie evaporation rate calculations for several dates during the study period are shown in Table 3.1. Although they show high summer and low winter values, the evaporation rates in Table 3.1 are low when compared with estimates for Moomba. However, accurate comparisons are difficult given the site, instrument(s) and sensor height differences between the two locations. At present, it is felt that estimates of monthly mean evaporation rates for any water budget analysis in the Coongie region should still use Moomba values.

A more detailed analysis of the weather station records and water temperatures plus FIAMS aircraft turbulent flux measurements taken at Coongie in 1987 may provide more information on hourly to diurnal evaporation rates. Certainly, any future studies could do well to closely examine instrument type and location in regard to producing meaningful measurements of evaporation.

Table 3.1

Coongie Lake Evaporation Rates during the 1987 Study Period.

Date	Evaporation rate (mm/day)	Wind Direction
23/1/87	12.8 - 10.3	NE
24/1/87	3.0 - 2.7	N
30/1/87	8.4 - 5.6	E
19/2/87	2.0 - 1.7	N
30/3/87	2.9 - 0.2	SE
1/6/87	1.0 - 0.0	ENE
2/7/87	1.4 - 0.3	ENE

3.3.3 Contemporary and Historical Evidence

A more complete understanding of the hydrology of the Coongie Lakes system requires more than just one year of data gathering. Unfortunately, longer term observations in this system are almost non-existent. To obtain some feeling for the contemporary and historical nature of the surface water regime in this region, a combination of aerial photographs and remotely sensed satellite imagery together with documentary evidence relating to Coongie water levels/floods was compiled. The results of this analysis are presented in the following sections.

a. Contemporary Photographs and Remotely Sensed Imagery

An attempt to reconstruct the recent history of water in the Coongie Lakes system from various photographic and remotely sensed images has resulted in 17 time 'slices' from 1958 to 1986. These are reproduced in Figs 3. 13-29. However, in any interpretation of these photographs and images with respect to lake water levels, it should be remembered that no account has been, or could be, made of the effect of strong winds on the water level distribution across the lakes at the time the photographs were taken.

From the photograph and remotely sensed imagery in Figs 3.13-29, the lowest water level for the entire Coongie Lakes system was observed in April 1983, when the level in Coongie Lake itself appears to be down to the 1.5m contour level (Fig. 3.24). The highest water levels for the whole system occurred in 1963 and 1974 (Figs 3.15 and 3.30, 3.20). In both of the 1963 and 1974 wet periods, water overflowed from the lakes system and the North-West Branch of the Cooper onto the surrounding flood plains and salt pans. The wider extent of the 1974 situation in the Cooper flood plain in the North East of

South Australia is also graphically shown in Fig. 3.20. In a comparison with the situation during the drier periods over the region, the 1974 event is seen to be in stark contrast with the 1980 and/or 1983 images (Figs 3.23 and 3.24).

The northern (Toontoowaranie and Goyder) and southern (Coongie, Marroocoolcannie, Marroocutchanie) lakes of the system show some periods of contrasting water conditions. These are most marked in 1962, 1970 and 1983. In the 1970 image (Fig. 3.17) both Lakes Goyder and Toontoowaranie appear to be dry, while there is reduced water extent, at the 1m contour level in the southern lakes. The 1962 and 1983 situations show a dry Lake Goyder, as in the previous period, but also a small area of water remaining in the northern portion of Lake Toontoowaranie. (Figs 3.14a, 3.14b, 3.24). Apart from these images, there is only the 1958 photograph of a dry Lake Goyder, with no information about the other lakes in the system. These types of scenarios are what one would tend to suspect from the structure of the Coongie Lakes system, with its North-West Branch feeding directly into Coongie and the southern lakes and overflow into the northern lakes if conditions of strong Cooper flooding occur.

From the photographs and images in Figs 3.13-29, there appears to be strong evidence for other pronounced wet periods in 1968, 1971 and 1977. (Figs 3.16, 18a,b & 21). Together with the 1963 and 1974 situations, these periods are directly associated with floodings/fillings of Lake Eyre noted in Allan (1985).

Any attempt to make a quantitative estimate of the water budget terms in the Coongie Lakes system using the photographic and remotely sensed imagery in Figs 3.13-29, needs the support of some flow measurements and reasonable assumptions regarding evaporative and groundwater losses and lake storages. Furthermore, it was found that such estimates would be more reliable if the time interval between photographs was not longer than one or two major flooding/drying events and where some change in water levels in the lakes system was detectable. Under these constraints, the best estimate of water budget terms was available from a comparison between the 1970 and 1972 aerial photographs and flow data at Nappa Merrie, plus some approximation for rainfall over the lakes from Cordillo Downs and Innamincka data. However, this still left one with the need for assumptions about evaporative and groundwater terms and lake storages. These were made using monthly mean pan evaporation data from Moomba, corrected to produce evaporation from water bodies, and lake areas and depths deduced earlier in this section. It was also assumed that the local water losses to or gains from groundwater storage were small compared with the other terms in the water budget.

The balance of inputs and outputs for the Coongie Lake system, that constitute the water budget terms, is shown in Table 3.2. From the stream gaugings at Nappa Merrie, it was seen that between the October 1970 and the September 1972 aerial photographs, approximately 3 Tl (km^3) of water passed the gauging station. This water, plus an estimation of total rainfall over the lakes from the average of Cordillo Downs and Innamincka Station falls (345mm), provides the best estimate of maximum water available to the Coongie system. The aerial photographs (Figs 3.17 and 3.19) show a lakes system in which conditions went from dry northern lakes in 1970 to full northern lakes in 1972, with an increase of about 0.4m in the depth of the southern lakes to reach full conditions by 1972. These changes required an increase in volumes of the northern and southern lakes of 0.104 and 0.01 Tl of water respectively. Rainfall estimates for the lakes suggest a total input of 0.028 Tl over this period. However, it must be remembered that it is not possible to say whether the Coongie Lakes system was completely flooded with water extending out into the flood plain during the peak rainfall event(s) in later summer of 1971. If this did occur, then it is possible that a flood-out of something of the order of twice the total lakes system area (approximately 0.15 x 10^9 m^2) with a depth of 1-2m could have been evaporated away in the 18 months between the march-April 1971 event(s) and the September 1972 aerial photograph. However, the October 1971 photographs (Figs 3.18a,b) do not support this inference, as they show that the southern lakes were confined to their full area and that there is no indication of flood-outs at this time (6-7 months afer the 1971 rainfall event).

Table 3.2

WATER BUDGET TERMS FOR THE COONGIE LAKES SYSTEM:

OCTOBER 1970 - SEPTEMBER 1972
(all terms in T1)

	Net Volume Increase	+	Evaporation	-	Rainfall on Lakes	=	Inflow
Southern Lakes	0.01	+	0.11	-	0.01	=	0.11
Northern Lakes	0.104	+	0.19	-	0.018	=	0.276
						Total	0.386 T1

Water available from Coopers Creek at Nappa Merrie = 3 T1

During this time major evaporative losses also occurred, with the southern lakes under the influence of a full 24 months of evaporation in which some 4.34m of water were evaporated, while the northern lakes, under apparently full conditions by the late summer of 1971, experienced the evaporation of 3.64m of water during 21 months. As a consequence, it was estimated that the Coongie Lakes system as a whole would have required 0.386 Tl of water to make the transition from the 1970 to the 1972 aerial photograph conditions. This result indicates that of the 3 Tl of water recorded at Nappa Merrie from October 1970 to September 1971, most of it (2.6 Tl) did not enter the Coongie system. This figure of 2.6 Tl would have included losses to evaporation and groundwater following flooding out onto the Cooper flood plains to the west of Innamincka and flow down the Main Branch of the Cooper towards Lake Eyre. The latter is supported by the brief 1987 monitoring of the Coongie system, where sharp peak flows, such as would have occurred in March-April 1971 (1.6 and 1.2 Tl at Nappa Merrie), are focused on the Main rather than the North-West Branch of the Cooper.

b. Historical Evidence

There is very little documentation of historical floodings in the Coongie Lakes system. Most of the available records contain scattered references to floods on Cooper Creek, particularly at Innamincka or upstream in the Queensland section of the drainage basin. Using a combination of a number of sources, Fig. 3.30 from Allan (1985) details many of the available reports of Cooper Creek floods. As far as the Coongie system is concerned, documentation of floods on Cooper Creek at Innamincka or Nappa Merrie are likely to also indicate water in the Coongie region. There is also strong evidence in Allan (1985) to link major extensive floods on Cooper Creek with one phase of the El Nino Southern Oscillation (ENSO) phenomenon. This large-scale fluctuation involves ocean-atmosphere interactions spanning the Indo-Pacific region, and major redistributions of rainfall systems influencing Australiasia.

The most direct references to floods in the Coongie system come from Lewis (1936). According to the above reference, water flowed into the Coongie Lakes system in 1904, 1910, 1913, 1923, 1924 and 1932. However, one can reasonably extrapolate from other observations of flow to Lakes Eyre or Hope, or of Strezelecki floods, that the Coongie system also received substantial water flows in 1891-93, 1898, 1903, 1906-8, 1912, 1917-18, 1920, 1922, 1930-31, 1933 and 1936. On the other hand, dry periods occurred in 1894-97, 1900-1902, 1909, 1911, 1914-16, 1919, 1926-27, 1929 and 1934-35. When these dates are examined in conjunction with Fig. 3.30, they indicate periods of regular water flows to the Coongie system punctuated by dry spells over about 100 years of record. Wet period dates often match closely with the evidence for Lake Eyre floodings/fillings in Allan (1985), especially during major anti-ENSO events. However, it is difficult to judge if the Coongie system has also been influenced drastically by climatic fluctuations over the last 100-120 years (Allan 1985, 1987, 1988).

The nature of climatic fluctuations influencing the Lake Eyre basin is suggested by the monthly mean rainfall distributions in District 17 (Bureau of Meteorology Rainfall District) during three time periods (Fig. 3.31). Data for this district, covering the north-eastern corner of south Australia and the Lake Eyre basin, suggest wetter summers and winters-springs during the 1946-85 as compared with the 1913-45 or 1870/80-1915 periods. This is supported by the studies of Gentilli (1971), Pittock (1983) and Kotwicki (1986, 1987). However, it is likely that such periods would be less evident in any Coongie records, even if sufficiently reliable and continuous data were available. This is supported by indications in the 1987 study and the contemporary section, that even minor floods at Innamincka and Nappa Merrie appear sufficient to put flood waters into at least the southern lakes of the Coongie system. It is thought that the years in which no water enters the Coongie system from the North-West Branch are rare indeed, especially in recent times.

3.4 Impacts and Recommendations

The major recommendations from this section centre on the need to improve existing meteorological and hydrological observations in the Coongie Lakes system. If implemented, such recommendations will have a direct bearing on the ability to provide quantitative information from which to assess the impacts of future developments and management practices in the region.

It should also be made very clear in this call for the implementation of both meteorological and hydrological recommendations, that at present, any report will be severely limited by the general lack of long-term data in this region. Meteorologically, the basic Bureau of Meteorology network of surface and rainfall stations in the north-east of South Australia has been reduced over the last 10 years. At present, rainfall observations in the northeast of South Australia are made at Innamincka, Cordillo Downs, Moomba, Clifton Hills, Pandie Pandie, Marree and Cowarie. Of these stations, only Moomba and Marree send in daily telegraphed rain gaugings to the Bureau of Meteorology. Moomba and Marree are also the only stations which record surface parameters such as wind, temperature, humidity, evaporation etc. Thus the current information on general weather and transport/road conditions in the northeast of South Australia depends on this sparse information. Hydrologically, the situation is far worse, with only one stream gauging station in the entire Lake Eyre basin in South Australia at Innamincka. Meteorological/hydrological monitoring of the Coongie Lakes system, or for that matter much of north-eastern South Australia, is severely limited by the present observation network.

From a meteorological/climatological perspective, it is recommended that a station be established near Coongie Lake to record standard meteorological parameters, as is currently undertaken by Bureau of Meteorology surface stations throughout Australia. Such a station could be installed at a location that may be developed as a ranger station, such as Kudriemitchie Outstation. It would also be desirable for there to be some deployment of automatic rain gauges, positioned around the northern and southern lakes, and linked to the central meteorological station set up in the area. In this way, a detailed network to record rainfall variations across the Coongie system could be developed. Such observations would be vital to an accurate assessment of the rainfall input in the water budget of the area. One other location that would be very important to monitor is Tirrawarra Swamp. Detailed measurements of the water budget of the Coongie system are likely to be dependent on a knowledge of the role that Tirrawarra Swamp plays both meteorologically and hydrologically.

Closely in hand with such meteorological requirements, is the need to seriously undertake regular hydrological measurements in the Coongie Lakes system. It would seem that the building of one new stream gauging station on the North-West Branch of the Cooper near Coongie Lake is paramount. This could be supplemented by a series of less costly flow measuring stations in the system (viz. regular current metering points and/or gauge boards). These would need to cover at least locations on the North-West Branch before it enters Tirrawarra Swamp (Tirrawarra Waterhole), on the Main Branch near Embarka Waterhole, down-stream on the Main Branch at Cuttapirie Corner Waterhole, and on both Browne and Ellar Creeks. Again, these types of remote stations could be read and checked by a ranger on regular duty in the region, or in some cases (e.g. Embarka Waterhole) by arrangement with SANTOS. Such arrangements may also be possible in terms of salinity and temperature measurements throughout the lakes system, if regular monitoring of the lakes by boat were to be undertaken. Regular salinity and temperature observations in the lakes would provide checks on the 'condition' of the water in the system. This could easily be linked in with any regular chemical and/or biological analyses of lake waters for environmental changes and water quality. Consideration must also be given to a programme of drilling to assess groundwater conditions in the region.

As mentioned in the meteorological recommendations, it is felt that a detailed study of the role that Tirrawarra Swamp plays in the water balance of the Coongie system is required. The present study had no data with which to make any analysis of this swamp in the context of Coongie Lakes hydrology. Thus it is felt that, in the light of the observed engineering works undertaken on Embarka Swamp and a lack of quantitative knowledge of their effect on large floods passing through this swamp and down the Main Branch of the Cooper, no developments take place on Tirrawarra Swamp. Any disturbance to this swamp in the absence of any useful quantitative data should not be permitted, as effects on the Coongie Lakes system are unknown.

The implementation of these meteorological and hydrological recommendations would have wide ranging benefits for both the Coongie system, and through better data coverage, this part of the State as a whole.

Acknowledgements

I would like to thank Julian Reid and Jake Gillen for making current meter measurements in the Coongie system and for 'tending' to the FIAMS remote weather stations. Bob Mossel provided some of his aerial photographs of various parts of the Coongie system over a number of years (Figs 3 18a,b; Fig.3.25; Figs 3.27a-d), and Vincent Kotwicki provided me with Innamincka stream gauging records and a copy of Lewis (1936). Dean Graetz provided me with LANDSAT Scenes (Figs 3.20 & 23).

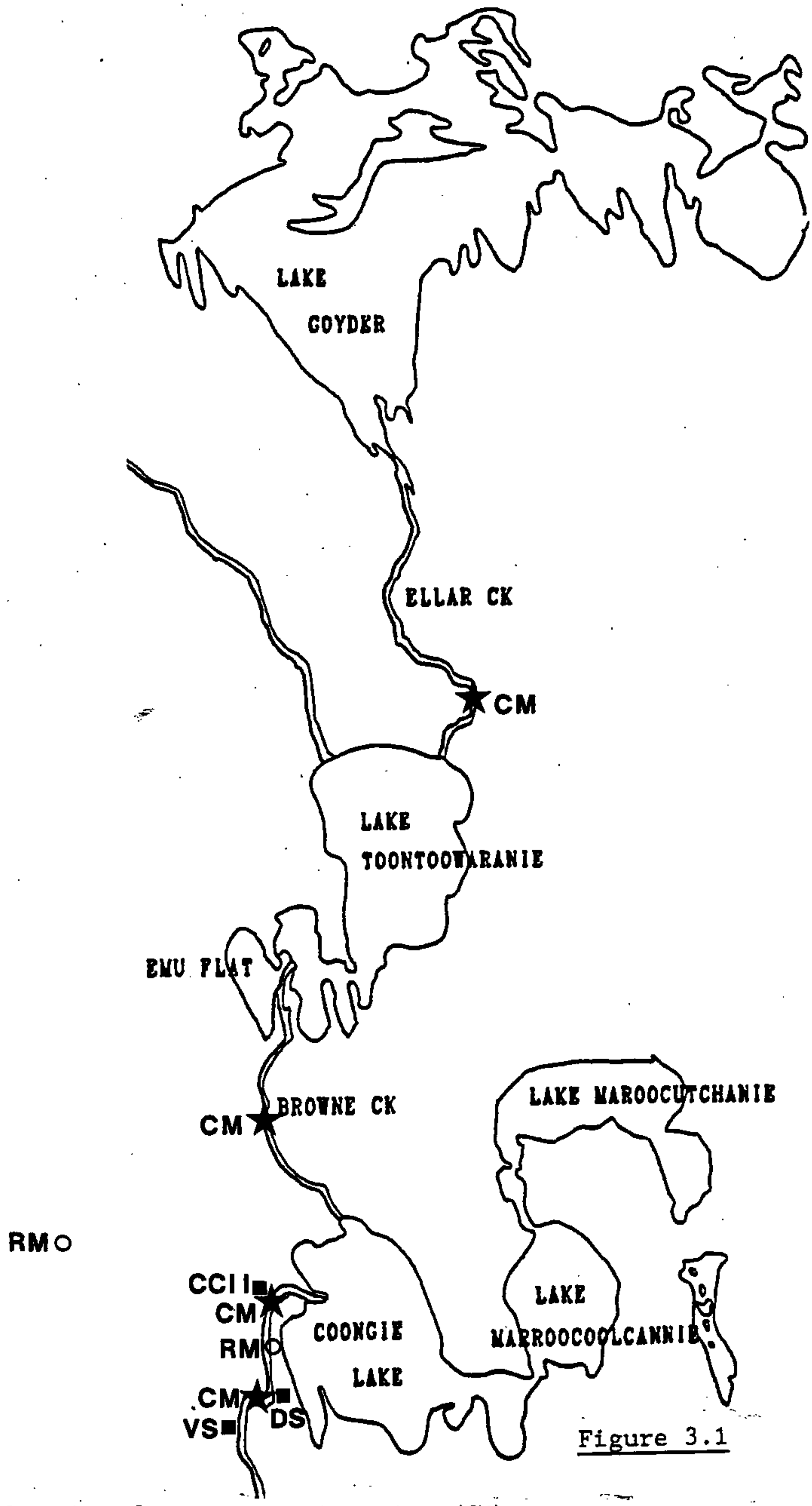


Figure 3.1

Location of current metering points (CM), remote weather stations(RM) and level pegs. For level pegs; VS=Van Site (base camp),CCII=Coongie Camp II, DS= Dune Site

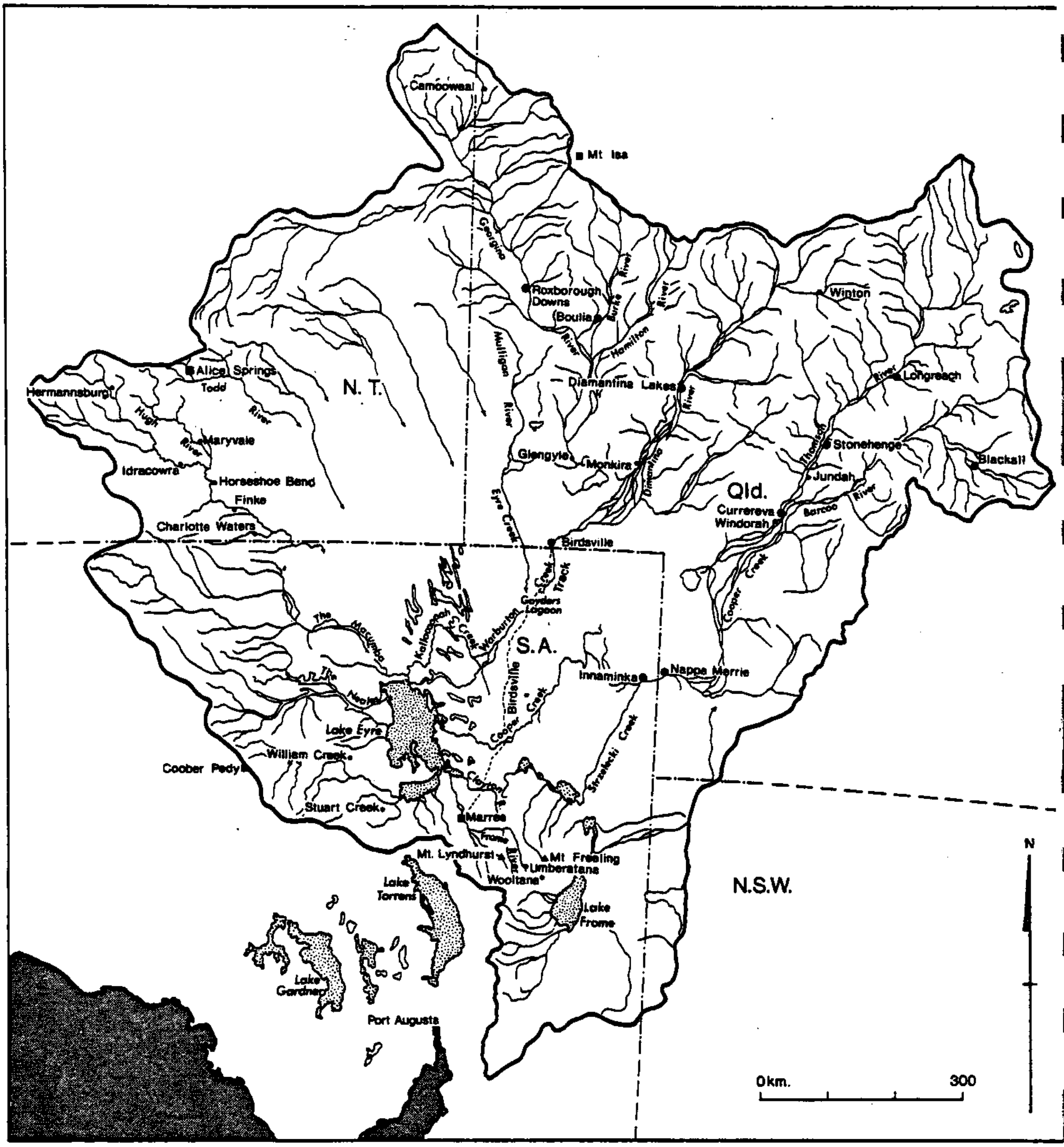


Figure 3.2

Location of the Innamincka stream guaging station with regard to other stream guages on various river systems in the Lake Eyre Basin. ● = stream guaging stations.

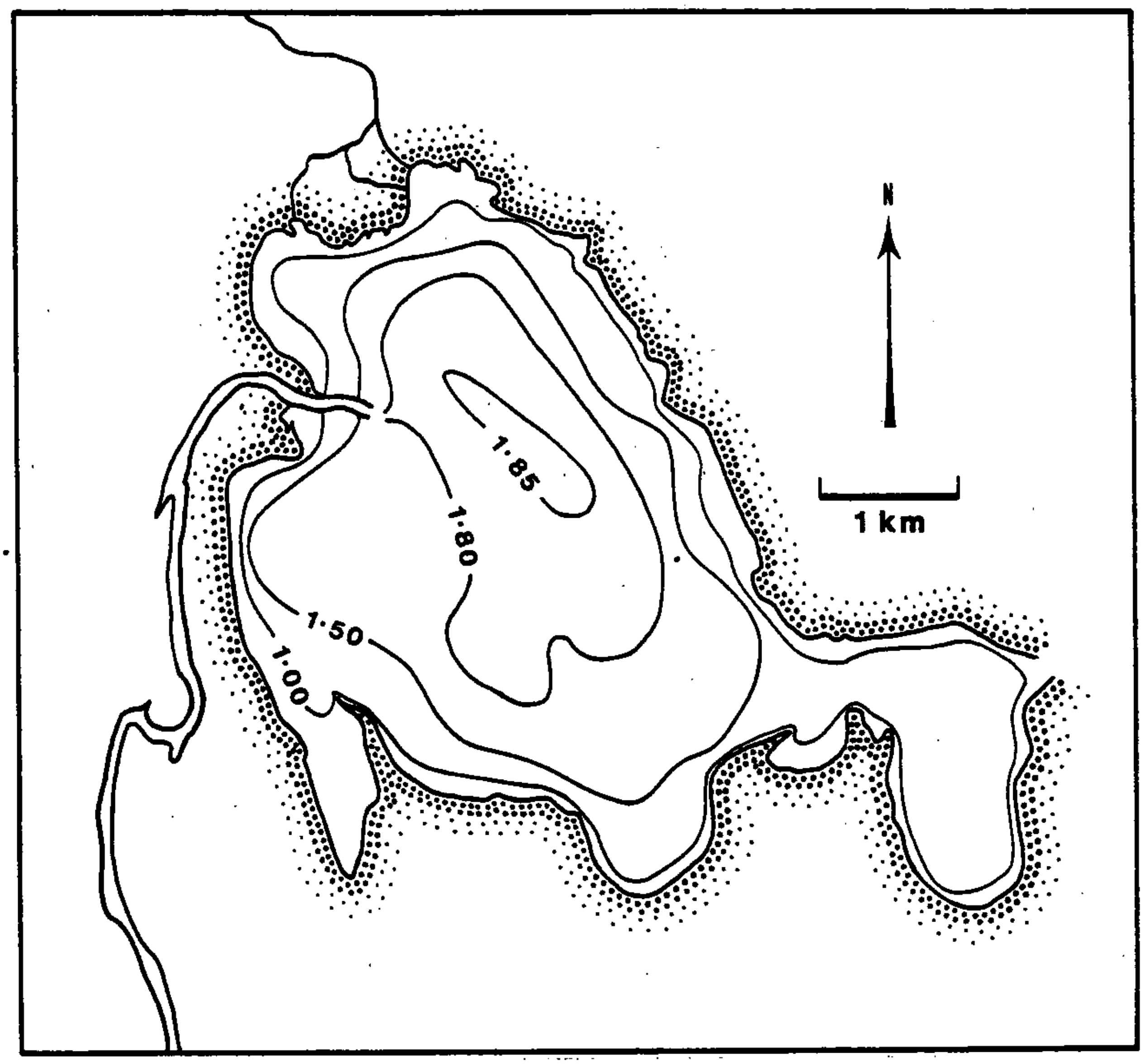
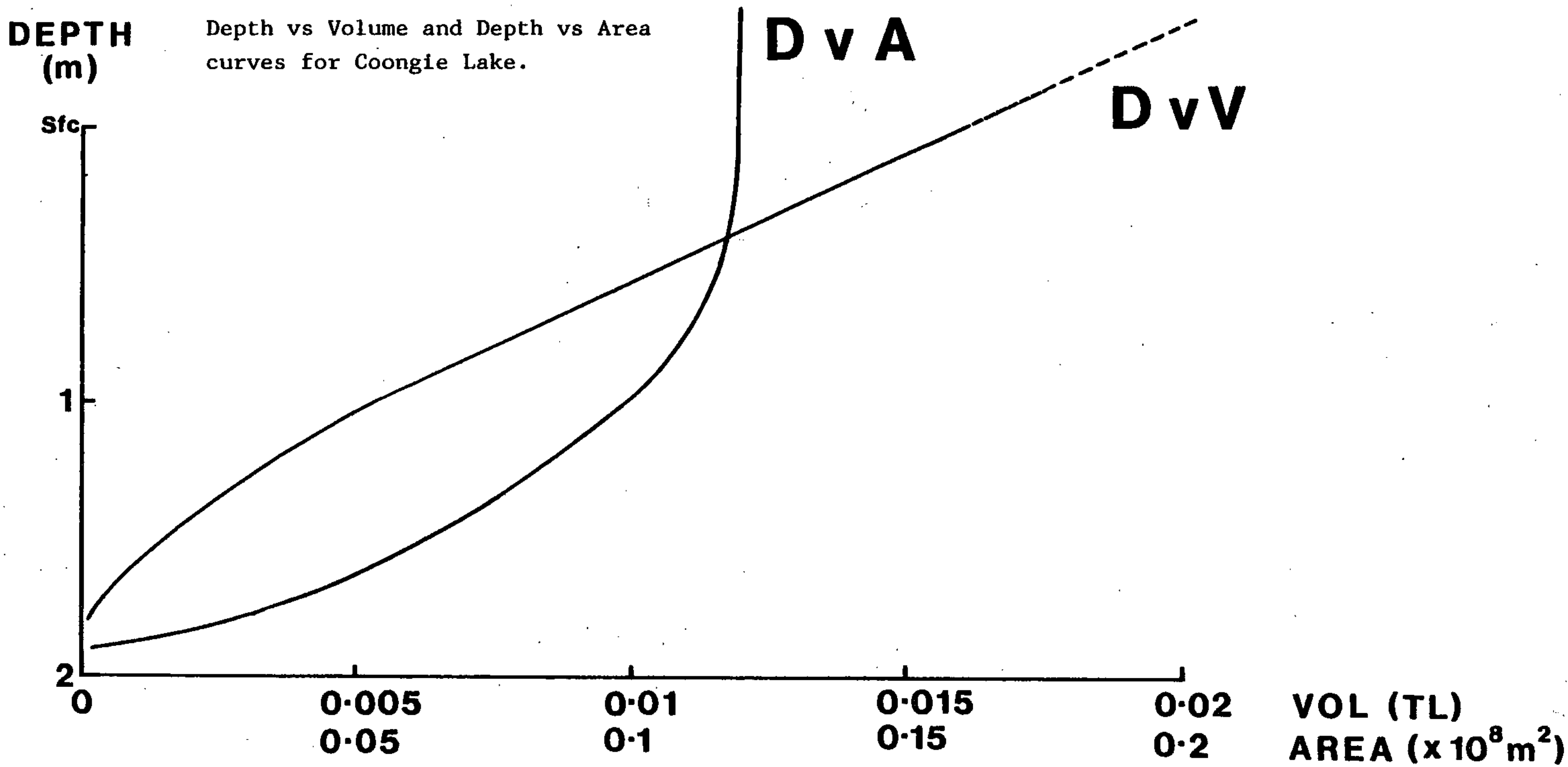


Figure 3.3

Bathymetry of Coongie Lake. Contours in meters.

Figure 3.4

Depth vs Volume and Depth vs Area curves for Coongie Lake.



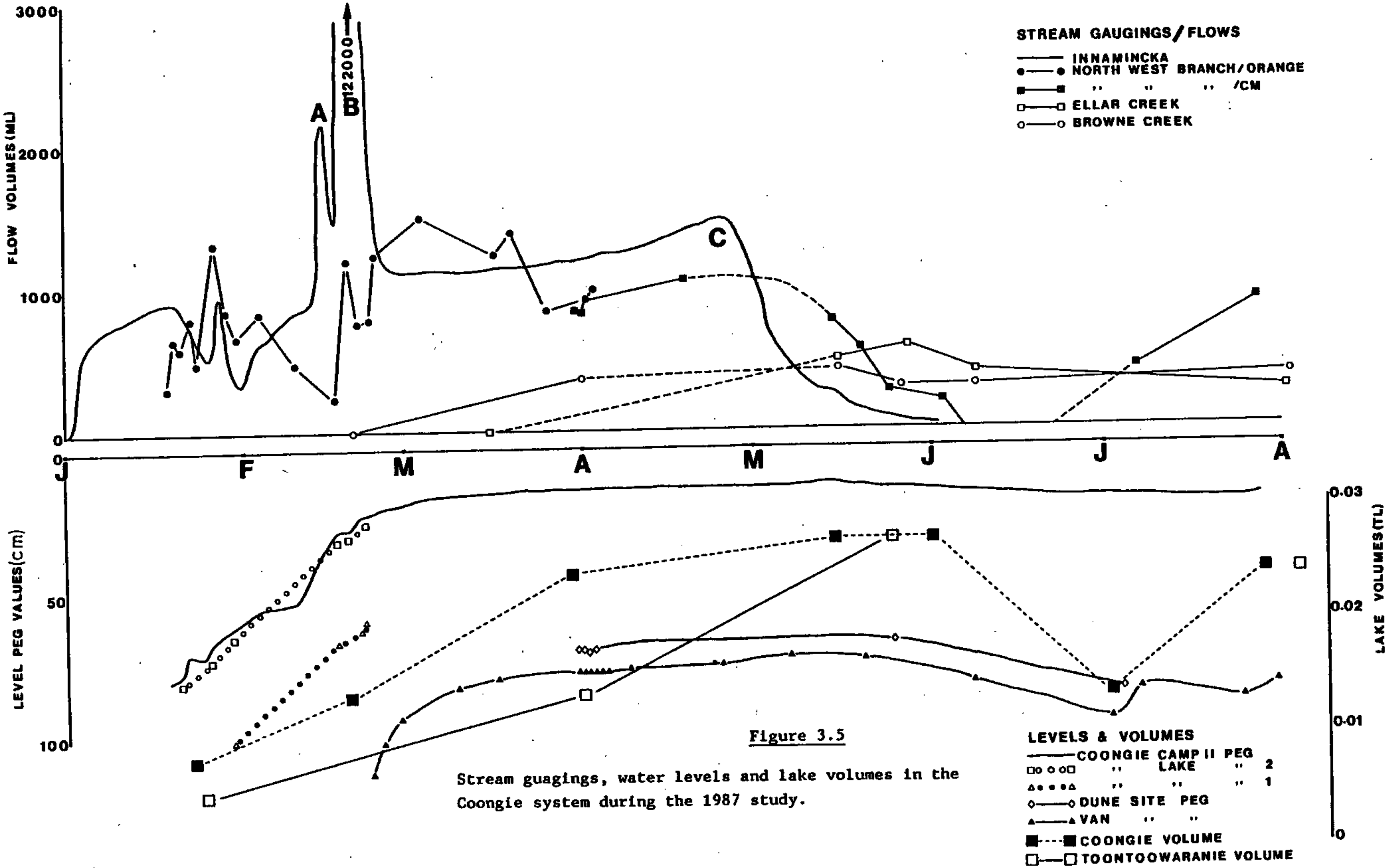


Figure 3.5

Stream guagings, water levels and lake volumes in the Coongie system during the 1987 study.

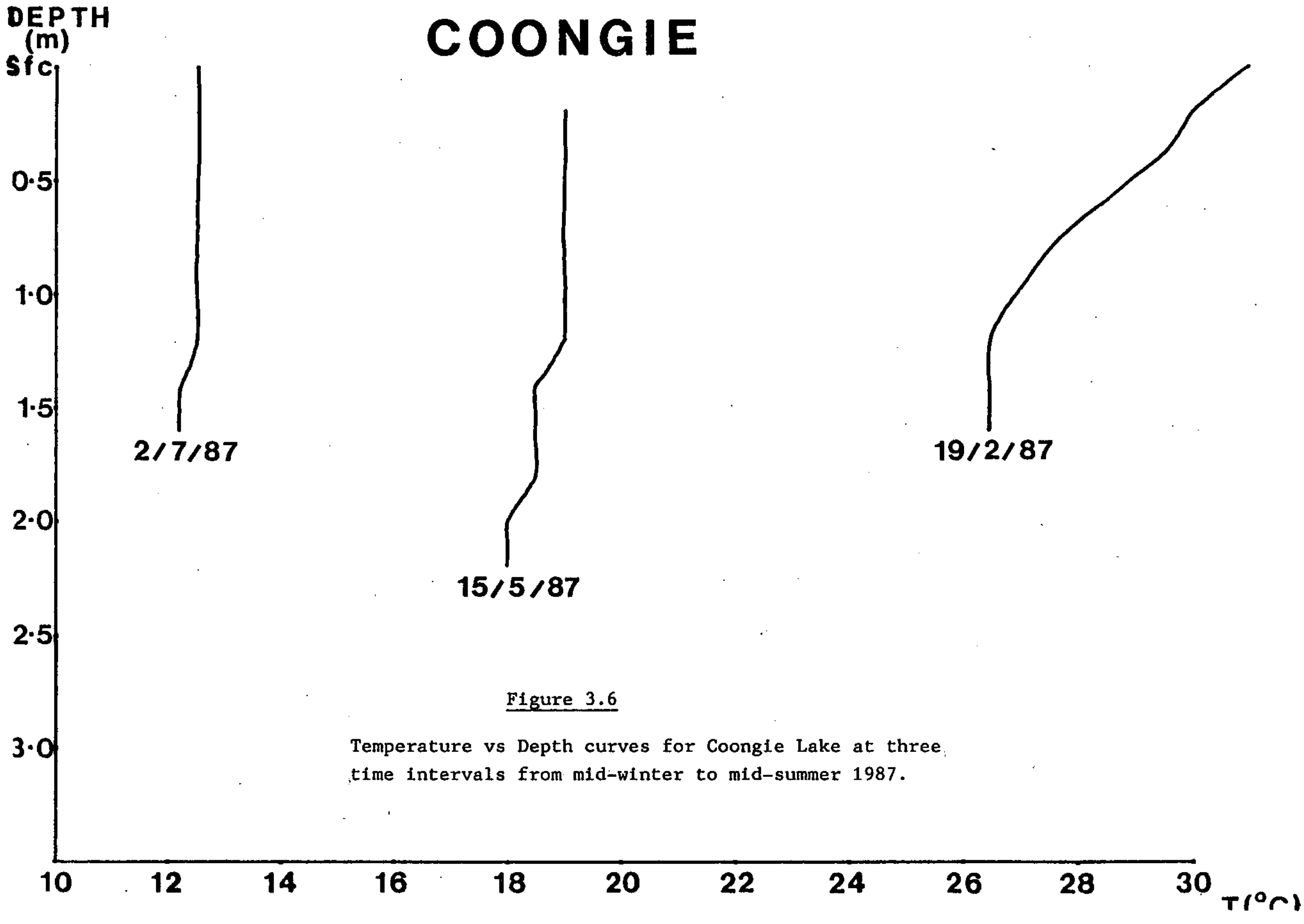


Figure 3.6

Temperature vs Depth curves for Coongie Lake at three time intervals from mid-winter to mid-summer 1987.

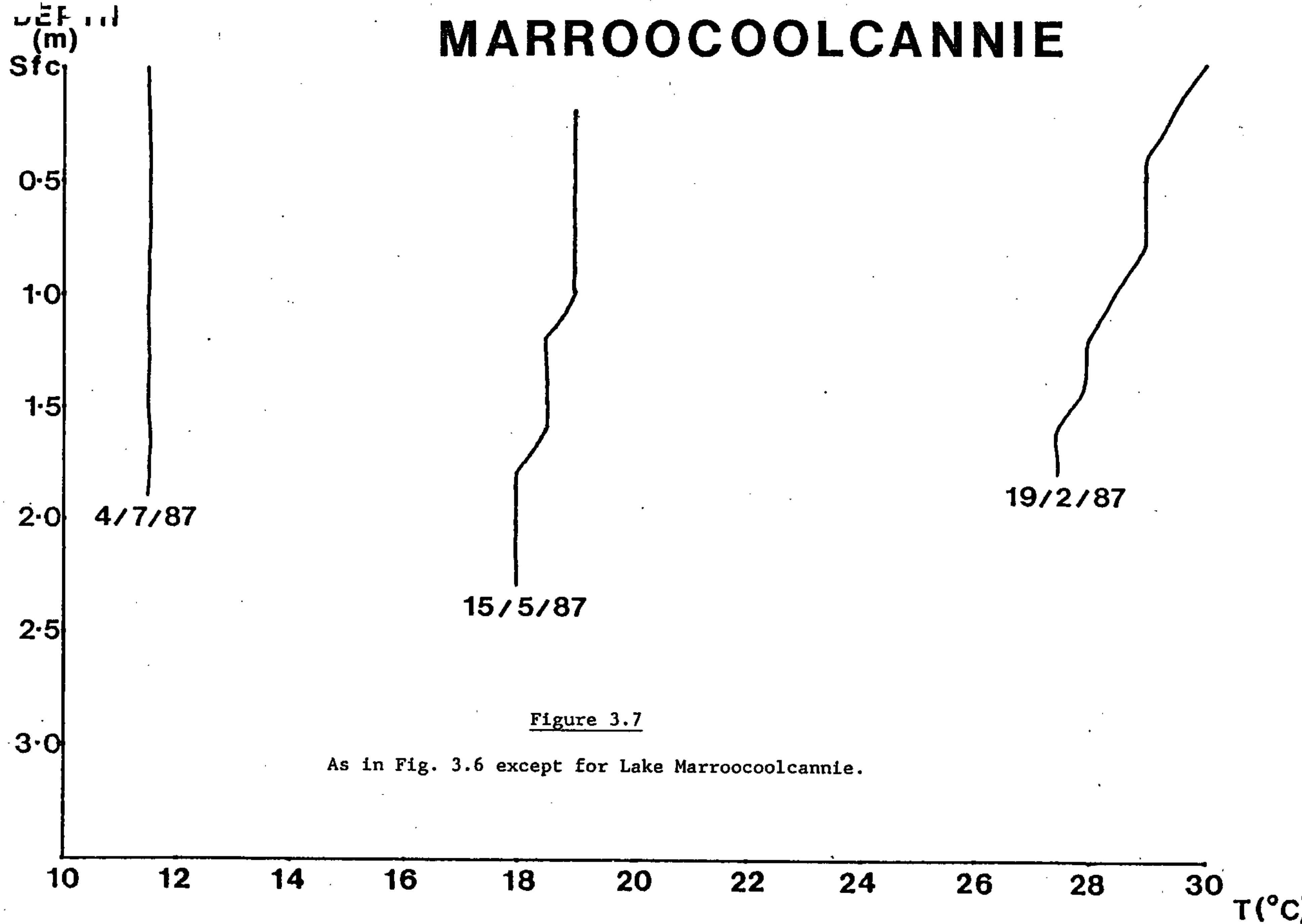
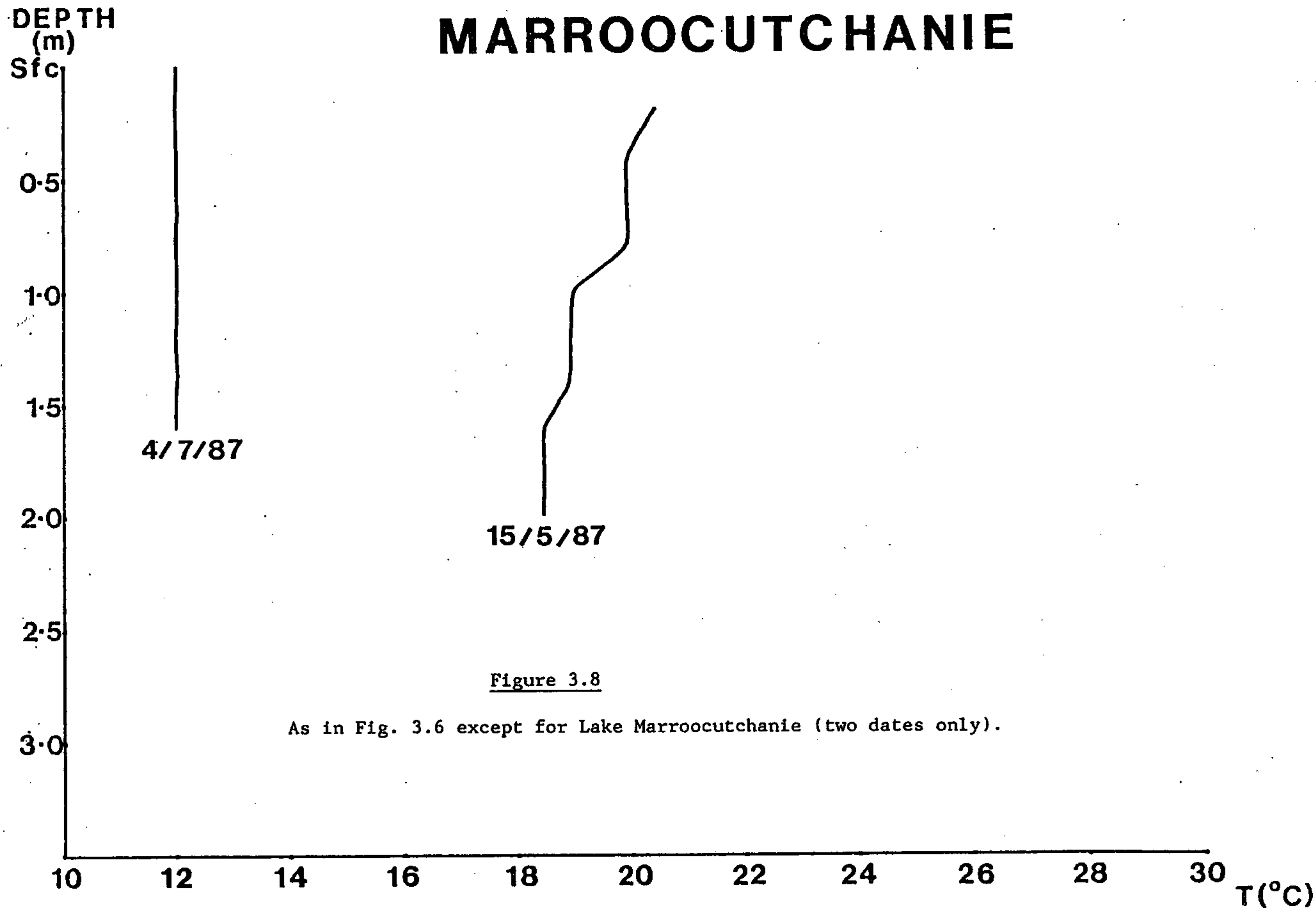


Figure 3.7

As in Fig. 3.6 except for Lake Marroocoolcannie.



<u>Figure 3.8</u>

As in Fig. 3.6 except for Lake Marroocutchanie (two dates only).

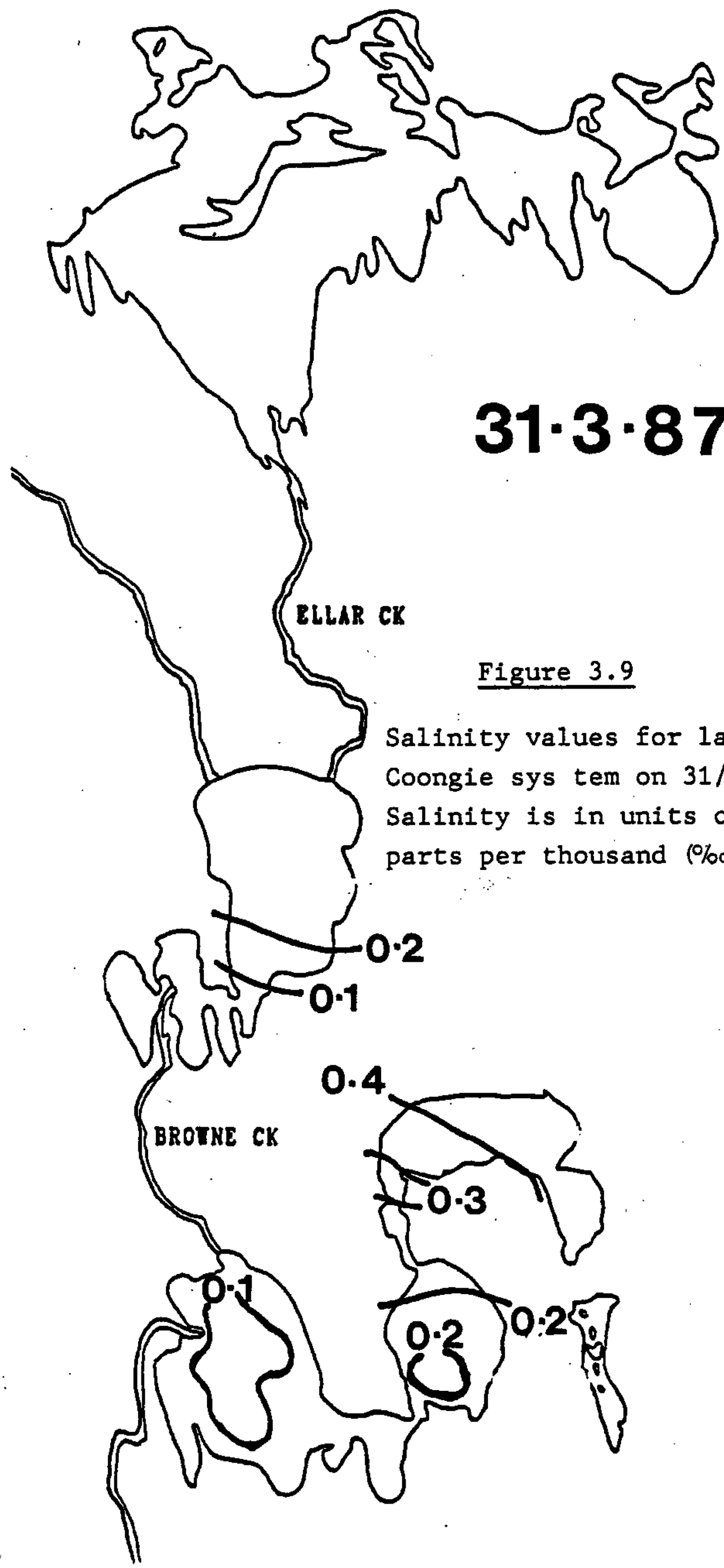


Figure 3.9

Salinity values for lakes in the Coongie sys tem on 31/3/87. Salinity is in units of parts per thousand (‰).

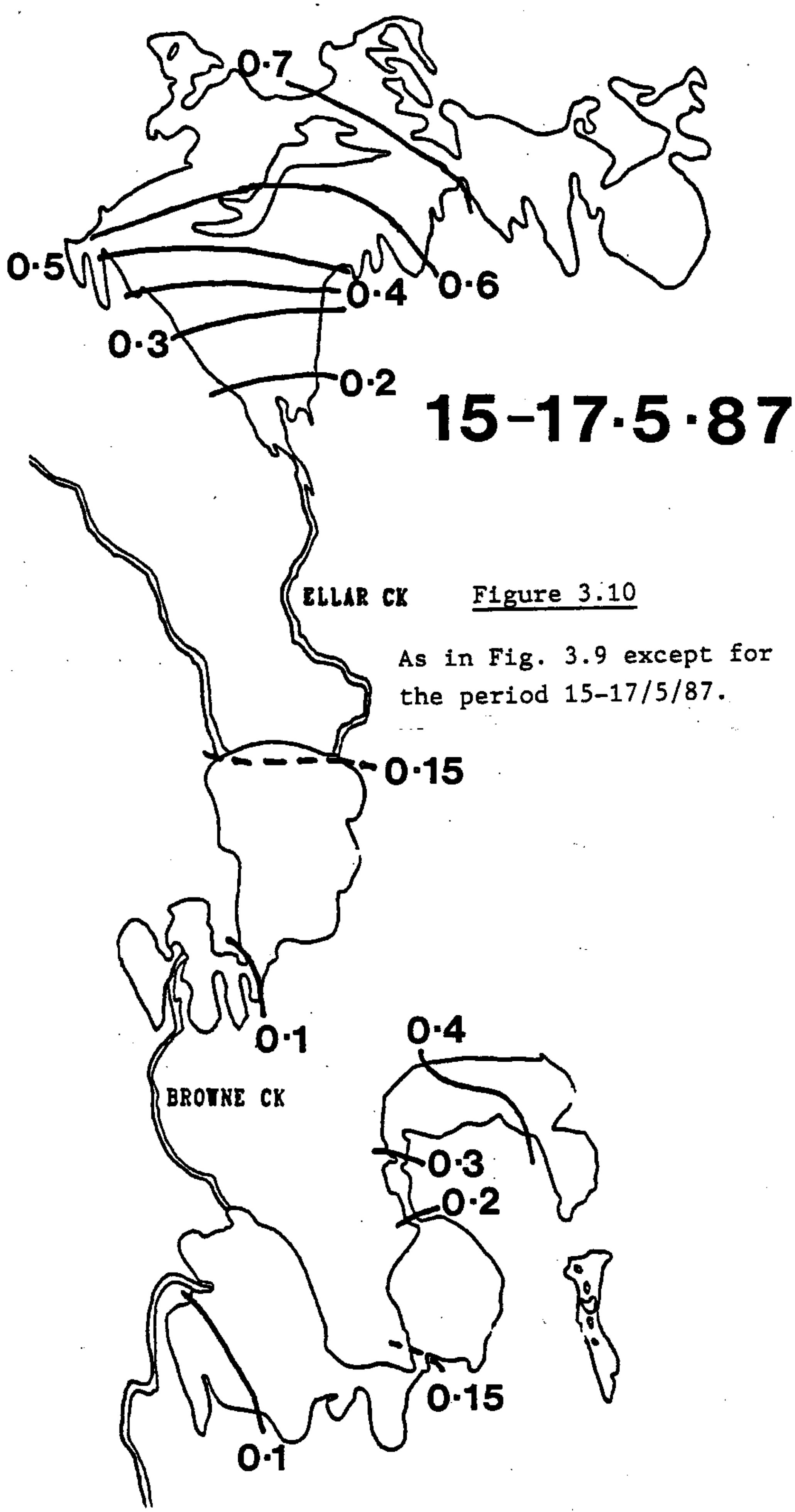


Figure 3.10

As in Fig. 3.9 except for the period 15-17/5/87.

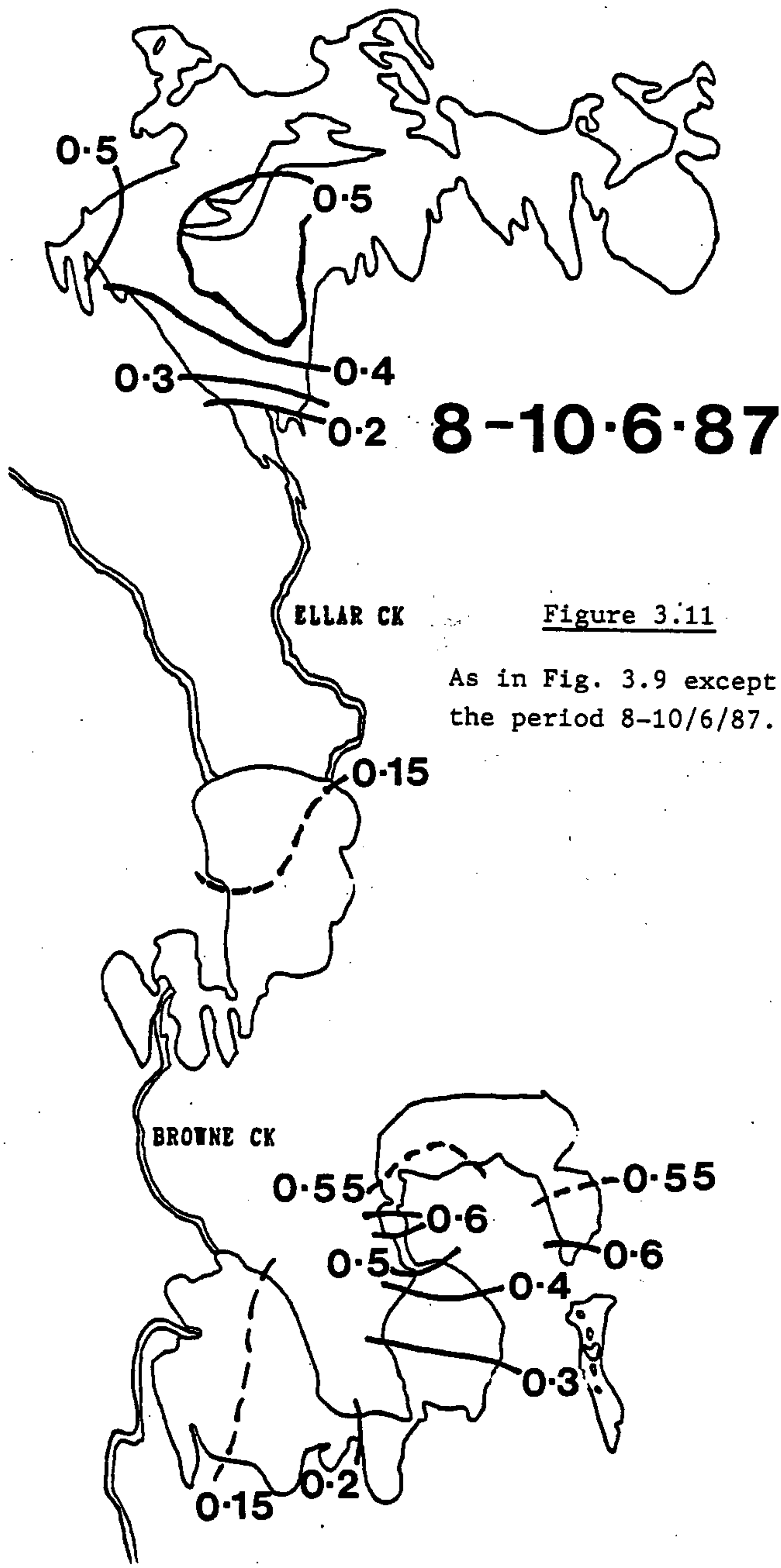


Figure 3.11

As in Fig. 3.9 except for the period 8-10/6/87.

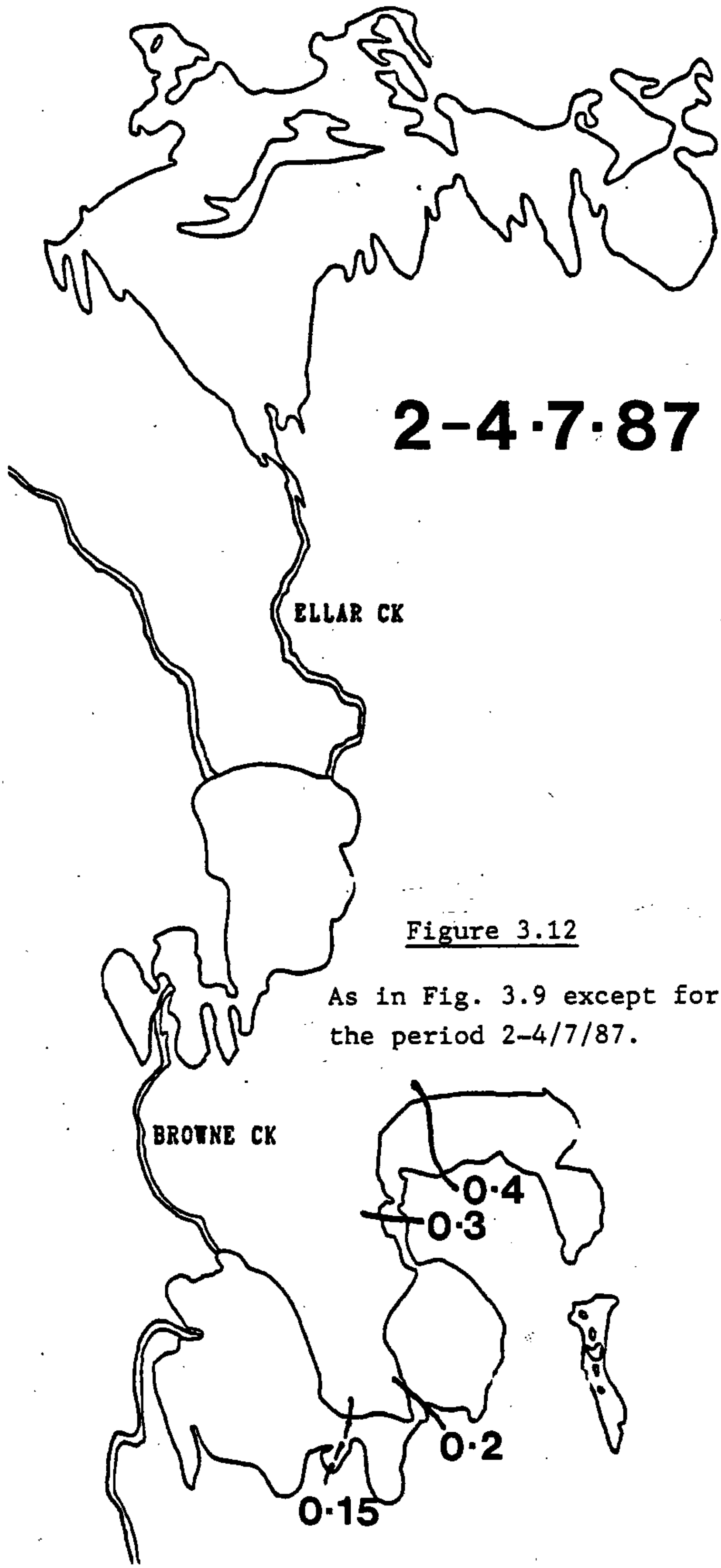


Figure 3.12

As in Fig. 3.9 except for the period 2-4/7/87.

Figures 3.13-29

The following series of aerial photographs and satellite images covers the Coongie Lakes system from 1958 to 1986. Figure captions are only given if there's ambiguity over the locality or direction of view (for oblique photographs).

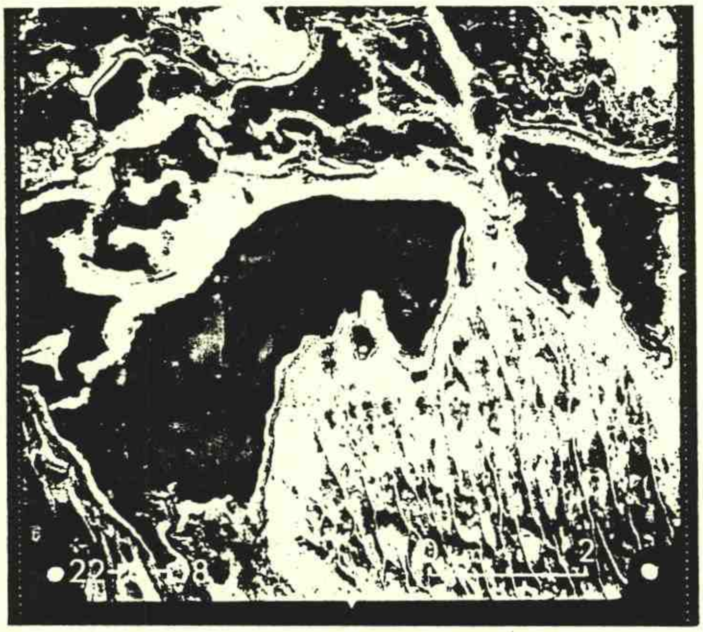


Figure 3.13

Lake Goyder

Figure 3.14a) Lake Goyder and Ellar Creek

Figure 3.14b)

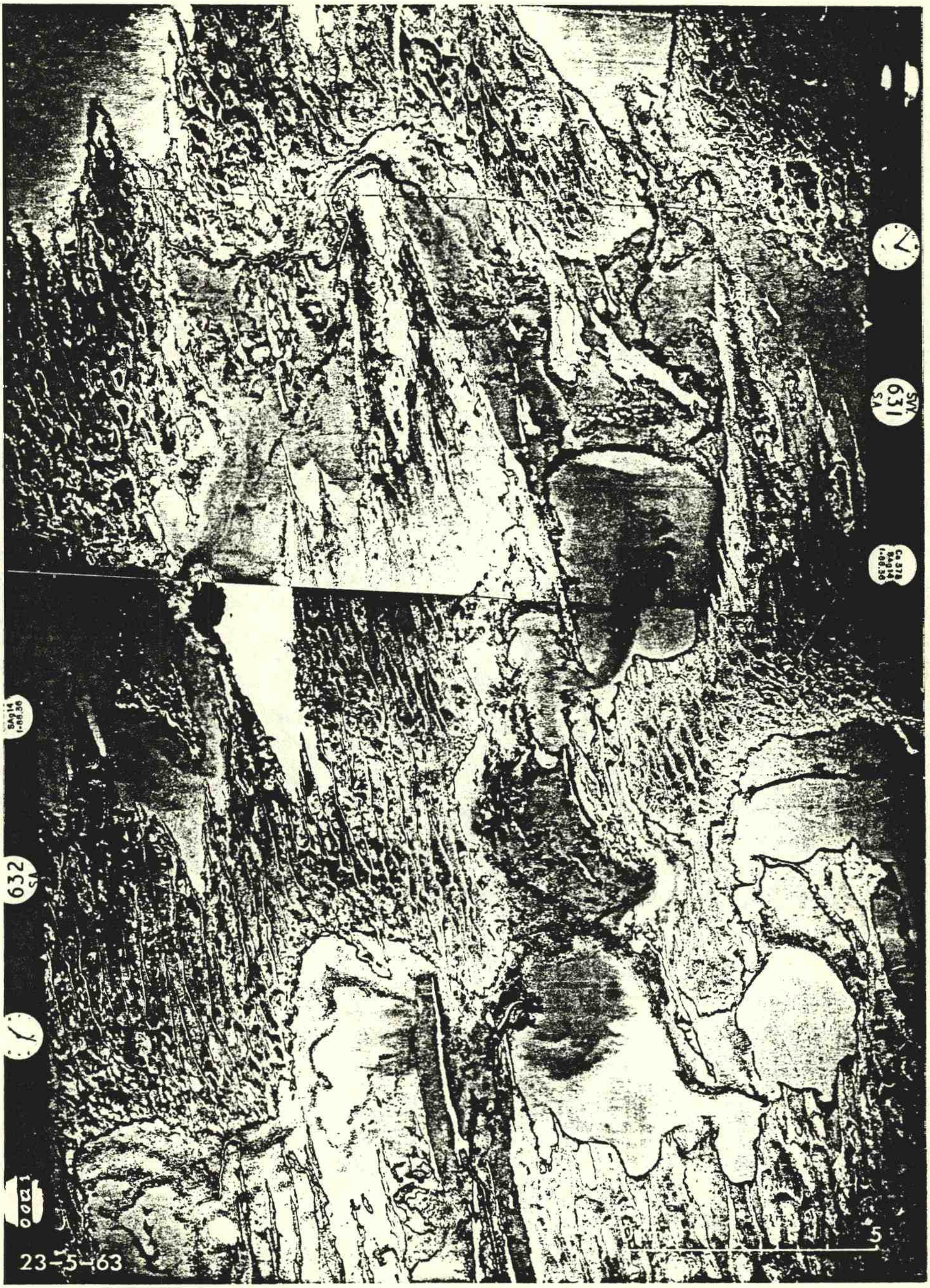


Figure 3.15

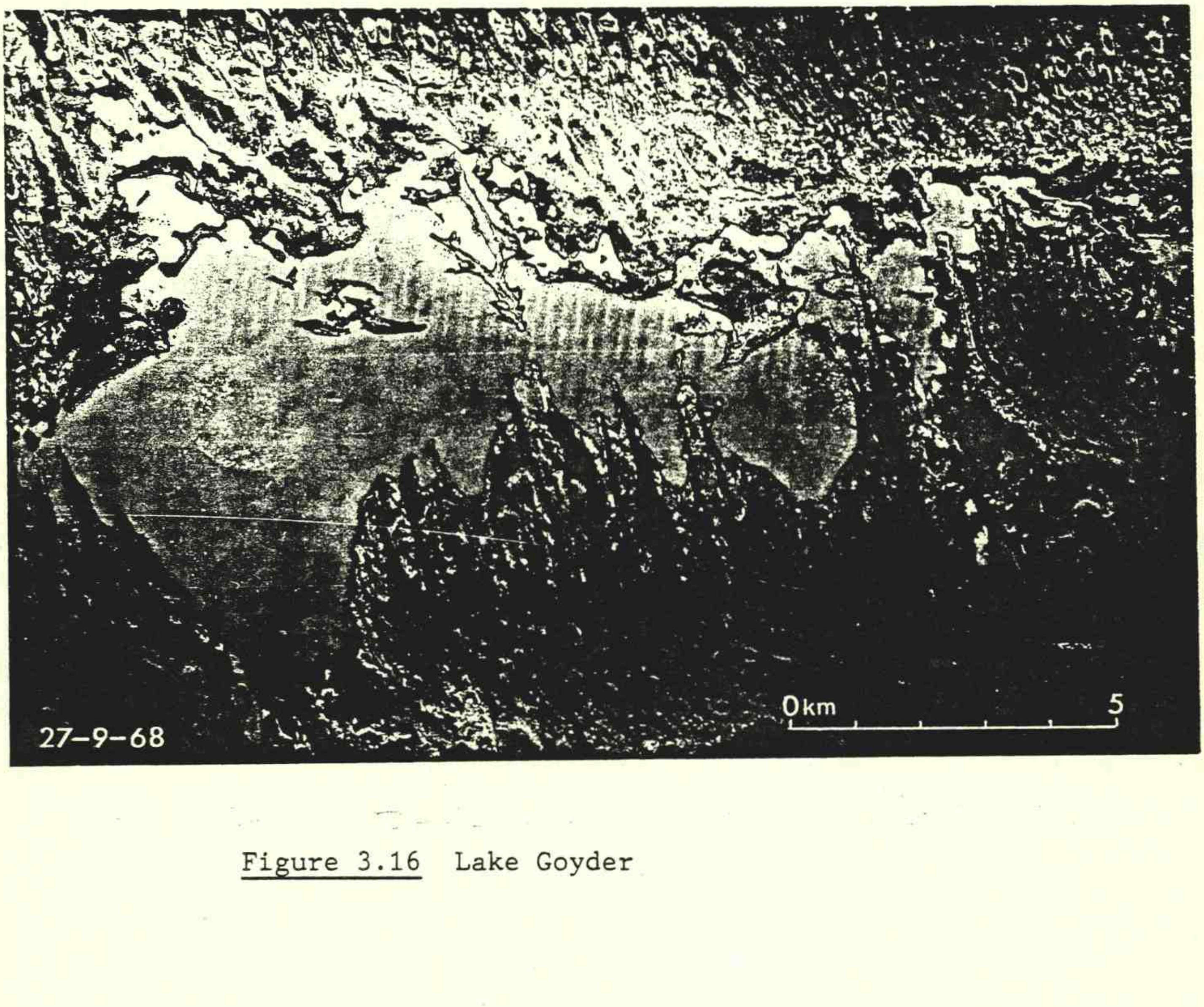


Figure 3.16 Lake Goyder

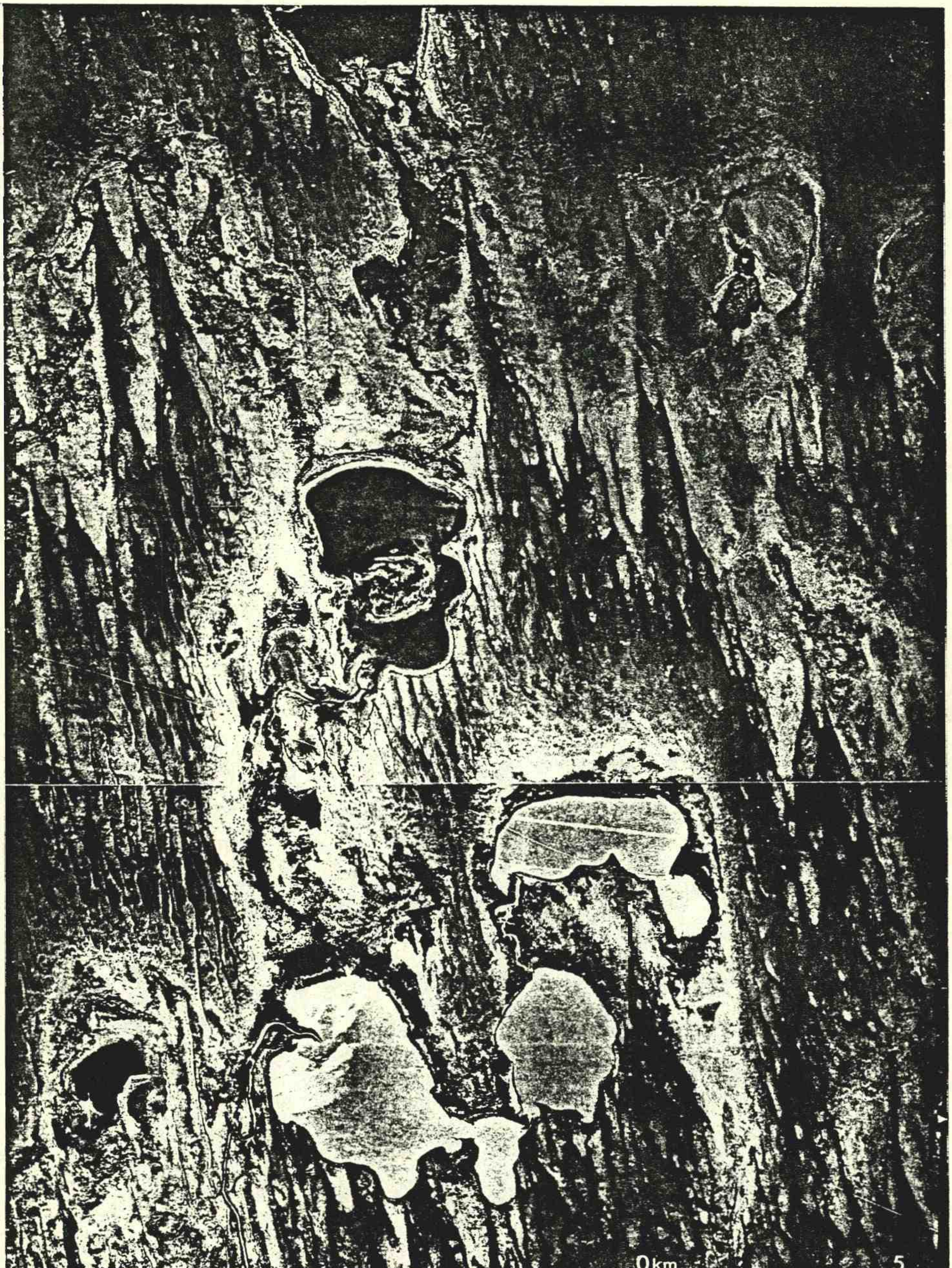


Figure 3.17

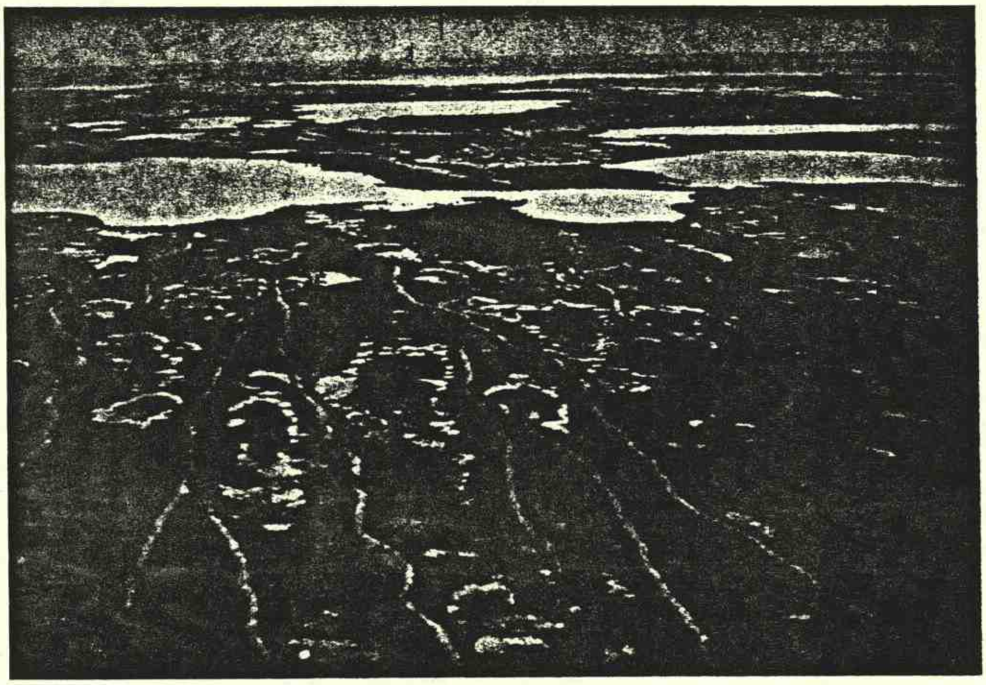


Figure 3.18a) North across Coongie (left) with Marroocoolcannie (right) and other three lakes visible.

October 1971.

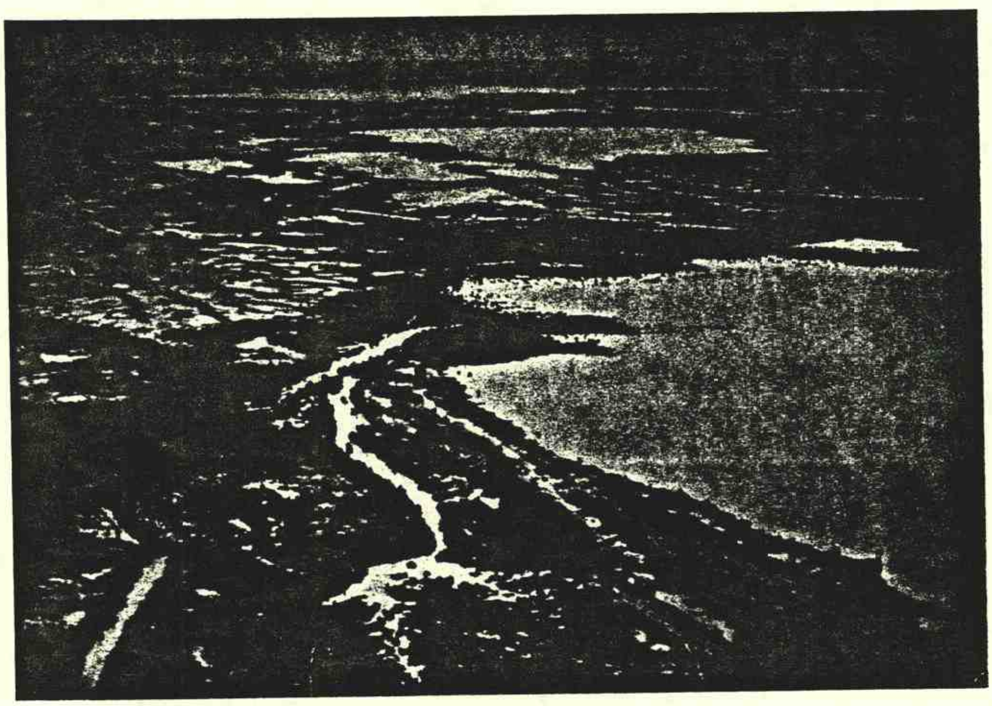


Figure 3.18b) North over the western and northern half of Coongie towards Toon-toowaranie and Goyder.

October 1971.

Figure 3.19

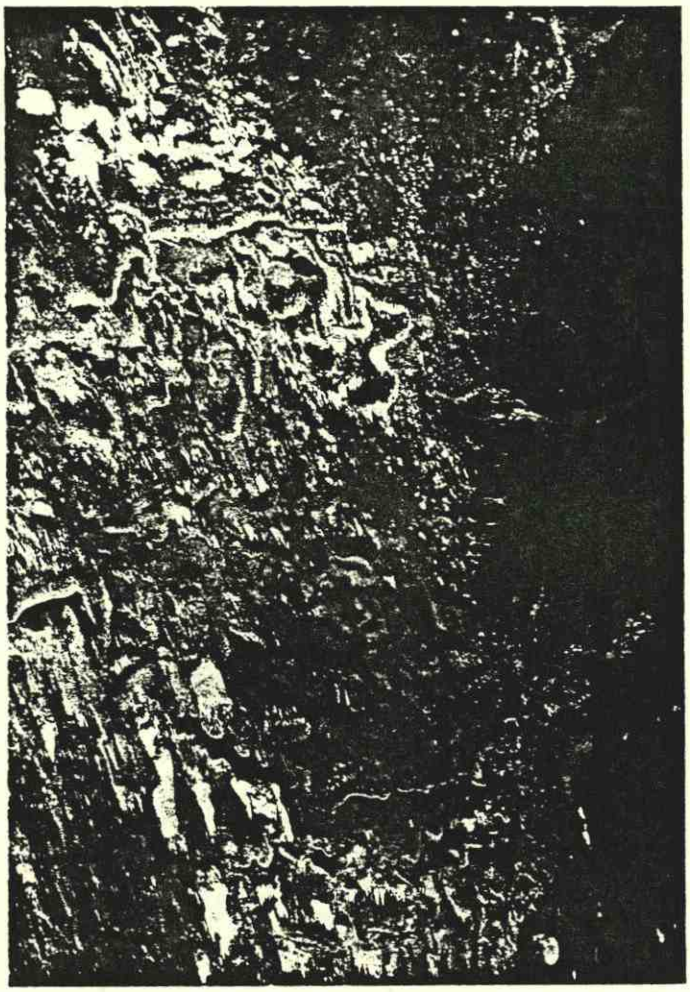


Figure 3.20 — Cooper Creek floodplain to west of Innamincka (Coongie Lakes system in upper-left quarter).

7/2/74.

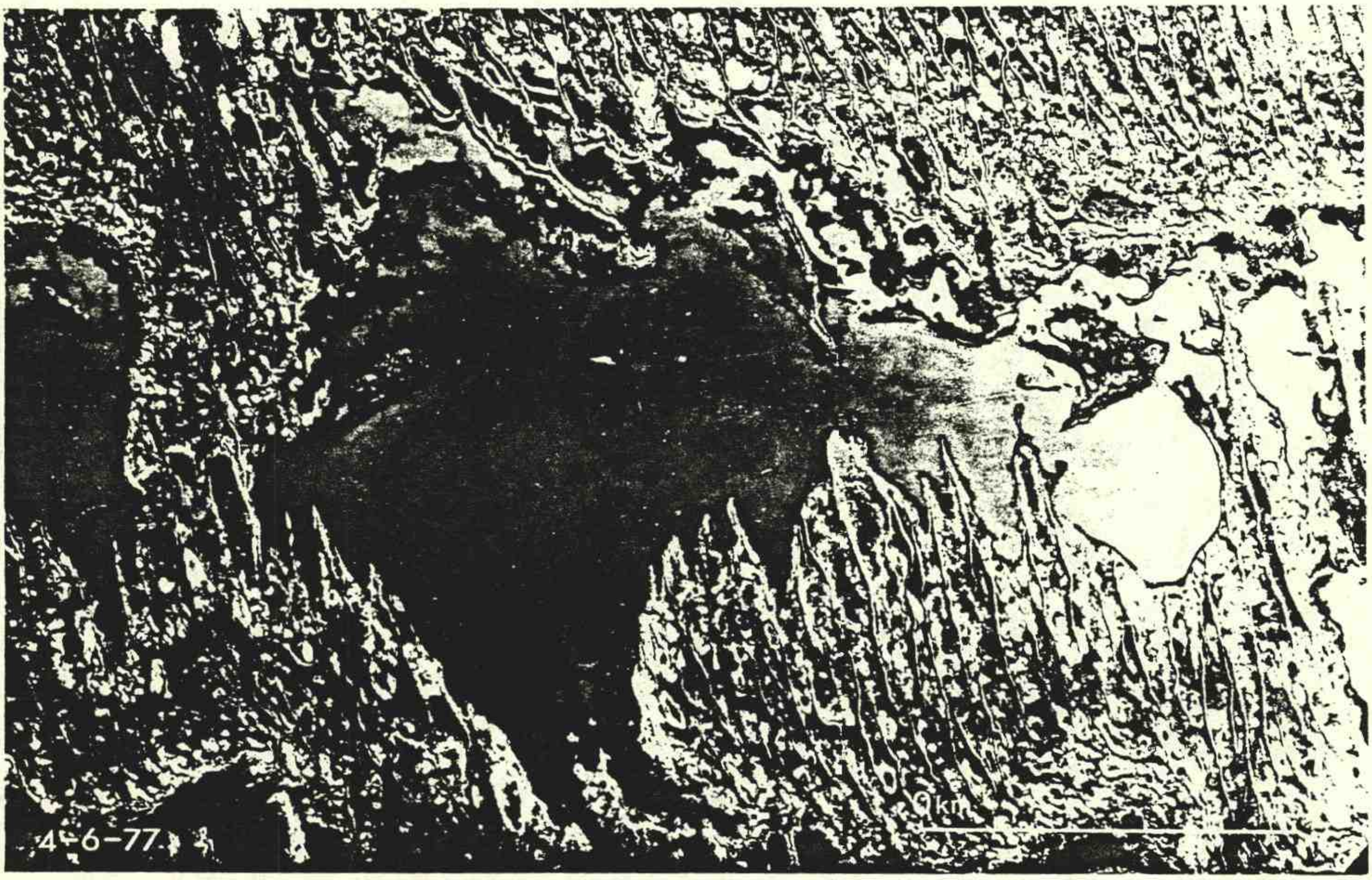


Figure 3.21 Lake Goyder (Marradibbadibba and Sturt Ponds at right).

Figure 3.22

Figure 3.23 24/9/80

Figure 3.24

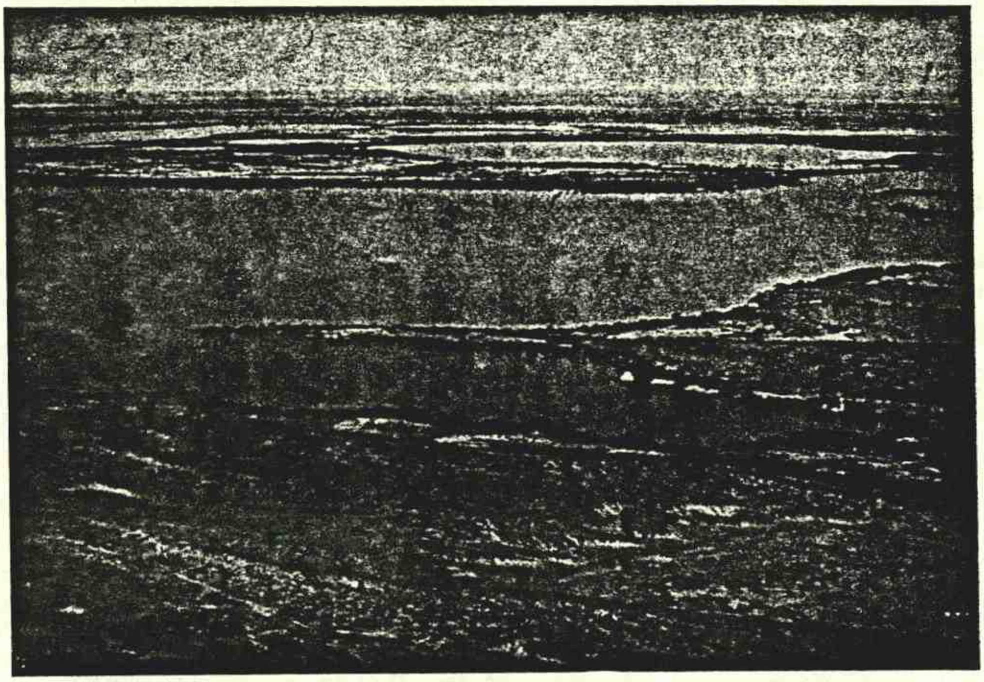


Figure 3.25a) ENE across the southern half of Coongie Lake (Marroocoolcannie behind).

September 83.

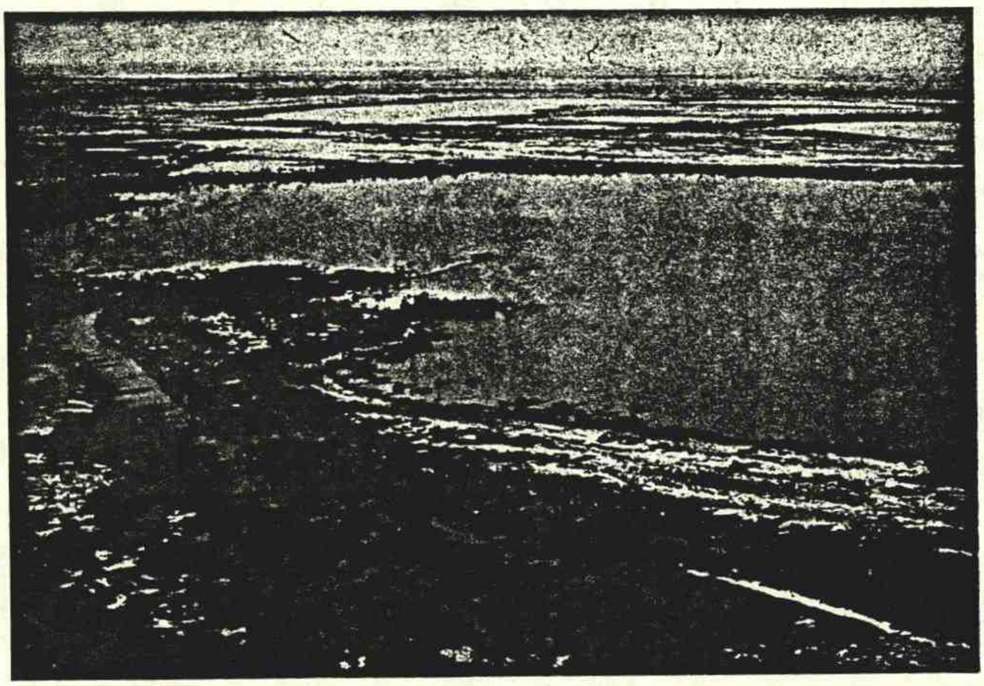


Figure 3.25b) NE across the delta area of Coongie Lake (Marroo-cutchanie behind).

September 83.

Figure 3.26

Figure 3.27a) WNW across Coongie Lake.

June 1985.

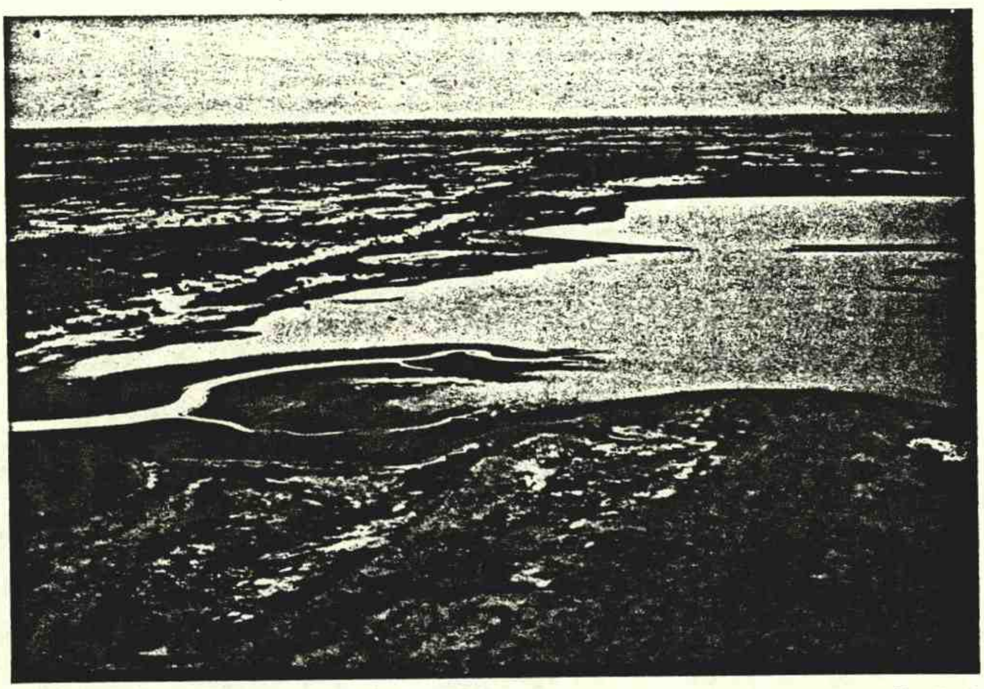


Figure 3.27b) NW across the southern end of Lake Toontoowaranie.

June 1985

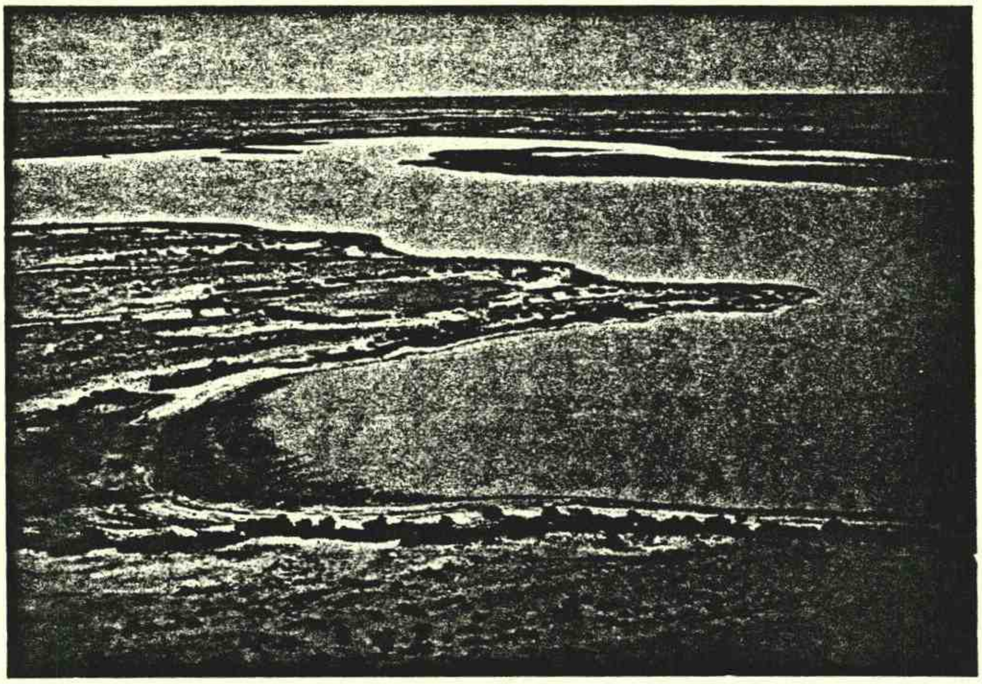


Figure 3.27c) NW across Toontoowaranie. June 1985.

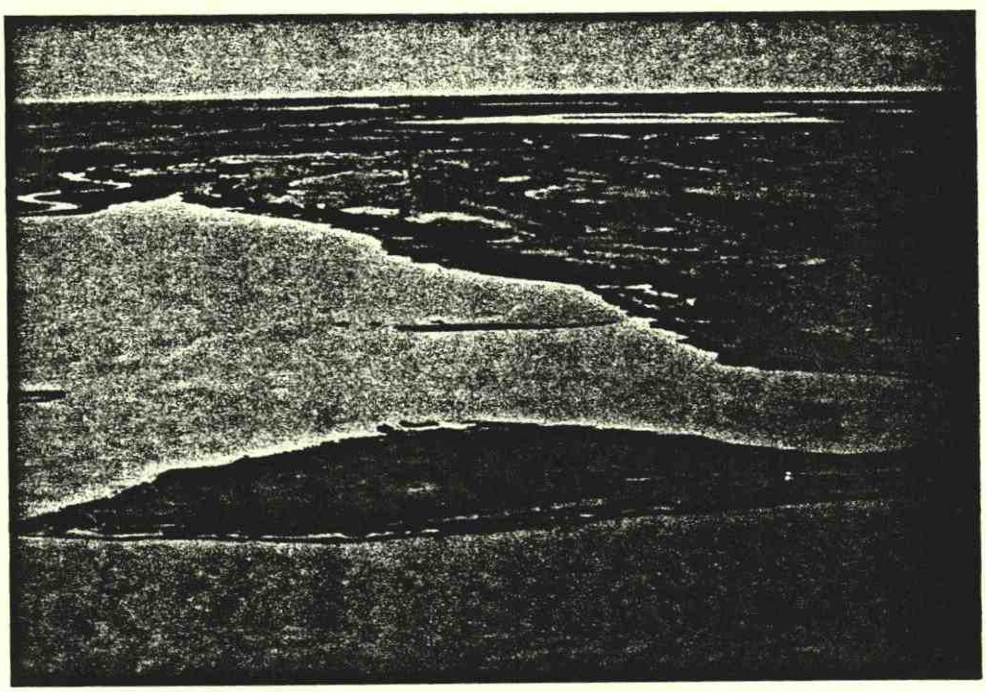
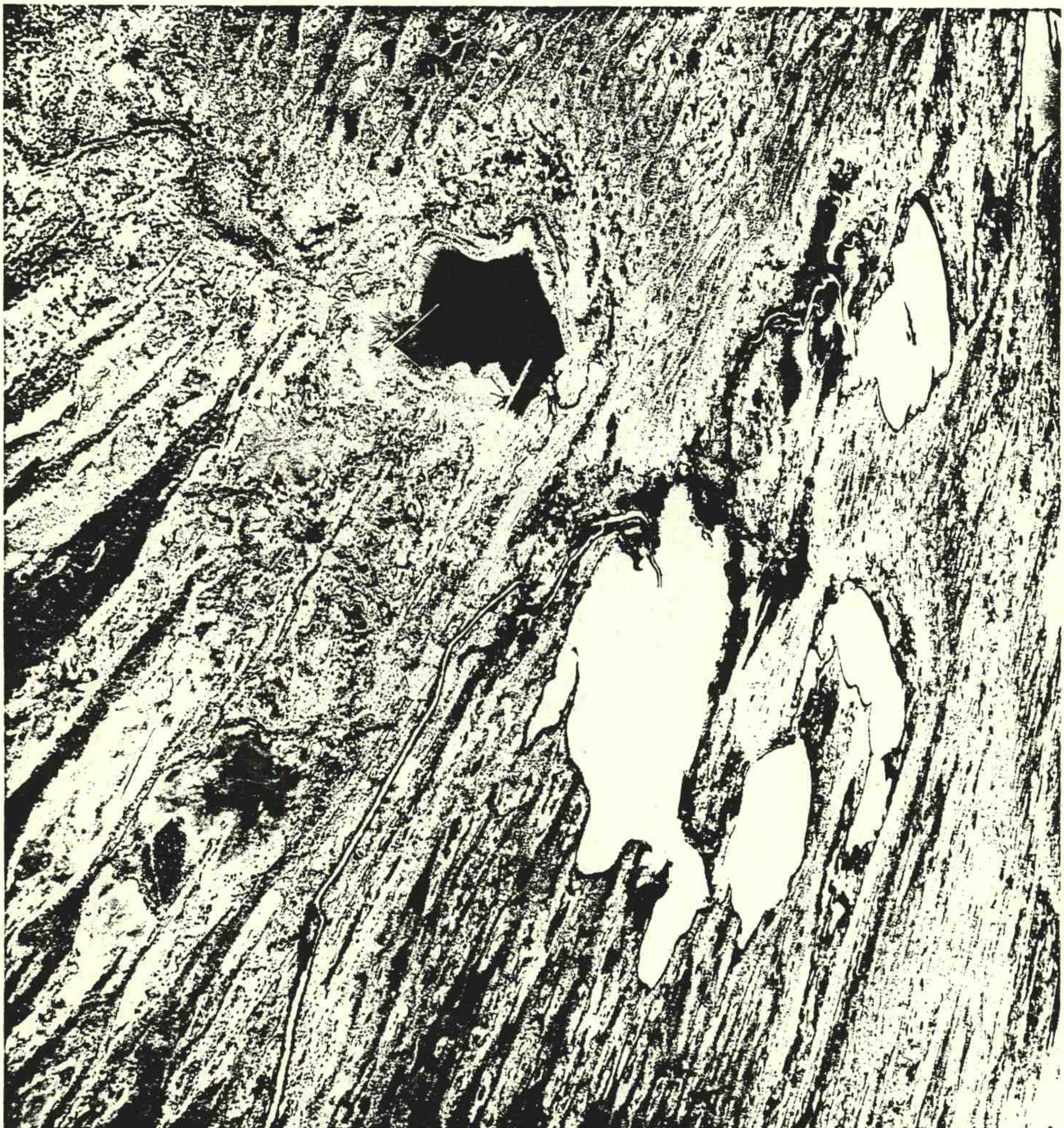


Figure 3.27d) South across the western shore of Goyder towards Toontoowaranie. June 1985.

Figure 3.29

Aerial oblique from the south-west.



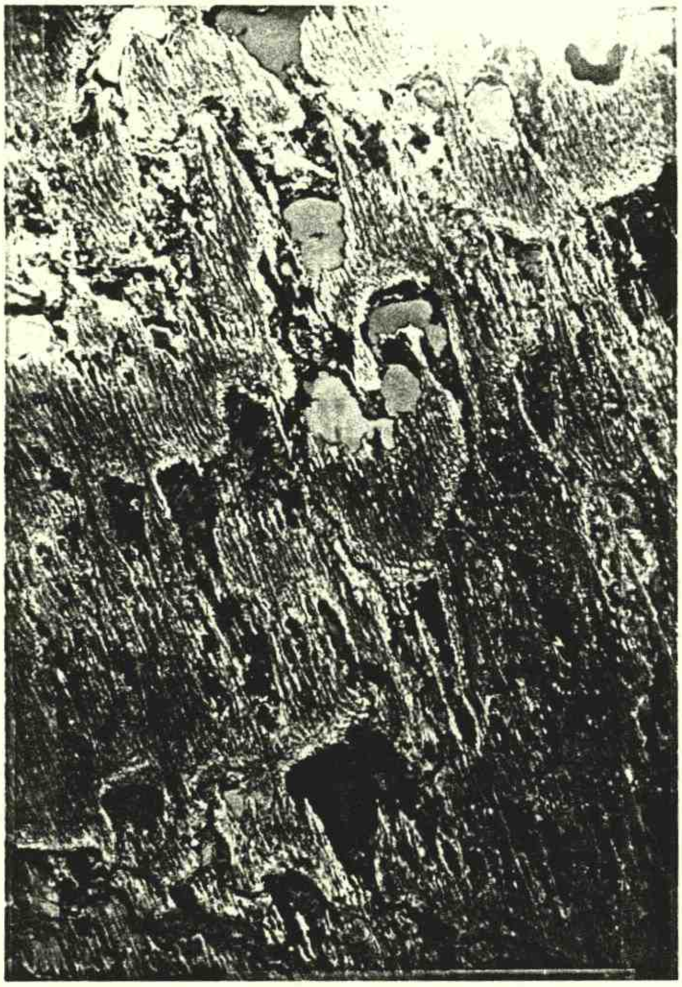


Figure 3.28 8/6/86.

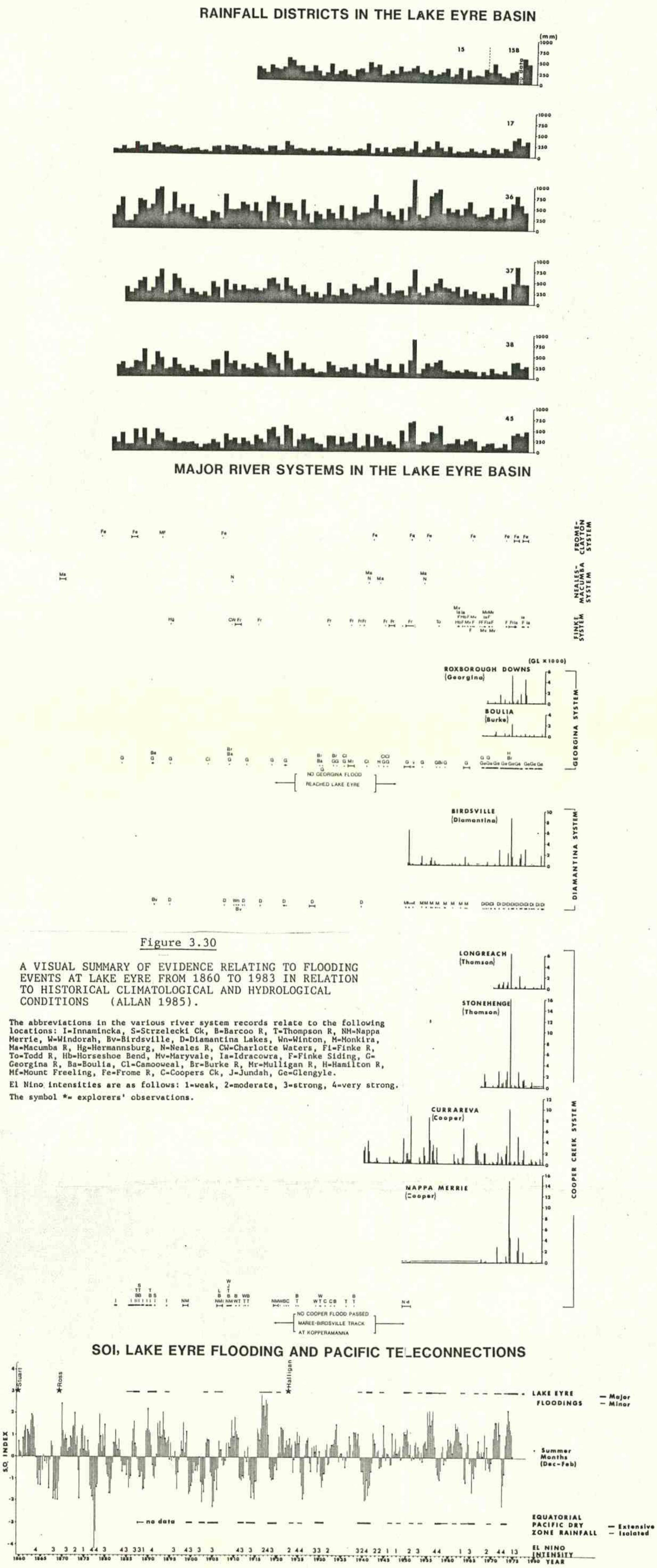


Figure 3.30

A VISUAL SUMMARY OF EVIDENCE RELATING TO FLOODING EVENTS AT LAKE EYRE FROM 1860 TO 1983 IN RELATION TO HISTORICAL CLIMATOLOGICAL AND HYDROLOGICAL CONDITIONS (ALLAN 1985).

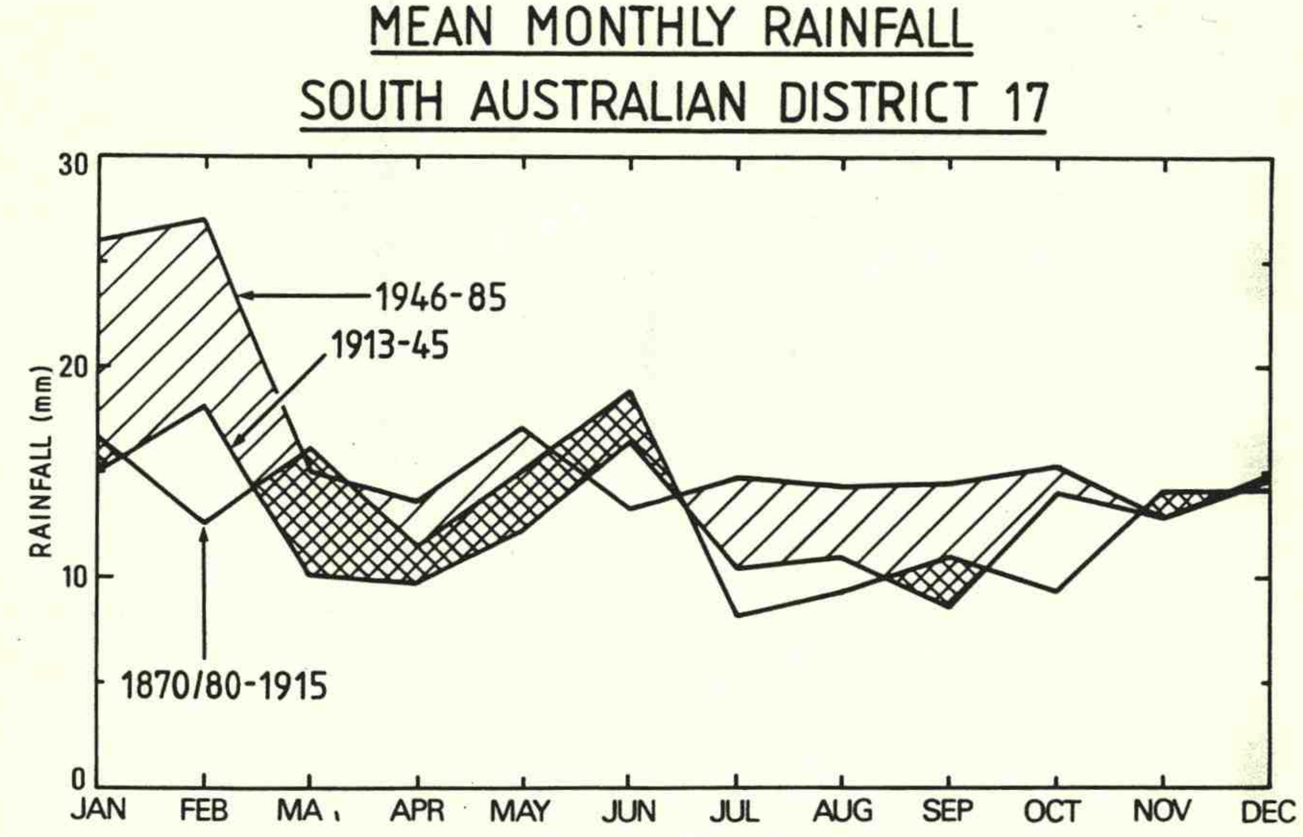
The abbreviations in the various river system records relate to the following locations: I=Innamincka, S=Strzelecki Ck, B=Barcoo R, T=Thompson R, NM=Nappa Merrie, W=Windorah, Bv=Birdsville, D=Diamantina Lakes, Wn=Winton, M=Monkira, Ma=Macumba R, Hg=Hermannsburg, N=Neales R, CW=Charlotte Waters, Fi=Finke R, To=Todd R, Hb=Horseshoe Bend, Mv=Maryvale, Ia=Idracowra, F=Finke Siding, G=Georgina R, Ba=Boulia, Cl=Camooweal, Br=Burke R, Mr=Mulligan R, H=Hamilton R, Mf=Mount Freeling, Fe=Frome R, C=Coopers Ck, J=Jundah, Ge=Glengyle.

El Nino intensities are as follows: 1=weak, 2=moderate, 3=strong, 4=very strong.

The symbol *= explorers' observations.

Figure 3.31

Monthly mean rainfall in District 17 covering the North East of South Australia for three time periods: 1870/80 - 1915, 1913 - 1945, 1946 - 1985 (Allan 1985).



4. AQUATIC BIOLOGY OF COONGIE LAKES

Jane Roberts

4.1 Introduction

Compared to terrestrial ecology, limnology is a relatively young science, and limnology of arid and semi-arid climates is one of its youngest branches. In hot dry climates, most limnological research is directed towards man-made storage and supply systems. The limnology of natural waterbodies is only beginning to be known and in South Australia, research has concentrated mainly on saline lakes (e.g. Williams 1985) and the small, popularly romantic mound springs (Mitchell 1985). The extent to which overseas research on shallow fresh lakes, such as Lake Chad, can be applied to inland lakes such as the Coongie Lakes, cannot be determined until our understanding of these lakes reaches a level where meaningful comparisons could be made.

Similarly, the ecology of flood-plain rivers in arid Australia is not well known and, with the exception of the River Murray, very little documented. This is especially true of Cooper Creek. Its remoteness and lack of economic significance mean that information on its water quality is limited and somewhat fragmented.

In 1978, the Engineering and Water Supply Department began a five year monitoring programme to establish surface water quality characteristics for all major catchments in South Australia (Glatz 1985). There were two sampling stations on Cooper Creek, both upstream of Innamincka or over one hundred kilometres from Coongie Lake. Water samples were collected from only one of these, the Callyamurra Waterhole, from July 1978 to June 1983.

In this period, river water at Callyamurra, was fresh (mean conductivity of 170 microSiemens cm^{-1}) and turbid (mean turbidity of 226 nephelometric turbidity units or NTU) with fairly high nitrogen and phosphorus concentrations, the mean total phosphorus (TP) and total Kjeldahl nitrogen (TKN) concentrations being 0.42 and 0.93 mg l^{-1} respectively (Glatz 1985). Because there are no surface water inflows between Callyamurra Waterhole and Coongie Lake, these characteristics might also be expected for river water in the North-West Branch, despite the intervening distance. However, an earlier record of 1270 microSiemens cm^{-1} from Coongie Lake itself, is well above the maximum of 270 microSiemens cm^{-1} at Callyamurra WH (Table 2 in Mollenmans et al. 1984) and shows that lake water may not be so fresh.

The biological characteristics of both Cooper Creek and Coongie Lakes have not been investigated, and consequently there are no estimates of primary or secondary production, nor even the abundance and standing crop of phytoplankton or zooplankton.

Scope of this study

Previous surveys in the area have concentrated on terrestrial ecology (Foale 1982, Mollemans et al. 1984), and in the absence of relevant biological data, wetlands were classified using morphological attributes, while open-water habitats were, of necessity, ignored (Mollenmans et al. 1984). Because the spatial and temporal variability within the aquatic habitats has not been explored, variability was chosen as the theme for this study.

The area has distinctive features. Many of the lakes and swamps, such as Coongie, Goyder and Tirrawarra, are part of the main channel of the North-West Branch. River and lake are directly connected, when the river is flowing. Variations in river flow mean this connection is not permanent, but the frequency, duration and likely variability of this has been only tentatively established (Mollenmans et al. 1984). This intermittent conection between river and lake adds another dimension to their variability. Thus the specific aim of this part of the Coongie Lakes study was to contrast the North-West Branch with Coongie Lake, first by comparing them as environments and second by comparing their respective species assemblage and abundance.

The two environments are described in terms of selected water quality parameters and patterns of diurnal change in stratification as shown by temperature and oxygen profiles. Phytoplankton standing crop was estimated as chlorophyll-a concentrations and zooplankton abundance as concentration of animals in the water. Estimates of primary and secondary production, although desirable, were beyond the personnel, analytical facilities and financial resources available. A further limitation was the short duration of the field trip, approximately two weeks in early December 1986, which meant seasonal dynamics and long-term change could not be observed.

A survey of macrophytes (aquatic plants other than microscopic algae) was also included because of their significant role in wetland ecology, as their presence gives structural diversity to a wetland. Stands of macrophytes alter water and flow characteristics, thus they offer a range of micro-habitats and substrates to invertebrates and fish which are not available otherwise. In addition their presence is an indication of water regime in that water is present long enough to complete their life cycle occasionally. This structural diversity is due in part to their variety of life-forms, the principal types being emergent, submerged, floating-leafed and free-floating plants. These names describe the usual position of the growing plant relative to the water surface, i.e. growing through, under or on the water.

4.2 Methods

Field

Diurnal changes in temperature and oxygen profiles were monitored at three sites in the main river channel on 6 December, and at three sites in the lake on 9 December (Figure 4.1). It was not feasible to monitor river and lake on the same day.

Profiles were also taken in the river at Site 1, near to midday, from 4 December to 9 December to monitor the persistence of flood conditions after heavy rain on the morning of 4 December. For each profile, the pH and conductivity of surface water was measured, and an integrated sample (see below) taken.

Integrated water samples were collected using a rigid PVC pipe (length 1515mm, internal diameter 38mm). Tube size and the shallow water column made it necessary to take multiple samples in order to get sufficient volume. These were mixed in a bucket, then subsampled. One litre was taken to Adelaide for laboratory analysis (Botany Department, University of Adelaide), for turbidity and total phosphorus. For chlorophyll-a estimates, a small volume (50-150ml, depending on sediment load) was concentrated on a Whatman GF/C filter within 3 hours of collections and the filter paper stored below freezing in a cannister of liquid nitrogen. For estimates of zooplankton abundance, fifteen litres were filtered through a 52 micron mesh net and the concentrate preserved in formalin. In addition, qualitative samples for zooplankton identification were taken by a single haul of a conical 52 micron net.

Temperature and oxygen profiles were done with a YSI Model 51B oxygen meter. The pH was measured using a Selby's pH 800 portable meter. Conductivity was measured using a conductivity bridge (Kent Electronic Instruments Ltd.), readings are in microSiemens cm^{-1} corrected to $25^{o}C$.

Macrophyte Survey

The distribution of river and lake macrophytes was qualitatively assessed on foot and by boat. Areas covered in this December trip were the south and west shores of Coongie Lakes and the banks of the North-West Branch within 10km of the Cooper delta into Coongie Lake. In addition, the eastern shore of Coongie Lake, part of the north-west shore of Lake Marroocoolcannie and the channel connecting Lakes Marroocoolcannie and Marroocutchanie were visited briefly. Care was taken to visit areas differing in aspect, exposure, substrate, water depth and flow, as these are all known to influence the distribution and abundance of macrophytes. Criteria for defining an "aquatic plant" vary according to author and none are perfect. A subjective definition was used on this survey, being those plants believed to be adapted to growing in a water environment. These were intended to be distinct from flood-plain species, defined here as plants germinating in saturated conditions such as a flood recession but without adaptations for growing in water.

Laboratory

Turbidity was measured using a Hach 2100 A turbidimeter. Chlorophyll-a was estimated spectrophotometrically after grinding in acetone and extracting cold for 12 hours. Concentrations were calculated following Talling and Driver (1963). Zooplankton were identified to species, where possible, by Dr. Russell Shiel, an expert on Australian Rotifera. Only the first 300-400 micro-invertebrates in each sample concentrate were considered. Reference slides have been sent overseas to Dr. Shiel's principal collaborator, Dr. Koste, world expert on Rotifera.

Regional water quality

Results of a regional survey done in July 1987 are presented here. Replicated samples were taken from eleven sites (Figure 4.2) covering a variety of habitats. Results are grouped into two types, lotic or flowing water, including main channel waterholes, interlake channels and the river itself (six sites), and those approximating lentic habitats or standing water which included Tirrawarra Swamp, Coongie Lake at two locations, and Lakes Toontoowaranie and Goyder. These samples were collected by a team of three persons between 0615 and 0745 hours on 28 July, stored on ice, and delivered to Moomba for air transport to Adelaide, reaching EWS laboratories on the same day as collected. Some samples were collected on 31 July following the same procedure because headwinds on 26 July made boat-dependent sections of the sampling trip impossible. These samples were analysed for soluble and total phosphorus, and total Kjeldahl nitrogen (TKN) by Engineering Water Supply Department, Adelaide using methods given in Glatz (1985).

4.3 **Findings**

Weather

Weather during the study period was generally unsettled, with a thunderstorm on the morning of 4 December (see "Flooding" below). The two days beforehand were sunny, hot and humid. Afterwards, the weather was changeable, being first sunny and clear (5 December), then overcast and wet (6 December), and finally becoming fine with light breezes (7-9 December). On the day of the river diurnal, 6 December, it was overcast until about 3 p.m.

Diurnal changes

The three river sites gave very similar results, so only one is presented and the three sites are treated as replicates where appropriate. This was also true for the three lake sites. The post-flooding sequence of river profiles at Site 1 are discussed below (see "Flooding").

On 6 December, river water was warm, in the range 22-26^{o}C throughout the day. Oxygen concentrations were moderately low in the top metre, being approximately 4 mg l^{-1}, and were much lower in the bottom metre, reaching 0.5-3.0 mg l^{-1}. Comparison of early morning profiles (A and B, Figure 4.3) with late afternoon profiles (D, Figure 4.3) shows that the 3 p.m. weather change mixed the water column, breaking down the thermal and oxygen structure. Mixing would also account for the decrease in chlorophyll-a from 26.4 to 9.3 micrograms l^{-1} (Table 4.1) and turbidity was 490-500 NTU.

In the morning of 9 December, lake water was comparatively cool at 19.5°C. Oxygen concentrations were high, 8.5 mg l^{-1}, which is 93% saturation. Early morning temperature and oxygen profiles (A and B, Figure 4.4) show the lake was well-mixed with no residual stratification from the fine calm weather of the previous afternoon. In contrast, late afternoon profiles show the effect of radiation, with a strong temperature gradient from top to bottom. This was not evident in the oxygen profiles which were close to saturation. There was much less oxygen depletion just above the sandy sediment of the lake than in the river where the substrate is an organic silt, often covered in coarse detritus. Chlorophyll-a concentrations were higher than in the river and changed very little through the day (Table 4.1). Turbidity was even higher, 595-620 NTU, and a Secchi disc reading was less than 4 cm.

This turbidity was due to fine particles, most of which passed through a GF/C filter with an average pore diameter of one micron but were retained on a 0.45 micron filter paper. The centrifuged filtrate had an absorbance of 0.049 at 440nm. This is half that for Mt Bold Reservoir near Adelaide, at 0.11 (A. Padovan pers. comm.) making this water exceptionally low in gilvin.

Nutrient analyses

Results are summarised in Table 4.2. Nitrogen and phosphorus concentrations were fairly high for a river in a remote, sparsely populated catchment. Soluble forms of nitrogen and phosphorus averaged 20-30% of total forms, thus nutrients were present mainly in particulate form. Differences in total phosphorus between July and December and between lentic and lotic habitats can be explained by prevailing flow conditions. Flood events are important for transporting large loads of total phosphorus, frequently as particulate matter in the water. The higher total-P concentrations in the lake in December 1986 correspond with its higher turbidity, relative to the river. Turbidity was not measured in July 1987, but flow conditions were not the same as in December. In mid-July the Cooper ceased flowing (J.Reid, pers. comm.) and weather was generally calm and fine. These conditions are likely to promote sedimentation of particulate matter in the lentic (lake) habitats.

Macrophytes

Only seven macrophyte species were found on this survey of Coongie Lake and the North-West Branch (Table 4.3) giving a low species richness even for macrophytes. This includes two Charophytes or "stoneworts", Chara ?corallina and Nitella sp. Two large green algae, the filamentous Spirogyra sp. and the net-forming Hydrodictyon reticulatum are also listed because in parts of the river (see below) their abundance makes them similar to a bed of submerged macrophytes.

The five vascular species are widely distributed in warmer regions of eastern Australia, and are commonly associated with the River Murray in South Australia. Charophytes are infrequently collected and their distribution in South Australia is not so well established. Six of these macrophytes are native to South Australia, the exception being Ludwigia peploides. This species was introduced last century (Kloot 1986) and is now so well established that it is virtually characteristic of slow-moving river water in warmer areas.

The seven macrophyte species covered a range of life-forms (Table 4.3). They also had specific distributions with four being restricted to the river and delta, compared to only one being restricted to the lake area. There was one generalist, Myriophyllum verrucosum. The range of this species has been extended through colonisation of watering points through central Australia; consequently it is widely distributed (Orchard 1985). The "lake only" species, Cyperus gymnocaulos, also occurred on banks of the North-West Branch, but on comparatively dry ground as occasional tussocks under river red gums, and not as an aquatic plant. Conversely, two "river" plants, Azolla filiculoides and Ludwigia peploides, were found in the delta area of the lake where they were always above waterlevel and dead. Unlike the other species, the "channel" plant, Nitella sp., was only found once.

Although species poor, the combination of diverse life-forms and specific distributions resulted in five recognizable aquatic vegetation types, two on the lake and three on the river. River and lake were thus structurally distinct, with the river characterised by less robust, floating and submerged forms, and the lake characterised by hardier generalists, the emerging herbs and medium sedge. These are referred to here as communities even though frequently monospecific. A brief description of their composition and habitat is given in Table 4.4.

Zooplankton

The 28 water samples examined had at least 41 Rotifer species, 12 Cladocerans and 4 Copepods (Table 4.5). Because this does not include invertebrates identified only to genus (see Table 4.5), the actual species list for December is probably much longer. All species listed have been previously recorded in Australia. Of the 41 Rotifer species found in the Coongie lakes area in December 1986, 37 had been previously recorded from the Murray-Darling basin and 31 from the Northern Territory (Tait et al. 1984). Similarly, out of 12 Cladoceran species, eight were known from the Murray-Darling basin, and seven from Northern Territory billabongs. This strong overlap with temperate and tropical habitats is not surprising considering the Cooper Creek catchment has an intermediate location, and that many micro-invertebrates, especially Rotifers, have pan-continental distributions (Shiel and Koste 1986).

Species richness was consistently higher in the river than in the lake. This was particularly evident in the Rotifers, with 13.6 species per sample concentrate compared to only 8.1 for the lake. Habitat differences are best exemplified by the Rotifers. Of the 41 species identified, 15 were recorded from river and lake, 24 from the river only and 2 from the lake only. Diversity in the river can be attributed to the range of ecological groups, which included some typically associated with shallow water and macrophytes, such as the eight Lecane species, and some which are truly planktonic, such as Polyarthra vulgaris and Euchlanis dilatata (Shiel and Koste 1986). Species common to river and lake were hardy plankter species, known to be tolerant of wide conditions (Shiel and Koste 1986).

River and lake as contrasting habitats

River and lake shared certain characteristics, namely high turbidity, high concentrations of total phosphorus and low conductivity. For some of these, the similarities are apparent rather than real.

First, the nature of turbidity was probably different. Whereas the river was brown after flooding, the lake retained its milky, opalescent colour throughout the December visit. This corresponded with substrate differences. The bed of the river was dark brown organic silt whereas that of the lake was coarse sand with fine white clay.

Second, temperature and oxygen profiles showed both river and lake were well-mixed at times, but again this appears to have different origins. Mixing in the river was probably due to flow turbulence resulting from run-off after heavy rain on 4 December, whilst mixing in the lake was probably wind-induced. The geomorphological characteristics of the lake basin, namely its width and shallowness, give it little protection from wind, no matter how slight. In contrast, the river channel is linear and protected by a tree fringe. Thus the river is likely to stratify in warm conditions when flow is low or negligible. As these conditions may persist for some time, especially in years of low flow, vertical separation of the river into two habitats may happen frequently. These two river habitats are an upper layer which is warm-hot with moderate-low oxygen and a lower layer which is warm with low-zero oxygen, resembling conditions before 4 December floods (see "Flooding" below). In contrast, the lake appears to readily thermally stratify when the weather is warm and calm. As calm conditions are unlikely to persist, this stratification must be temporary. It is not clear whether high oxygen concentrations in the lake were caused by wind-induced mixing or phytoplankton. For either reasons, anoxic conditions are unlikely.

Spatial variability in river and lake

In terms of water and substrate, there was comparatively little variation within river and lake. This meant river and lake had few sub-habitats. In the river, these were backwaters or aquatic "cul-de-sacs" with no through-flow, and islands. Sub-habitats in the lake were protected bays, islands and channels or creeks connecting the lakes. These roughly corresponded with differences in distribution of macrophyte communities (Table 4.4). Two sub-habitats are discussed below. Deep river waterholes referred to by Mollenmans et al. (1984) were not found in the area.

Islands were significant in both the delta area of the river and the south-west bay of Coongie Lake for the species richness and high cover of their flood-plain and emergent plants. This was in marked contrast with the shores of Coongie Lake and the channel banks of the river. Species found in these islands in December 1986 are given in Table 4.6.

Backwaters from the main river channel had shallower standing water and a fringing vegetation which was typically lignum. In the delta area of the North-West Branch, some backwaters were steep-sided channels with patches of sand on the bottom whereas elsewhere they were flat shallow bays over deep organic silt with coarse litter. Differences in substrate, exposure to wind action and direct sunlight, and water flow make the backwaters a sheltered environment compared to the main river channel.

In this protected environment the less robust aquatic plants, in this case those without woody tissue or root systems, such as free-floating Azolla and macroalgae such as Charophytes and Hydrodictyon reticulatum, can grow undisturbed. Consequently these are likely to be more abundant in backwaters, and will become abundant in the main river channel only if washed out by floods (see "Flooding" below) or if the river itself changes character, i.e. ceases flowing and is undisturbed by wind for any length of time. The three occasions in 1987 when *Azolla* mats completely covered the surface of the North-West Branch, in mid-June, mid-July and early September (J. Reid pers. comm.), were all times of very low to no flow.

Profiles on 9 December in a sandy-bottomed backwater in the delta area show that conditions in these shallow still backwaters can be extreme, with strong thermal stratification even when the water surface is partly shaded (Figure 4.5). Surface temperatures were very warm, ranging from 27.8 to 33.5^{o} C regardless of plant cover. Oxygen concentrations, although variable at the surface, were remarkably consistent at approximately 5mg l^{-1} down the water column until close to the bottom. Bottom water was relatively cool with a 20-40cm layer below 20^{o}C which was cooler than bottom river on the same day (Fig. 4.3). The thermal gadient ranged from 7.2 to 11.6^{o}C drop per 1 metre.

Thermal stratification can be expected in the main river channel and waterholes at times of low flow, such as during a drying phase, but such cool bottom waters would probably only occur in deep waterholes or shaded backwaters. The importance of these places as a comparatively cool habitat is difficult to assess as oxygen concentrations are likely to be lower than in the sandy-bottomed delta backwaters, because of the oxygen-demand from organic silts.

Productivity

Water samples collected in December 1986 and July 1987 showed the Cooper Creek system was turbid, high in nutrients, particularly phosphorus, and had a high chlorophyll-a content, indicating high phytoplankton biomass. The turbidity of the water is such that radiation could be expected to be the factor limiting phytoplankton growth, but continual mixing would overcome this limitation to some degree. This is more likely to be true for the lake, with its wide surface exposed to wind action, than for the river, and may explain why chlorophyll-a concentrations were as high as 20 micrograms l^{-1}. Samples were not preserved for systematic phytoplankton identification, but some samples were rich in large Desmids.

Regrettably, the quantitative zooplankton samples collected in December 1986 could not be analysed within the time and resource scale available, and therefore there are no estimates of micro-invertebrate abundance. (These samples have been retained by Dr. Shiel.)

Flooding

There was heavy rain (69mm) soon after sunrise on 4 December. This resulted in such extensive run-off that there was flooding in swales between sand-dunes, and a bubbling creek 20-30 cm deep flowed past the campsite (CCI) into the North-West Branch. River levels rose at least 7cm as a result.

River water entering Coongie Lake on 6 December was well-mixed with a low oxygen content, high turbidity and high phosphorus concentrations. These are characteristic of both flood-plain rivers and flood conditions. Distinguishing between them with the available data is difficult, but it seems probable that river water quality was a flooding response. Measurements made before this rain show the river was well-stratified with marked surface heating, 30°C at 1430 hours on 2 December, and well oxygenated in the top 20cm, whereas the bottom 100 cm was comparatively cool and low in oxygen (Figure 4.6). Comparison with profiles done on 4-9 December, shows that the effect of the flood was to break down stratification completely. Thus profiles of 4 December, measured only five hours after the rain began, are nearly uniform from top to bottom. Only one set of pH and conductivity readings was made before the rain. On 2 December pH was 8.2, compared to 7.6-7.9 afterwards. Similarly, conductivity before was 280 microSiemens cm^{-1} compared to 190-214 for 4-9 December. This was nearly 50% change showing the diluting effect of floodwater on ionic concentrations.

Biological sampling did not begin until after the rain, and so the effect of flooding on aquatic biota cannot be shown. It can be anticipated however, by classifying organisms as "passive", that is those whose location is determined by flow, and "active" or those that determine their location despite prevailing flow. Obviously an individual's classification is not fixed but is flow-dependent. For the December flooding, it is postulated that the active organisms were fish and the passive ones were phytoplankton, zooplankton and non-rooted macrophytes. These plants were apparently flushed out of backwaters by floods for the re-appearance of Azolla mats in the main river channel in early December and late February coincided with flooding events.

Flood events and their effects on water quality typically have sudden beginnings and a slow ending, that is they can be described by a strongly skewed curve, with a long tail. The December rain, although intense, lasted only a few hours. To the observer on the ground, the flood seemed a relatively minor event. Nonetheless, flood conditions persisted for at least 4–5 days, for it was not until 9 December that the river showed evidence of beginning to return to its pre-flood condition. Post-flood conditions in the river were perpetuated, in part, by local weather effects such as rain and overcast conditions on 6 December. These are probably an integral part of weather patterns which produce such minor flooding events and would be unlikely to be relevant in the case of major regional floods.

The well-mixed, fairly uniform profile of 4 December (Figure 4.6) was still evident on 7 December but by 9 December, as weather warmed up and began to be sunny again, thermal stratification was beginning to be evident. Thus profiles for 9 December, five days after flooding, were more similar to those of 2 December, two days before flooding, than any in the intervening days. There was also a reduction in chlorophyll-a concentration from more than 20 micrograms l^{-1} on morning of 6 December to 6–7 micrograms l^{-1} on 8 and 9 December. This was probably caused by death of algal cells (i.e. epiphytic and filamentous algae as well as phytoplankton) washed out of backwaters and swamps into the river.

Lake sampling points were near the Cooper Creek delta (Figure 4.1), and so would be expected to show evidence of river inflow. Despite this, and despite having received floodwater for 5 days, water quality in Coongie Lake on 9 December was quite different from river water, being well-mixed and well-oxygenated. Lake pH and conductivity of 8.5 and 330 microSiemens cm^{-1} were close to pre-flood conditions in the river, 8.2 and 280 microSiemens cm^{-1} on 2 December.

This shows the lake has some capacity to receive floodwater without being extensively changed. This "buffering capacity" under different conditions is relevant to understanding the role of flood regimes in the life history of longer-lived aquatic organisms such as turtles and fish.

Cooper Creek in context

Mean values for conductivity, turbidity, total phosphorus, total Kjeldahl nitrogen and NOx were within the max-min range for Callyamurra waterhole (Glatz 1985). Compared to 5 year mean values for River Murray at Morgan, South Australia, (Glatz 1985), the North-West Branch of Cooper Creek was about 4 times fresher, at least 5 times more turbid with 3-4 times more Total and soluble phosphorus, as well as higher concentrations of all forms of nitrogen.

Conductivity and turbidity are both influenced by changes in flow, and so are inversely related. Within a given season, the lake will therefore remain fresh provided there is sufficient water present to dilute the salts. The record of 1270 microSiemens cm^{-1} at Coongie Lake was made in March 1978, a time when summer flows of Cooper Creek at Currareva were very low (records supplied by Water Resources Commission of Queensland), and so give a representative idea of lake salinity in a drying phase. The process of salt concentration in river and lake during a drying phase may be compounded by brackish water soaks, assuming that the district's samphire flats indicate saline soils.

4.4 Management Considerations

The Coongie Lakes are distinct from other arid zone wetlands of South Australia, such as the Mound Springs, which are permanent, brackish, small, phosphorus limited and devoid of micro-plankters (Mitchell 1985), and lakes such as Lake Eyre which are large, irregularly filled and saline (Williams 1985).

In limnological terms, the single most significant aspect of Coongie Lakes is the extraordinarily unusual combination of a large, fresh semi-permanent lake and its location in the arid zone. The locality of Coongie Lakes, on the North-West Branch of Cooper Creek, is significant for other reasons. The Cooper Creek is the largest catchment in the Lake Eyre Division, which is an endorheic drainage basin, the largest in Australia. This, combined with irregular flows mean the concept of rivers as "self-purifying" must be challenged. Unless adequately protected, Lake Eyre could easily become the sink for all pollutants, and the dumping ground for all non-degradable rubbish.

A TN:TP weight ratio of 2.0-3.2 (Table 4.2) strongly suggests algal productivity is nitrogen limited. This means that nitrogen additions, particularly in the form of vertebrate waste and fertilisers, are likely to cause increased plant growth. This would have a different outcome in the lake, where mixing probably means radiation is not limiting, compared to the river, where it may be limiting. Increased nutrient loading to the lake could result in dense algal crops and green water, whilst the probable result of unrestricted camping or cattle access to a river waterhole is dense surface growths, such as strands of filamentous algae or floating plants. Both these changes have implications for other organisms.

It should be noted that the TN:TP weight ratio is a simplification which does not consider questions of nutrient availability and dynamics. It does give a reasonably good first-order approximation (M. Burch, EWS, pers. comm. 1987) which requires verification.

In order to manage the Coongie Lakes as wetlands, it will be necessary to understand the role of flooding and associated changes in water quality, specifically to what extent these "drive" the system, and how dependent the organisms are on it, as well as defining the nature of the flooding regime itself. Most of the Cooper catchment is outside South Australia and changes to the river are outside its direct regulatory power. Although brief, this study showed how local flooding might affect habitat characteristics, and reaffirmed the significance of temporal change.

The prevalence of rabbits and their effect on the aquatic and riparian habitats is a matter for concern. The beauty of the lakes area, its character and presumably a part of the organic matter input to the river, is due to the trees and associated riparian and flood-plain plants, perhaps even more than to the aquatic vegetation itself. Regrettably, there is little tree recruitment beside Coongie Lake. Lake shores have a zonation pattern of an emergent medium sedgeland dominated by *Cyperus gymnocaulos*, then a medium-tall, sparse species-poor herbland dominated by *Morgania*. Neither of these dominants are preferred grazing for rabbits. In December, there was a forceful contrast between the sparsely covered species-poor shores of the lake and the dense species-rich vegetation of the islands and open areas of the delta region, suggesting that the vegetation present was already under grazing pressure. This interpretation requires substantiation, for it is directly relevant to both maintenance of vegetation cover and soil conservation in the long-term. Management decisions, even in the short-term, may have to recognize that recreation and grazing are likely to be stress factors for plants growing in an already stressed, and naturally difficult environment. Recommendations for the Murray wetlands (Pressey n.d., pp. 10-13) are pertinent to Coongie Lakes.

Acknowledgements

Field equipment was the property of the Engineering and Water Supply Department, the Botany Department, University of Adelaide, and Dr R. Shiel. Laboratory facilities were made available by Dr George Ganf, University of Adelaide.

Figure 4.1

Location of sampling sites on Coongie Lake.

COONGIE LAKES DISTRICT

SOUTH AUSTRALIA

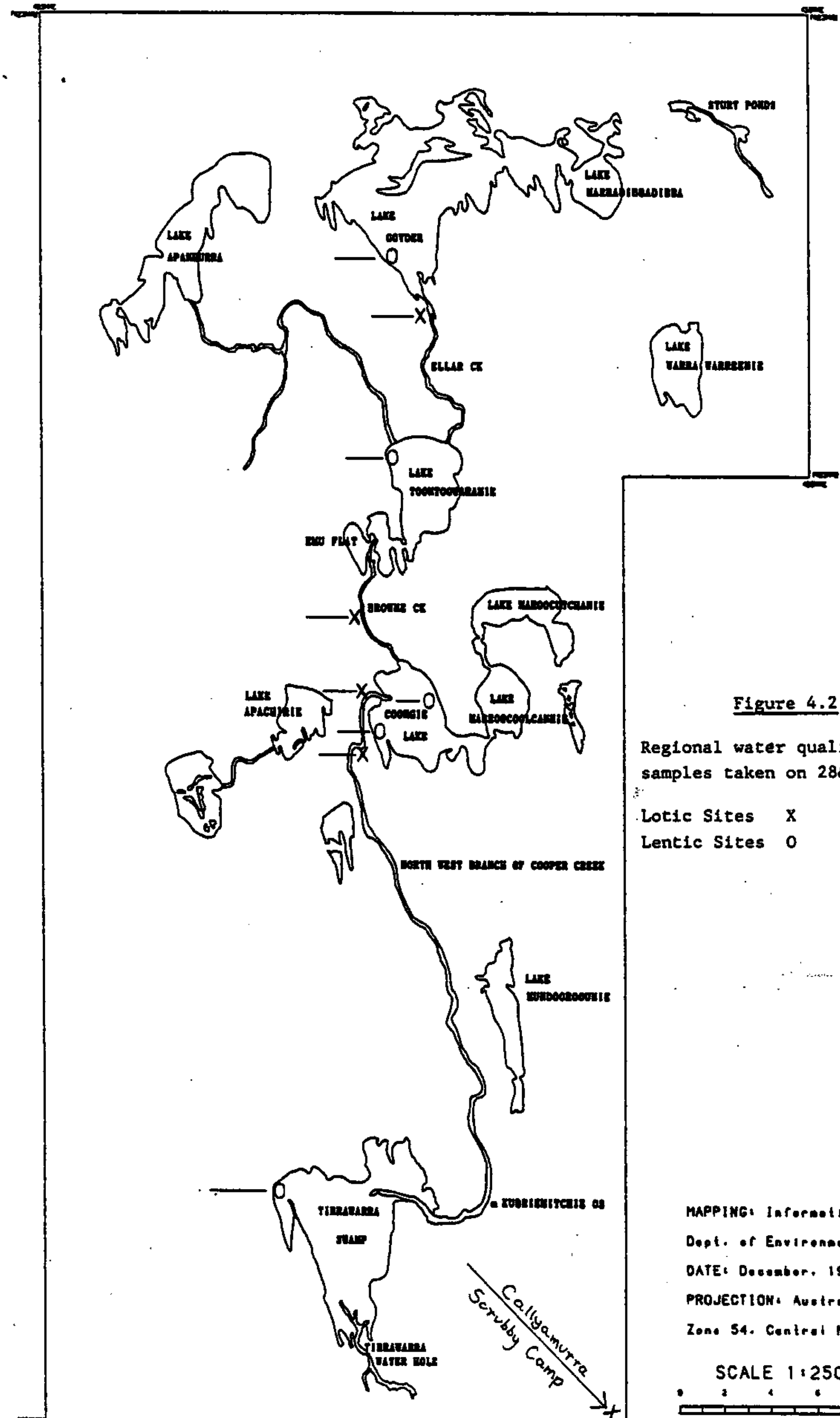


Figure 4.2

Regional water quality sampling sites-samples taken on 28&31/7/87.

Lotic Sites X

Lentic Sites O

MAPPING: Information Systems Branch.

Dept. of Environment & Planning.

DATE: December, 1987.

PROJECTION: Australian Map Grid.

Zone 54. Central Meridian 141 degrees E.

SCALE 1:250 000

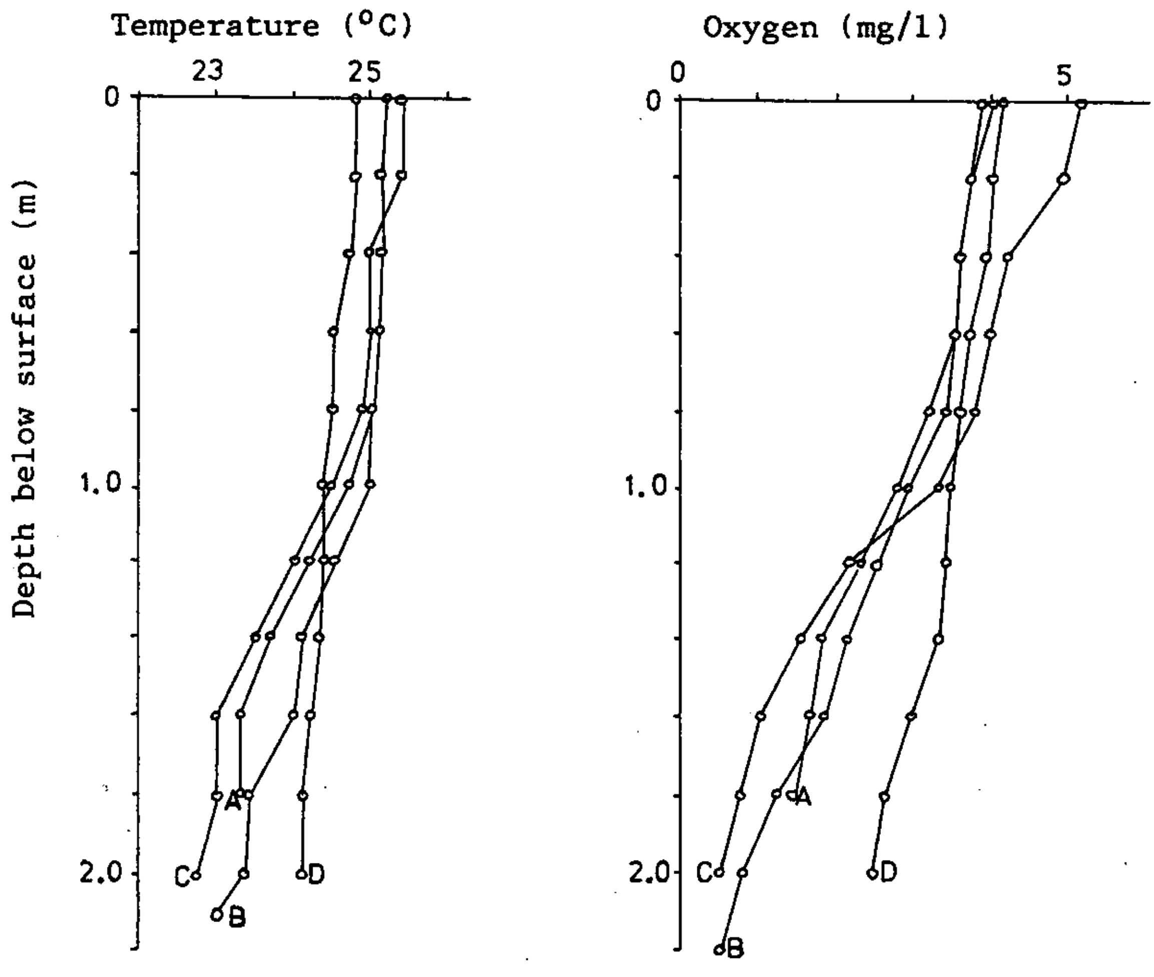
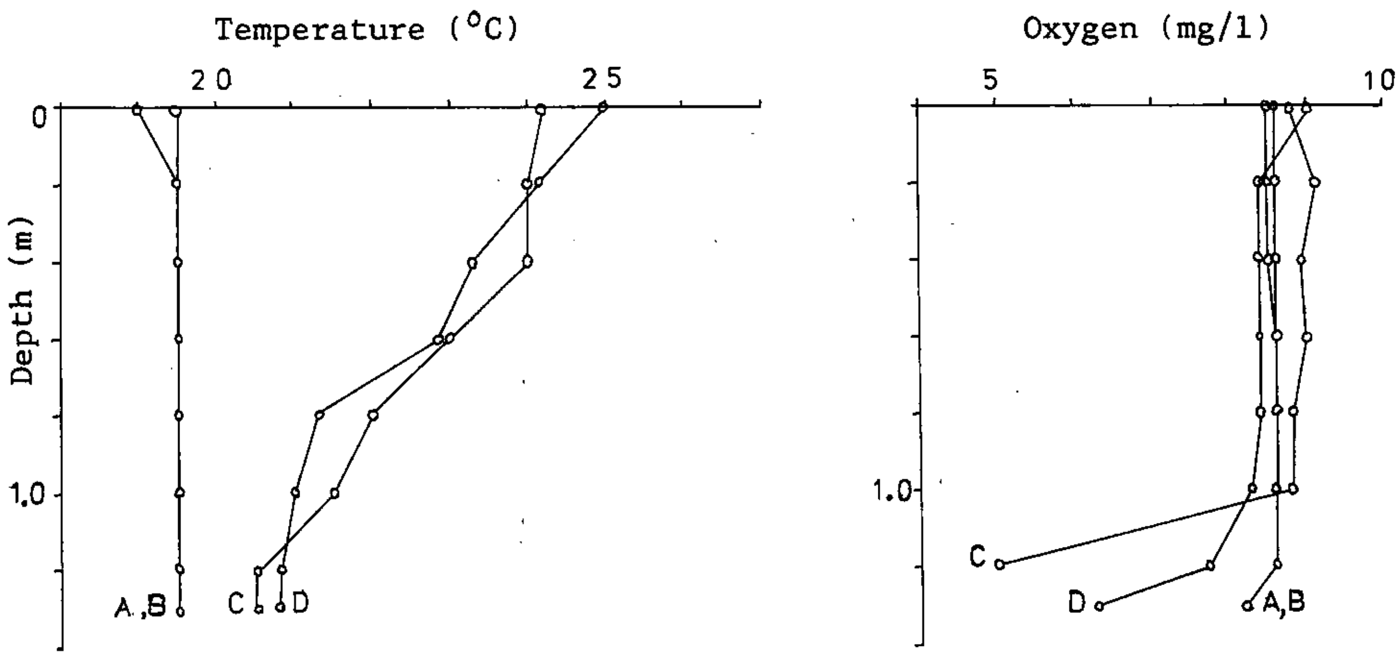


Figure 4.3

Diurnal changes in temperature and oxygen profiles at the River Site (2) on 6/12/86.

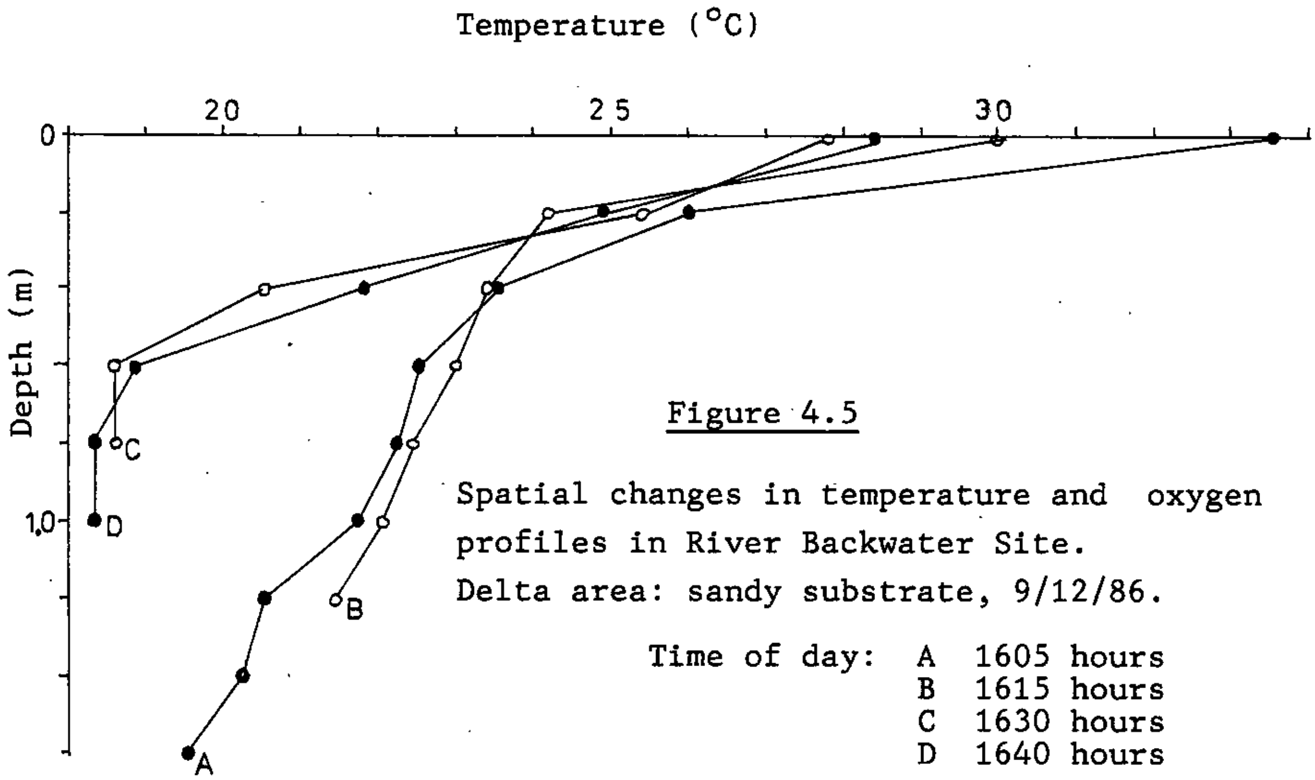
Time of Day:
A 0725 hours
B 0930 hours
C 1355 hours
D 1735 hours



<u>Figure 4.4</u>

Diurnal changes in temperature and oxygen profiles in Coongie Lake (Site 2) on 9/12/86.

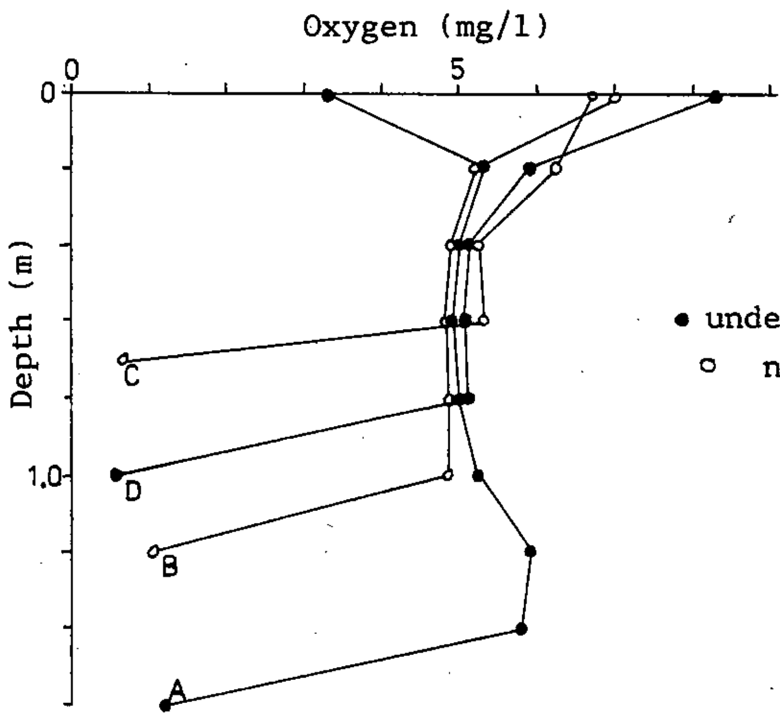
Time of Day: A 0820 hours
B 0935 hours
C 1505 hours
D 1820 hours



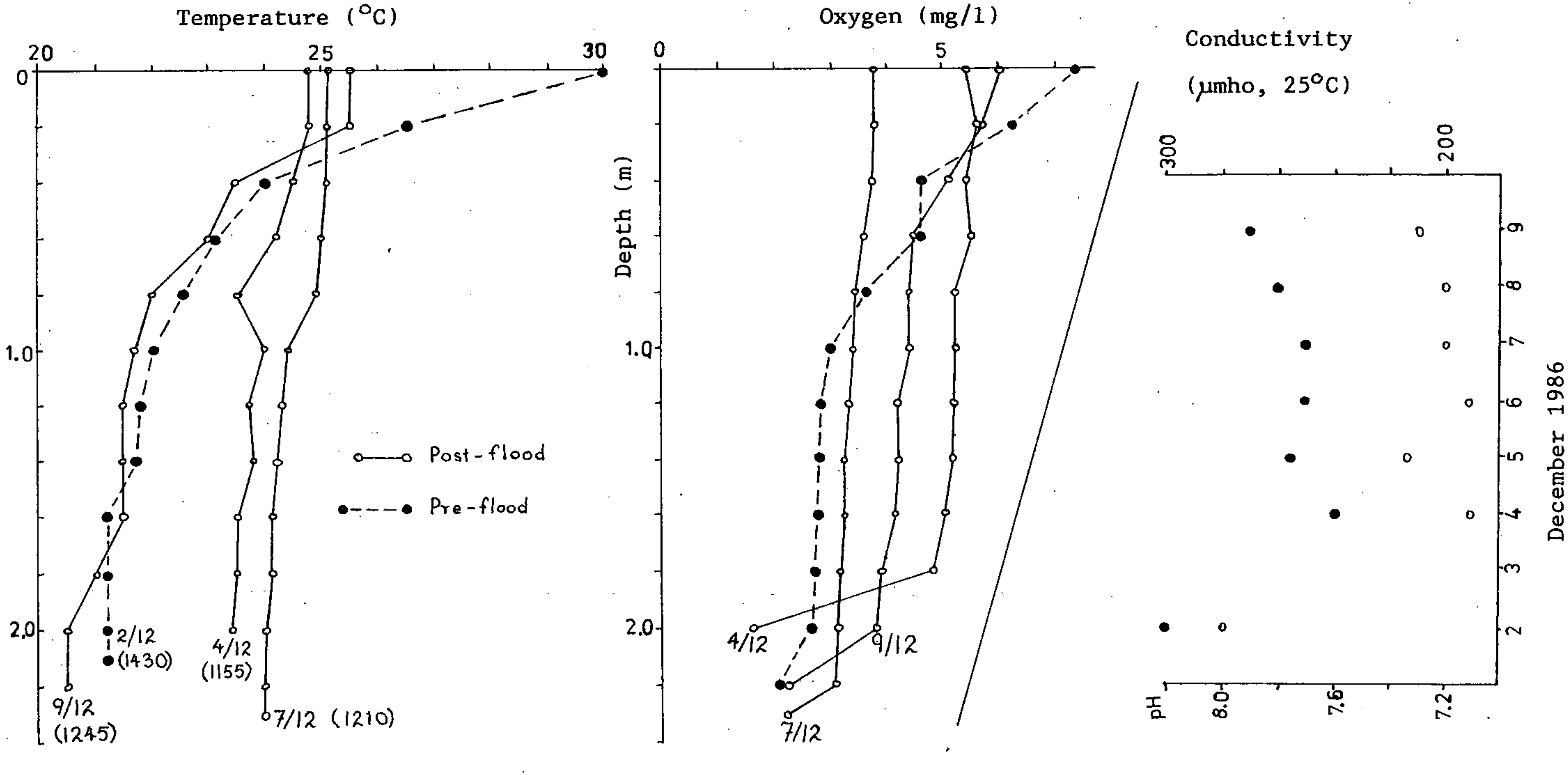
<u>Figure 4.5</u>

Spatial changes in temperature and oxygen profiles in River Backwater Site. Delta area: sandy substrate, 9/12/86.

Time of day: A 1605 hours
B 1615 hours
C 1630 hours
D 1640 hours



• under Azolla mat
○ no Azolla mat



<u>Figure 4.6</u>

Effects of heavy rain/local flooding on water characteristics.

River temperature and oxygen profiles, 2–9/12/86

Conductivity & pH change
○ ●

Table 4.1

Diurnal changes, December 1986

Mean (n = 3) chlorophyll-a concentrations in micrograms l^{-1} in River and Lake at five and three sequential times during the day. Letter codes given on Figures 4.3 and 4.4.

Run	River	Lake
A	26.40	20.1
B	18.5	-
C	15.1	18.5
D	14.0	-
E	9.3	18.6

Table 4.2

Nutrient analyses

Nutrient concentrations given as mean (x) micrograms $litre^{-1}$ with standard deviation (s) underneath. Sample size for lotic and lentic habitats in December 1986 was 8 and 12 respectively, and for lotic and lentic in July 1987 was 12 and 10, with the exception of ammonia, which was 6 and 5.

NOx is the sum of nitrate and nitrite concentrations.
TN:TP ratio is (TKN + NOx) / (TP), and is a weight ratio.

December 1986		**Lotic**	**Lentic**
Total P	x =	594.5	732.2
	s =	334.1718	88.0124
28–31 July 1987		**Lotic**	**Lentic**
Total P	x=	595.0	398.10
	s=	46.8171	37.0890
Soluble P	x=	117.75	118.9
	s=	46.8171	37.0890
TKN	x=	913.3	1089.0
	s=	344.8671	163.2619
Ammonia	x=	438.3	188.60
	s=	161.4208	177.2422
NOx	x=	329.2	102.00
	s=	202.9984	105.9140
TN:TP	x=	2.0205	3.2096
	s=	0.3966	1.0461

Table 4.3

Macrophyte species found in December 1986
Table shows macrophytes species, life-form and distribution in river, lake, delta, and inter-lake channel (R L D and C) as described in the text. The number of sites for these was 13, 10, 4 and 2 respectively. For the delta, three were on lake, and only one was in the river channel (with Ludwigia peploides).

Also listed are two grass species found growing in mud and on water.

	SPECIES	LIFE-FORM	R	L	D	C
Chlorophyta	Hydrodictyon reticulatum	Submerged	x	-	-	-
	Spirogyra sp.	Submerged	x	-	-	-
Characeae	Chara sp. (?corallina)	Submerged	x	-	-	-
	Nitella sp.	Submerged	-	-	-	x
Azollaceae	Azolla filiculoides	Free-floating	x	-	-	-
Haloragaceae	Myriophyllum verrucosum	Submerged-emerging	x	x	x	x
Lemnaceae	Lemna disperma	Free-floating	x	-	-	-
Onagraceae	Ludwigia peploides	Floating, rooted	x	-	x	-
Cyperaceae	Cyperus gymnocaulos	Emergent	-	x	x	-
Poaceae	Cynodon dactylon	Amphibious	-	-	x	-
	Pseudoraphis spinescens	Amphibious	-	-	x	-

Table 4.4

Macrophyte communities

1. Medium sedgeland
   Cyperus gymnocaulos dominant and frequently monospecific; to 50cm tall. Generally sparse. Associated plants were Myriophyllum verrucosum and an unidentified, heavily grazed grass.
   Found on sandy soils and exposed positions. In December 1986, extended from 5 m above to 17 m below the waterline, or 30 cm depth.
   Occasionally grazed.
2. Short emerging herbfield
   Myriophyllum verrucosum dominant and frequently monospecific; less than 20 cm tall. Associated plants were scattered C. gymnocaulos.
   Found on brown silt in protected areas such as lake embayments. In December 1986, found in shallow water up to 10 cm deep and as far as 2-3 m above the water's edge.
3. Submerged herb-like community
   One or more of the macro-algae (Spirogyra sp. and Hydrodictyon reticulatum), the Charophytes (Chara ?corallina and Nitella sp.) and submerged herb (Myriophyllum verrucosum).
4. Floating mat
   Ludwigia peploides dominant and frequently monospecific. Associated plants are Azolla filiculoides and Lemna disperma.
   Found on surface of slow-moving and still water in protected areas.
5. Free floating community
   One or more of Azolla filiculoides and Lemna disperma.
   Found on water surface, forming dense aggregations downwind or amongst other communities where these are adventive.

Table 4.5

Frequency of micro-invertebrates in river and lake samples. Maximum frequency is 18 and 10 respectively.

Table 4.5a: Rotifera

Species	River	Lake
Ascomorpha ecaudis	17	10
Ascomorphella volvocicola	3	0
Asplanchna brightwelli	2	0
A. sieboldi	15	1
Brachionus angularis	1	0
B. bidentata	4	0
B. keikoa	3	10
B. patulus	17	0
B. plicatilis	1	0
B. quadridentatus	5	0
Conochilus dossuarius	9	5
C. natans	9	4
C. unicornis	0	1
Epiphanes clavulata	8	2
Euchlanis dilata	6	0
E. dilatata lucksiana	2	0
Filinia australiensis	0	9
F. longiseta limnetica	3	5
F. opoliensis	2	0
F. pejleri	2	6
Hexarthra mira	18	10
Keratella australis	17	9
K. procurva robusta	1	1
Lecane bulla	1	0
L. curvicornis	6	0
L. hamata	1	0
L. leontina	10	0
L. ludwigi f. laticaudata	1	0
L. papuana	1	0
L. quadridentata	5	0
L. signifera	1	0
Mytilina mucronata	6	0
M. ventralis	5	2
Platyias quadricornis	8	0
Polyarthra vulgaris	17	1
Pompholyx complanata	13	0
Rotoria neptunia	12	1
Synchaeta pectinata	1	0
Testudinella patina	2	0
Trichocerca similis	2	0
T. similis grandis	7	4

Identified to genus

Cephalodella sp.
Collotheca sp.
Euchlanis sp.
Lecane sp.
Lepadella sp.
Synchaeta sp.
Trichocerca sp.

Table 4.5b: Cladocera

Species	River	Lake
Alona diaphana	14	1
A. cf. quadrangularis	6	0
A. cf. rectangula	1	0
A. rigidicaudis	1	0
Alonella cf. clathratula	6	0
A. karua	1	0
Camptocercus australis	9	0
Ceriodaphnia cornuta	14	0
C. cf. quadrangula	14	8
Daphnia carinata s.l.	6	7
Diaphanosoma unguiculatum	18	9
Euryalona orientalis	14	0
Ilyocryptus sordidus	5	0
Kurzia longirostris	4	0
Leydigia australis	6	0
Moina cf. micrura	18	10
Pseudochydorus globosus	1	0
Simocephalis cf. vetulus	13	0

Identified to genus

Alona sp.
Biapertura sp.
Chydorus sp.
Macrothrix sp.

Table 4.5c: Copepoda

Species	River	Lake
Boeckella triarticulata	18	10
Calamoecia canberra	7	2
C. lucasii	17	10
C. zeidleri	2	1

Identified to genus

Australocyclops sp.
Mesocyclop sp.
Microcyclops sp.

Table 4.5d: Protozoa

Arcella sp.
Centropyxis sp.
Cucurbitella sp.
Difflugia acuminata
D. corona
D. urceolata
Lesquereusia sp.

Table 4.6

Flood-plain herbs and forbs found on islands and in the delta area of Coongie Lakes.

MARSILEACEAE
Marsilea drummondii
Marsilea hirsuta

ASTERACEAE
Centipeda cunninghamii
Epaltes australis
Minuria sp.
Pseudognaphalium luteo-album
Senecio cunninghamii
Sonchus sp.

BORAGINACEAE
Heliotropium supinum

EUPHORBIATCEAE
Phyllanthus lacunarius

FABACEAE
Sesbania cannabina

GENTIANACEAE
Centaurium spicatum

LYTHRACEAE
Ammania multiflora
Lythrum hyssopifolia

POLYGONACEAE
Polygonum lapathifoliun
Rumex crystallinus

RUBIACEAE
Dentella sp.

SCROPHULARIACEAE
Mimulus prostratus
Morgania floribunda

VERBENACEAE
Verbena officinalis

CYPERACEAE
Cyperus bifax
Cyperus difformis
Cyperus gymnocaulos
Eleocharis pallens

JUCAGINACEAE
Triglochin hexagonum

POACEAE
Agrostis avenacea
Cynodon dactylon
Pseudoraphis spinescens
Sporobolus sp.

5. THE AQUATIC FAUNA OF THE NORTH-WEST BRANCH OF COOPER CREEK: SYNECOLOGY OF FISHES, WITH PRELIMINARY NOTES ON MACROINVERTEBRATE TAXONOMY AND DISTRIBUTION.

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5.1 Introduction

For several reasons, a major study of the aquatic fauna of the North-West Branch of Cooper Creek is overdue.

1. Taxonomically, the fish community of the area is of interest because, although most species appear to be widespread, little electrophoretic work has yet been done on these populations, and forms unique to the Cooper may well be found. Work on the Cooper system callop (Macdonald 1978) shows it to be electrophoretically distinct. The taxonomy of Central Australian neosilurid catfishes is in disorder and the status of the Cooper forms uncertain. The Cooper tortoise, *Emydura* sp., remains undescribed. Although certain components of the macroinvertebrate fauna have been identified, no protracted, intensive sampling has been done in the area.

2. Most work on fish communities has been done in temperate coastal rivers (Cadwallader 1979, Lloyd & Walker 1986, Lloyd in prep.) and the northern tropics (Beumer 1980, Bishop 1980). The South Australian section of the Cooper is unusual in being endorheoic, subject to an extreme desert climate and terminating in fresh, not saline lakes. Worldwide, there is little ecological work on such systems, Lake Chad being a notable exception (see Carmouze *et al*. 1983). Aquatic invertebrate studies show a similar pattern.

3. The Lower Cooper has components of both tropical and temperate faunas, as well as uniquely Central Australian species.

4. The North-West Branch of the Cooper has a great diversity of aquatic habitats - both spatially and temporally. Many species are subject to severe physiological stresses for periods in this cycle and face high risks of desiccation during migration and dispersal. This makes the system ideal for the study of the effects of environmental extremes on aquatic communities.

5. The Cooper is virtually pollution free, with a near-pristine fauna. It is entirely unregulated and very little of its floodplain has been alienated. These are increasingly unusual features in a major river system. Most Australian coastal rivers and major rivers world-wide have been drastically modified, and their faunas affected (Walker 1983a, Harris 1984). The importance of flooding to recruitment in riverine fish communities has been demonstrated by considerable research overseas (see Welcomme 1985 for a review). However, in Australia, river regulation and depletion of native fish stocks have preceded biological research in the Murray-Darling River system and many of the east coast rivers, so that researchers have had to infer what the original patterns were (Bishop & Bell 1978, Cadwallader 1986, Pierce 1987).

6. Studies of the Magela Creek system in the Northern Territory (Bishop et al. 1980) and of the Black-Alice system in North Queensland (Beumer 1980) are two of the few Australian accounts of the ecology of intact riverine fish faunas in unregulated rivers. The Cooper provides an opportunity, in an arid rather than tropical environment, for a comparative study. The Cooper is also of particular importance, because it shares dominant species with the Murray-Darling system, and may provide insights into the pre-regulation ecology of these species.

Earlier work in the Cooper area was concerned principally with taxonomy and distribution (McCulloch & Waite 1917, review by Glover & Sim 1978), but more recent work has begun to explore features of the ecology of desert fishes - particularly their physiological tolerances (Glover & Sim 1978, Glover 1982).

The present study aims

(a) to describe the structure, distribution and abundance of the Coongie Lakes district fish community, particularly in relation to climatic and hydrological cycles, and over a broad range of environmental conditions.

(b) to infer habitat preferences of the fish species.

(c) to outline life history patterns, especially spawning, disease cycles, migration and diurnal movements, for the major species.

(d) to frame hypotheses on the role of flooding in life history patterns of the Cooper fish community.

(e) to describe the macroinvertebrate community of the North-West Branch of the Cooper in broad terms, and distinguish major invertebrate habitats.

(f) to use a-e above to shape recommendations for management of the aquatic system and to direct future research.

5.2 Methods

5.2.1 Sites

There were 42 sites sampled in the river watercourse, flood plain and lakes (Fig. 5.2). Sites were chosen to provide as wide a range as possible along such environmental axes as frequency of inundation, flow, vegetation cover, depth, exposure to wave action, bank incline, temperature, dissolved oxygen and conductivity. In general, the North-West Branch river channel sites were deeper, more sheltered, more frequently inundated, more heavily vegetated, more subject to flow, with steeper banks, lower oxygen levels, conductivity, pH and Secchi readings than the northern lakes. Lake Goyder, at the other extreme, was shallower, very exposed, with slight gradients, low frequency of inundation, sparse fringing vegetation, negligible flow, high conductivity and pH. Ephemeral pools presented even more extreme environments. Not all sites could be sampled with all gear and many were made inaccessible to some or all gear by water level changes during the year. In addition, some sites were abandoned later in the year in order to focus effort on the events of the flood-front as it moved north. However, sampling was maintained in a core of sites (the northern NW branch, Coongie Lake, Lake Toontoowaranie and Lake Goyder) through 1987 (Fig. 5.3). Eleven rain-filled ephemeral pools were sampled with dip, plankton and 2m seine nets after summer rains and Innamincka Crossing and Scrubby Camp waterhole (south of Fig. 5.2 map boundary) with a sweep net for aerial forms of aquatic insects.

5.2.2 Habitat Parameters

Weather, basin morphology, substrate, hydrology, physico-chemical features, vegetation types and cover were recorded for each site on each sampling occasion (App. 5.1). Measurements of pH were discontinued late in the programme because of equipment malfunction. Dissolved oxygen and temperature were recorded for the whole water column at deep water sites (App. 5.2). From March 1987, certain parameters (water depth, temperature, dissolved oxygen, flow, inundation frequency, vegetation type and cover) were recorded for each haul of the 20m and 2m seines (App. 5.3), since it was apparent these features varied within the sites (See Section 5.2.4 for equipment lists).

5.2.3 Zooplankton

1. Littoral: 5m sweeps of 0.3m diameter x 150µ mesh dip net.
2. Open water: 0.3m diameter aperture x 150µ mesh surface trawl.

5.2.4 Aquatic Macroinvertebrates

All samples were preserved in 80% alcohol and sorted under a dissecting microscope.

1. Freeswimming Species

   (i) Littoral:
   - (a) Dipnet 500µ mesh, aperture 60x30 cm, 5m sweeps.
   - (b) 2m x 1.2m x2mm mesh seine, 5m sweeps

   (ii) Open water:
   - (a) 20m x 1.6m x 16mm mesh x 10 sweeps
   - (b) 500µ mesh seine trawl, aperture 0.5m diameter 10 x 3 minute hauls at 4 km/hr

2. Benthos

   - (a) Kick sample: sweeping dipnet for 5m through shallows disturbed by shuffling feet.
   - (b) Artificial substrates (WH1 and Coongie Lake only): 30 immersed over the interval Jan - Mar 1987

24 immersed over the interval April - June 1987 (Each substrate consisted of a half house brick wrapped in one and a half onion bags enclosed in a 2cm mesh plastic cage.)

(c) Substrate samplers

(i) littoral: 15 cm diameter plastic tube, plunged 5cm into substrate. Total water and substrate column sieved through 4mm, 1mm and 0.5mm mesh sieves.

(ii) deep water: gillnet anchor used to retrieve clay sample, sieved as above.

(d) Adult mussels collected by diving.

(e) Baited traps 30cm x 17cm diameter (cylindrical) x 5mm mesh: soap bait.

(f) Hard parts of molluscs and crustaceans collected from banks and middens.

3. Interstitial

80cm depth shafts sunk 0.5m from water's edge on Cooper main channel and Coongie Lake

4. Epiphytic

Samples preserved of submerged terrestrial and aquatic vegetation.

5. Adults - aerial stages

Sweep netting amongst fringing vegetation

5.2.5 Fish Sampling

a. GEAR

Fish were collected by four main gear types, not all of which were applicable in all habitats

Trawl

0.5m diameter circular ichthyoplankton surface trawl, 500μ mesh. 10 x 3 minutes trawls at 4 km/hr in open water of lakes and main channel.

Seines

1. Seine, 2m x 1.2m, 2mm mesh
   5m hauls in shallow littoral zone and against banks of heavily vegetated habitats. (e.g Tirrawarra Swamp). Usually 10 hauls/site.

2. Seine, 20m x 1.6m, 16mm mesh
   20m hauls used in open water of backwaters, main channel shallows and deeper littoral zones of lakes. Usually 10 hauls/site.

3. Seine, 120m x 3.0m, 30mm wings, 10mm bag

Gillnets

Length (m)	Drop (m)	Mesh (mm)
50	2.2	28
50	2.2	38
50	2.4	48
50	2.2	75
50	2.3	110

Used across main channel, across lake interconnecting channels and in mid-lake sites.

Drum nets

1m diameter hoops x 100mm mesh set along banks of main channel.

b. DATA RECORDED

At collection, data recorded depended on gear type and phase of survey.

(i) Basic data

For all fish collected, species, development stage (larva/juvenile/adult), reproductive state and disease condition were recorded.

TRAWL: Contents preserved in 10% formalin and processed later under dissecting microscope. (App. 5.4)

2m SEINE: Most specimens processed on site and returned alive

20m SEINE: Doubtful specimens preserved in 10% formalin (App. 5.4)

GILLNETS: Set mid to late afternoon, ten minutes to four hours, depending on fish density and activity. Most specimens processed on site and returned alive. Depth in net recorded for all specimens. (App. 5.5, 5.6)

(ii) Special topics data

1. Size selectivity of gear: Total lengths (TL) of all initial catches were measured (Dec. 86).

2. Disease aetiology:

(i) Some diseased specimens of all species were photographed, and the area of lesion mapped on a gridded fish diagram. (App. 5.7)

(ii) Samples of fungal mycelium transferred with flamed forceps to (a) sterile H_2O and (b) Chloramphenicol - cornmeal agar for culture and identification

(iii) Samples of infected tissue excised with a flamed scalpel and preserved in 10% formalin. These were sent to Dr. J.S. Langdon of the Australian Fish Health Reference Laboratory for histopathological examination.

3. Migration

(a) Longitudinal (App. 5.8)

(i) From March 1987 on, the direction of fish movement in relation to channel upon encounter with gillnets was recorded for all specimens.

(ii) In December '86 and January '87 specimens of bony bream and callop were fin-clipped (left pectoral in WH1 mid-channel and right pectoral in Coongie Lake, C2).

(b) Lateral

From March 1987 on, transects across floodplain habitats from flood fringe to maximum seining depth (approx. 1.2m) were made morning and evening using repeated hauls of the 20m seine and in some habitats, also the 2m seine.

5.2.6 Analysis

1. R-mode Principal Components Analysis based on a centred correlation matrix (Multivariate Statistics Package - MVSP) was performed on 15 habitat variables at 55 2m seine sites and 55 20m seine sites (pH was not included in this analysis because of malfunction of the pH meter).

2. Average linkage cluster analyses of sites on macroinvertebrate family presence/absence, sites on fish catch, and fish catch on sites were made for each gear, each trip, and for all trips with both Sorensen's (presence/absence) and Czekanowski's (abundance) coefficients (BASIC programs "Cluster 3" and "L Cluster" by Dr. K.F. Walker). However, for the sake of simplicity of interpretation in the all-trips clusters only the more frequently sampled sites were included and where sampling was duplicated in morning and afternoon, only morning samples were used.

3. Differences between numbers of upstream and downstream travelling fish caught in gillnets were analysed by Chi-square test.

4. Fish catch across floodplain transects was correlated with distance from the flood fringe by Spearman Rank Correlation (NWA Statpak).

5. A comparison of median floodplain and backwater 20m seine catches in the NW branch was made using Mann-Whitney U-Test (NWA Statpak). Mean catch per site of the 20m seine was compared for morning and afternoon hauls by paired-sample t-test (NWA Statpak).

6. All catch figures for seines and trawls were converted to means/haul (usually $n = 10$).

5.3 Results and Discussion

5.3.1 Fish

1. TAXONOMY, DISTRIBUTION AND RICHNESS

Eleven species were found in the NW Branch over the survey period. (Figs 5.4, 5.5). Of these, two (Gambusia affinis and Carassius auratus) are exotic. C. auratus has not been recorded from the catchment before. Samples of the Neosilurus species have been sent to Dr. N. Feinberg (American Museum of Natural History, New York), who is engaged in a revision of the group. Identification prior to this revision must be tentative.

This species list exceeds by three the catch by the Australian Geographic Expedition, May 1986 (Glover, unpub.) The additions are goldfish, spangled perch and yellow-fin tandan. However, the list falls short of the sixteen species recorded for the whole Cooper Creek drainage basin (Glover, 1982), which adds the Lake Eyre hardyhead Craterocephalus eyresii, the western chanda perch Ambassis castelnaui, hyrtl's tandan Neosilurus hyrtlii, the leathery grunter Scortum hillii, the barcoo grunter Scortum barcoo, and the redfin Perca fluviatilis. The redfin record is probably erroneous (Glover pers. comm.) but this still leaves a substantial discrepancy. The grunters and the western chanda perch were collected in the upper catchment streams (Glover, pers. comm.) and are almost certainly confined to them. A decision on the number and identity of catfish species in the Cooper must await a revision of the genus. However, there were no grounds to distinguish more than two species in the collections made in this survey, and these were tentatively referred to N. argenteus and N. glencoensis. The specimen of N. hyrtilii recorded for the catchment was captured at Innamincka. It may be that this species is present in the N.W. Branch in small numbers, perhaps in the deeper waterholes. The Lake Eyre hardyhead collections were made in isolated water bodies in the lower reaches of the Main Branch (Kannuwaukaninna Bore and Lake Palankarinna). Why the species should be confined to this more extreme environment is not obvious. It has been present in millions in Lake Eyre during floods (Ruello 1976) and unless low salinity is disadvantageous the North-West Branch should provide a suitable habitat. The significance of the presence of the two exotics will be discussed under "Impacts".

Of the eleven species recorded on this survey, bony bream and top minnow are cosmopolitan within Australia, smelt, callop, goldfish and western carp gudgeon have a temperate - central Australia range, spangled perch, yellow-fin tandan, and silver tandan are tropical - central, and the desert rainbowfish and Welch's grunter are principally central Australian (Merrick and Schmida 1984). The Cooper therefore features overlap of northern and southern faunas. On Welcomme's (1985) regression of log species richness against log basin area for the world's major rivers, the Cooper system, with its catchment area of 300,000 square km, and its species total of 16, is an extreme outlier below the line - a very depauperate system. This may be attributed at least in part to the exceptional slope of its flow - exceedance curve (Graetz 1980), which is a measure of the unpredictability of its flood magnitudes.

2. HABITATS

(i) Habitats defined by gear type

Figure 5.6 depicts the overall catch per unit effort for the 4 gear types in the different habitats in which they were necessarily used. The community composition differs markedly between them, with the water's edge community the most diverse. Both the 20m seine (littoral) and gillnet (deep open water) catches are dominated by bony bream. All species are represented in the water's edge habitat, although bony bream, smelt, top minnow, rainbow fish and western carp gudgeon are characteristic of it. All species also occur in the littoral, and if 500μ trawl and gillnet catches are united for the open water habitat, all species also occur here, with the exception of gold-fish.

(ii) Habitats defined by multiple parameters

In Principal Component Analysis (PCA) performed on 15 habitat parameters at the 2m seine sites (App. 5.9), the first four eigenvectors account for 71.4% of the variation. Eigenvector 1 (38.2% variation) is dominated by a river channel - lakes contrast (Fig. 5.7), with large positive coefficients for sheltered-habitat vegetation, flow, depth and bank incline, and negative coefficients for exposed-shore vegetation, wave action and dissolved oxygen. The remaining three eigenvectors feature contrasts between several physico-chemical and vegetation parameters, principally submergence frequency, temperature, conductivity, attached emergent vegetation and turbidity. Overall, the first four eigenvectors are dominated by 10 of the 15 original variables.

For the 20m seine sites analysis (App 5.9), the first five eigenvectors account for 76.6% of the variation, and eigenvector 1 (35.4% variation) is again dominated by a river channel - lakes contrast (Fig. 5.7), with large positive coefficients for sheltered-habitat vegetation, submergence frequency and bank incline, and negative coefficients for exposed-shores vegetation, wave action and dissolved oxygen. The remaining eigenvectors present a series of contrasts between various physico-chemical and morphological parameters - principally temperature, average depth, conductivity, secchi depth and flow. Overall the first five eigenvectors are dominated by 8 of the 15 original variables.

The most significant outcome of this analysis is the importance of the river - lakes contrast, which is most strongly demonstrated in the variables: terrestrial adjacent vegetation, floating attached aquatic vegetation, and wave action.

(iii) Habitats defined by fish community

Habitats were delineated according to the fish communities found in them, by cluster analysis. Since the different gear types essentially sampled different sites, fish populations, communities and size ranges, the catches of these gear types were not pooled. Clusters were performed separately on each.

(a) 2m seine - sampling at the water's edge

Sites clustered on fish species presence/absence per trip show a general distinction between river channel sites, southern lake sites, northern lake sites, and Tirrawarra Swamp. (App 5.10). Shallow and deep lake shores also differ strongly, but interlake channels do not stand out as a distinct group, being allied sometimes with lake habitats, sometimes with the river channel. Tirrawarra Swamp - initially a very species-rich habitat - became, through winter and with the receding of floodwaters, an extremely deoxygenated environment, inhabited only by G. affinis. It therefore clusters with the other extreme, (but highly oxygenated) Lake Goyder west shore. The Coongie Lake floodplain clusters with the river channel rather than the lake in the early stages of the flood. In the later stages, it is again linked to the lakes cluster. Clustering on species abundance (Czekanowski's) shows similar patterns, although distinctions are less consistent, probably because of local peaks in larval abundance.

When habitats are clustered against qualitative fish occurrence for all trips (Fig. 5.8A), Tirrawarra Swamp in late winter is most distinct. There is also a strong separation between a group of lake sites and a large group of predominantly river channel sites. Lake Goyder in winter splits off early from the lake group. The all-trips quantitative clustering (Fig. 5.8B) shows an early separation of the winter northern lakes, then a major division of mainly river channel from mainly lakes habitats. Two groups of mixed Tirrawarra Swamp and Lake Goyder sites are also clearly defined. The remaining 4 major groups consist approximately of a winter lakes group, a summer lakes group, a pairing of summer river channel and a spring Coongie Lakes groups, and a large river channel group.

In general then, the all-year clusters confirm several features of the 2-monthly clusters, viz: the distinction between river and lake sites, the uniqueness of Tirrawarra Swamp and Lake Goyder, the similarities between these extreme sites at certain times of the year, and a winter-summer dichotomy.

When a mean catch/haul for different species in these habitats (summed over all trips) is considered, (Fig. 5.9) many of the above distinctions are confirmed. Overall, river sites exhibit both greater abundance and species richness. The northern lakes are distinct in their depauperate and low density faunas, dominated by Gambusia and smelt. Tirrawarra Swamp is distinguishable from the river sites in its combination of a temporary high species richness, and low abundance. The general importance of temporal change (involving climatic and hydrological cycles) is illustrated in the graph of mean catch/haul summed for all sites per trip (App. 5.11). Species richness does not decline markedly over winter but abundance of most species does.

(b) 20m seine - deeper littoral sampling

Qualitative clusters per trip (App. 5.12) showed little distinction between river channel and lake sites in December and January, but dissimilarities emerged between lake, river channel and floodplain habitats in March-April. In May-June, floodplain habitat remained distinct in the lake, but differences between morning and afternoon samples became as important as inter-site differences. Morning-afternoon differences in sites persisted in July-August, but also strong dissimilarities appeared between different floodplain sites in the river channel. The per trip clusters on species abundance followed similar trends, but also notable was the isolation of Lake Goyder in March-April and September-October, and of Lake Toontoowaranie in May-June and July-August.

For habitats qualitatively clustered over all trips, (Fig. 5.10A), afternoon samples were omitted, so that the strong diurnal divisions are not present. Major divisions occurred at a much higher level of similarity than for the 2m seine clusters. The most significant grouping was between Coongie Lake and river floodplain sites. The all-trips cluster on species abundance (Fig. 5.10B) begins division at lower similarities, with delineation of a winter lakes/river floodplain group, then a summer river floodplain/Coongie group.

Overall, the 20m seine clusters define fewer clear-cut groups. Particularly, distinctions between river and lake sites are not so clear. Seasonal effects appear stronger, overriding lake-river distinctions. River floodplain and Coongie sites are closely associated in summer, as are the lakes and river floodplains in winter. However, in the graph of catch/20m seine haul/site summed over all trips (Figs 5.11A, 5.11B), abundance and species richness of the river sites far exceed those of the lakes, and the northern lakes are particularly depauperate. The absence of strong distinction between lake and river sites in clustering is partly due to the temporal variation amongst river floodplain sites. In winter these sites become very depauperate. The dominance of bony bream also tends to unite sites in the Czekanowski clusters. Seasonal effects are clearly apparent in mean catch/haul per trip (App. 5.13).

(c) Gillnets - open water samples

In the clustering of sites by total gillnet catch/hour, inter-lake channel sites (G3,BC1) were omitted to facilitate comparisons between the lakes and the river channel. The qualitative all-trips cluster (Fig. 5.12A) shows a first division between Toontoowaranie/Goyder and river channel/Coongie. The later divisions illustrate an equivalence of season and site.

The quantitative all-trips cluster (Fig. 5.12B) gives little consistent clustering either by site or season. A plot of mean catch/hour per site over all trips (Figs

5.13A, 5.13B) supports the Sorensen cluster outcome, in that the river and Coongie Lake are quite distinct from the northern lakes on species richness. The inter-lake channels are intermediate. The absence of distinctions in the Czekanowski cluster may be a consequence of bony bream dominance in all habitats. This probably overrides differences in richness of the rarer species. The effect of season is illustrated by the plot of mean catch/hour per trip over all sites (App. 5.14), where there is a drastic drop in all-sites catch over winter.

(d) Trawl - surface open water:

The qualitative clustering by trawl catch/haul per site over all trips (Fig. 5.14A) excluded Lake Goyder in May and July, because catches then were zero. The first division separates the remaining Goyder sample. Otherwise, differences between the major open water sites are not strong, and are equivalent to seasonal changes at each site. The quantitative cluster (Fig. 5.14B) segregates a winter Toontoowaranie site and then an early summer Coongie/river channel group. Beyond this there is no clear segregation on site or season.

A plot of catches / site summed over all trips (Fig. 5.15) shows an exponential decline in catch northward, and a less regular decline in species numbers. However, because both Goyder and Toontoowaranie were too shallow to sample in summer when larval and juvenile densities peak, this picture is somewhat misleading, and conceals great seasonal changes which explain why clustering of site types is not apparent. In particular both the river channel and Coongie catches collapse in March-April (App. 5.15). However species richness actually increases over this period.

<u>Habitats Summary</u>

As might be expected, highly structured habitats at the water's edge inhabited by immature or small and often sedentary fishes, show more distinct groupings than relatively homogeneous offshore habitats frequented by mobile pelagic species. Also the water's edge habitats show the highest species diversity (Fig. 5.6), and so Czekanowski clustering based on fish species results in clearer distinctions. However, some habitat distinctions are sustained across all gear types, viz: river vs. lake, south vs. north lakes and summer vs. winter. Also Coongie Lake and the river channel are similar, and the morning - afternoon distinction, although not tested with all gear types, appears strong. The river - lake distinction reflects a similar result for the PCA analysis of habitat parameters described above.

3. HABITAT PREFERENCES

(i) Correlation

The results of Multiple Spearman Rank Correlation for 2m seine catches against 16 environmental variables are given in figure 5.16. Although 10 species were correlated, catches of goldfish, silver tandan, yellow-finned tandan, callop, and Welch's grunter were so low that correlations were not meaningful. Juvenile and larval bony bream catches however show significant positive correlations with extent of floating attached vegetation, flow and average depth, and particularly with submergence frequency and temperature. Juvenile and larval smelt catches show highly significant positive correlations with average depth and submergence frequency. The absence of correlations with vegetation suggests a preference for open waters. The low number of highly significant correlations for smelt and to a lesser extent for bony bream suggests a generalised habitat preference. Juvenile and adult top minnow catches correlate positively and significantly with floating unattached aquatic vegetation, flow, temperature, bank incline, and particularly with submergence frequency, terrestrial adjacent vegetation and floating attached aquatic vegetation. Top minnow abundance shows significant negative correlation with wave action, conductivity and interestingly, dissolved oxygen. This suite of parameters defines sheltered, shallow, highly vegetated and even stagnant habitats. Juvenile and larval rainbow fish catches correlate positively and highly significantly with both terrestrial submerged and terrestrial adjacent vegetation, floating unattached and attached vegetation, flow, bank incline and average depth, and negatively with attached emergent aquatics, wave action, and conductivity. These parameters define sheltered, vegetated channel habitats, and suggest avoidance of the lakes. Larval, juvenile and adult western carp gudgeon catches show significant positive correlation with terrestrial adjacent vegetation, attached submergent aquatics, bank incline, average depth, flow, and especially submergence frequency. Catches have significant negative correlations with conductivity. Again these parameters define sheltered, highly vegetated channel habitats. In fact the general features associated with the southern, permanent habitats of the river channel such as low conductivity, high submergence frequency, high bank incline, high flow, high average depth and high levels of terrestrial and aquatic vegetation, appear to correlate strongly with catches of all species except smelt and perhaps bony bream.

This matches well the separation of river sites and northern lake sites from cluster analysis (Figs 5.8A, 5.8B) and the ubiquity of smelt and bony bream evident in plots of mean catch per site (Fig. 5.9).

The results of Spearman Rank Multiple Correlation for 20m seine catches against 16 environmental variables are given in figure 5.17. Although 11 species were correlated, catches of top minnow, western carp gudgeon, goldfish, yellow fin tandan, Welch's grunter and spangled perch were too often zero for meaningful correlation. Juvenile bony bream catches show significant positive correlations with bank incline and most significantly with flow, submergence frequency and temperature. Negative correlations appear with conductivity and - surprisingly - with dissolved oxygen. These correlations, and the lack of association with vegetation, suggest a preference for open water river and lower lake floodplain sites, which may develop oxygen deficits. (Association of bony bream with a wide range of oxygen concentrations has been reported for the Magela Creek (Bishop et al. 1980)). This pattern of correlation differs from that for larval and smaller juveniles in the absence of significant association with depth and floating attached vegetation. Both growth stages of bony bream show strong correlations of catch with temperature, a fact relevant to the later discussion of diurnal migration in this species.

Adult rainbow fish catches yield significant positive correlations with attached submergent, floating unattached and floating attached vegetation, temperature, bank incline, and particularly with terrestrial adjacent vegetation, flow and submergence frequency. The only significant negative correlation is with wave action. This set of correlations suggests, as for juveniles, a preference for river channel backwater and interlake channel habitats, and an avoidance of the open lakes. It differs from that for juveniles principally in the strong correlation with submergence frequency and temperature.

For juvenile silver tandan catches, there are significant positive correlations with terrestrial adjacent, floating unattached and attached vegetation, flow, submergence frequency, temperature, bank incline and average depth. This pattern is suggestive of river channel, swamp and backwater habitats. Juvenile callop catches show few significant correlations, except for positive ones with flow, submergence frequency and temperature. Callop are therefore habitat generalists, like bony bream and smelt. They also share with bony bream and rainbow fish a positive correlation of catch with temperature. These three are therefore all potential diurnal migrants.

Adult smelt catches are the only ones showing significant positive correlations with attached emergent and submergent vegetation, and wave action. These correlations suggest a preference for lake sites, but all coefficients are low, so smelt are also habitat generalists. This pattern differs from that for larvae and juveniles in the presence of positive correlations with lake side vegetation and wave action.

In summary, for both 2m and 20m seine correlations, there is a strong distinction between habitat generalist and specialist fishes. The generalists appear to be tolerant of both lakes and channel conditions while the specialists prefer river channel sites. There is some indication of a subgroup of thermophiles, a pair tolerant of low oxygen concentrations, and one lentic species (smelt). The parameter most frequently positively correlated with catch is submergence frequency, which suggests that this factor has overriding ecological implications. In a system in which flood magnitude is as unpredictable as the Cooper, the stability provided by permanent sites may be critical. Significantly, this factor was not dominant in the PCA analysis of habitat variables. Fish are distinguishing habitats on different criteria.

(ii) Catch per unit effort per site

This provides direct evidence for species' habitat preferences. Within the shallow littoral (Fig. 5.9), juvenile and larval smelt, bony bream and juvenile and adult top minnow are habitat generalists, although juvenile and larval rainbow fish also extend in low numbers into the lakes. Juvenile, larval and adult western carp gudgeon and juvenile silver tandan are largely confined to river channel sites, while juvenile gold fish, juvenile yellow-fin tandan, juvenile Welch's grunter and juvenile and larval callop appear to be exclusively riverine.

Within the deeper littoral (Figs 5.11A, 5.11B) juvenile bony bream dominate all habitats. Adult smelt and rainbow fish are also ubiquitous, although in varying densities, and juvenile callop are also wide-spread. Welch's grunter and silver tandan are confined to the river channel and Coongie Lake, spangled perch and goldfish occur only in the river channel. In the deeper offshore waters (Figs 5.13A, 5.13B), again bony bream (adults and juveniles) are dominant throughout. Callop juveniles and adults are the only other ubiquitous species, although adult silver tandan and Welch's grunter venture into the northern interlake channels. Adult spangled perch are found in both Coongie Lake and the river channel, but the yellow-fin tandan is confined to the river channel. The distribution of juveniles and adults in open waters (500μ trawl) is depicted in Figure 5.15. Of the common species, smelt are widespread, and are the only species caught in open waters of Lake goyder. Bony bream are abundant in all habitats except Lake Goyder, and western carp gudgeons appear in both the river channel and Coongie, but are rare in Toontoowaranie. Of the rarer species, callop are widespread, top minnow occur occasionally, Welch's grunter is confined to Coongie and the river channel, and rainbow fish are completely confined to the river channel. Rainbow fish in fact occur widely in the system, but evidently avoid open water.

Thus mean catch/effort per site confirms the findings from correlation, but there is one substantial point of difference: top minnow, rainbow fish and western carp gudgeon are all more wide-ranging in the lakes than the correlation result implies. Western carp gudgeons may be quite abundant in the open waters of Coongie Lake; rainbow fish and top minnow avoid open water, but occur at the margins of the lakes.

4. GROUPING DEFINED BY HABITAT PREFERENCE (do the groupings of fishes implied by 2. and 3. above emerge from inverse cluster analysis - i.e. from clustering of fish species by habitat?)

Fish groupings from inverse clustering of fish species groups against site catches:

The inverse qualitative cluster of 2m seine catches for all months (Fig. 5.18A) shows little significant grouping, with only the generalist smelt and bony bream closely tied. The inverse quantitative cluster (Fig. 5.18B) groups callop with Welch's grunter, yellow fin tandan, silver tandan and gold-fish. It also groups rainbow fish, top minnow and western carp gudgeon with smelt and bony bream. This is a grouping primarily on rarity/abundance, but it also matches the grouping of habitat range derived from catch/effort.

The inverse qualitative cluster of 20m seine catches(Fig. 5.19A) separates a group of smelt, callop, rainbow fish and bony bream. The presence of rainbowfish in this group contradicts the result from correlation, but supports evidence from catch/effort/site. The inverse quantitative cluster (Fig. 5.19B) strongly isolates bony bream - presumably because of its numerical dominance - and otherwise gives little significant clustering.

Quantitative inverse clustering of gillnet catches (Fig. 5.20A) pairs two restricted habitat species (yellow fin tandan and spangled perch) and two generalist species (callop and bony bream) although silver tandan is also closely linked to the latter group. The quantitative cluster (Fig. 5.20B) repeats the isolation of bony bream seen in the quantitative 20m cluster, presumably for the same reason. Again, the above two restricted habitat species are paired, as are Welch's grunter and silver tandan, which have intermediate habitat ranges. However these pairings are probably principally based on rarity/abundance.

Both the qualitative and quantitative clusters of surface trawl catches for all trips (Figs 5.21A, 5.21B) quickly separate all species except western carp gudgeon, bony bream and smelt. The latter two are clearly wide-spread, pelagic species. However the association of western carp gudgeon with this pair, although at a lower similarity, is interesting. It appears that the gudgeon, generally considered a sedentary, shelter-seeking species, (Merrick and Schmida 1984) may adopt a pelagic mode in the Cooper. The strong separation of callop from smelt and bony bream (despite its link in open water gillnet catches) may be due to a habit of benthic feeding.

Overall, the findings on species groupings from inverse clustering match those from catch/effort/site. Correlation analysis produces similar habitat specialist-generalist distinctions, but because all species with severely restricted ranges are rare and so could not be correlated (yellow fin tandan, spangled perch, goldfish), distinction between these species and those with an intermediate range (western carp gudgeon, top minnow, rainbow fish) could not be made by this method.

5. ECOLOGICAL CYCLES

1. Reproduction

a. General

Although all fish collected were tested for release of gonadal products, only spangled perch and bony bream were captured in a running ripe state. Captures of larvae, however, were extensive and occurred in all sites, with a greatest species richness in the river channel sites (TW1, WH1, Fig. 5.22). Species for which larvae were never captured were goldfish, silver tandan, yellow-fin tandan, Welch's grunter and spangled perch. Overall, larval abundance peaked in December - January when the river was low and immediately before regional flooding. The massive catches of larval western carp gudgeon, smelt and bony bream declined over winter, but great densities of smelt larvae returned in early spring (Fig. 5.23). Inshore (2m seine) catches and offshore (500u trawl) catches differ to some extent in species composition, with rainbow fish confined to inshore catches, callop to offshore.

b. Particular species

(i) Bony bream larval abundance (App. 5.16) peaks in early summer (December - January) immediately before flooding, but some spawning continues through winter. This pattern is intermediate between that in the lower Murray, which is strongly seasonal (Puckridge, in prep.) and that in Magela Creek, which is more aseasonal but with a peak in the early wet which is probably flood-cued (Bishop et al. 1980). Larvae in the Cooper appear first offshore in December, and are concentrated inshore in January.

(ii) Smelt larvae (App. 5.17) appear primarily in late winter - early spring, although some spawning occurs through to late summer. This matches the breeding cycle for South-Eastern Queensland (Milton and Arthington 1985). Larvae are distributed in all open waters of the system.

(iii) Top minnows (App. 5.18) being live-bearers do not produce larval offspring. Although records were not kept for December, incidence of juveniles suggests more or less continuous breeding, with peaks (for example in May - June) when flooding creates sheltered habitats.

(iv) Rainbow fish larvae (App. 5.19) do not generally appear in offshore samples. Inshore larvae are present throughout the year except for mid-winter. This species evidently selects sheltered breeding and nursery grounds.

(v) Western carp gudgeon larvae (App. 5.20) appear in great densities in December - January but catches are zero through winter; breeding is therefore strongly seasonal, as it is in Narranderra N.S.W., where spring - early summer are peak spawning periods (Lake 1967). Larvae appear offshore as well as inshore even in the lakes.

(vi) Callop larvae (App.5.21) appear only briefly, first in the inshore catches in January, upstream in the North-West Branch, and later in March/April in offshore catches in the lakes. The model proposed by Reynolds (1983) for callop in the Murray Darling - of upstream spawning early in the flood, with downstream drift of larvae - fits these results well.

(vii) Spangled perch males were running ripe in December and January. This timing matches that found at Narrandera, N.S.W. (Llewellyn 1973). However, no larvae were subsequently collected. The species was surprisingly rare in the system for the remainder of the year.

Breeding of other species - particularly the two catfish - requires further study. From local concentrations of catfish at the Innamincka causeway during flooding, it seems likely there is an upstream spawning migration in at least one of these species. In the Ross River, north Queensland, N. hyrtlii and N. ater undergo upstream spawning migrations, and lay demersal eggs in gravel substrates (Orr & Milward 1984). If the Cooper neosilurids do the same, spawning activity may be confined to reaches upstream of our sampling sites, and larvae may have become juveniles by the time of their arrival at Coongie. One very young juvenile did appear in an ephemeral pool in February 1987.

The importance of flooding to fresh water fish reproduction in hydrological systems as extreme as the Cooper has not been addressed in Australia. In such systems, although the likelihood of a regional flood occurring each year is high, its timing is variable and its magnitude highly unpredictable (Graetz 1980). In this situation, both aseasonal and flood-cued spawning would seem adaptive. Of the species dealt with here, smelt breed in early spring, months before flooding is likely; bony bream, western carp gudgeon and spangled perch breed principally in the month or two before the flood season, but may extend beyond this. These four species are therefore primarily seasonal breeders, either gambling on correct flood-timing, or independent of flooding. Callop breed in the early flood and are therefore probably flood-cued, and top minnow and rainbow fish are relatively aseasonal. Perhaps there is a high incidence of seasonality because the temperature regime of the Cooper is predictable and seasonally extreme. Or perhaps flood-cued spawning is too prone to error in an environment where local flash-flooding is common. In the Magela Creek, a tropical and more predictable system, peak spawning (probably flood-cued) is in the early wet (Bishop <u>et al</u>. 1980).

2. <u>Migration</u>

a. In response to Local Flooding

On 18th February, five juvenile bony bream, one juvenile rainbow fish and one juvenile silver tandan were collected in the 2m seine in an ephemeral pool (EPH (F) one km from North West Branch site WH2A - Fig. 5.24. This pool had been briefly linked with the backwater during heavy rain the previous day; thus fish had migrated upstream against the inflow from the floodplain, were then isolated and probably doomed to dessication. The adaptive advantage of such extreme behaviour is not obvious. Evidently, given a low level of predictability in the environment, colonisation ensures gene survival in the long term, despite the high mortalities. Certainly this is evidence in support of the mode of dispersal proposed by Glover (1982). It is also of interest that juvenile migration in this case is against the flow from the flood plain - the opposite of what happens during regional flooding (see Whitehead 1959).

b. In response to Regional Flooding

(i) Lateral migration

Three floodplain habitat-types were sampled during flooding: river channel floodouts (WH1N, WH2(A,B),WH5) lake shore floodouts (C5) and flooded meadows (T3). Only WH2 (A,B) and C5 will be considered here. Before flooding in January, the North-West Branch floodplain extended from a Ludwigia peploides-covered backwater into a dense lignum-coolibah association (App. 5.22A). The Coongie Lake flood plain (C5) extended from a Cyperus shore onto a coolibah woodland, with occasional lignum stands (App. 5.23A). After regional flooding in March - April, the habitats were inundated to a distance of about one km., and emergent aquatics such as Aeschynomene were flourishing (Apps 5.22B, 5.23B).

Transects of 20m seine hauls across these habitats between the flood fringe and the main waterbody produced highly significant rank correlations between catch per haul and distance from the flood fringe. In the case of the C5 transect, there was also a highly significant negative correlation between catch per haul and depth (Figs 5.25, 5.26). The proposal that the flood fringe provides a favoured fish habitat is supported by a Mann-Whitney U-test of catches in river channel backwaters versus floodplains (App. 5.23). Median floodplain catches were significantly higher at P=0.001. Although flood waters remained high, the use of flood plain habitats declined in winter. This was particularly the case for the river flood plain, where sediment settling and growth of both emergent and submergent aquatics (Aeschynomene and Myriophyllum) changed the nature of the habitat. Since 20m seine catches are dominated by juvenile bony bream, numbers caught of other species were too low for analysis, and so lateral migration onto the flood plain has not been established for other species. The reason for this strong migration to the flood fringe in the early flood phase is not known. Plankton and macroinvertebrate samples across the flood plain showed no obvious gradient. However, such lateral migrations occur in overseas flood-plain rivers (Welcomme 1969, Benech et al. 1983) and in the Magela Creek (Bishop et al., 1980)

(ii) Longitudinal migration

Results of chi-square tests of direction of travel of fish caught in cross-channel gillnets are plotted against flood progress in figures 5.27-31. Unfortunately full scale sampling of fish movement did not begin until March - April. However in January (Fig. 5.27) tests for movement of bony bream adults were negative. In March - April (Fig. 5.28), when floodwaters had reached Toontoowaranie, bony bream juveniles showed significant downstream movement in gillnets. Bony bream adults still showed no significant movement. Juvenile callop, although too few to test in gillnets, must have travelled downstream through Brown's Creek because they appeared in Lake Toontoowaranie, which had until then been isolated, and had contained no callop. By May - June (Fig 5.29) flood waters had reached Lake Goyder, and significant downstream movement of bony bream juveniles was apparent in the North-West Branch and Ellar Creek. Bony bream adults were still not migrating. In July - August (Fig. 5.30) flow continued with a second flood pulse, and juvenile bony bream were still moving significantly downstream in the North-West Branch and Brown's Creek. Adults were still sedentary. In September - October (Fig. 5.31) flow and levels had dropped drastically in the North-West Branch, although levels were still rising in Lake Goyder. Bony bream juveniles were still moving down-stream in significant numbers in Brown's Creek and Ellar Creek. Adults were still sedentary. In none of these samples were other species caught in sufficient numbers to allow statistical analysis. However, juvenile callop appeared in the northern habitats in increasing numbers as the flow events progressed.

The movement of bony bream juveniles could be part of a diurnal cycle, with movement upstream occurring at night. This seems unlikely, but should be checked. Bishop et al. (1980) describe downstream movement of juveniles during flooding in the Magela Creek, but otherwise the Australian literature on migration documents only upstream migration of adults (Kowarsky & Ross 1981, Beumer & Harrington 1982, Harris 1986). The function of downstream juvenile migration may be to disperse young fish to unutilised habitats (Benech et al. 1983), particularly newly flooded areas where plankton blooms are likely. In fact, Lakes Toontoowaranie and particularly Goyder experienced massive blooms of cladocerans after inundation (May -September). Juveniles may have more to gain from high food densities, because they need to both outgrow predators and reach reproductive age quickly. For adults, the risk of isolation and death on the falling flood may exceed the benefit of enhanced food supply. In fact the proportion of juvenile bony bream in the catch increases northward, until no adults are present in Lake Goyder. It is difficult to determine what numbers of juvenile bony bream actually arrive in the northern lakes by testing for changes in fish density over the flood cycle, because fish size-range, water-body volume, fish activity levels and diurnal movements all change during the flood event, and affect catch/effort.

(iii) Diurnal migration

Winter 20m seine transects across the Coongie coolibah floodout (C5) produced dramatically different results in morning and afternoon (Figs 5.32, 5.33). The morning sample gave no significant correlation of catch of juvenile fish with depth or distance from the flood fringe, the afternoon hauls gave significant correlations with both. A diurnal movement of juveniles was occurring between the lake proper and the flood fringe. However, no such difference was apparent on the river channel floodplain (WH2 A,B) which had been virtually abandoned by juvenile fish (Fig. 5.34). Unfortunately, incremental temperature gradients across both flood plains were not recorded, but measurements at the extremes suggested a strong temperature gradient developing from the open lake to the flood fringe (C5), but not across the river floodplain (WH2). Paired sample t-testing of subsequent paired morning and afternoon samples over a range of sites in July - August and September - October, confirmed the generality of this diurnal pattern (mean PM catch greater than mean AM catch at P=0.04, n=12). Again however, the inadequate numbers of species other than bony bream caught in these hauls did not allow statistical evaluation of their movement.

Bony bream are a highly mobile, schooling species, tolerant of high temperatures (Bishop et al. 1980). Such daily migrations may maximise temperature-dependent metabolism and activity levels, and perhaps give access to high food densities as well.

3. Disease

In December 1986, a skin disease outbreak, involving shallow ulceration infested with fungal mycelium, was apparent in bony bream adults and goldfish in the river channel (Figs 5.35, 5.36). This spread to other species during the flood cycle, and died out finally in September - October. Although sample size for these species was very low, incidence appeared to be highest in juvenile callop, juvenile Welch's grunter and goldfish. However, because of the abundance of this species, the disease was most apparent in bony bream - particularly adults.

Foci of infection were the head and fins. The principal fungal pathogen isolated from the lesions was Achlya sp. Histopathology on the lesions by Dr. J.S. Langdon (Fish Health Reference Laboratory, Benalla, Victoria) revealed a fungal dermatitis extending to myositis in specimens of bony bream, callop and rainbow fish. Hyphae penetrated epidermis, dermis and muscle, and were associated with haemorrhage and moderate inflammation.

Reports of fungus disease in inland Queensland rivers have a long history (Johnston 1917, Johnston and Bancroft 1921). However, a conclusive study of the epidemics has not been done. Annual fungus epidemics also occur in bony bream in the lower Murray (Puckridge et al. in prep.), but differ in several respects:

(a) The principal fungal pathogen is Saprolegnia sp.
(b) Peak incidence occurs in early spring
(c) Only bony bream are affected
(d) No juveniles are affected
(e) The focus of infection is the mid-flank.

The precipitating conditions in the Cooper Creek syndrome may be high temperatures, low dissolved oxygen and overcrowding - all conditions which develop in the river channel waterbodies during drought. This is well documented for tropical rivers (Bishop 1980, Awachie 1980). Such conditions may make fish survival in these refuges uncertain in times of prolonged drought.

4. Vertical habitats

Effects of Flooding.

As described in limnology section (4) above, the main river channel was strongly stratified in early December, before rain fell. The downpour and local flood on 4th December produced a temporary destratification and deoxygenation of the whole water column. Oxygen levels were again elevated over the whole water column by regional flooding in late January. In parallel with these changes, the vertical distribution of fish caught in gillnets changed. The pre-flood distribution showed a marked concentration - especially of juvenile bony bream and silver tandan - near the surface (Fig. 5.37). With the destratification and deoxygenation caused by the local flood, the high oxygen environment of the surface layer was lost, and fish were more dispersed through the water column, giving a distribution significantly different on Chi-square test (Fig. 5.38). During regional flooding, the whole water column was well oxygenated, and fish dispersed even more uniformly (Fig. 5.39). Flooding, therefore, strongly affects physico-chemistry, and alters habitat dimensions on a vertical as well as a horizontal scale. In the Magela Creek, first floods after the dry season may cause fish kills through destratification (Bishop 1980). The same process may occur in the Cooper after prolonged drought.

5.3.2 Macroinvertebrates

The results of the macroinvertebrate studies must be considered preliminary, because although all material has been sorted, identification to species - particularly of the insects - will take many months. Identifications to date are listed (App. 5.25) and distribution of families between sites is illustrated (App. 5.26). Some observations can be made even at this stage. Sponges (Porifera) are common throughout the system, colonizing live mussels and wood debri. Molluscs are abundant and widespread, with Velesunio wilsonii ubiquitous in the more frequently inundated waters, and a variety of gastropods - particularly Austropeplea lessoni, Physastra gibbosa and Vivipara sublineata - form a significant biomass in the highly vegetated littoral zones. Gabbia australis seems to be characteristic of ephemeral water bodies. Of the crustacean macro-fauna, Macrobrachium australiense is the dominant detritivore in all frequently inundated areas, but is replaced by Triops australiensis, Branchinella spp. and a variety of conchostracans in ephemeral pools. Cherax destructor is widespread in both ephemeral and permanent waters, but is nowhere common. Of the insects, the river channel harbours a wide range of species, particularly odonates; the ephemeral pools and lakes are dominated by hemipterans feeding on the post-flood cladoceran blooms.

With the identifications only at a preliminary stage, the cluster analysis of sites had to be performed against macroinvertebrate families. Also, some sites were eliminated because sampling effort in them was not comparable. This analysis (Fig. 5.40) compares 14 sites on presence/absence of 46 families. There is a broad division, as expected, between isolated rainfilled waterbodies (AO1,MW1,TAL,EPH,EP) and those which still held water from the last regional flows.

Interestingly, AO1, MW1, & TAL, which are deep anabranch pools filled by rain, have quite distinct faunas, and are distinct also from the shallow more ephemeral pools (EP & EPH) which cluster together. There is a great variety of hydrological regimes amongst these waterbodies; not only are they subject to different regional flood frequencies, but they may be filled by erratic local downpours. The aquatic communities in them are also influenced by chance colonisations, and by the interval over which the community has been developing since the last desiccation. It would be surprising if these communities were not distinct, in these circumstances. The flood-filled waterbodies separate into a group of the northern lakes and floodplain (T1,T3,G1) and the southern river channel sites with Coongie Lake (TS1,WH2, WH1, C1) This approximately matches the distinction between river and lake habitats given by PCA analysis. These three groups, from the ephemeral pools to the river channel, form a sequence of increasing inundation frequency, matching a similar division in the clusters of sites against fish catch. As for the fish community, the northern habitats are less species-rich.

5.3.3 Other Fauna

The taxonomy of the Cooper tortoise, Emydura sp., is at present under review by Dr. A. Georges (Canberra College of Advanced Education). The species is an important component of the aquatic biota; its densities are very high in the river channel (drum-net catches of tortoises exceeded those of callop), and it ranges widely through the lakes. An indication of the density of these animals was given when in response to heavy rain and brief flow in the North-West Branch in December 1986, they began drifting downstream with their heads held above water. Twenty or thirty could be counted in each fifty metre reach.

5.4 **Significance**

The importance of the Cooper to aquatic zoological research has already been discussed in general in the introduction but it should be re-emphasised that similar aquatic systems, especially in the

Cooper's pristine state, are rare world wide. Some of the particular outcomes of this survey also have considerable significance.

(1) The bony bream is one of the most widespread and abundant Australian fresh water fish. Yet the only major ecological study of this species (Puckridge, in prep.) is in a temperate system, the Murray-Darling. Bishop et al. (1980) consider it as a component of the tropical Magela Creek community, but it is a relatively minor component. The Cooper provides an opportunity for study of this important species in a quite different system, where it is the dominant species.

(2) The callop is a major commercial species, supporting a valuable fishery in the Murray-Darling system. Several studies have considered its ecology (Robinson 1982, Reynolds 1983, Merrick and Midgley 1985) but there is little knowledge of its spawning behaviour in the wild. The Tirrawarra Waterhole - Tirrawarra Swamp complex represents the only breeding site for this species known in South Australia.

(3) The ecology of the central Australian neosilurid catfishes is little known, and any study of them is likely to yield surprises (see Orr & Milward 1984). In the Cooper, for example, the consistent surface position of the silver tandan in gillnet catches is unexpected for a member of a benthic feeding group (Bishop et al. 1980). The Cooper is a major habitat for this group, and species there may prove to have unique forms and adaptations.

(4) Even well known species show unexpected features in this system. Western carp gudgeons, for example, generally considered a sheltered habitat species (Merrick & Schmida 1984), become pelagic in Coongie Lake in summer. Spangled perch, well known for their wide tolerances, distribution and colonizing ability (Bishop & Larson 1984, Glover 1982), appear in this study to be extremely habitat-restricted. Juvenile callop, on the other hand, are strong colonizers.

(5) The data on fish movements suggest that there is a complex suite of these - vertical, lateral, longitudinal and diurnal - which must affect management of fresh water environments.

Australian work in this area has been principally confined to longitudinal movements in coastal rivers (Bishop & Bell 1978, Reynolds 1983, Harris 1984). Only Bishop et al. (1980) present some of this complexity. To some extent this is because in most coastal rivers, the floodplain has been alienated, and flooding curtailed. In the Cooper, as in Magela Creek, the complexity of natural patterns may still be seen. Moreover, the consequences of downstream migration in the Cooper to a closed lake system rather than an estuary, should be considered.

(6) A thorough study of the Cooper macroinvertebrate fauna will take years. However, what has been done suggests a great range of invertebrate habitats, with a variety of distinct communities. The likelihood of discovery of new taxa and new life history adaptations is therefore high.

5.5 Impacts

(1) Tirrawarra Waterhole, and the adjacent Tirrawarra Swamp, appear to be major breeding and nursery grounds for most species, and it is here that callop larvae were found. However, seismic lines through the swamp have locally altered the drainage patterns, and formed still pools which become breeding grounds for exotic top minnow. This is an example of the sometimes unpredictable chain of events which follow intervention. Embarka Swamp has been much more severely altered by the construction of levees, roads, and wellheads, and the surrounding area gives ample evidence of the impacts of oil and gas mining infrastructure on the floodplain.

(2) Fish populations in the late stages of drought are intensely concentrated in river channel refuges, and are extremely vulnerable to any intervention including fishing, eutrophication and chemical pollution. Most visitors fish, and illegal fishing certainly occurs. It is also well known that the Queensland waterholes are seined during low water (Dr. Dean Graetz, CSIRO pers. comm.), and so the populations are under considerable fishing pressure. Populations of callop are still dense compared with the lower Murray, but spangled perch, Welch's grunter and yellow-fin tandan - all target

species for fishermen - are surprisingly rare. Spangled perch, particularly, is normally an abundant species (Glover 1982, Bishop & Larson 1984).

(3) The addition of another exotic species to the Cooper fish fauna must be a cause for great concern. Top minnow alone is likely to have had considerable effects - its potential for damaging native fish populations is well known (Hurlbert 1972, Lloyd 1986). Fortunately, the strain of goldfish introduced to the Cooper shows no tendency to dominance, and is restricted to the most sheltered habitats. However, the species is recognised as the Australian vector for a virulent fish pathogen, Aeromonas salmonicida, unknown in Australia until its discovery in gold fish in 1980 (Trust et al. 1980). This case illustrates the dangers an extensive river system like the Cooper faces. Without public education on the issue, further introductions are bound to occur, and they will be, like the introduction of european carp, irreversible. Carp are already in the Lake Eyre drainage at Leigh Creek, and Queensland coastal rivers now harbour a wide range of aquarium-trade exotics - some more potent colonizers than top minnow (Tilzey 1980, Arthington 1986).

(4) Fringing emergent aquatic vegetation (chiefly Cyperus spp.) correlates highly with the catch of rainbowfish and smelt, and is important as the major aquatic vegetation cover in the lakes. It is however, vulnerable to grazing by both rabbits and cattle.

(5) The removal of terrestrial shoreline vegetation, evident along the whole of the North West Branch, affects the aquatic system. Catch of several fish species correlates highly with such vegetation cover. Bank vegetation provides shade and nutrient input to waterbodies, and reduces bank erosion. Submerged timber (snags) plays a vital role in aquatic communities, and desnagging for boat passage is biologically damaging (Walker & Lloyd 1987).

(6) Power boating (a common recreational activity in the area) apart from being disruptive to bird life and other human users of the area, causes erosion of banks and damage to water's

edge vegetation (Liddle & Scorgie 1980) and fish nesting sites, and displacement of fish larvae from suitable habitats (Holland 1986).

(7) The recent (September 1987) Santos gas blow-out west of Moomba took two weeks to cap. If that had been an oil blow-out in or adjacent to a water body of the North-West Branch, the results would have been disastrous for the Cooper fish and macroinvertebrate communities (see Ikoporuko 1985).

5.6 Recommendations

5.6.1 Management

a. Rationale

1. Lateral and longitudinal migration in bony bream juveniles (likely to be important for other species as well), the timing of reproduction in relation to the flood season, the predominance of submergence frequency as a correlate of fish catch and as a major axis for distinction of macroinvertebrate communities, all indicate the critical role of flooding in the ecology of the aquatic fauna. Any interference with the arrival time, volume, frequency and areal extent of flooding will have profound effects. Causeways, culverts, levees and roads have altered the flood regime already on the Main Branch of the Cooper, particularly in Embarka Swamp. Irrigation developments also impose demands on flow, and have potential for eutrophication and salinisation.

2. Eutrophication and demands on flow are also potential outcomes of development of tourist facilities at Innamincka. Such impacts may be trivial in periods of flood, but during drought, decline in water quality could threaten fish communities with disease epidemics and even total kills (when flash floods destratify eutrophic waterholes).

3. The impact of grazing on patterns of runoff, the shape of the flood pulse, and sedimentation and turbidity in the Cooper is difficult to determine. Experience in other

catchments suggest these effects will have been substantial, with marked biological impacts. It should be recognised that the Cooper is an extreme example of a floodplain river (sensu Walker 1983b) and that floodplain vegetation is a component of the aquatic ecosystem, and its nature and extent have effects on that system.

4. The importance of the permanent waterholes as refuges must be stressed. After drought, these are the reservoirs from which the system is repopulated. Certain species (e.g. yellow fin tandan) are restricted to them even during flooding, and they are the sites of greatest macroinvertebrate diversity. The high correlations between vegetation of these habitats and catch of many species suggests that such vegetation is an important component of these habitats, and should be protected from impacts such as grazing.

5. Oil and gas development imposes multiple impacts on the aquatic system. Oil spills, seismic lines, and construction activity on the floodplain are obvious examples, but it is important to recognise that while the direct impact of installations (such as Tirrawarra Satellite) may be controlled, these represent beachheads for invasion by a wide range of activities (monitoring, maintenance, provisioning, recreation) which would sum to an unacceptable impact, if such installations were established on the North-West Branch.

b. Proposals

Ideally, the Cooper Creek catchment should be proposed for World Heritage listing. There is no doubt it would qualify, and conservation measures confined to South Australia cannot ensure protection. In the interim, certain measures should be taken:

(1) No developments on the Cooper floodplain which affect the movement of floodwaters should be permitted.

(2) Tourist developments at Innamincka should be strictly controlled, to ensure that there is no discharge of effluent to the river, and water use is minimal.

(3) The South Australian Government should initiate negotiations with the Queensland Government to conserve Cooper Creek on a catchment basis.

(4) Grazing should be excluded from the floodplain of the North West Branch.

(5) Fishing should be banned in the North-West Branch.

(6) Education of both visitors and residents in the dangers of fish introductions should be pursued vigorously.

(7) Oil and gas exploration and development should be excluded from the floodplain of the North-West Branch.

(8) Destruction of vegetation or removal of fallen wood should be banned in the North-West Branch floodplain. Interference with submerged timber should not be permitted.

(9) Use of power boats in the North-West Branch should not be allowed.

(10) Rabbit control in the area should be intensified.

5.6.2 Research

The following are priority areas:

MANAGEMENT - ORIENTED

(1) Monitoring of fish densities and water quality in the river channel, particularly during drought.

(2) Monitoring of disease incidence, and associated environmental parameters.

(3) Extension of the present sampling program over three years, to form a more reliable base for management in a highly unpredictable environment.

(4) A systematic survey of the Cooper fish community from Coongie Lakes to the head waters, to establish the longitudinal ranges of all species, and determine the extent to which South Australian populations can be replenished from upstream.

OTHER

(1) A study of the pathology and aetiology of the fungus disease in Cooper Creek.

(2) Feeding ecology of the major fish species, especially in relation to the flood cycle.

(3) Reproduction - particularly the timing and siting of spawning activity - in relation to the flood cycle.

(4) Migration in relation to the flood cycle - including nocturnal migrations - and its role in feeding and reproduction.

(5) The ecology of the Cooper floodplains - including temporal changes in nutrients, vegetation and utilisation by fish.

(6) A long term taxonomic study of the aquatic macroinvertebrates of the region

(7) Selected life history studies of dominant invertebrates - for example Macrobrachium australiense, Velesunio wilsonii

(8) A life history study of the tortoise Emydura sp.

(9) A study of the cladoceran/hemipteran predator - prey interactions in Lake Goyder.

Acknowledgements

This study would have been impossible without the enthusiastic and unselfish efforts of volunteers too numerous to list. Outstanding even in this company however, has been the help of J.P.'s dear friends, Lena Lapinski, Jack Porter and Zoey Porter. Thanks must also go to Dr. Phil Suter (Engineering & Water Supply Department, South Australia), Dr. Alice Wells (Department of Zoology, University of Adelaide), John Glover (South Australian Museum) and Dr. Keith Walker, Lance Lloyd and Bryan Pierce (Department of Zoology, University of Adelaide) for expert advice. Finally, J.P. would like to thank Kathryn Corbett for patience in typing from a barely legible manuscript.

SITES - SOUTH TO NORTH

IC	COOPER MAIN BRANCH CHANNEL AT INNAMINCKA CROSSING
SC	NORTH-WEST BRANCH CHANNEL WATERHOLE AT SCRUBBY CAMP, SOUTH OF TIRRAWARRA
MWI	RAIN-FILLED MAIN CHANNEL WATERHOLE NEAR CHILLIMOOKOO WATERHOLE
TWI	TIRRAWARRA WATERHOLE
TSI	TIRRAWARRA SWAMP
WH3	NORTHERN NORTH-WEST BRANCH - ANABRANCH
EPH (A) - (F)	EPHEMERAL POOLS ON EAST SIDE OF COOPER CREEK BETWEEN WH2 AND WH3
WH2(A,B),WH5,WHIN	NORTHERN NORTH-WEST BRANCH - BACKWATERS
WHI(MC)	MIDWATER OF NORTH-WEST BRANCH
EP 1-5	EPHEMERAL POOLS BETWEEN COONGIE LAKE WEST AND COOPER CREEK
WHI	COONGIE CROSSING ON N.W. BRANCH
AOI	RAIN-FILLED OUTLET CHANNEL OF LAKE APACHIRIE
CI	COONGIE LAKE WEST SHORE
CIN	COONGIE LAKE WEST SHORE (SHALLOWS)
C2	MID-LAKE COONGIE
C3	COONGIE LAKE EAST SHORE
C4	COONGIE LAKE NORTH SHORE
C5	COONGIE LAKE WEST-FLOODPLAIN
MCI	COONGIE LAKE-LAKE MAROOCOOLCANNIE CHANNEL
MI	LAKE MAROOCOOLCANNIE - LAKE MAROOCUTCHANIE CHANNEL (SOUTH)

MK2	LAKE MAROOCOOLCANNIE - LAKE MAROOCUTCHANIE CHANNEL (NORTH)
MKI	LAKE MAROOCUTCHANIE SOUTH-WEST SHORE
TAL	RAIN-FILLED OUTLET CHANNEL OF LAKE TALINNIE WEST OF BROWNE CREEK
BC1	BROWNE CREEK NORTH
T3	FLOODOUT WEST OF BCI
TI	LAKE TOONTOOWARANIE WEST SHORE
T2	MID-LAKE TOONTOOWARANIE
G2	ELLAR CREEK-NORTH
G3	MID-LAKE GOYDER
GI	LAKE GOYDER WEST SHORE

FIG 5.2

SITES - COONGIE LAKES DISTRICT

SOUTH AUSTRALIA

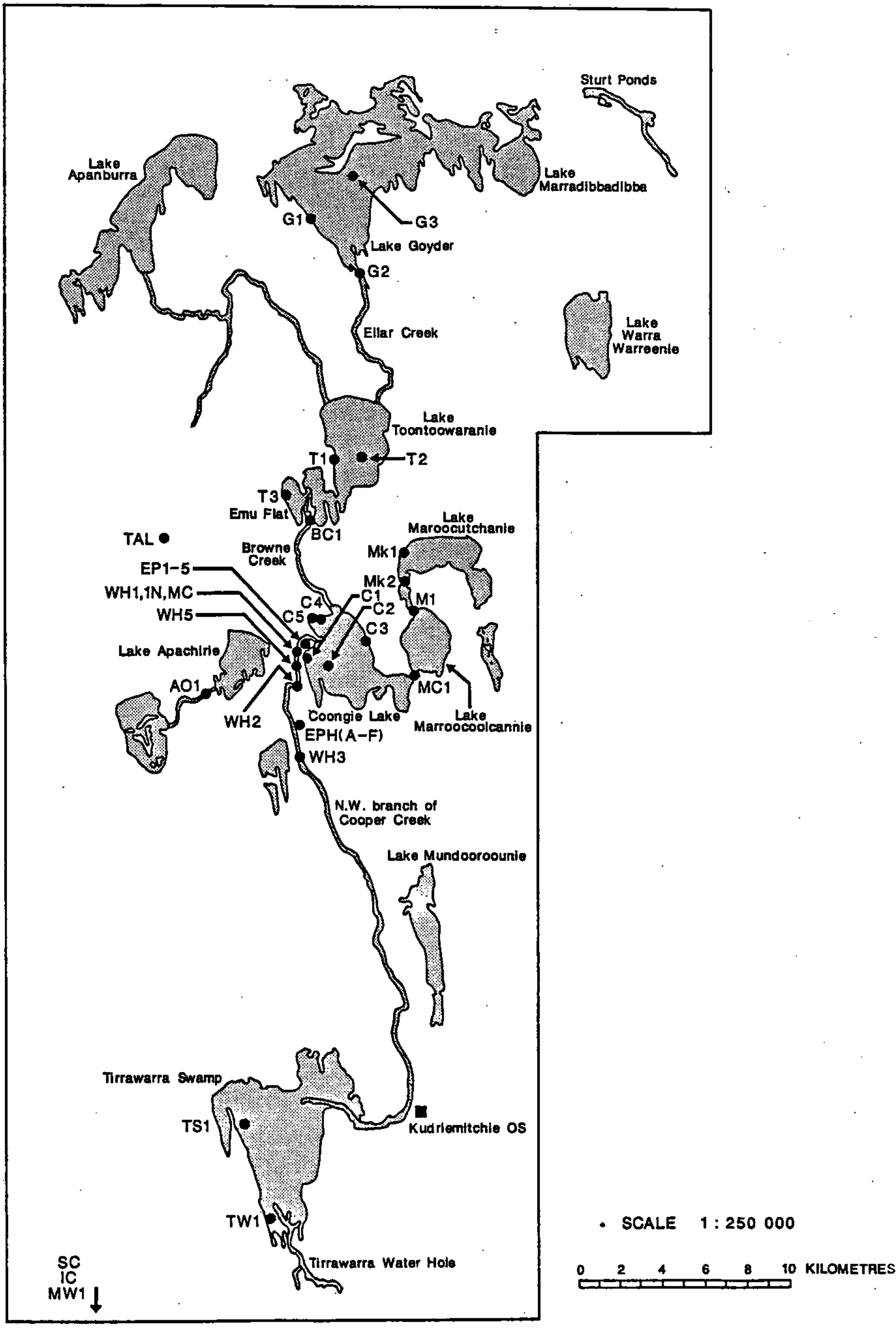


FIG 5.3

OCCASIONS ON WHICH SITES WERE SAMPLED

COONGIE LAKES REGION 1986-87

	MW1	TW1	TS1	WH3	EPH	WH2AB	WH5	EP	WH1N	WH1	WH1MC	AO1	C1	C1N	C2	C3	C4	C5	MC1	M1	MK1	MK2	BC1	T3	T1	T2	G2	G3	G1
DEC	-	-	-	*	-	*	-	*	-	*	*	-	*	*	*	*	-	-	-	*	-	-	-	-	-	-	-	-	-
JAN-FEB	*	*	*	-	*	*	-	-	-	*	*	*	*	-	*	*	*	-	*	-	*	*	*	-	*	*	-	-	*
MAR-APR	-	*	*	-	-	*	-	-	-	*	*	-	*	-	*	*	-	*	-	*	-	-	-	-	*	*	*	-	*
MAY-JUN	-	*	*	-	-	*	*	-	*	*	*	-	*	-	*	-	-	*	-	-	-	-	*	*	*	*	*	*	*
JUL-AUG	-	*	*	-	-	*	*	-	*	*	*	-	*	-	*	-	-	*	-	-	-	-	*	-	*	*	*	*	*
SEP-OCT	-	*	*	-	-	*	*	-	*	*	*	-	*	-	*	-	-	*	-	-	-	-	*	-	*	*	*	*	*

FIG 5.4

GRAPHICAL KEY TO FISH SPECIES

GROUPED SPECIES

SPANGLED PERCH (SP) *Leiotherapon unicolor*

WELCH'S GRUNTER (WG) *Bidyanus welchi*

CALLOP (C) *Macquaria ambigua*

YELLOWFIN TANDAN (?) (LC) *Neosilurus* sp. B

SILVER TANDAN (?) (SC) *Neosilurus* sp. A

GOLDFISH (GF) *Carassius auratus*

WESTERN CARP GUDGEON (WCG) *Hypseleotris klunzingeri*

RAINBOW FISH (RF) *Melanotaenia splendida tatei*

MOSQUITO FISH (MF) *Gambusia affinis*
(TOP MINNOW)

SMELT (SM) *Retropinna semoni*

BONY BREAM (BB) *Nematalosa erebi*

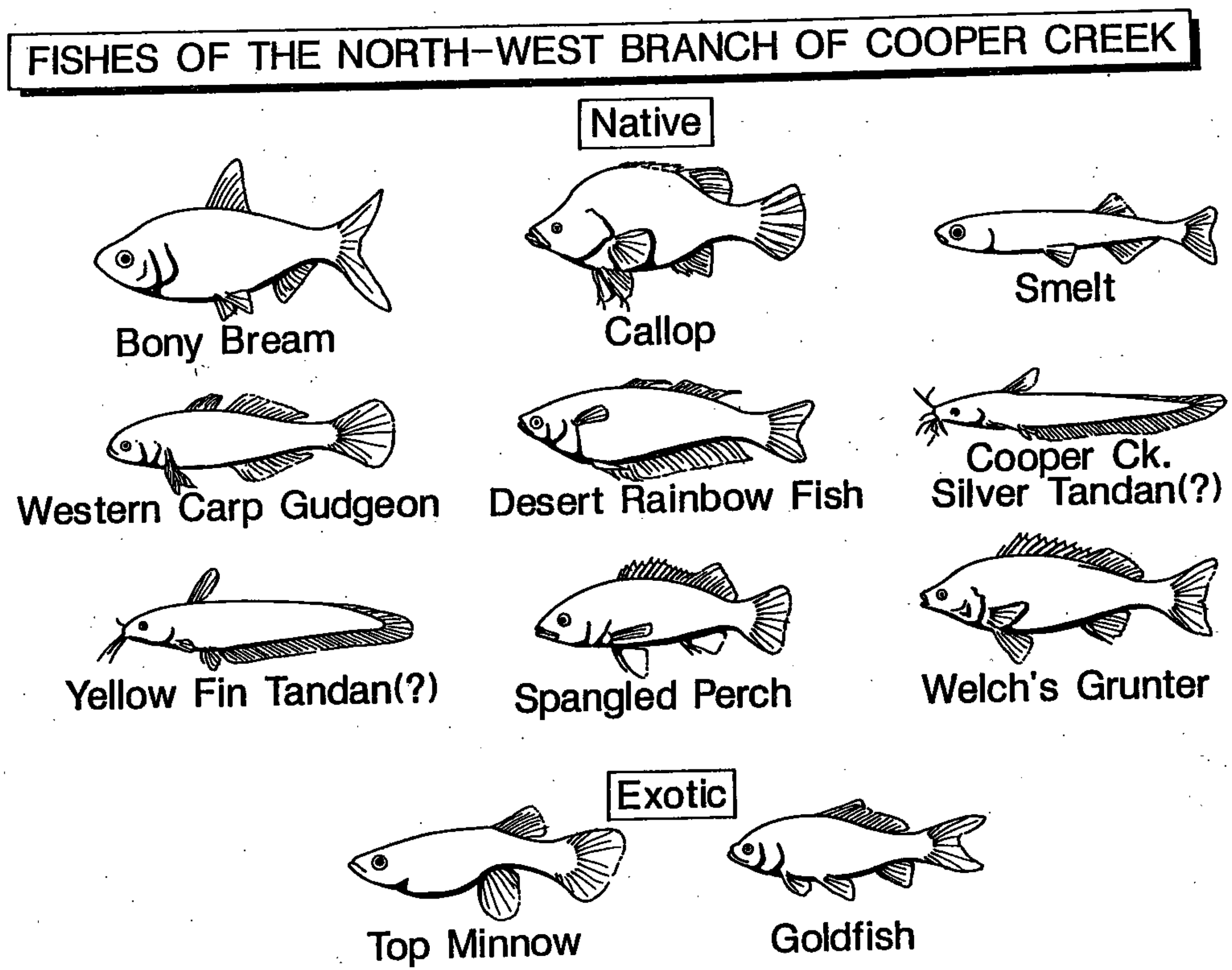

FISHES OF THE NORTH-WEST BRANCH OF COOPER CREEK
Native
Bony Bream
Callop
Smelt
Western Carp Gudgeon
Desert Rainbow Fish
Cooper Ck. Silver Tandan(?)
Yellow Fin Tandan(?)
Spangled Perch
Welch's Grunter
Exotic
Top Minnow
Goldfish

FIG 5.5

PERCENT GRAND MEANS OF TOTAL YEAR'S CATCH PER EFFORT FOR DIFFERENT GEARS, ALL SITES, ALL TRIPS.

(* = CATCH TOO SMALL TO GRAPH)

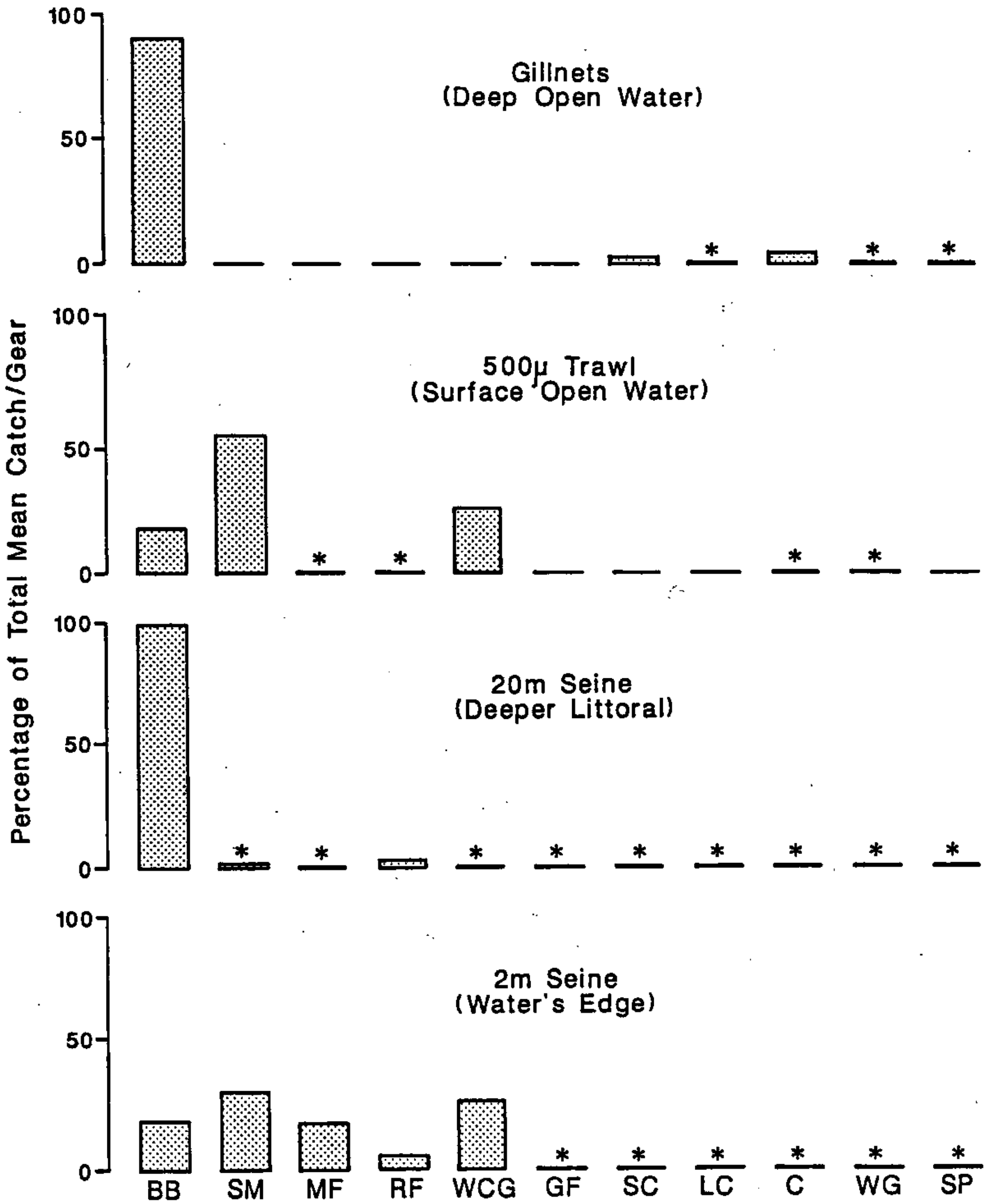


FIG 5.7

PRINCIPAL COMPONENTS ANALYSIS

(FIRST EIGENVECTORS ONLY, COMPONENT LOADINGS > 0.2)

				SITES: 2M	20M
				PC1	PC1
VEGETATION:	TERRESTRIAL:	adjacent	(TA)	+	+
		submerged	(TS)	+	+
	AQUATIC :	emergent	(AE)	-	-
		submergent	(AS)		+
		floating unattached	(FU)	+	+
		floating attached	(FA)	+	+
OTHER :		wave action	(WA)	-	-
		flow	(F)	+	
		submergence frequency	(SF)		+
		temperature	(T)		
		dissolved oxygen	(DO)	-	-
		bank incline	(BI)	+	+
		average depth	(AD)	+	
		conductivity	(CON)		
		secchi depth	(SEC)		

FIG 5.8A

CLUSTER ANALYSIS OF SITES AGAINST FISH OCCURRENCE
(2m SEINE ALL TRIPS)

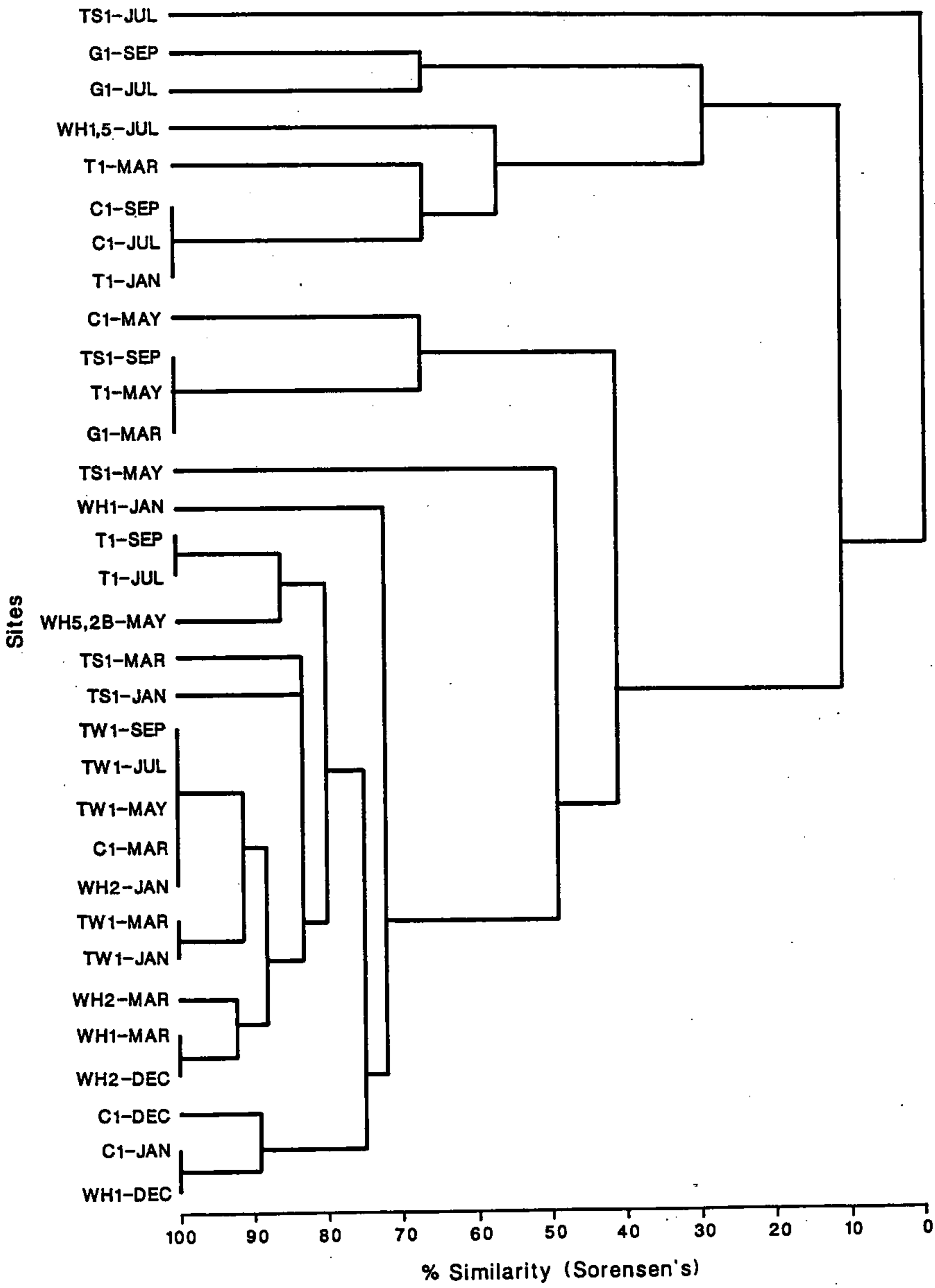


FIG 5.8B

CLUSTERING OF HABITATS SAMPLED BY 2m SEINE
ALL MAJOR SITES ALL TRIPS

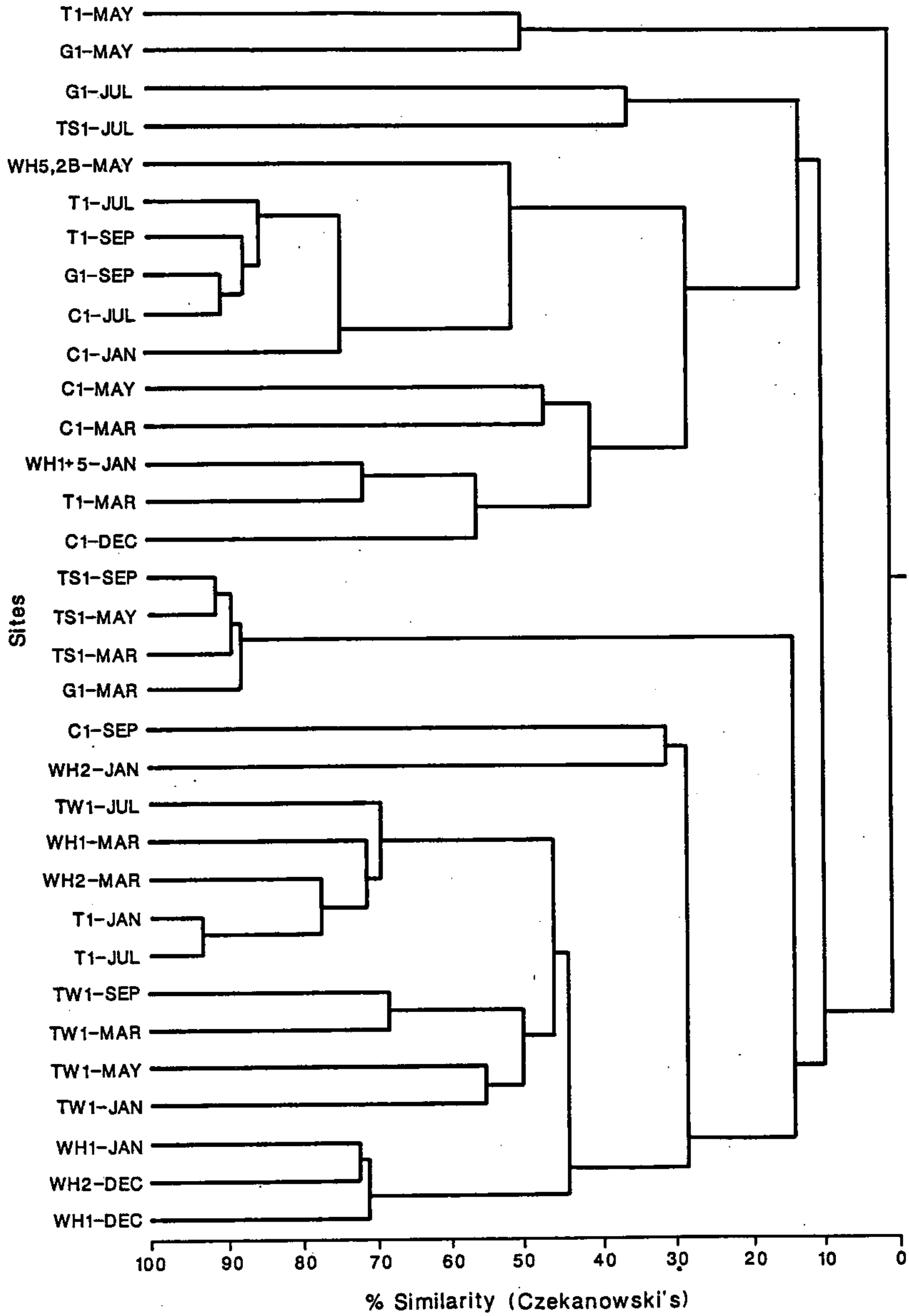


FIG 5.9

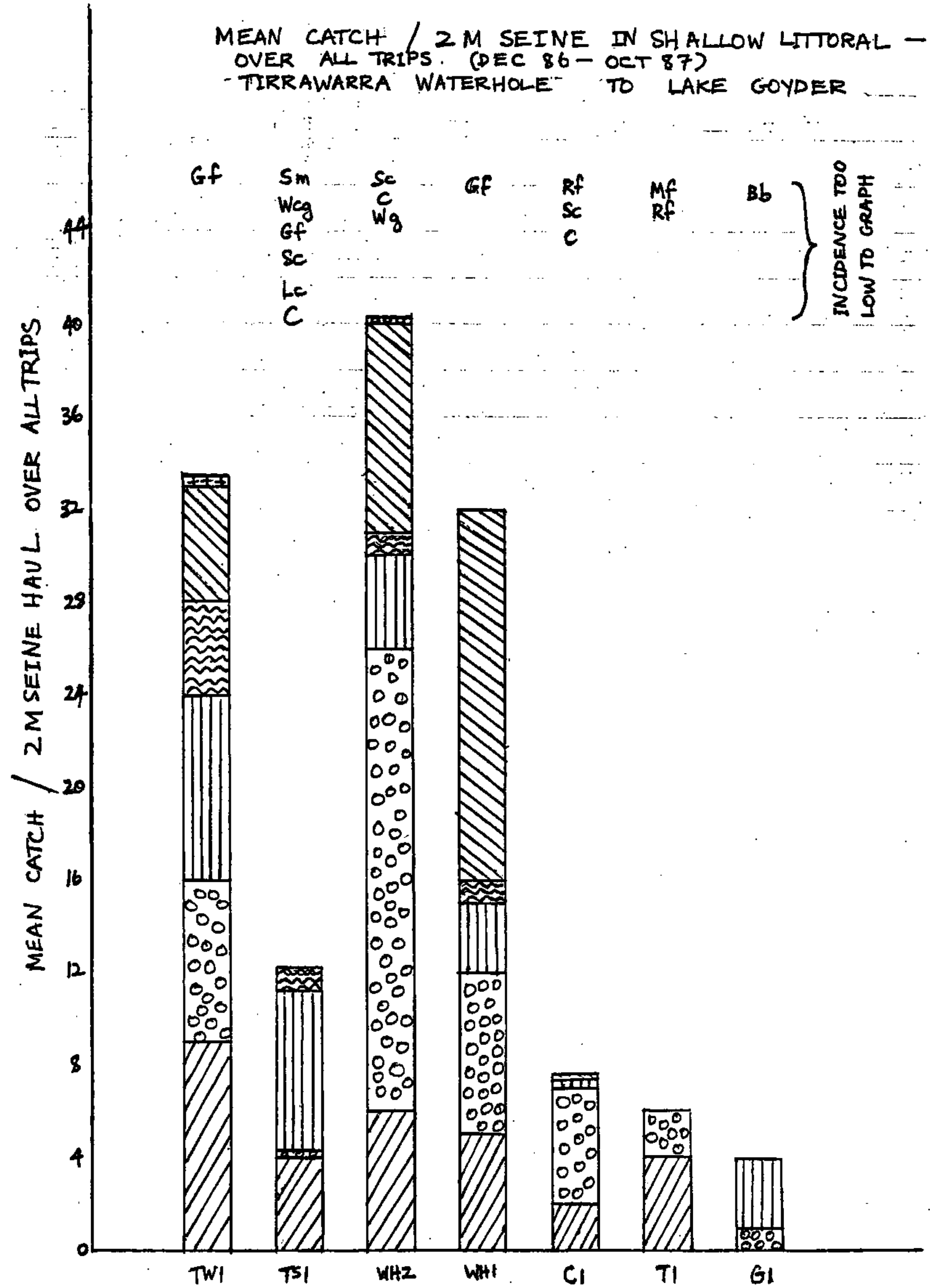

MEAN CATCH / 2M SEINE IN SHALLOW LITTORAL — OVER ALL TRIPS (DEC 86 – OCT 87) - TIRRAWARRA WATERHOLE TO LAKE GOYDER
MEAN CATCH / 2M SEINE HAUL OVER ALL TRIPS
0
4
8
12
16
20
24
28
32
36
40
44
TW1
TS1
WH2
WH1
C1
T1
G1
Gf
Sm
Wcg
Gf
Sc
Lc
C
Sc
C
Wg
Gf
Rf
Sc
C
Mf
Rf
Bb
INCIDENCE TOO LOW TO GRAPH

FIG 5.10A

CLUSTER ANALYSIS OF SITES AGAINST FISH OCCURRENCE
(20m SEINE ALL TRIPS)

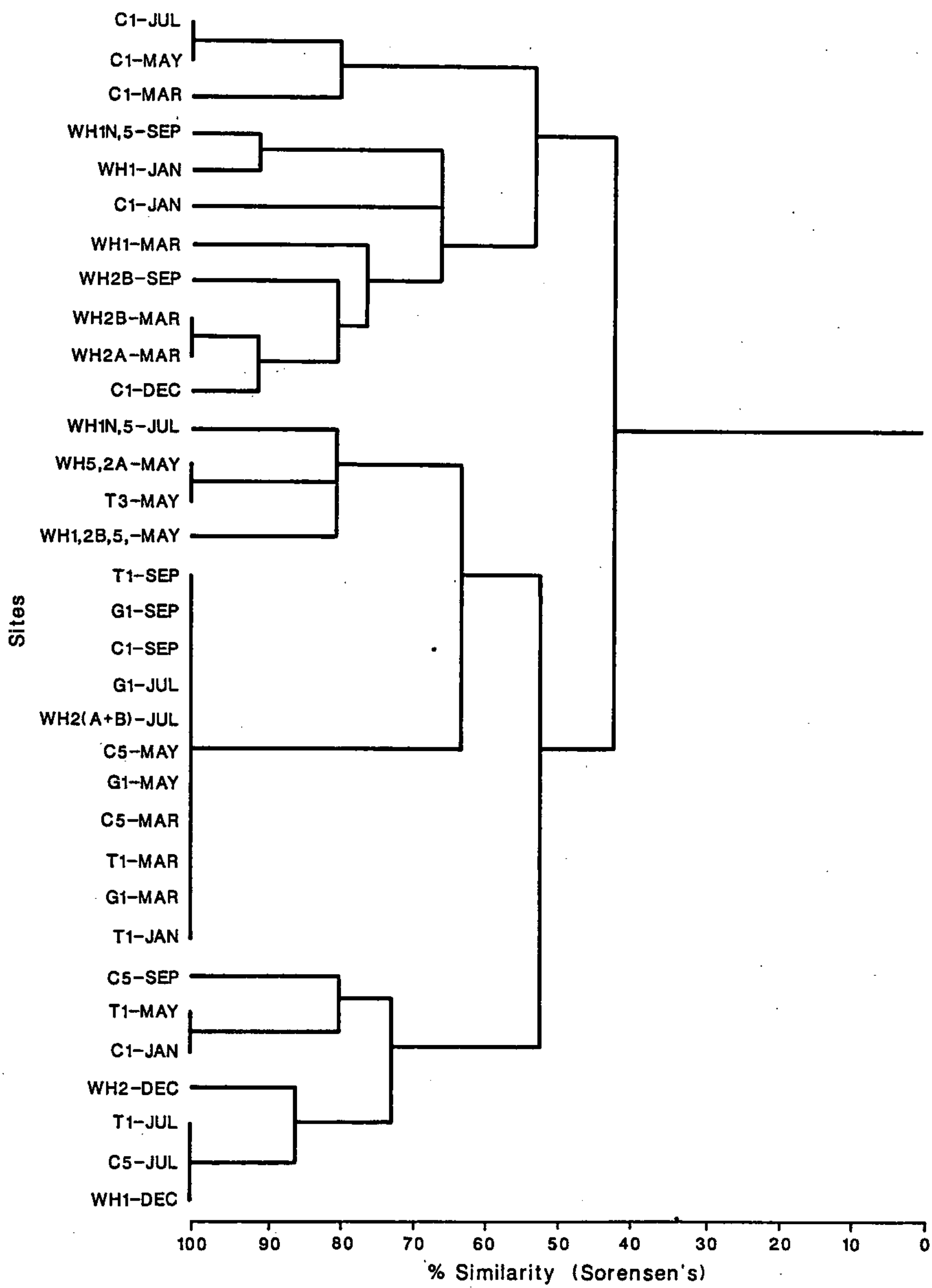


FIG 5.10B

CLUSTER ANALYSIS OF SITES AGAINST FISH ABUNDANCE
(20m SEINE ALL TRIPS)

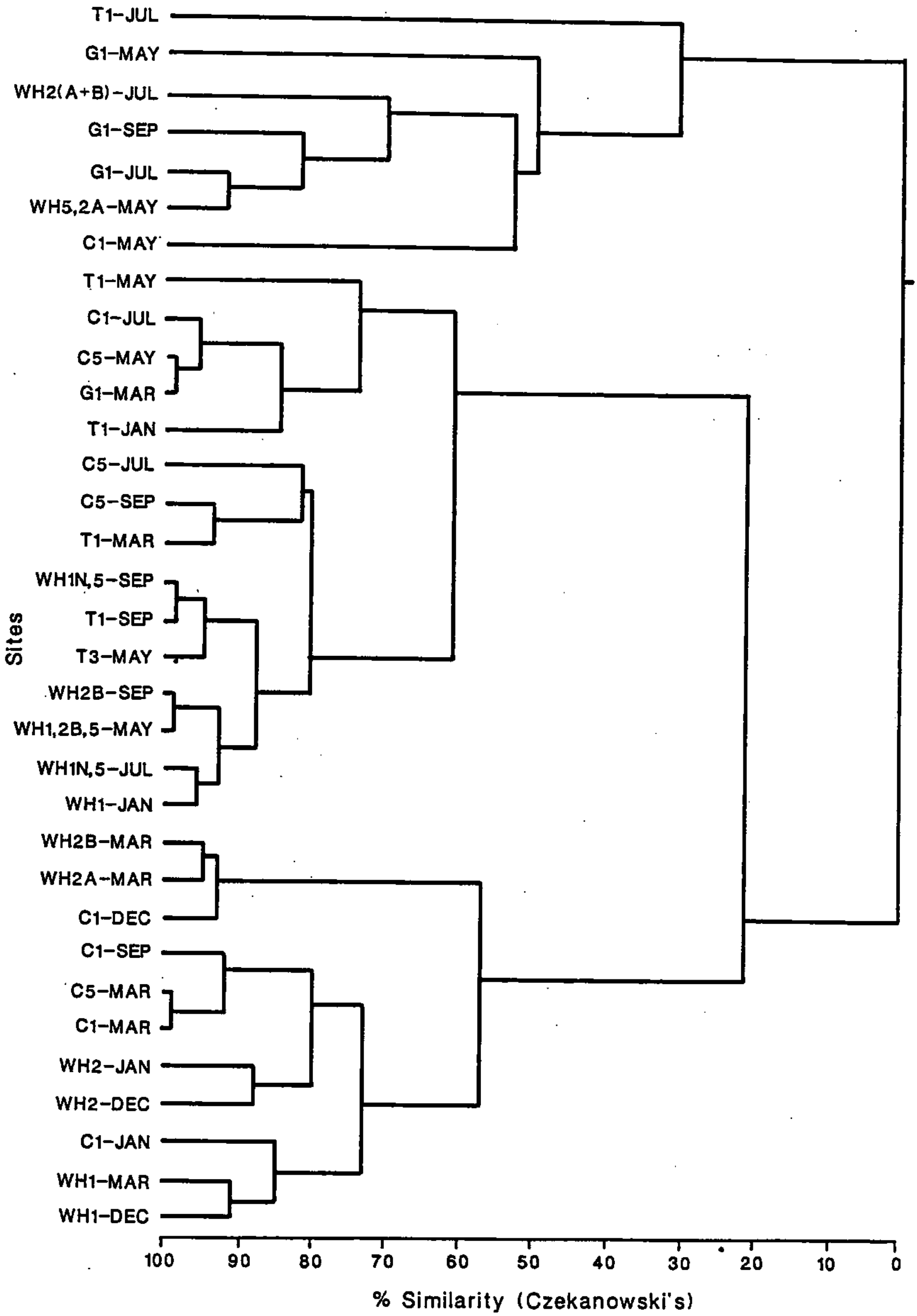


FIG 5.11A

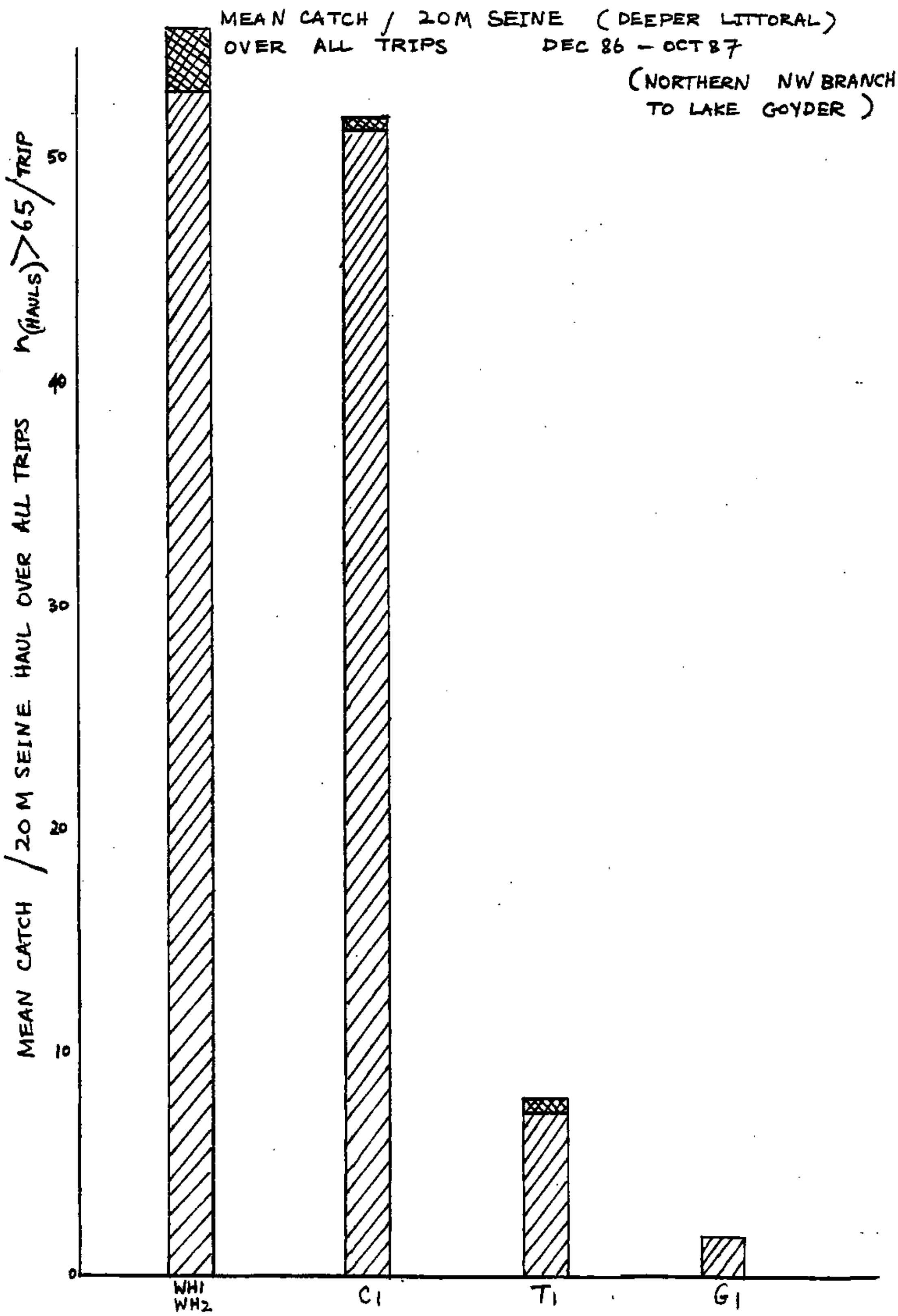

MEAN CATCH / 20M SEINE (DEEPER LITTORAL)
OVER ALL TRIPS DEC 86 – OCT 87
(NORTHERN NW BRANCH TO LAKE GOYDER)
MEAN CATCH /20 M SEINE HAUL OVER ALL TRIPS n(HAULS) > 65/TRIP
0
10
20
30
40
50
WH1
WH2
C1
T1
G1

FIG 5.11B


MEAN CATCH / 20M SEINE (DEEPER LITTORAL)
OVER ALLTRIPS, EXCLUDING BONY BREAM
DEC 86 – OCT 87, NORTHERN NW BRANCH TO LAKE GOYDER
MEAN CATCH / 20M SEINE HAUL OVER ALL TRIPS n(HAULS) > 65/TRIP
0
0.5
1.0
1.5
2.0
2.5
WH1
WH2
C1
T1
G1

FIG 5.12A

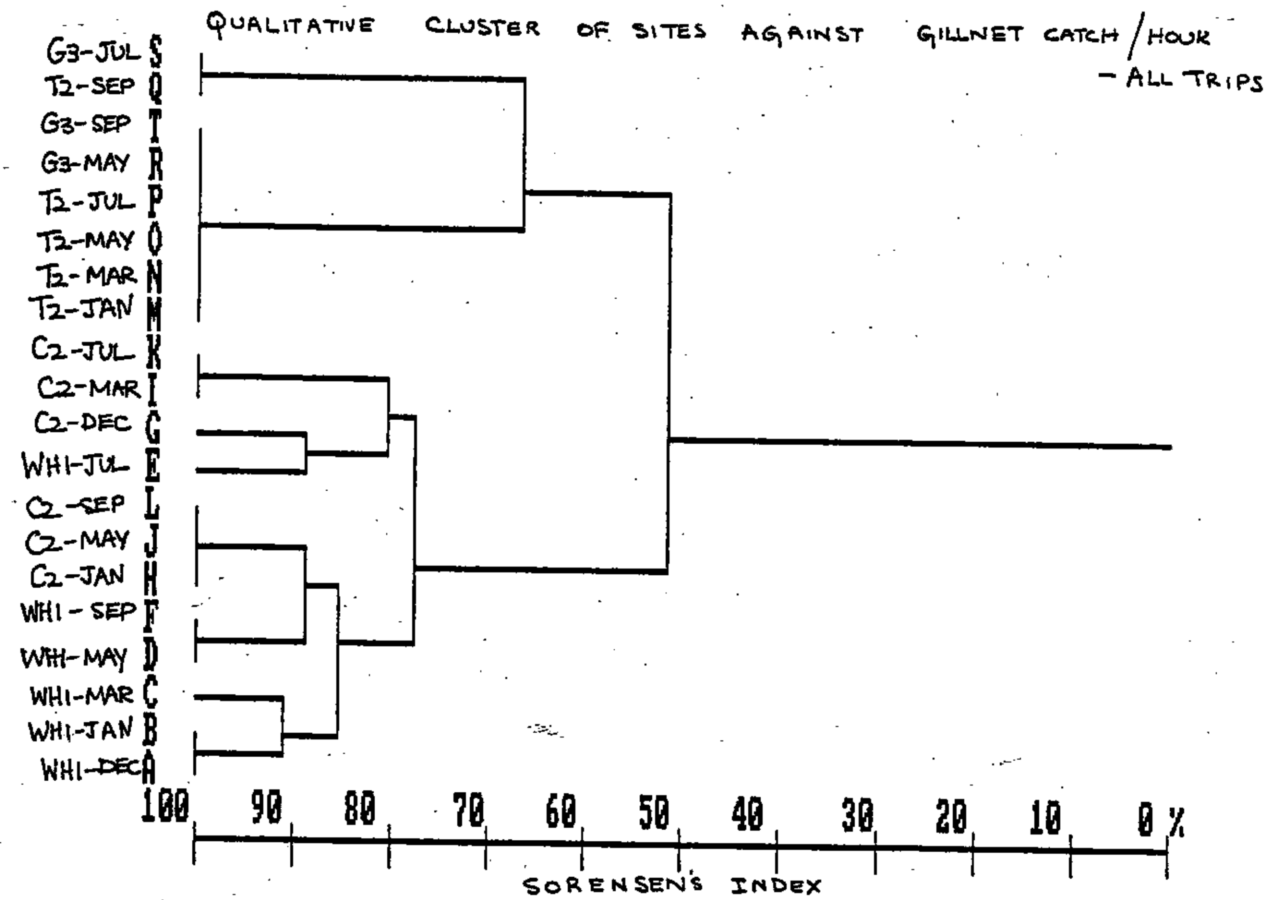


FIG 5.12B

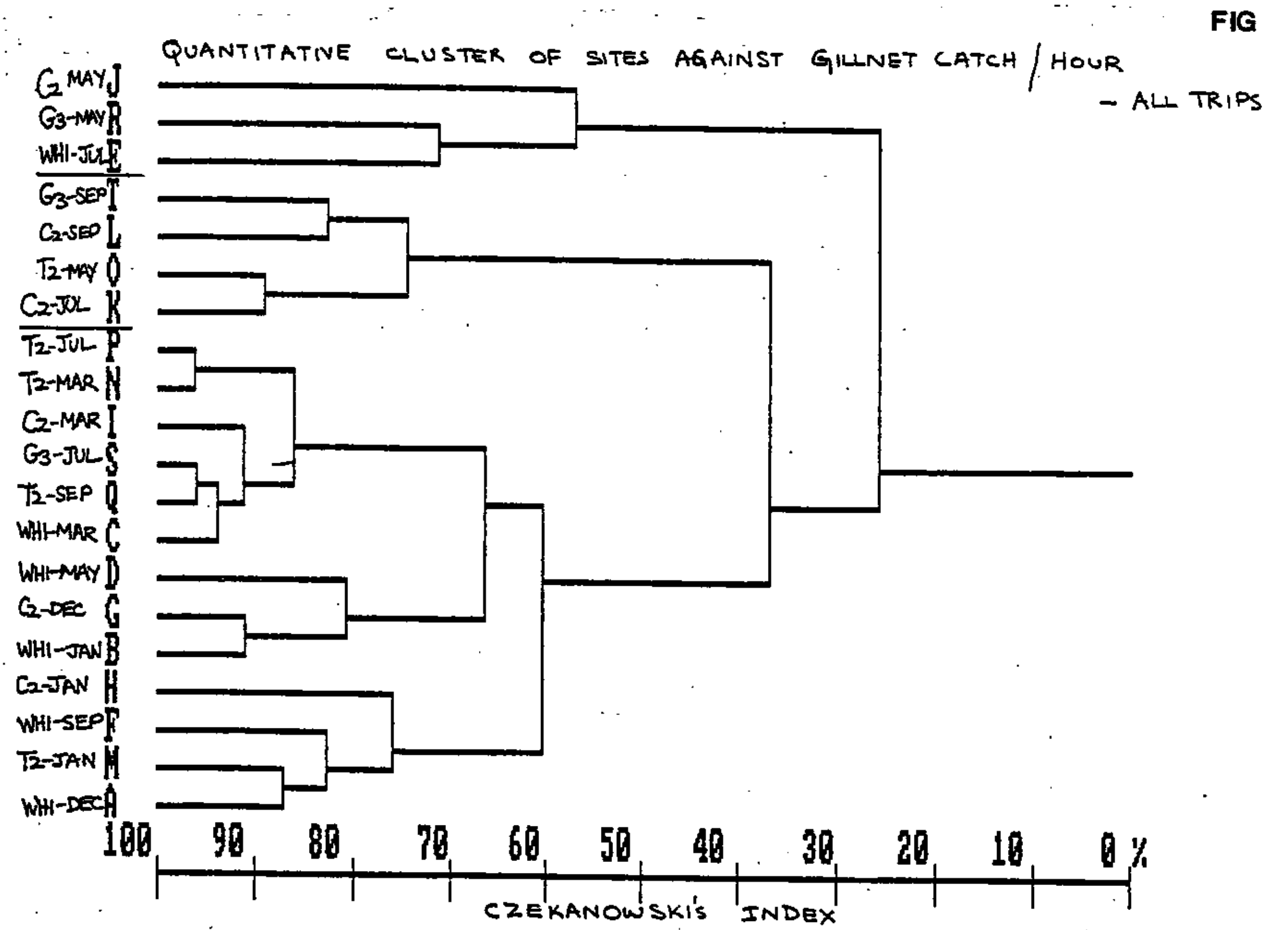


FIG 5.13A

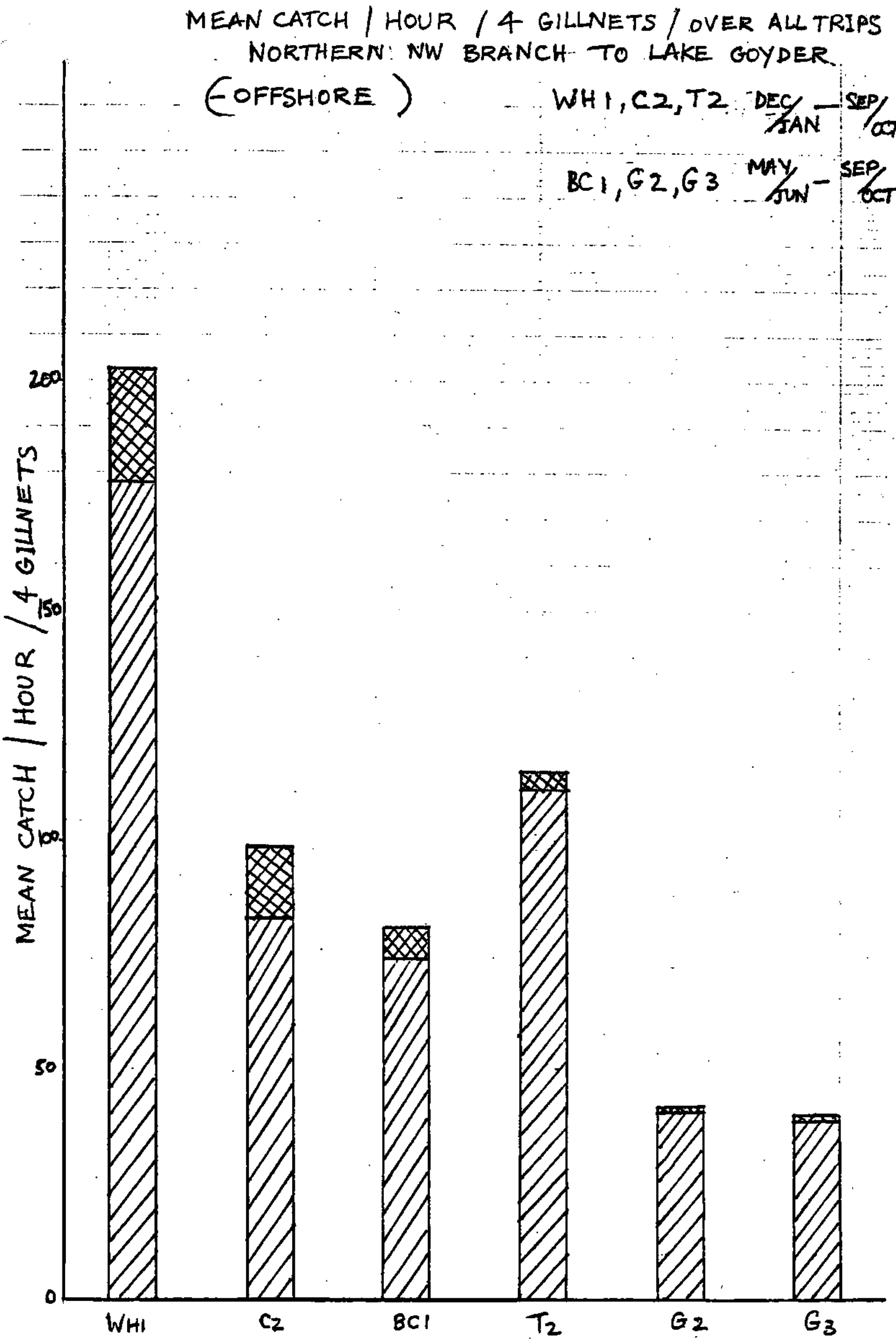

MEAN CATCH / HOUR / 4 GILLNETS / OVER ALL TRIPS
NORTHERN: NW BRANCH TO LAKE GOYDER
(OFFSHORE)
WH1, C2, T2 DEC/JAN – SEP/OCT
BC1, G2, G3 MAY/JUN – SEP/OCT
MEAN CATCH / HOUR / 4 GILLNETS
200
150
100
50
0
WH1
C2
BC1
T2
G2
G3

FIG 5.13B

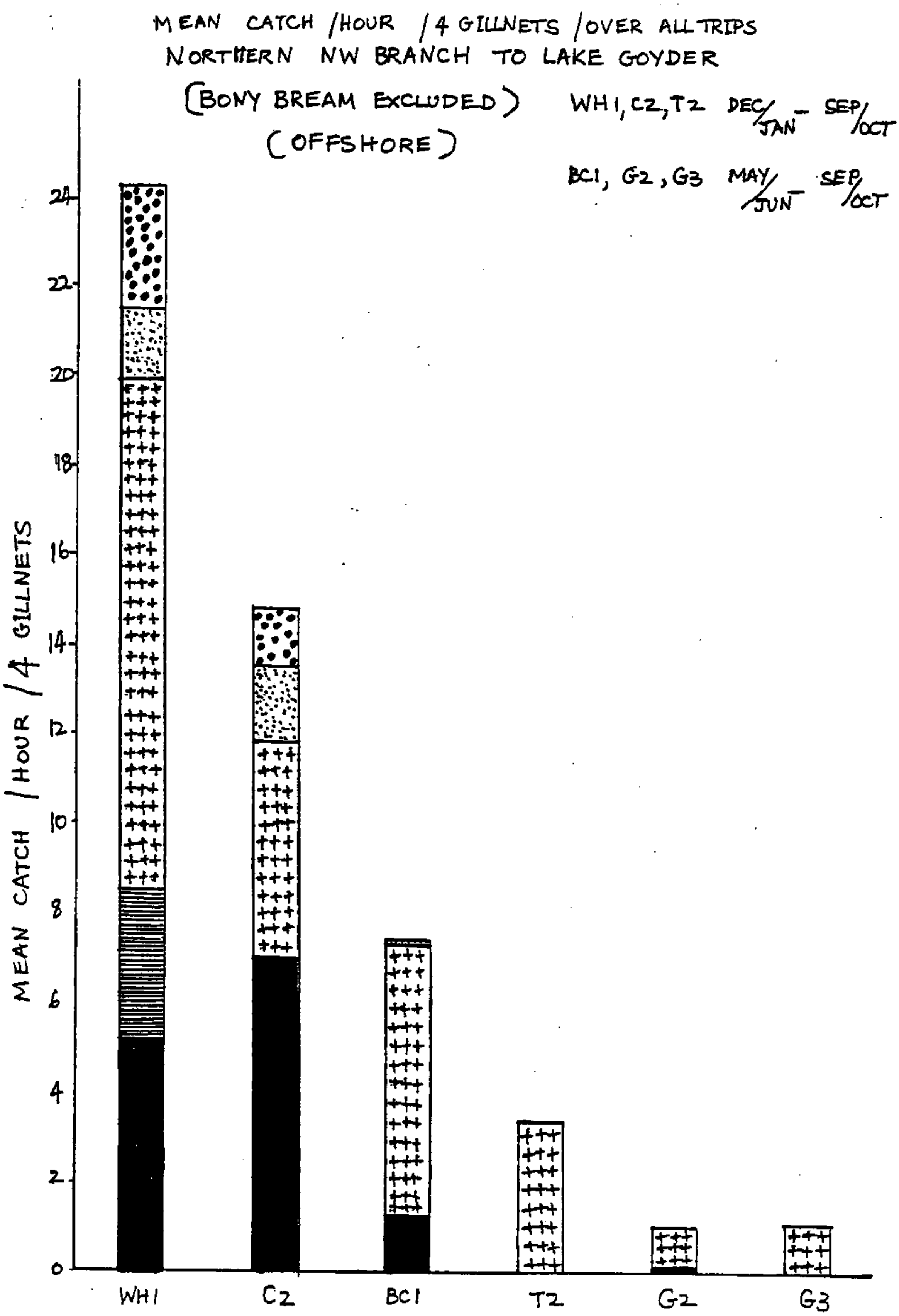

MEAN CATCH /HOUR /4 GILLNETS /OVER ALL TRIPS
NORTHERN NW BRANCH TO LAKE GOYDER
(BONY BREAM EXCLUDED)
(OFFSHORE)
WH1, C2, T2 DEC/JAN - SEP/OCT
BC1, G2, G3 MAY/JUN - SEP/OCT
MEAN CATCH /HOUR /4 GILLNETS
0
2
4
6
8
10
12
14
16
18
20
22
24
WH1
C2
BC1
T2
G2
G3

FIG 5.14A

QUALITATIVE CLUSTER OF SITES AGAINST TRAWLCATCH/HAUL — ALL TRIPS

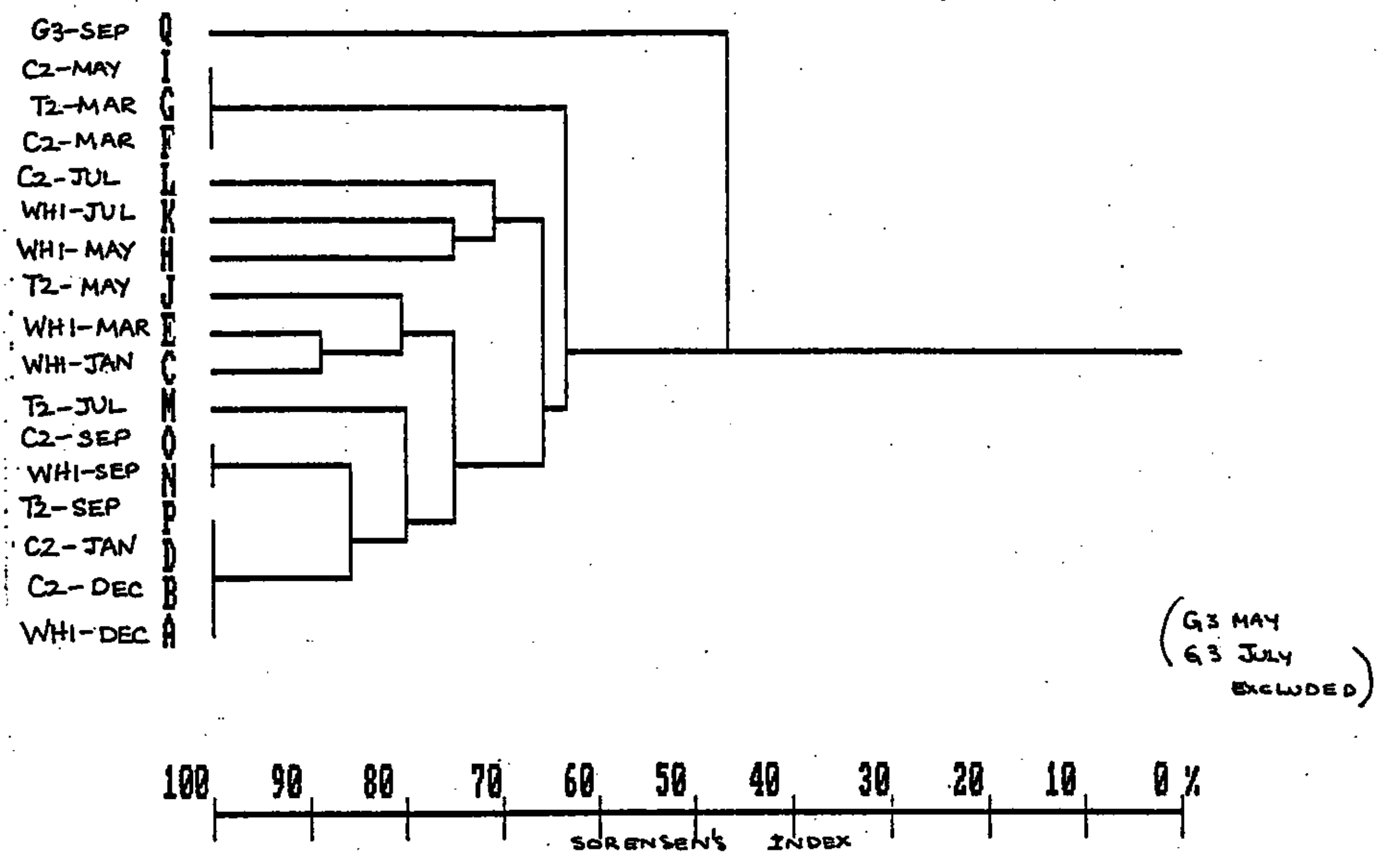


FIG 5.14B

QUANTITATIVE CLUSTER OF SITES AGAINST TRAWLCATCH/HAUL — ALL SITES

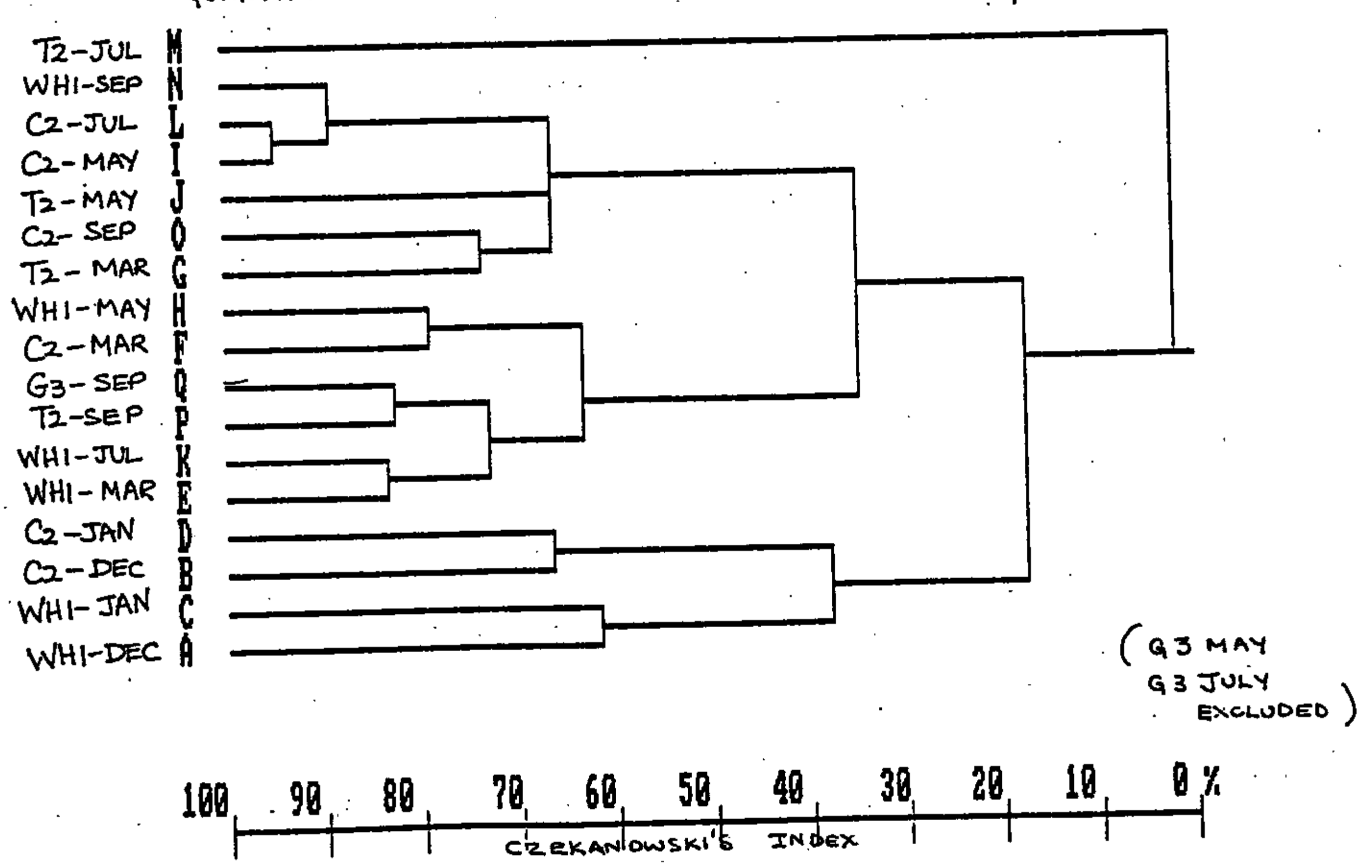
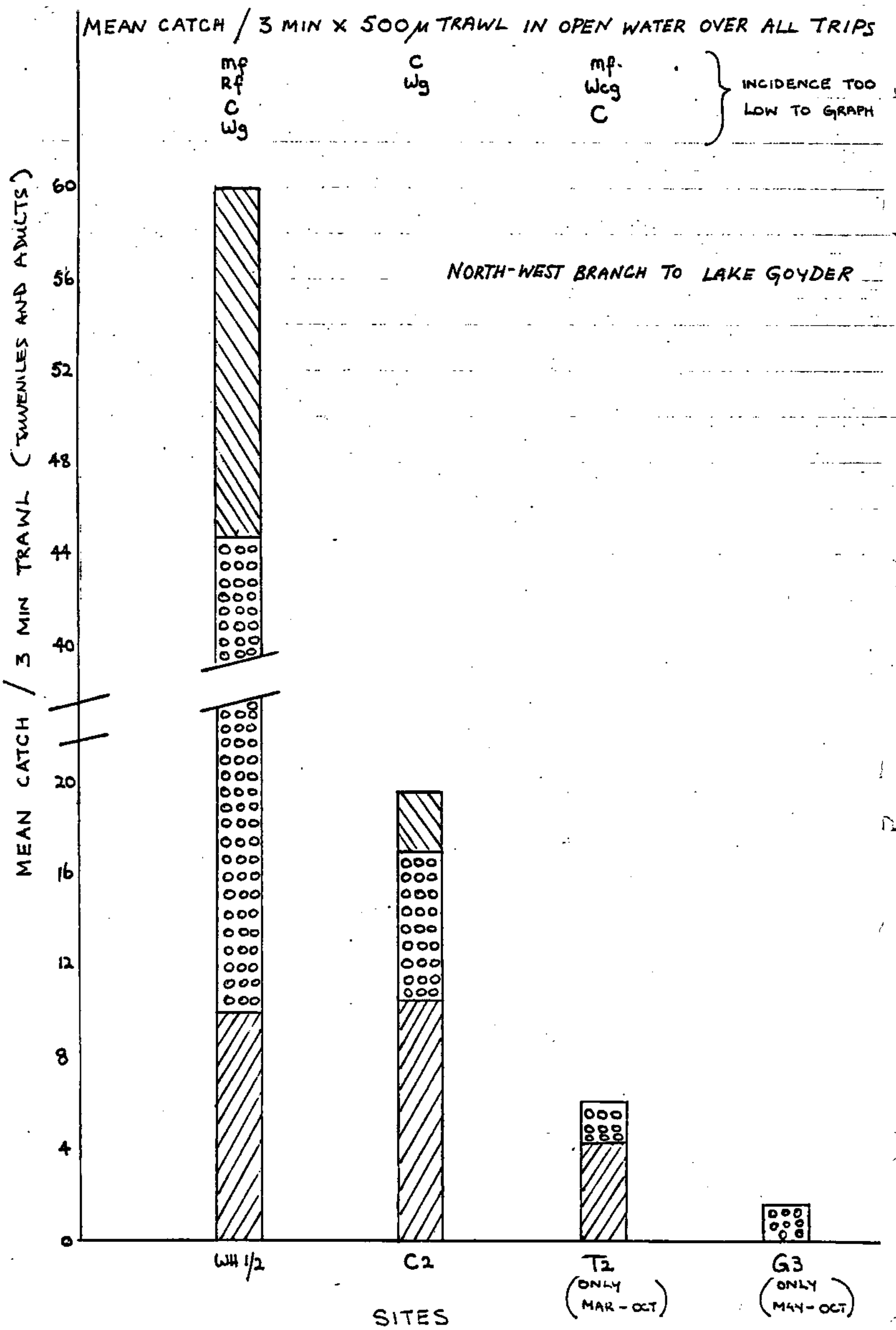


FIG 5.15



MEAN CATCH / 3 MIN x 500 m TRAWL IN OPEN WATER OVER ALL TRIPS
mf Rf C Wg
C Wg
mf. Wcg C
INCIDENCE TOO LOW TO GRAPH
NORTH-WEST BRANCH TO LAKE GOYDER
MEAN CATCH / 3 MIN TRAWL (JUVENILES AND ADULTS)
0
4
8
12
16
20
40
44
48
52
56
60
WH 1/2
C2
T2 (ONLY MAR - OCT)
G3 (ONLY MAY - OCT)
SITES

FIG 5.16

SPEARMAN RANK CORRELATION COEFFICIENT MATRIX

2 M SEINE HAULS, 56 SITES, ALL MONTHS

FISH SPECIES	VEGETATION: TERRESTRIAL ADJACENT	VEGETATION: TERRESTRIAL SUBMERGED	VEGETATION AQUATIC: ATTACHED EMERGENT	VEGETATION AQUATIC: ATTACHED SUBMERGENT	VEGETATION AQUATIC: FLOATING UNATTACHED	VEGETATION AQUATIC: FLOATING, ATTACHED	WAVE ACTION	FLOW	SUBMERGENCE FREQUENCY	TEMPERATURE AT 0.2 M	DISSOLVED OXYGEN	BANK INCLINE	AVERAGE DEPTH	CONDUCTIVITY AT 25°C	SECCHI DEPTH
BB (LARVAE + JUVENILES)	.24	.02	-.08	.16	.21	.27 *	-.15	.27 *	.37 **	.41 **	-.25	.18	.32 *	-.18	-.05
SM (LARVAE + JUVENILES)	.05	-.18	.12	.21	.06	.24	.24	.12	.44 ***	.25	-.11	.16	.35 **	-.23	-.01
MF (JUVENILES + ADULTS)	.42 ***	.19	-.15	.14	.37 **	.48 ***	-.27 *	.37 **	.41 ***	.38 *	-.50 **	.31 *	.16	-.37 **	.01
RF (JUVENILES)	.54 ***	.33 **	-.30 *	.14	.43 ***	.53 ***	-.40 **	.49 ***	.25	.08	-.18	.44 ***	.41 **	-.44 ***	.07
WCG LARVAE + JUVENILES + ADULTS	.35 **	.04	-.14	.27 *	.40 **	.44 ***	-.07	.38 **	.66 ***	.24	-.22	.34 **	.37 **	-.30 *	-.05

ENVIRONMENT PARAMETERS

.05 > P > .01 *
.01 ≥ P > .001 **
.001 ≥ P ***

FIG 5.17

SPEARMAN RANK CORRELATION COEFFICIENT MATRIX

20 M SEINE HAULS
58 SITES, ALL MONTHS
ENVIRONMENT PARAMETERS

FISH SPECIES	VEGETATION: TERRESTRIAL ADJACENT	VEGETATION: TERRESTRIAL SUBMERGED	VEGETATION: AQUATIC: ATTACHED EMERGENT	VEGETATION: AQUATIC: ATTACHED SUBMERGENT	VEGETATION: AQUATIC: FLOATING UNATTACHED	VEGETATION: AQUATIC: FLOATING ATTACHED	WAVE ACTION	FLOW	SUBMERGENCE FREQUENCY	TEMPERATURE AT 0.2 M	DISSOLVED OXYGEN	BANK INCLINE	AVERAGE DEPTH	CONDUCTIVITY AT 25°C	SECCHI DEPTH
BB (JUVENILES)	·16	-·06	·03	-·05	·09	·19	-·14	*** ·42	*** ·51	*** ·51	** -·39	* ·26	·05	* -·29	·18
RF (ADULTS)	*** ·57	·08	-·20	** ·38	** ·36	*** ·49	* -·26	*** ·64	*** ·57	** ·34	-·17	** ·40	-·04	-·24	·09
SC (ADULTS)	** ·36	·24	·22	·24	** ·37	** ·40	·23	*** ·51	*** ·51	*** ·46	·07	** ·40	* ·31	·13	·12
C (JUVENILES)	·25	-·15	·03	·07	·25	·25	-·07	*** ·51	** ·35	* ·27	-·09	·23	-·11	-·18	·14
SM (ADULTS)	·08	-·08	** ·35	* ·33	·19	·19	* ·32	·17	* ·27	·005	·15	·13	·23	-·04	·08

·05 > P > ·01 *
·01 ≥ P > ·001 **
·001 ≥ P ***

FIG 5.18A

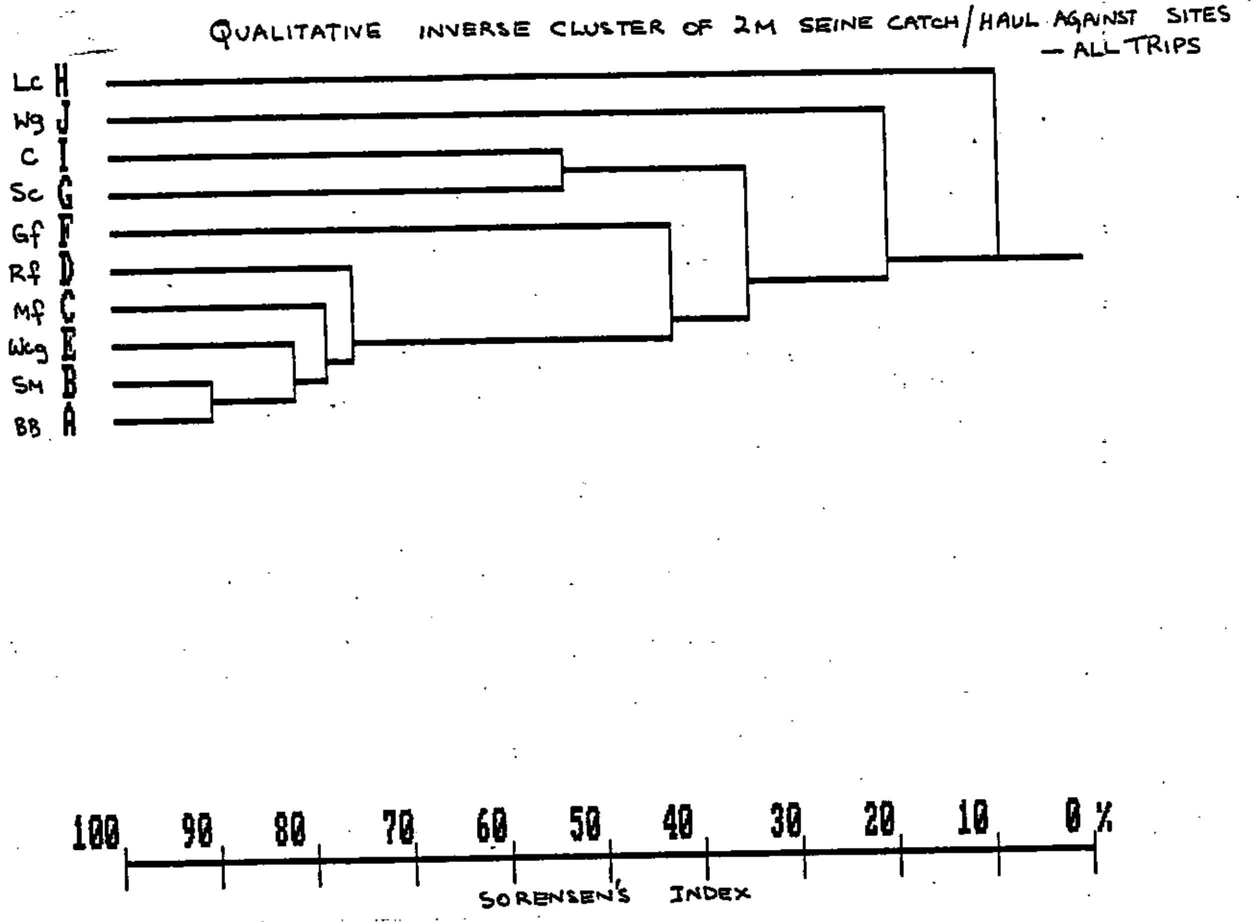


FIG 5.18B

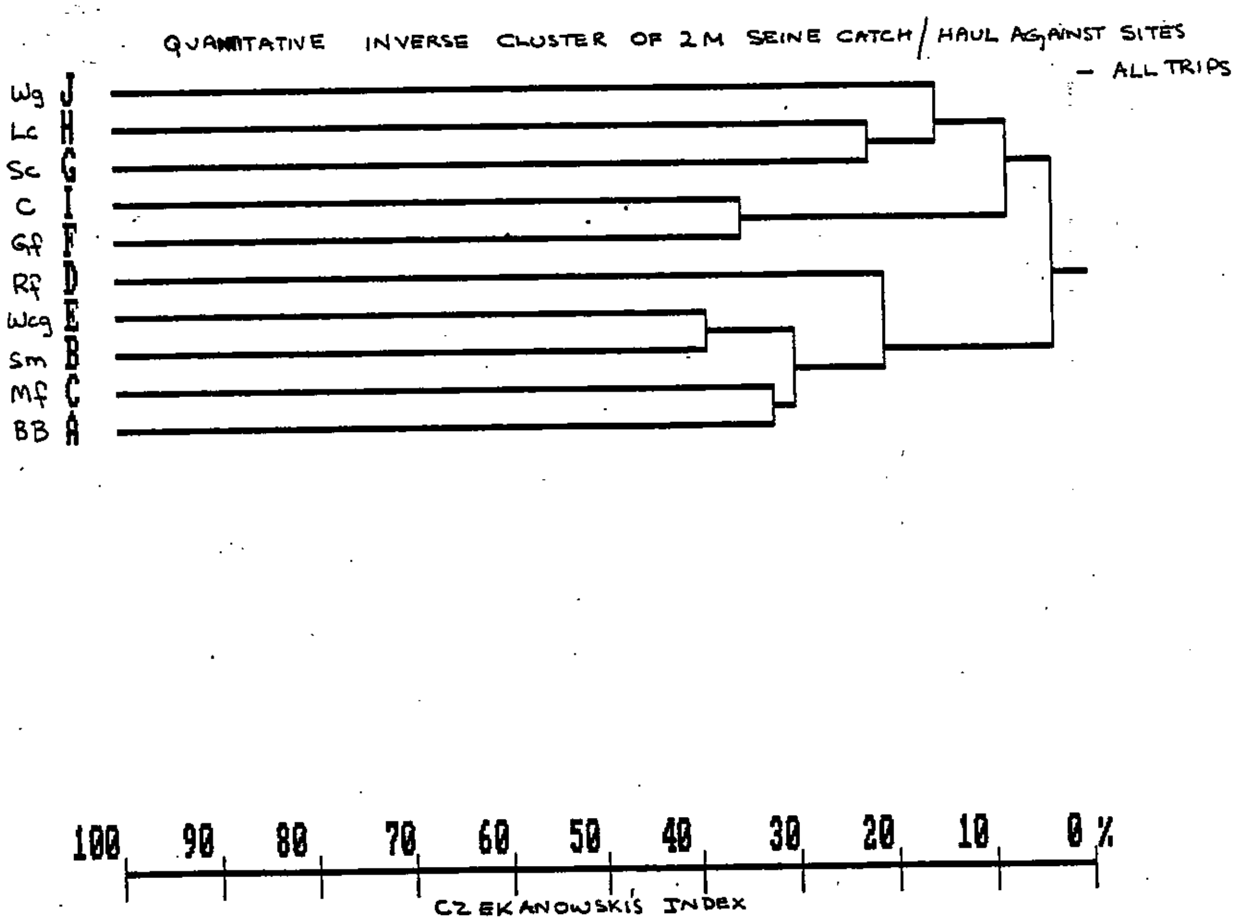


FIG 5.19A

QUALITATIVE INVERSE CLUSTER OF 20M SEINE CATCH/HAUL AGAINST SITES – ALL TRIPS

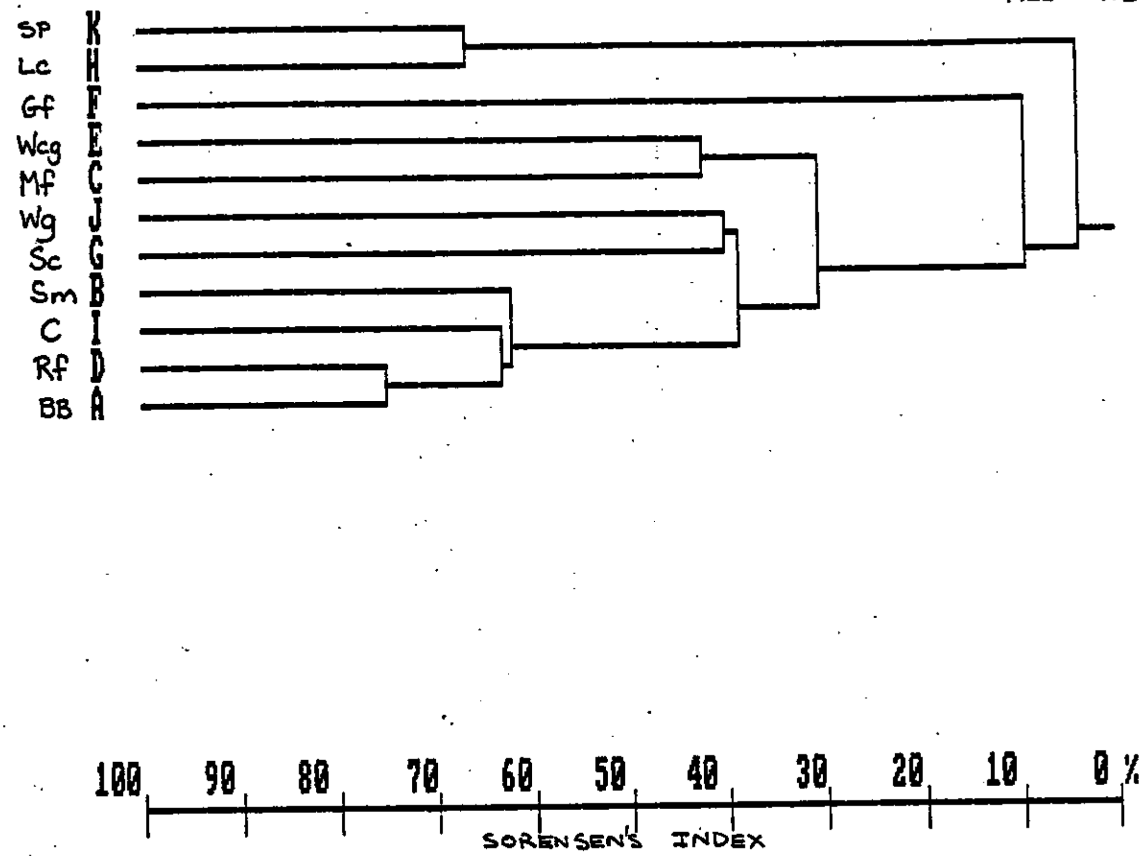


FIG 5.19B

QUANTITATIVE INVERSE CLUSTER OF 20M SEINE CATCH/HAUL AGAINST SITES – ALL TRIPS

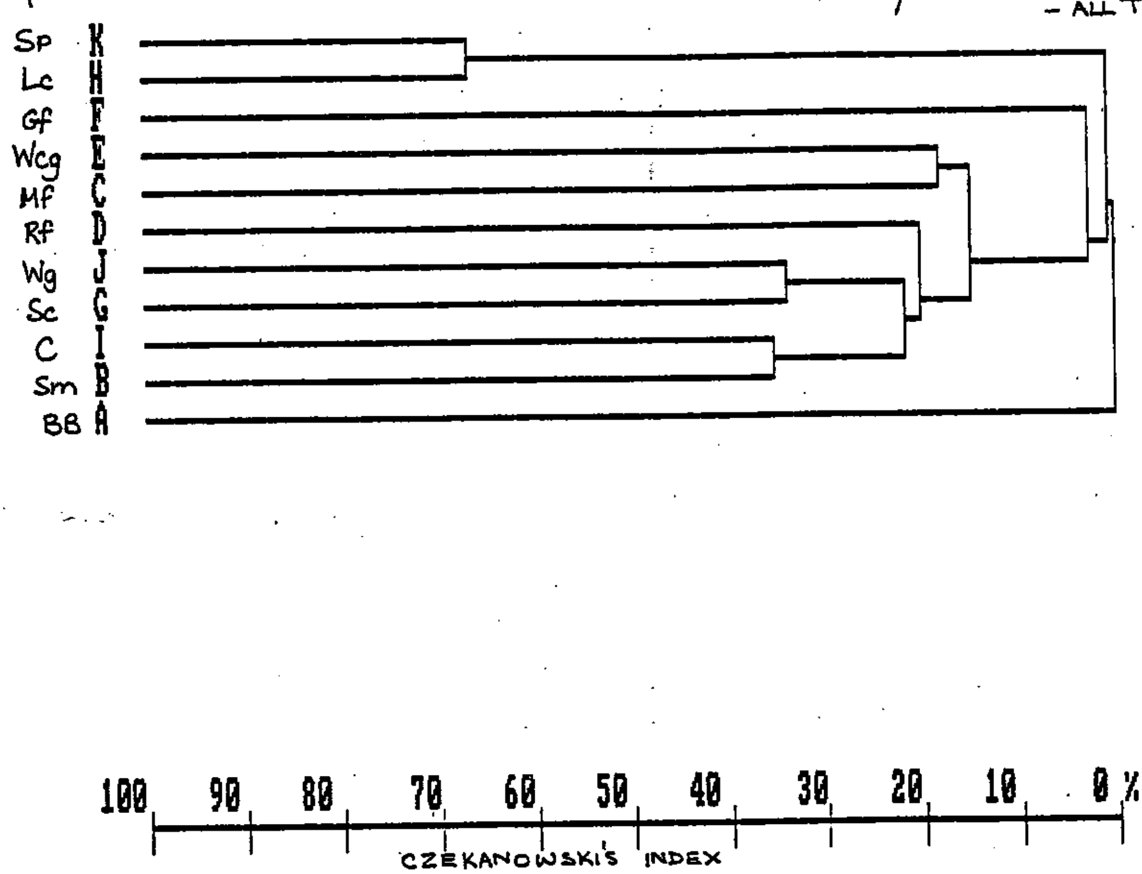


FIG 5.20A

QUALITATIVE INVERSE CLUSTER OF GILLNET CATCH/HOUR AGAINST SITES — ALL TRIPS

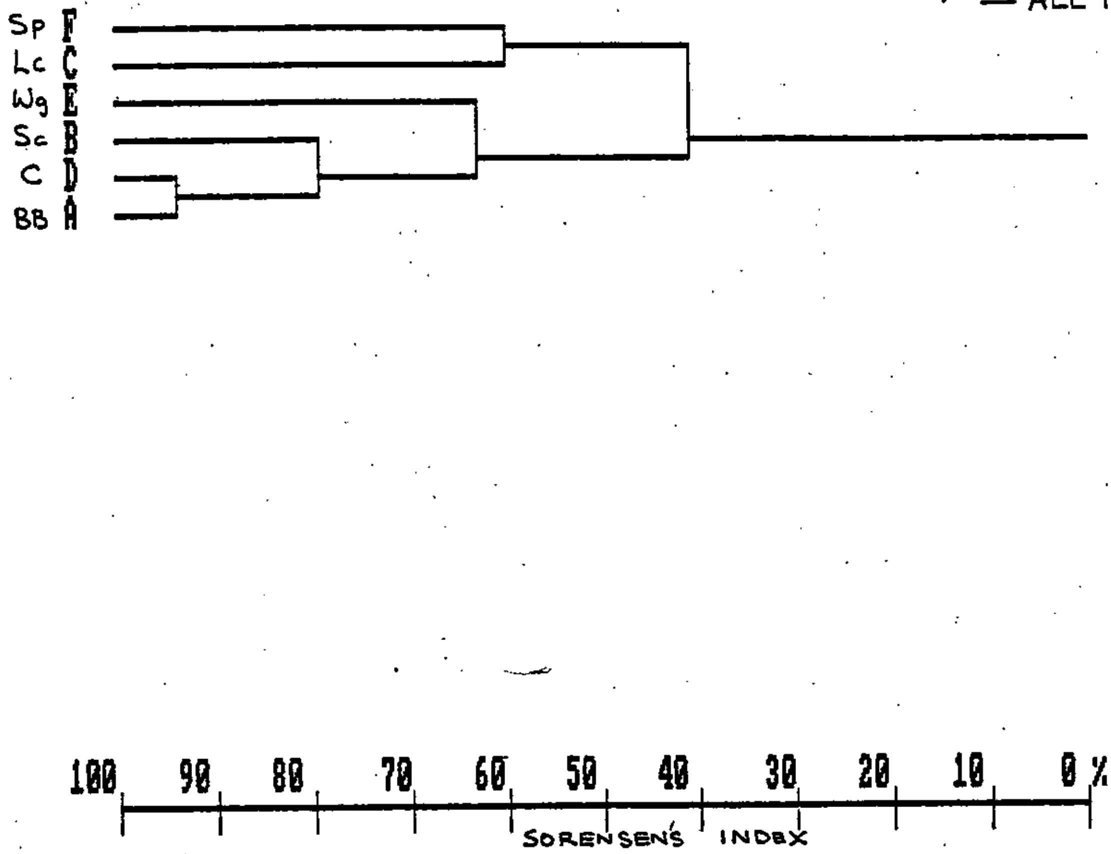


FIG 5.20B

QUANTITATIVE INVERSE CLUSTER OF GILLNET CATCH/HOUR AGAINST SITES — ALL TRIPS

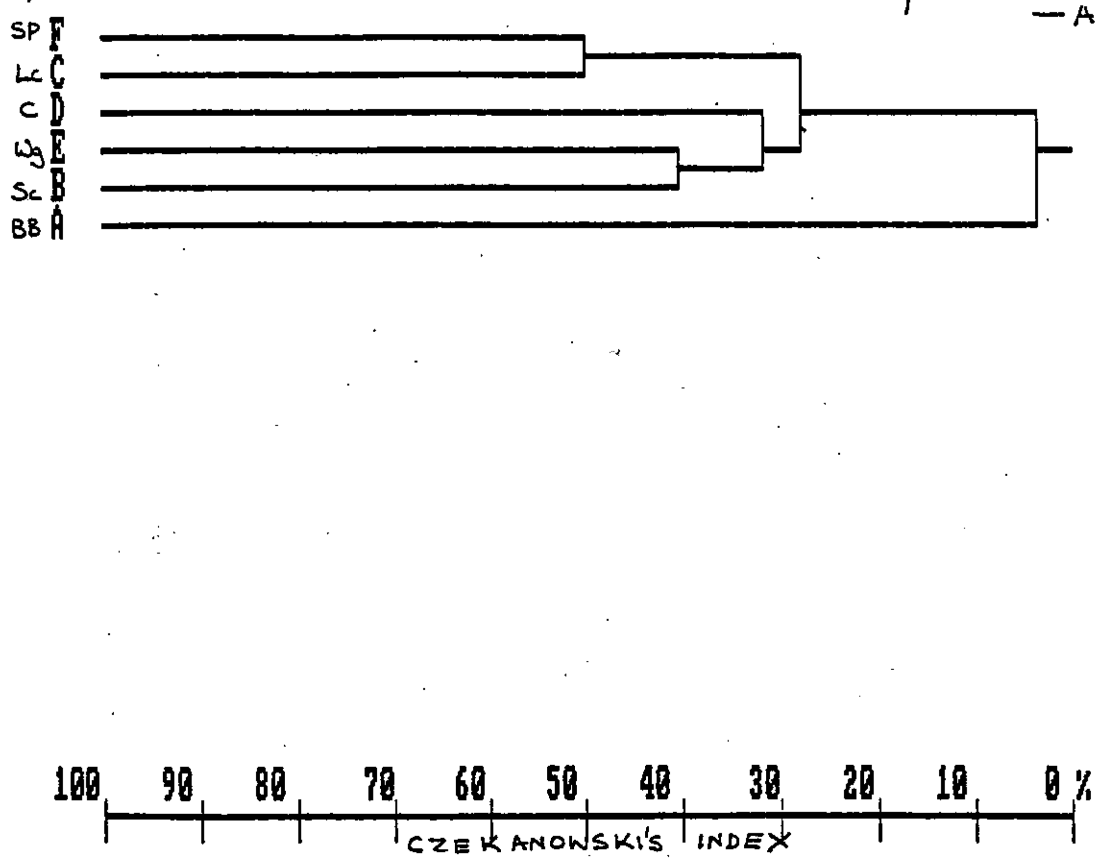


FIG 5.21A

QUALITATIVE INVERSE CLUSTER OF TRAWL CATCH | HAUL AGAINST SITES - ALL TRIPS

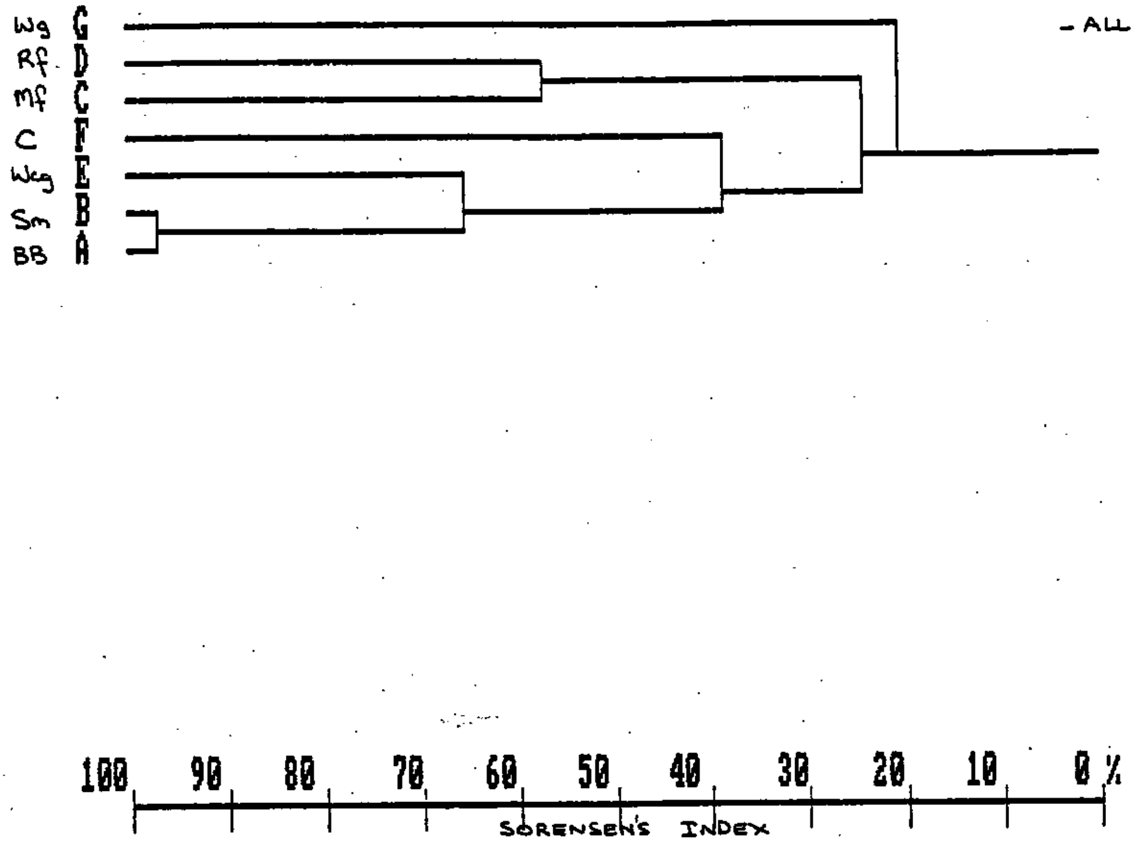
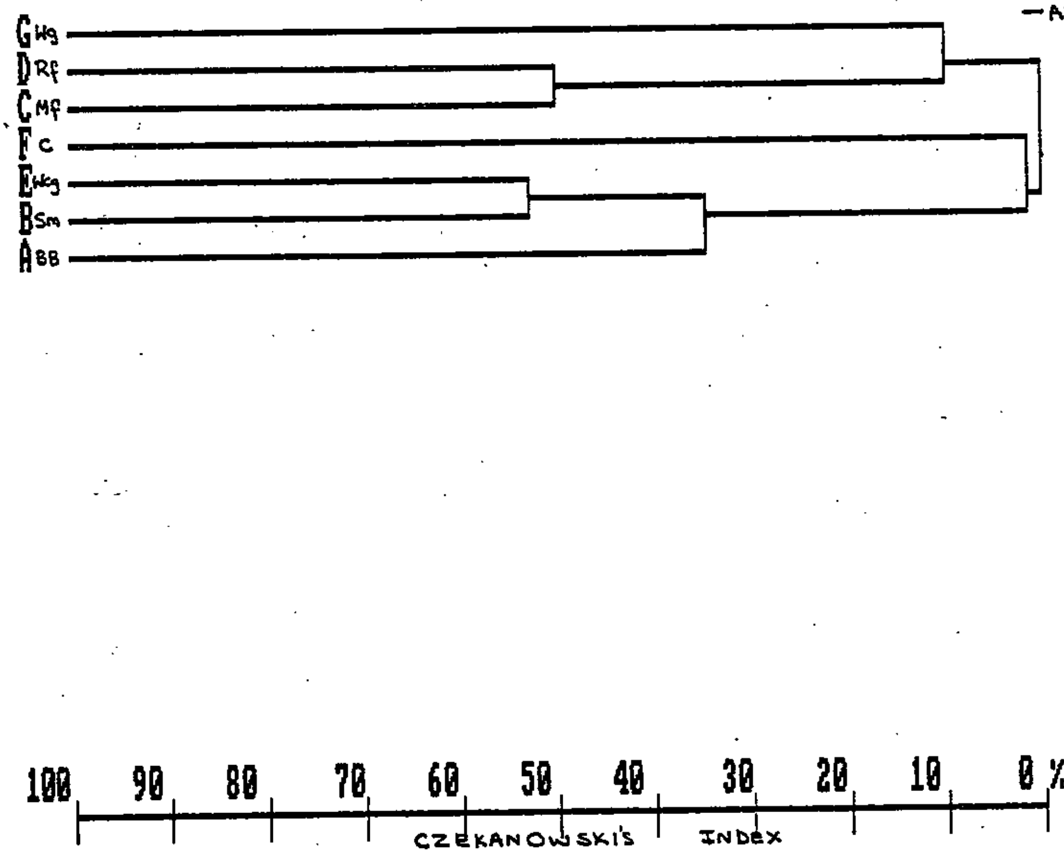
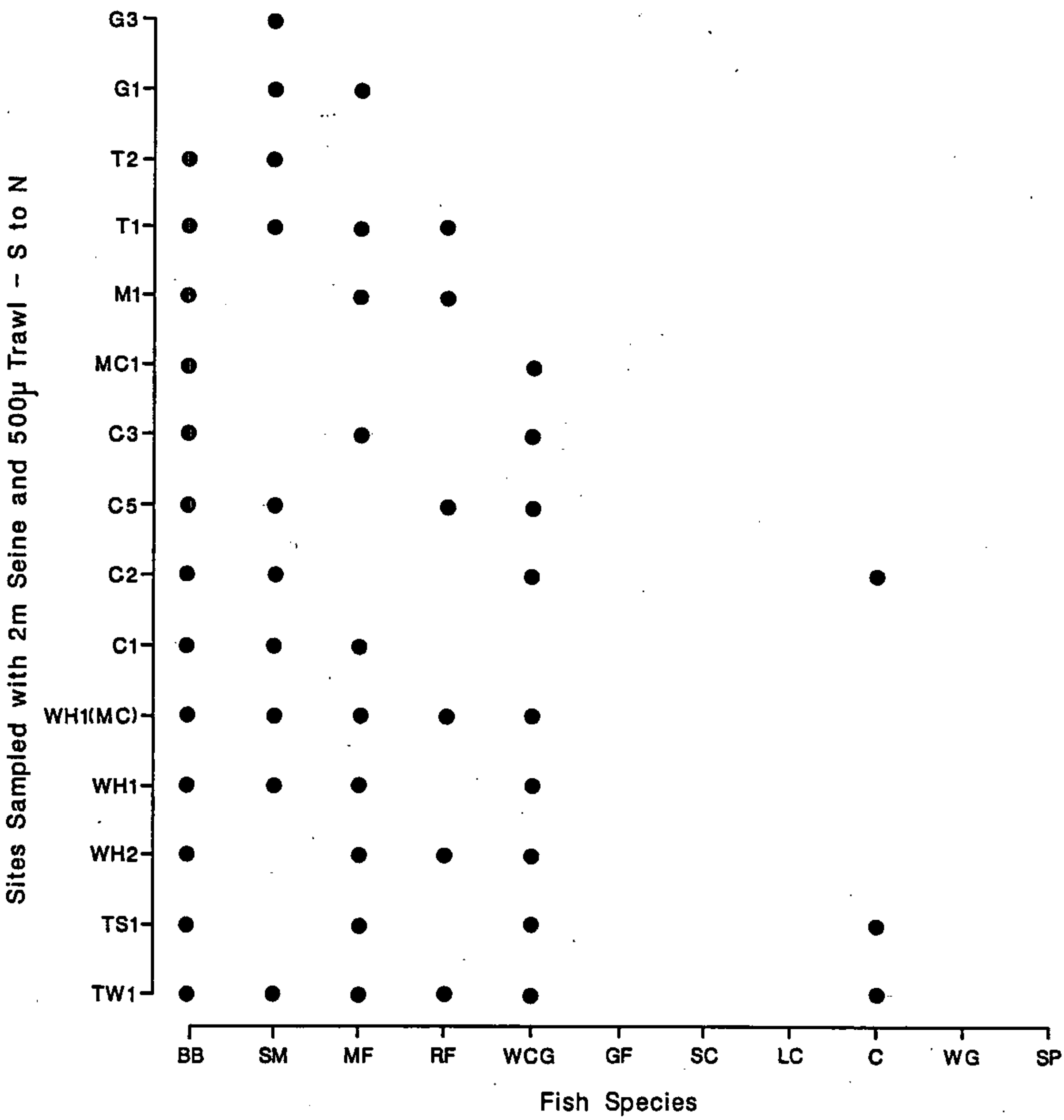


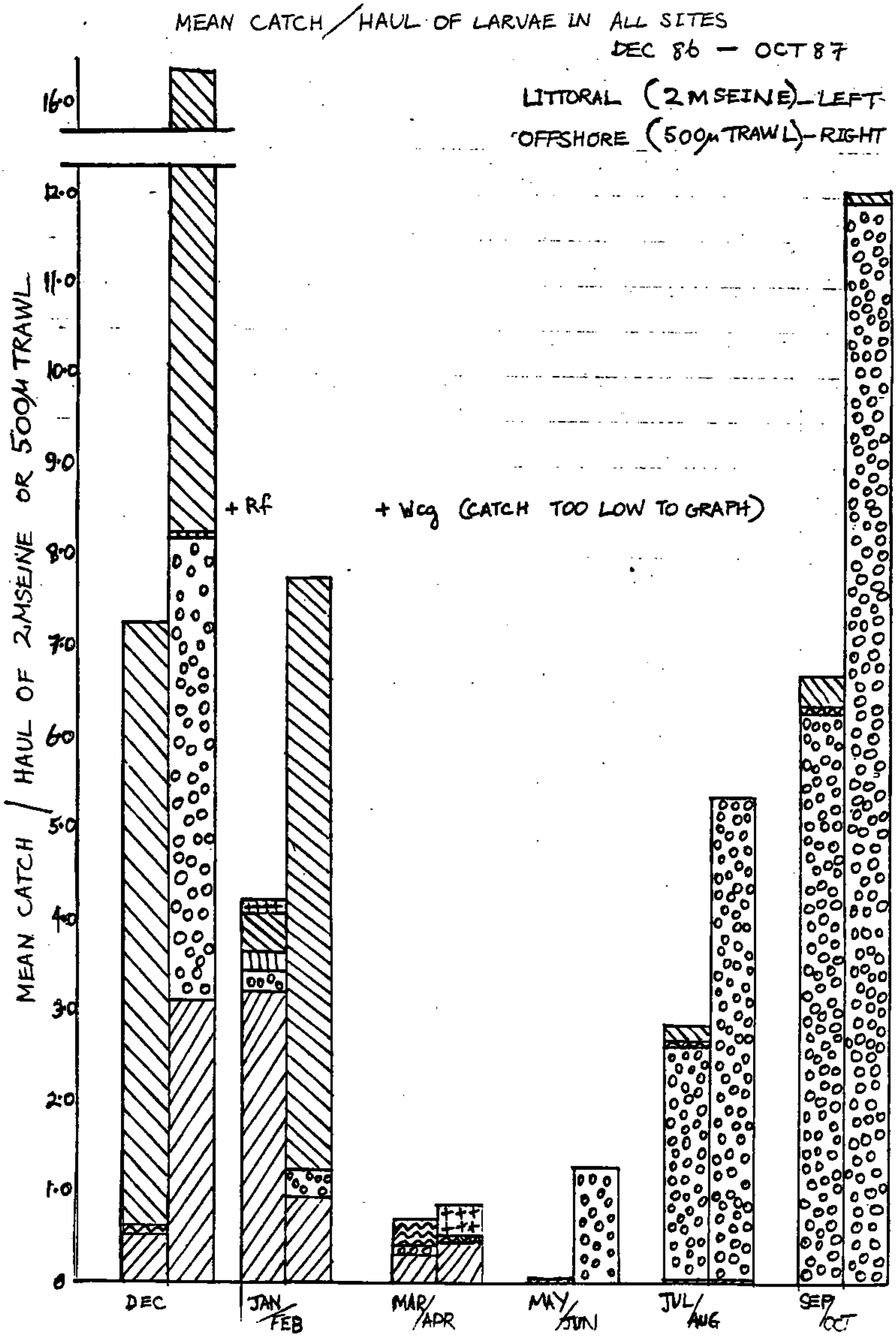
FIG 5.21B

QUANTITATIVE INVERSE CLUSTER OF TRAWL CATCH / HAUL AGAINST SITES - ALL TRIPS



LARVAL OCCURRENCE PER SITE : SUMMED OVER DEC '86 – OCT '87, BOTH 2m SEINE AND 500μ TRAWL




MEAN CATCH / HAUL OF LARVAE IN ALL SITES
DEC 86 — OCT 87
LITTORAL (2M SEINE) - LEFT
OFFSHORE (500μ TRAWL) - RIGHT
MEAN CATCH / HAUL OF 2M SEINE OR 500μ TRAWL
16.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
+ Rf
+ Wcg (CATCH TOO LOW TO GRAPH)
DEC
JAN/FEB
MAR/APR
MAY/JUN
JUL/AUG
SEP/OCT

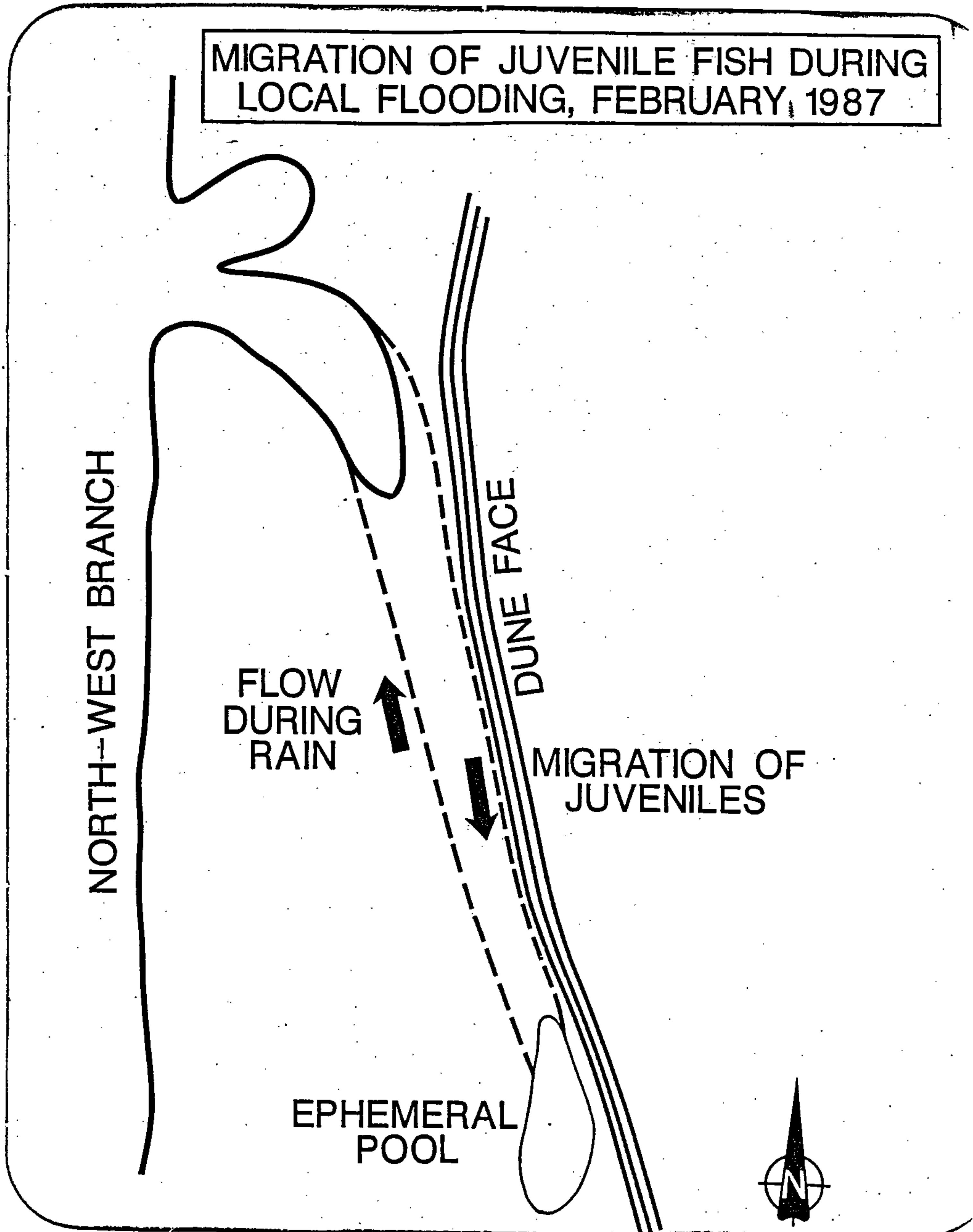
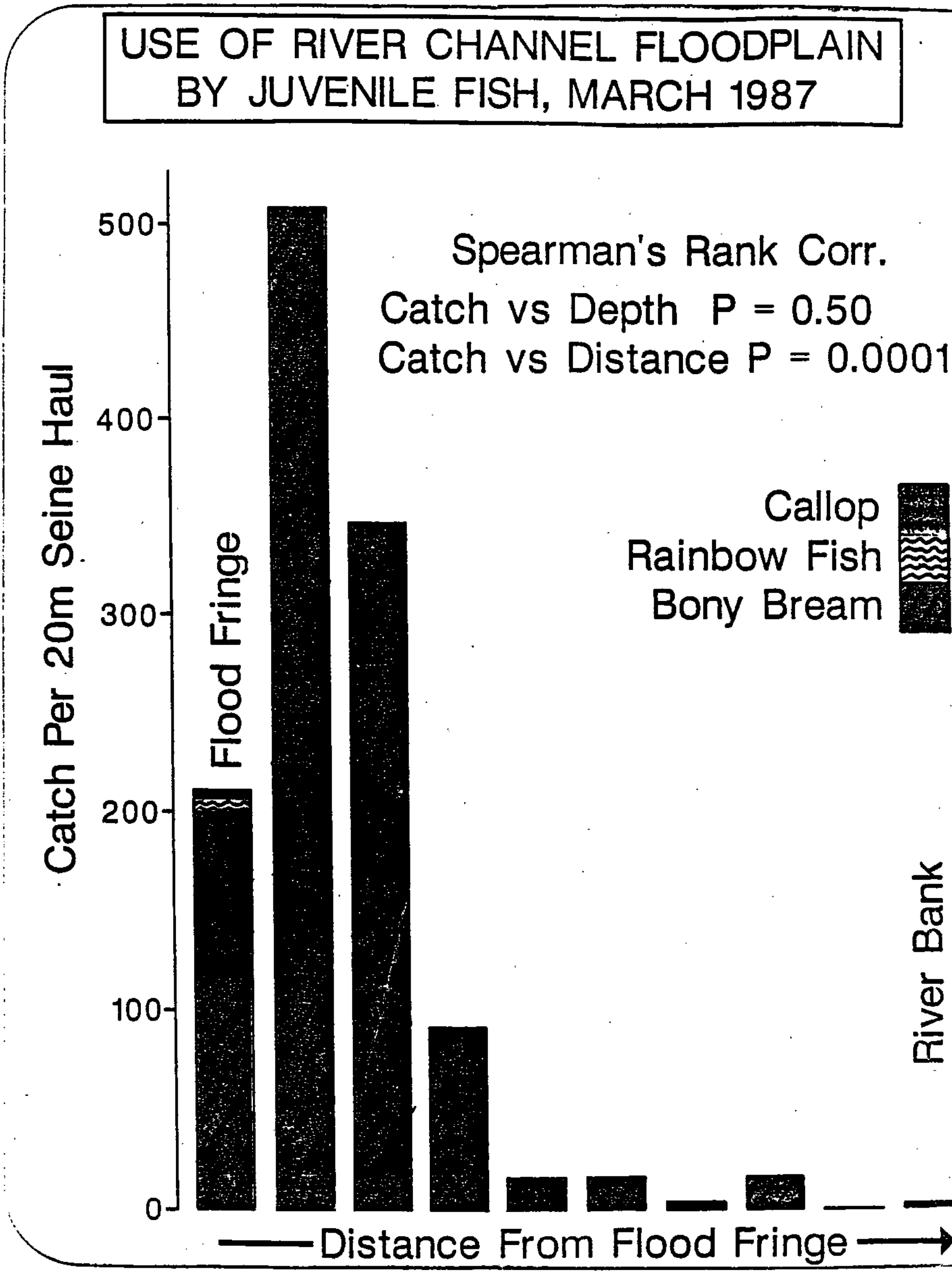

MIGRATION OF JUVENILE FISH DURING LOCAL FLOODING, FEBRUARY 1987
NORTH-WEST BRANCH
DUNE FACE
FLOW DURING RAIN
MIGRATION OF JUVENILES
EPHEMERAL POOL
N

FIG 5.25


USE OF RIVER CHANNEL FLOODPLAIN BY JUVENILE FISH, MARCH 1987
Spearman's Rank Corr.
Catch vs Depth P = 0.50
Catch vs Distance P = 0.0001
Callop
Rainbow Fish
Bony Bream
Catch Per 20m Seine Haul
500
400
300
200
100
0
Flood Fringe
River Bank
Distance From Flood Fringe

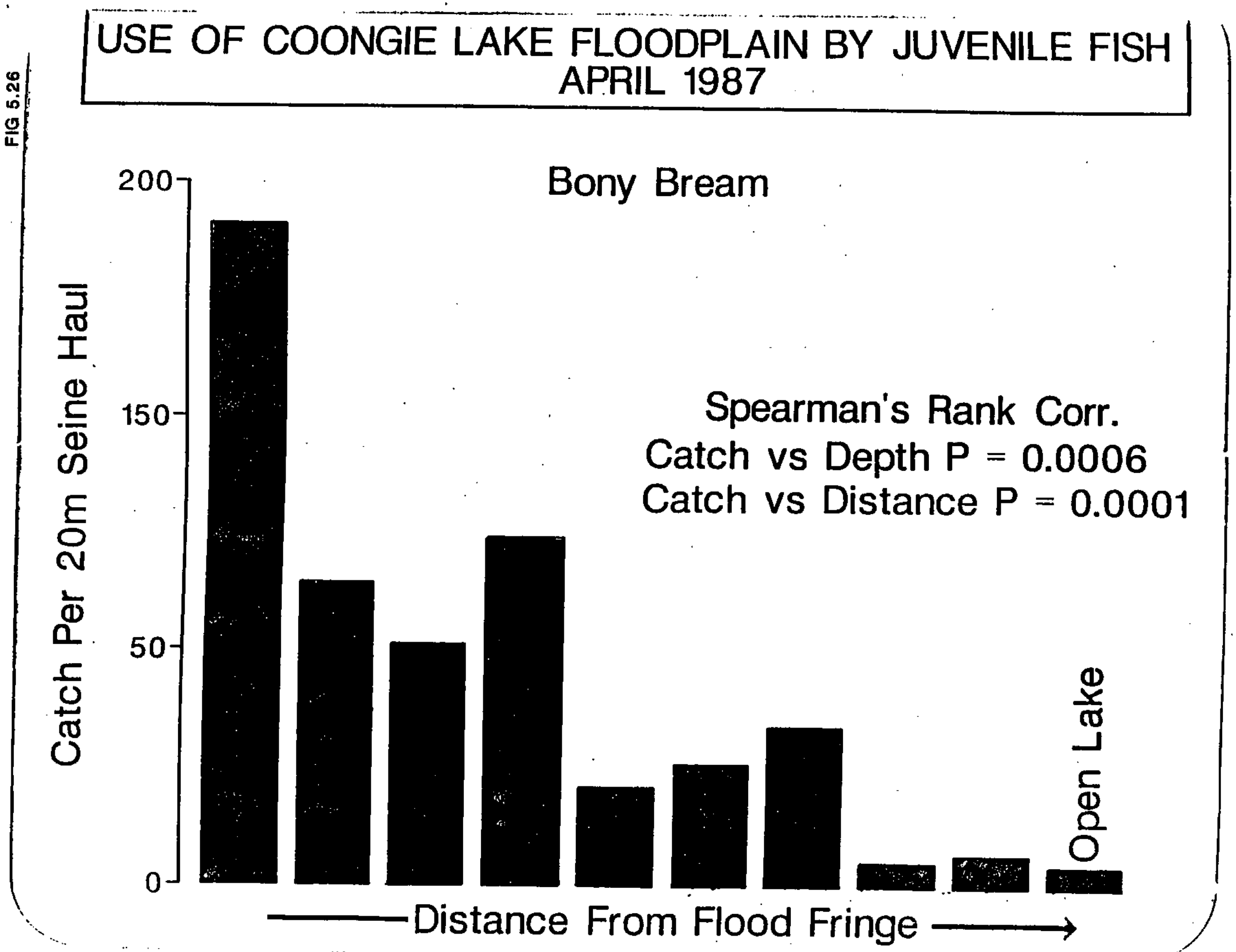
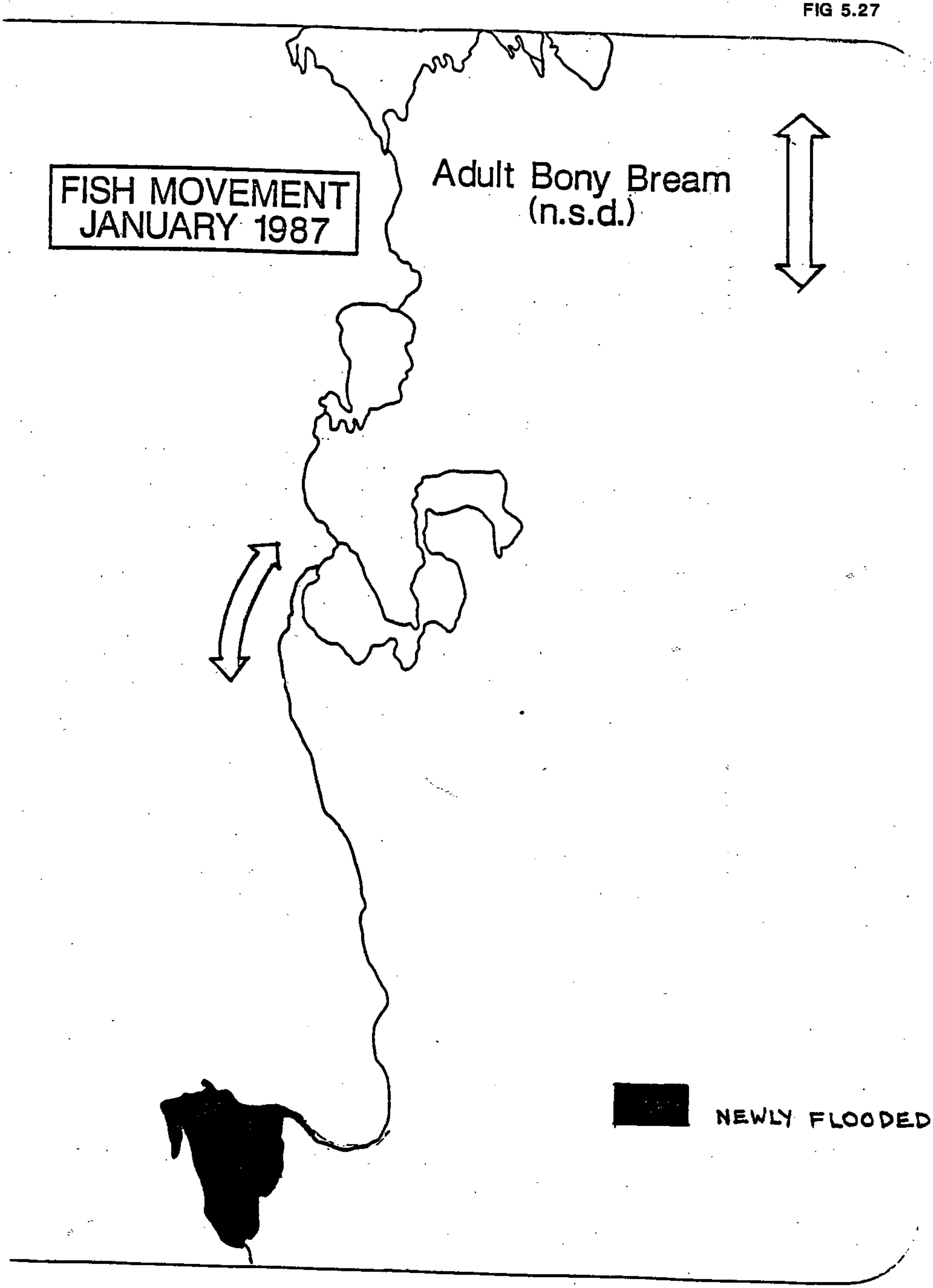


FIG 5.26
USE OF COONGIE LAKE FLOODPLAIN BY JUVENILE FISH
APRIL 1987
Bony Bream
200
150
50
0
Catch Per 20m Seine Haul
Spearman's Rank Corr.
Catch vs Depth P = 0.0006
Catch vs Distance P = 0.0001
Open Lake
Distance From Flood Fringe

FIG 5.27



FISH MOVEMENT
JANUARY 1987
Adult Bony Bream
(n.s.d.)
NEWLY FLOODED

FIG 5.28

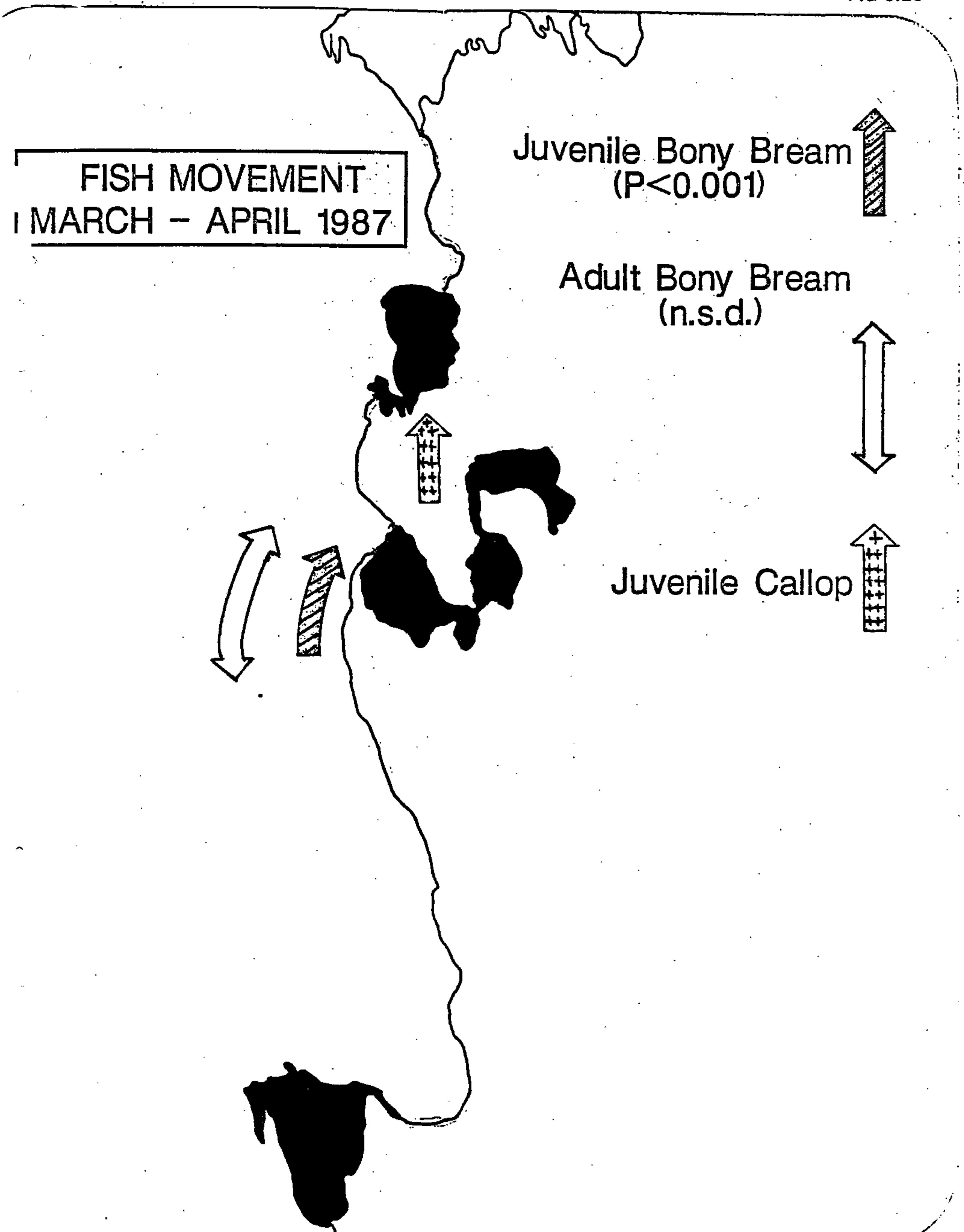
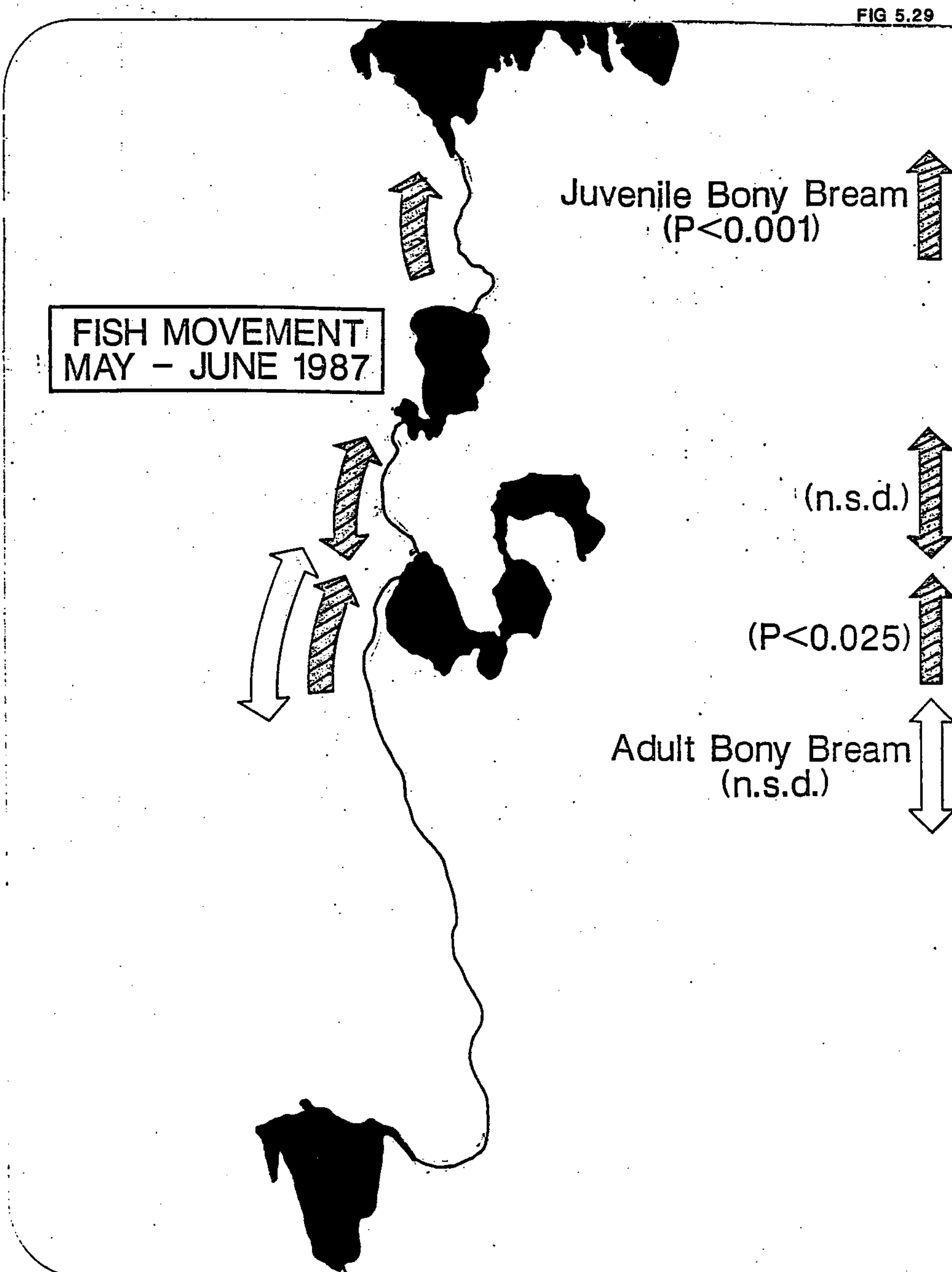

FISH MOVEMENT
MARCH - APRIL 1987
Juvenile Bony Bream
(P<0.001)
Adult Bony Bream
(n.s.d.)
Juvenile Callop

FIG 5.29



FISH MOVEMENT
MAY - JUNE 1987
Juvenile Bony Bream
(P<0.001)
(n.s.d.)
(P<0.025)
Adult Bony Bream
(n.s.d.)

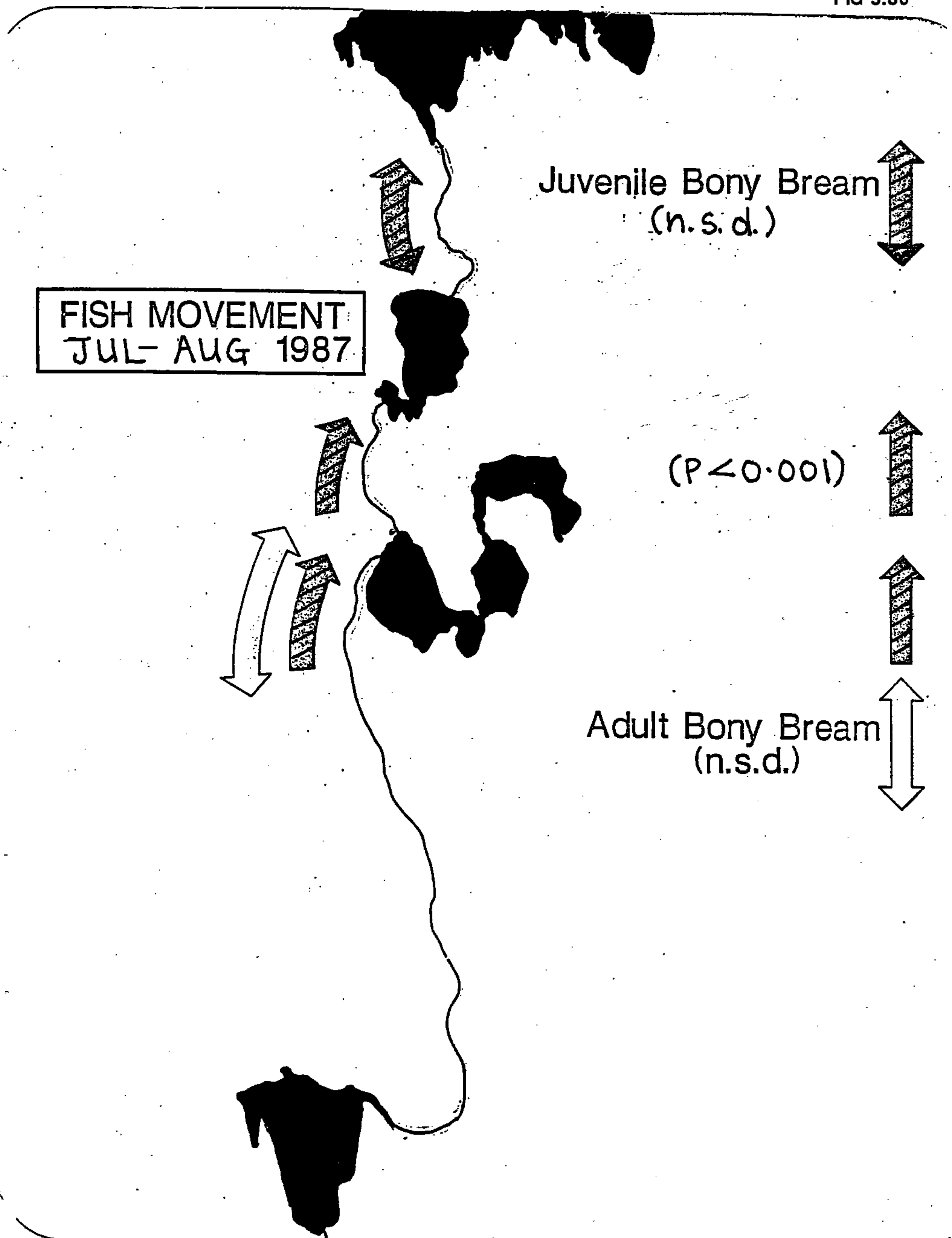
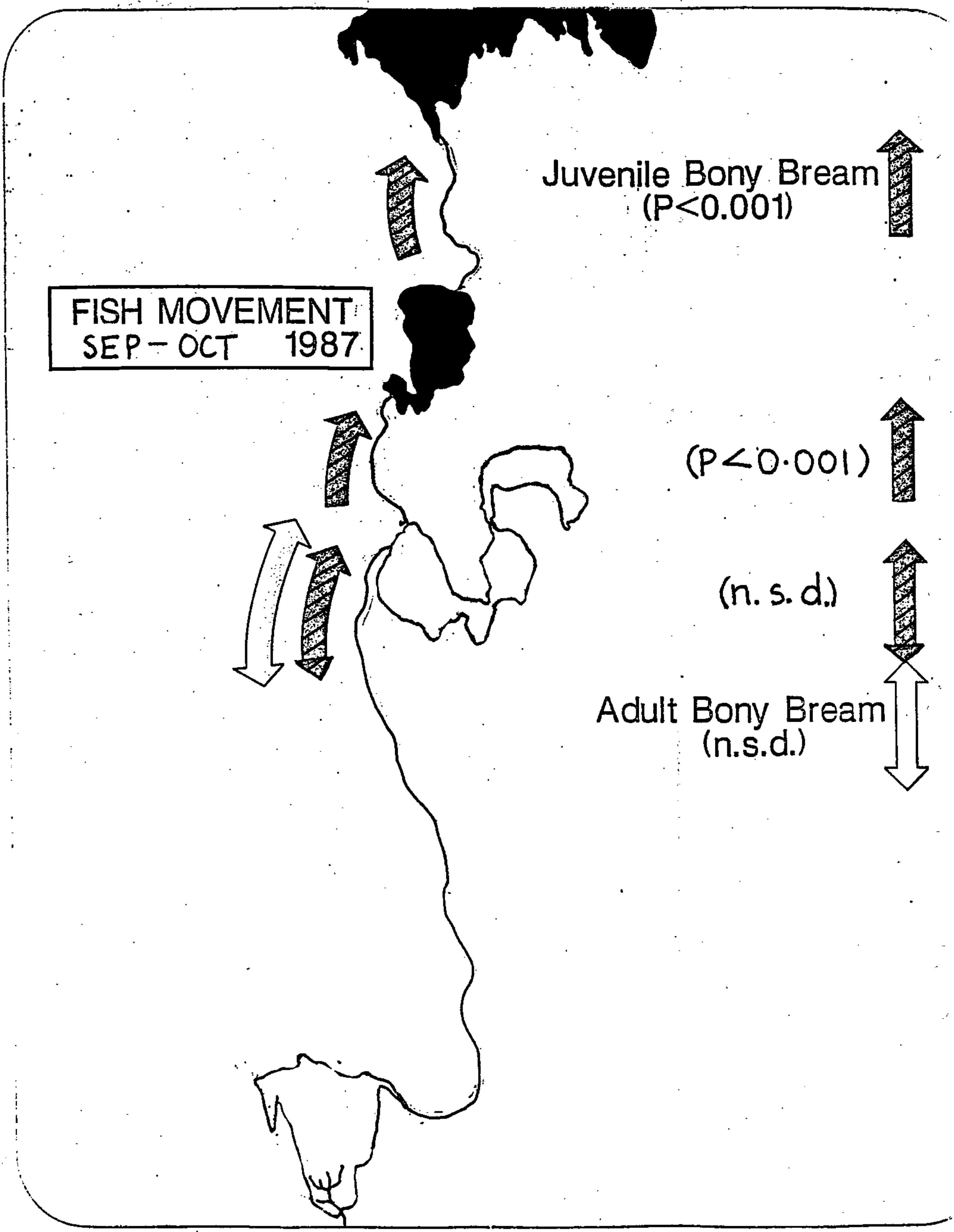

FISH MOVEMENT
JUL- AUG 1987
Juvenile Bony Bream
(n.s.d.)
(P<0·001)
Adult Bony Bream
(n.s.d.)

FIG 5.31



FISH MOVEMENT
SEP - OCT 1987
Juvenile Bony Bream
(P<0.001)
(P<0·001)
(n. s. d.)
Adult Bony Bream
(n.s.d.)

FIG 5.32

USE OF COONGIE LAKE FLOODPLAIN BY JUVENILE FISH
A.M., JUNE 1987

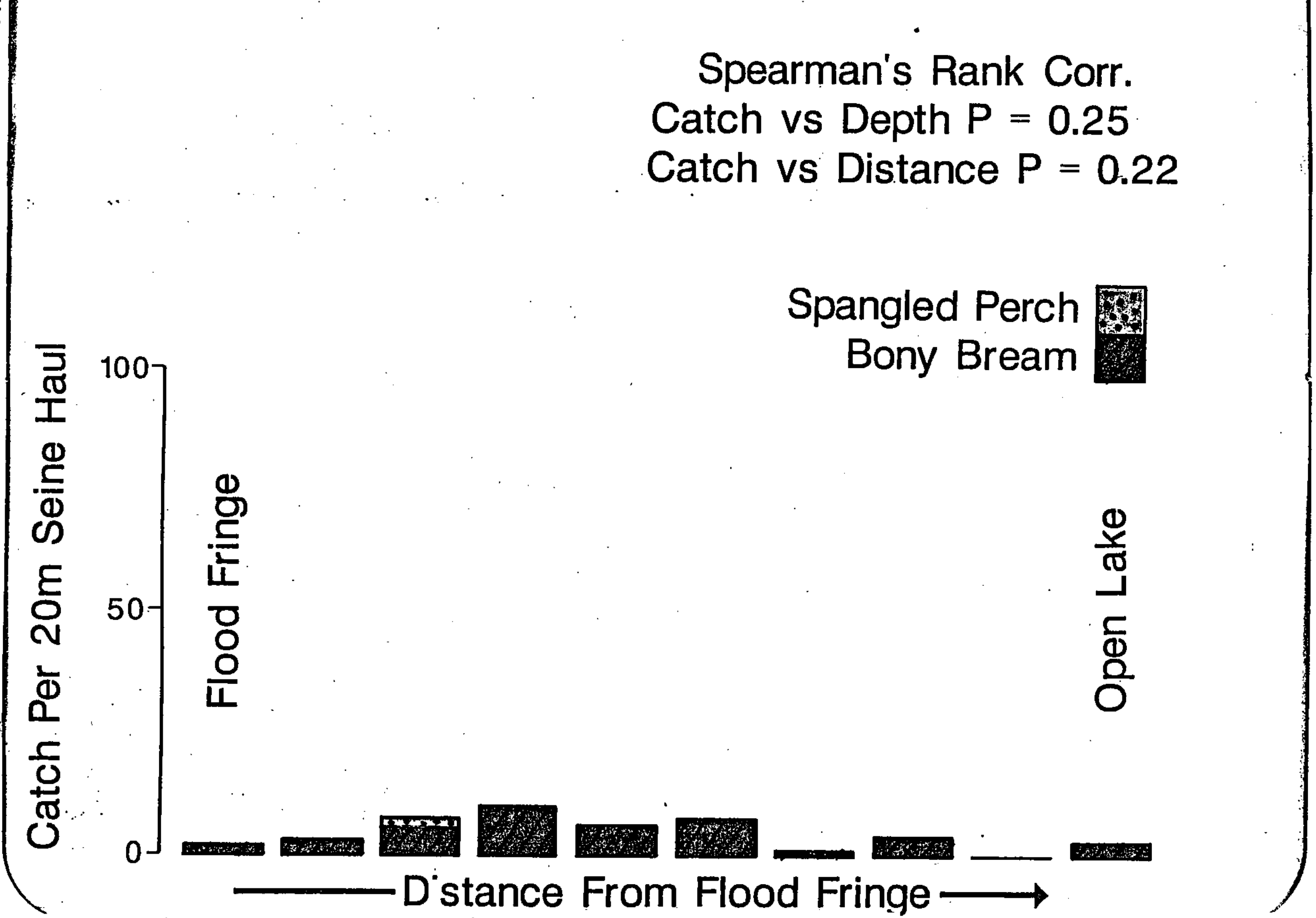
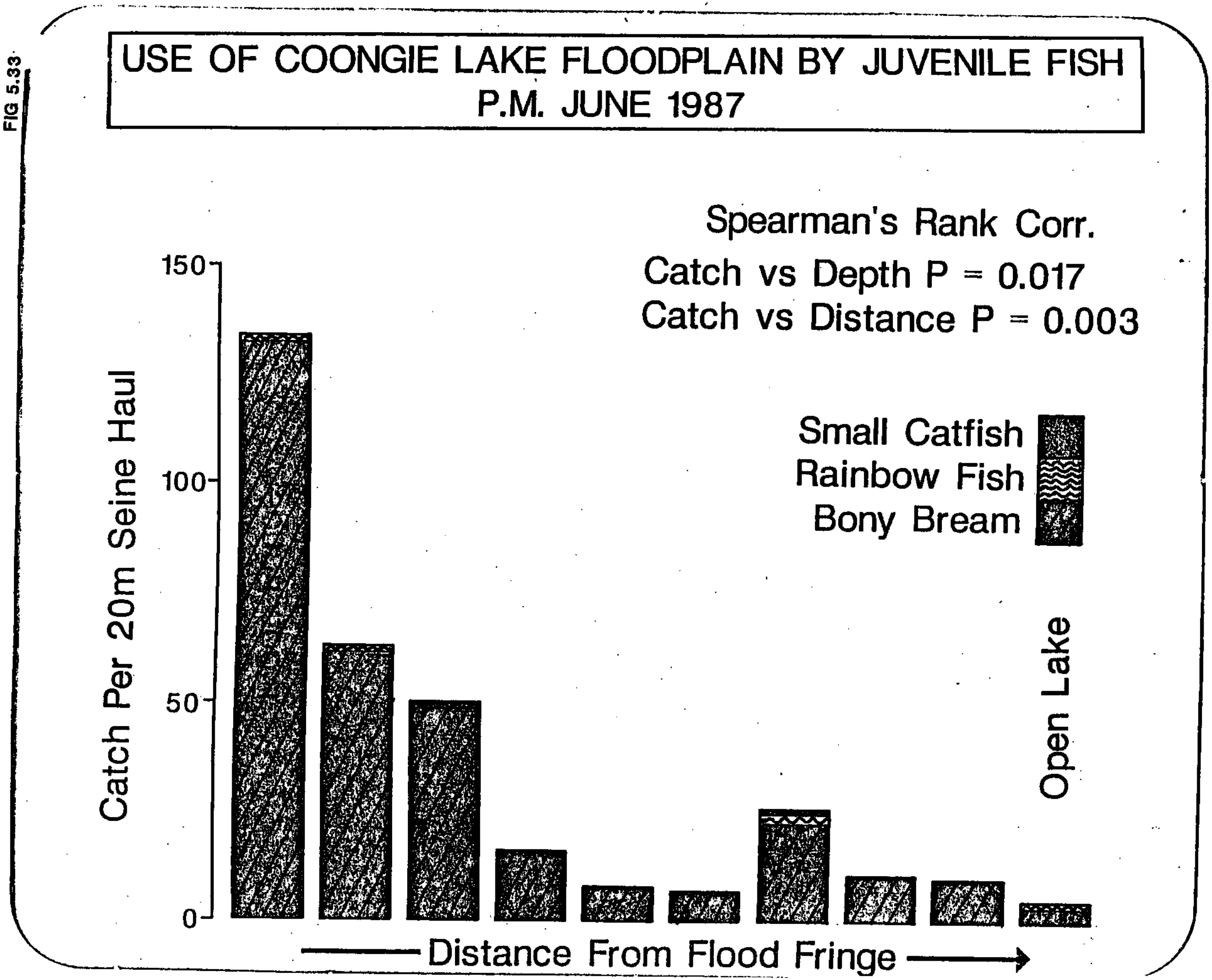


FIG 5.33


USE OF COONGIE LAKE FLOODPLAIN BY JUVENILE FISH
P.M. JUNE 1987
Spearman's Rank Corr.
Catch vs Depth P = 0.017
Catch vs Distance P = 0.003
Small Catfish
Rainbow Fish
Bony Bream
Open Lake
Catch Per 20m Seine Haul
150
100
50
0
Distance From Flood Fringe

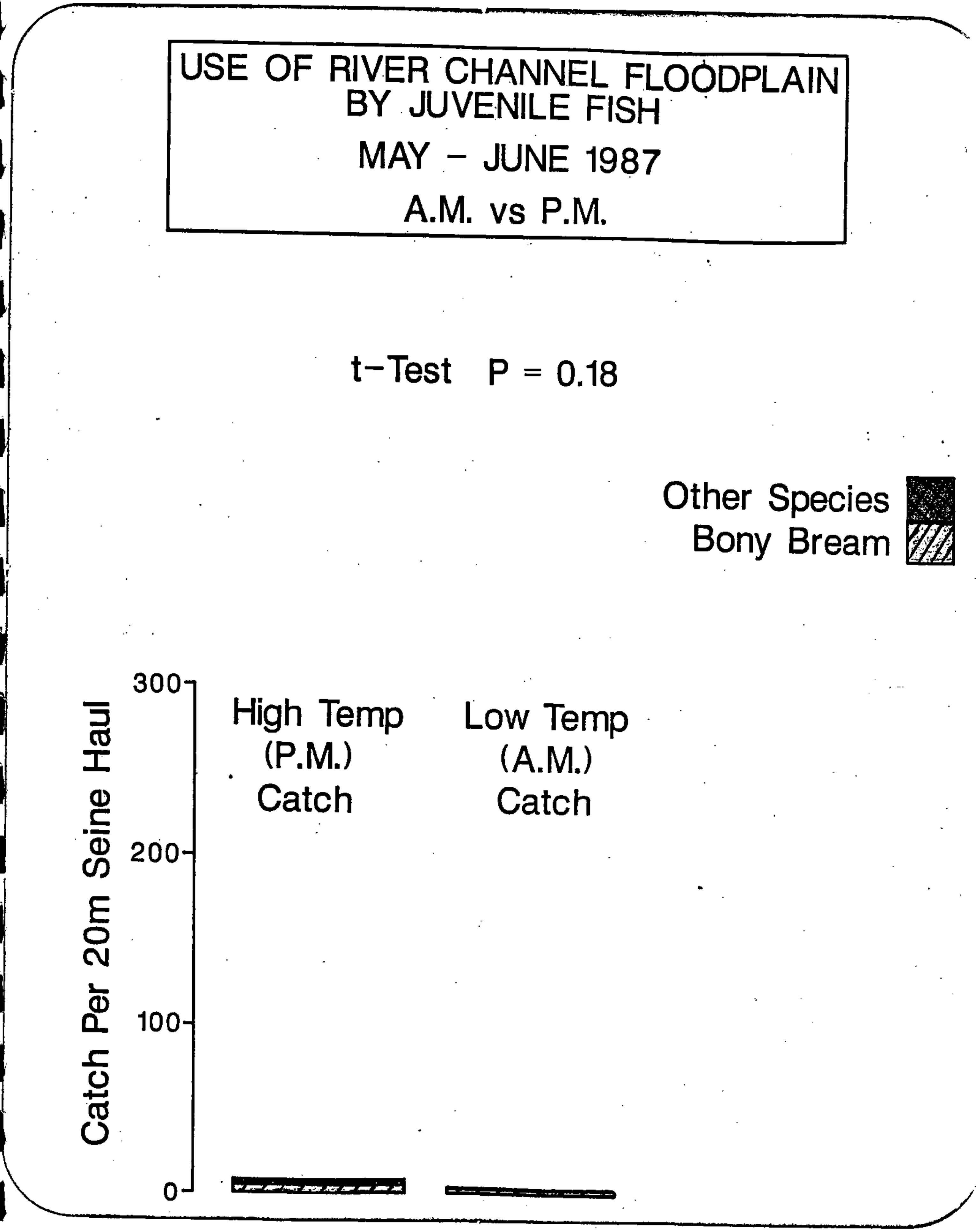
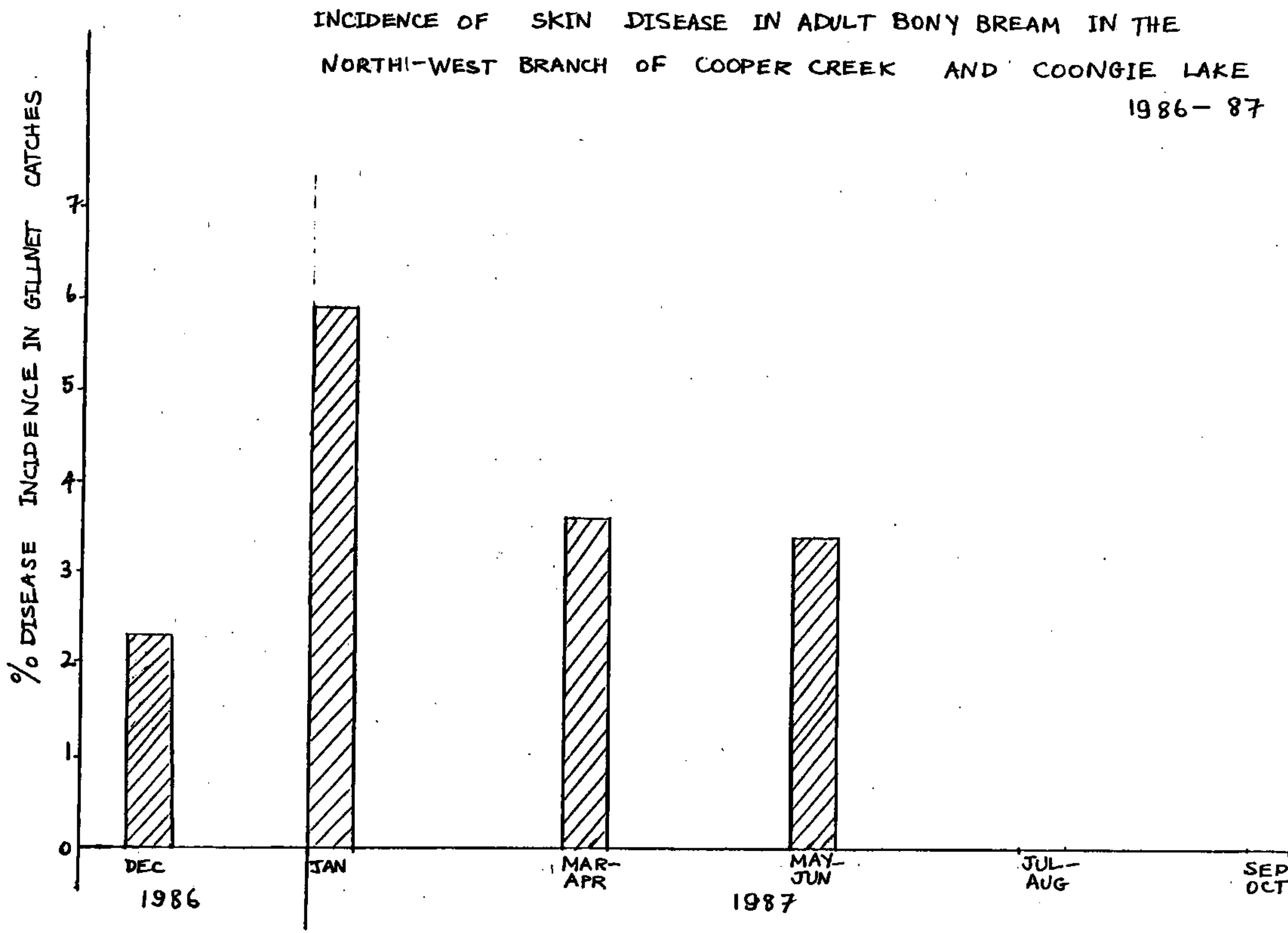
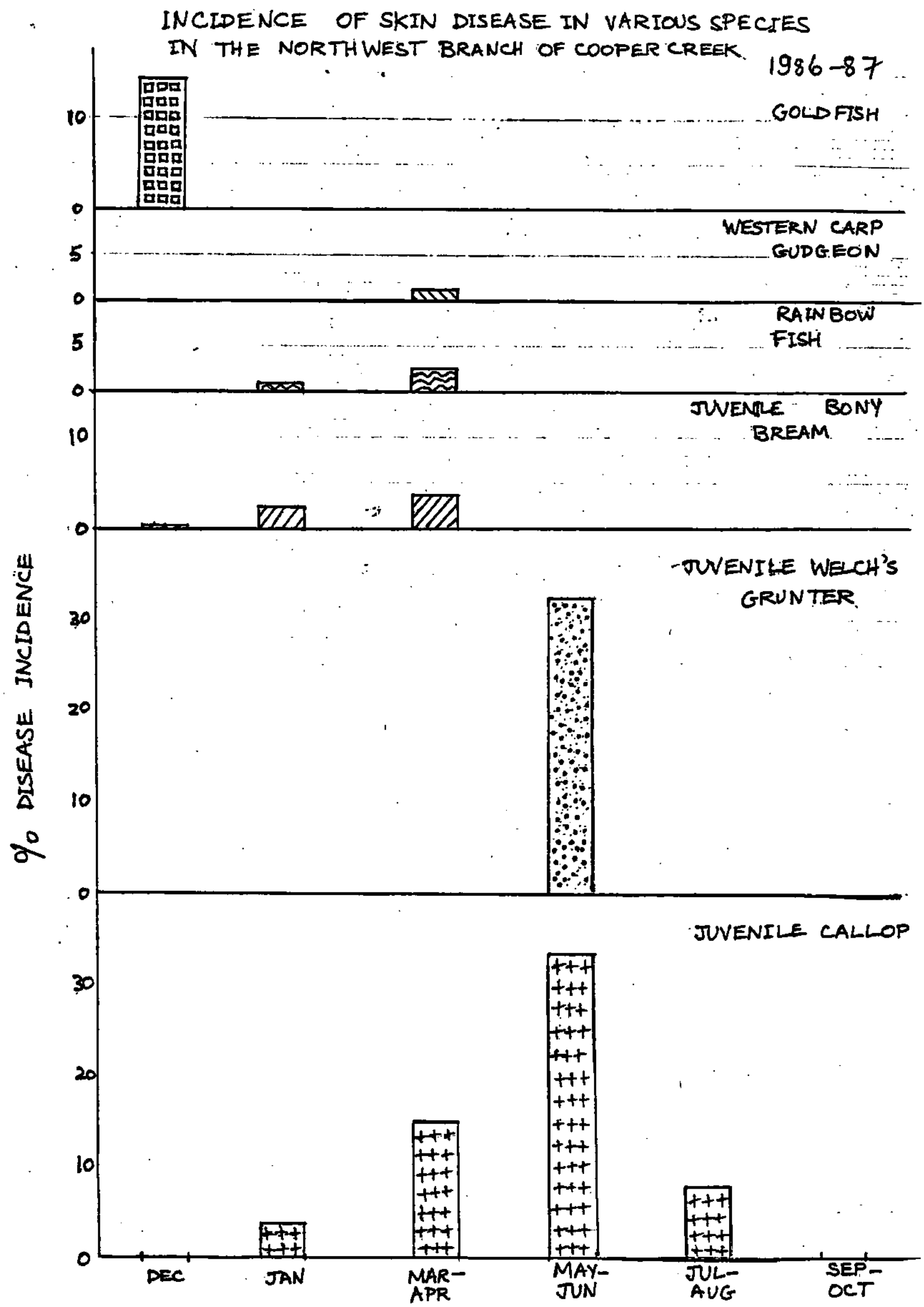
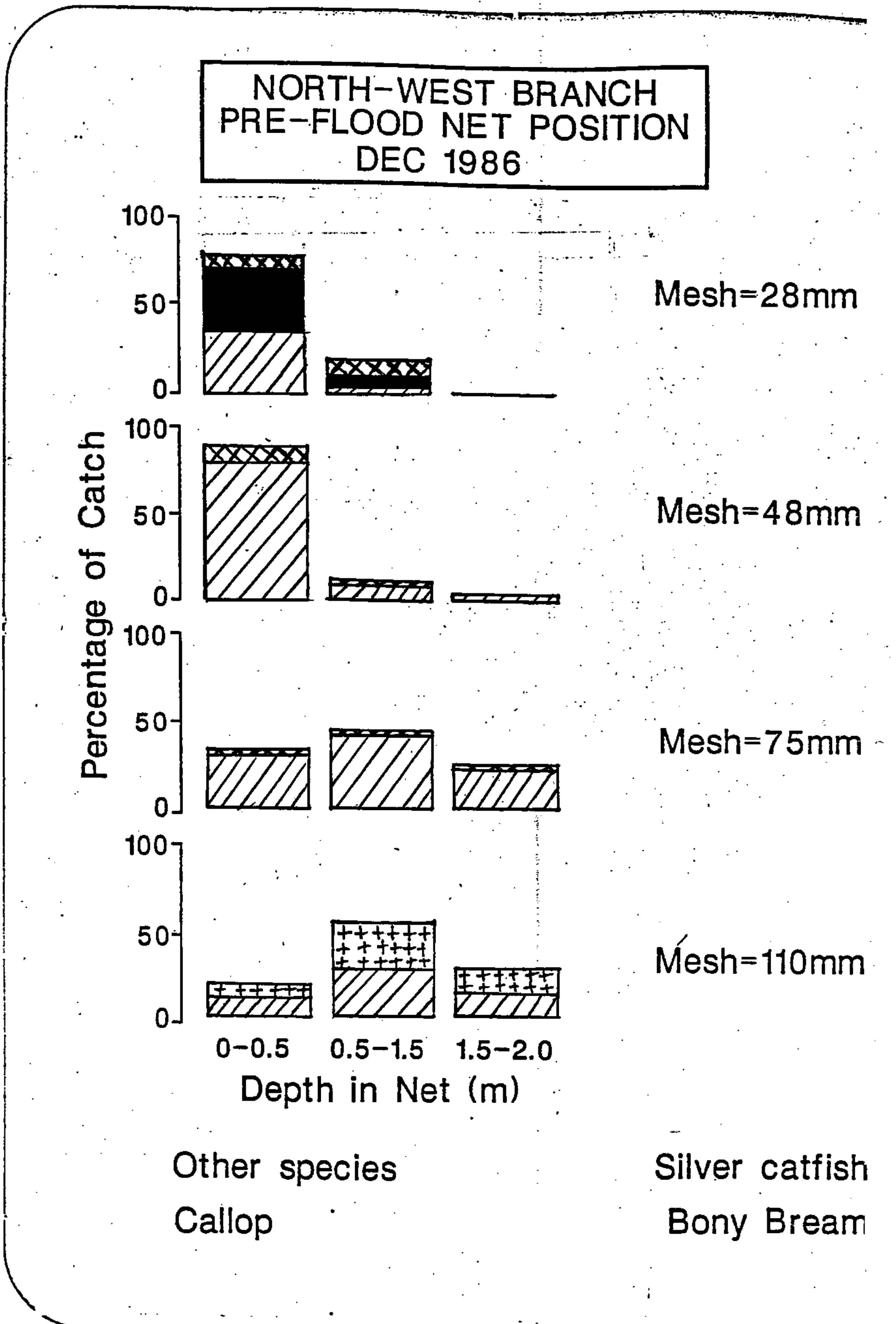

USE OF RIVER CHANNEL FLOODPLAIN
BY JUVENILE FISH
MAY - JUNE 1987
A.M. vs P.M.
t-Test P = 0.18
Other Species
Bony Bream
Catch Per 20m Seine Haul
300
200
100
0
High Temp
(P.M.)
Catch
Low Temp
(A.M.)
Catch

FIG 5.35



INCIDENCE OF SKIN DISEASE IN ADULT BONY BREAM IN THE NORTH-WEST BRANCH OF COOPER CREEK AND COONGIE LAKE 1986-87
% DISEASE INCIDENCE IN GILLNET CATCHES
0
1
2
3
4
5
6
7
DEC
JAN
MAR-APR
MAY-JUN
JUL-AUG
SEP-OCT
1986
1987


INCIDENCE OF SKIN DISEASE IN VARIOUS SPECIES
IN THE NORTHWEST BRANCH OF COOPER CREEK 1986-87
GOLDFISH
WESTERN CARP GUDGEON
RAINBOW FISH
JUVENILE BONY BREAM
JUVENILE WELCH'S GRUNTER
JUVENILE CALLOP
% DISEASE INCIDENCE
0
5
10
20
30
DEC
JAN
MAR-APR
MAY-JUN
JUL-AUG
SEP-OCT


NORTH-WEST BRANCH
PRE-FLOOD NET POSITION
DEC 1986
Percentage of Catch
100
50
0
Mesh=28mm
Mesh=48mm
Mesh=75mm
Mesh=110mm
0-0.5
0.5-1.5
1.5-2.0
Depth in Net (m)
Other species
Silver catfish
Callop
Bony Bream

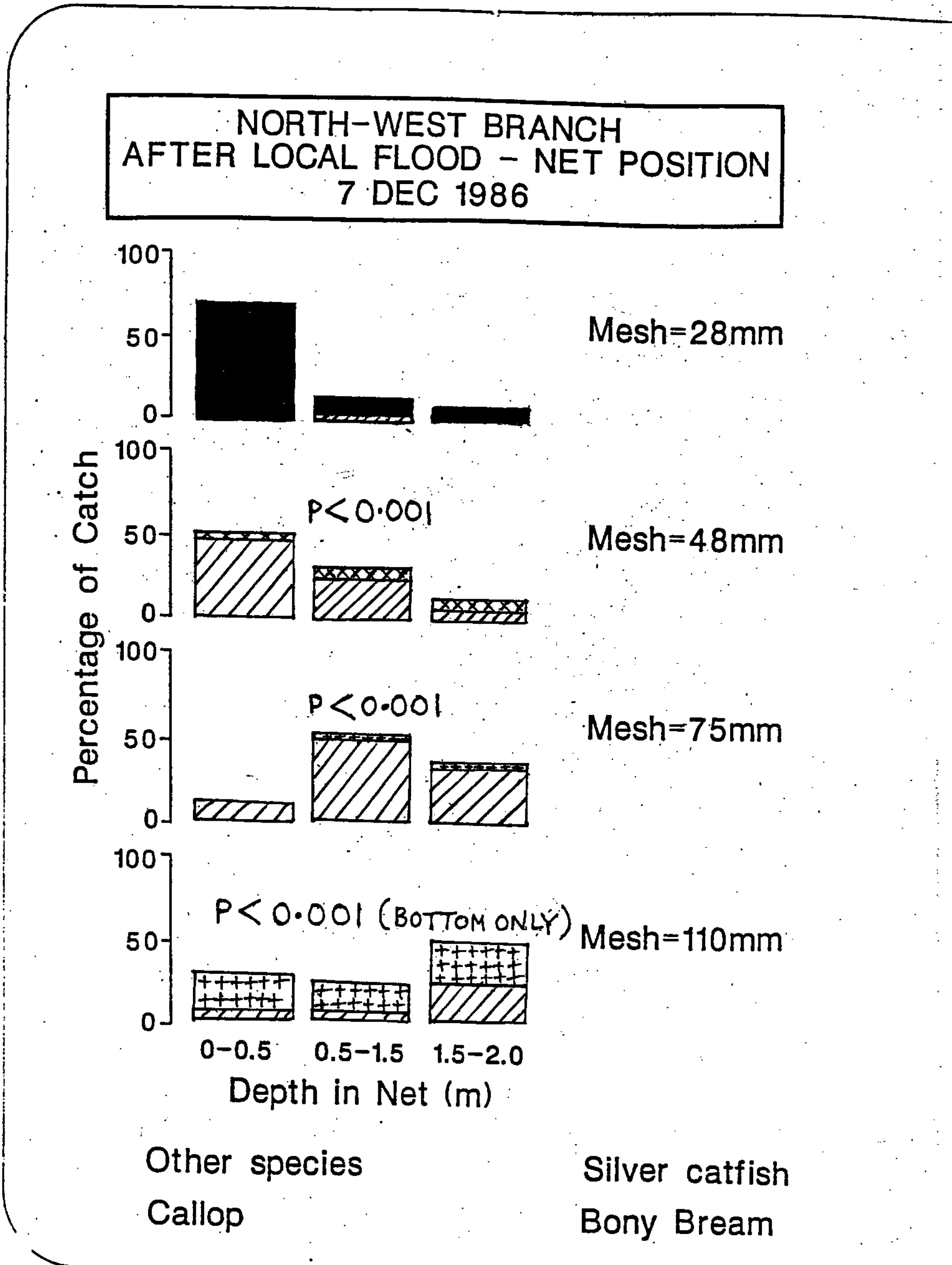
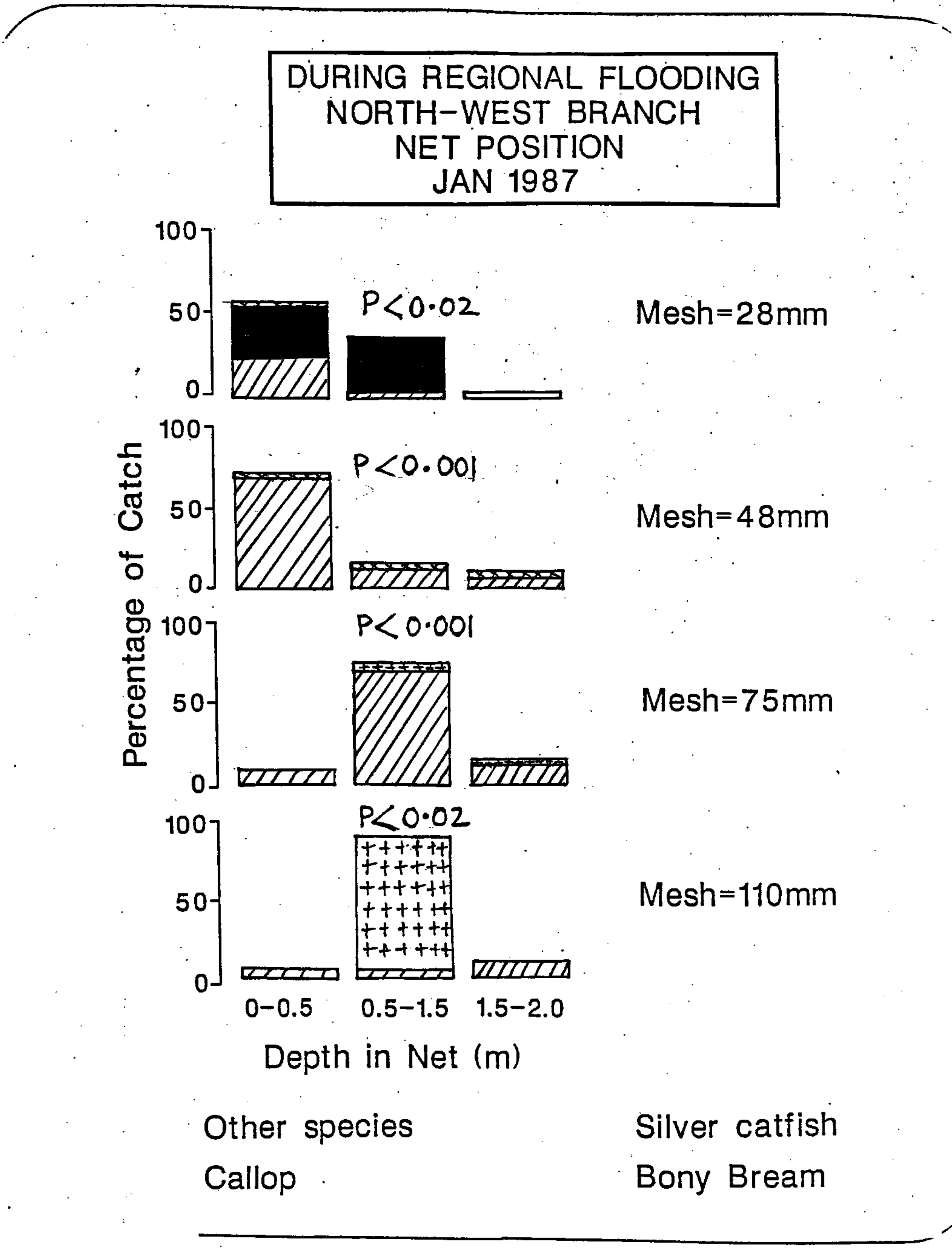

NORTH-WEST BRANCH
AFTER LOCAL FLOOD - NET POSITION
7 DEC 1986
Percentage of Catch
100
50
0
Mesh=28mm
P<0·001
Mesh=48mm
P<0·001
Mesh=75mm
P< 0·001 (BOTTOM ONLY)
Mesh=110mm
0-0.5
0.5-1.5
1.5-2.0
Depth in Net (m)
Other species
Silver catfish
Callop
Bony Bream

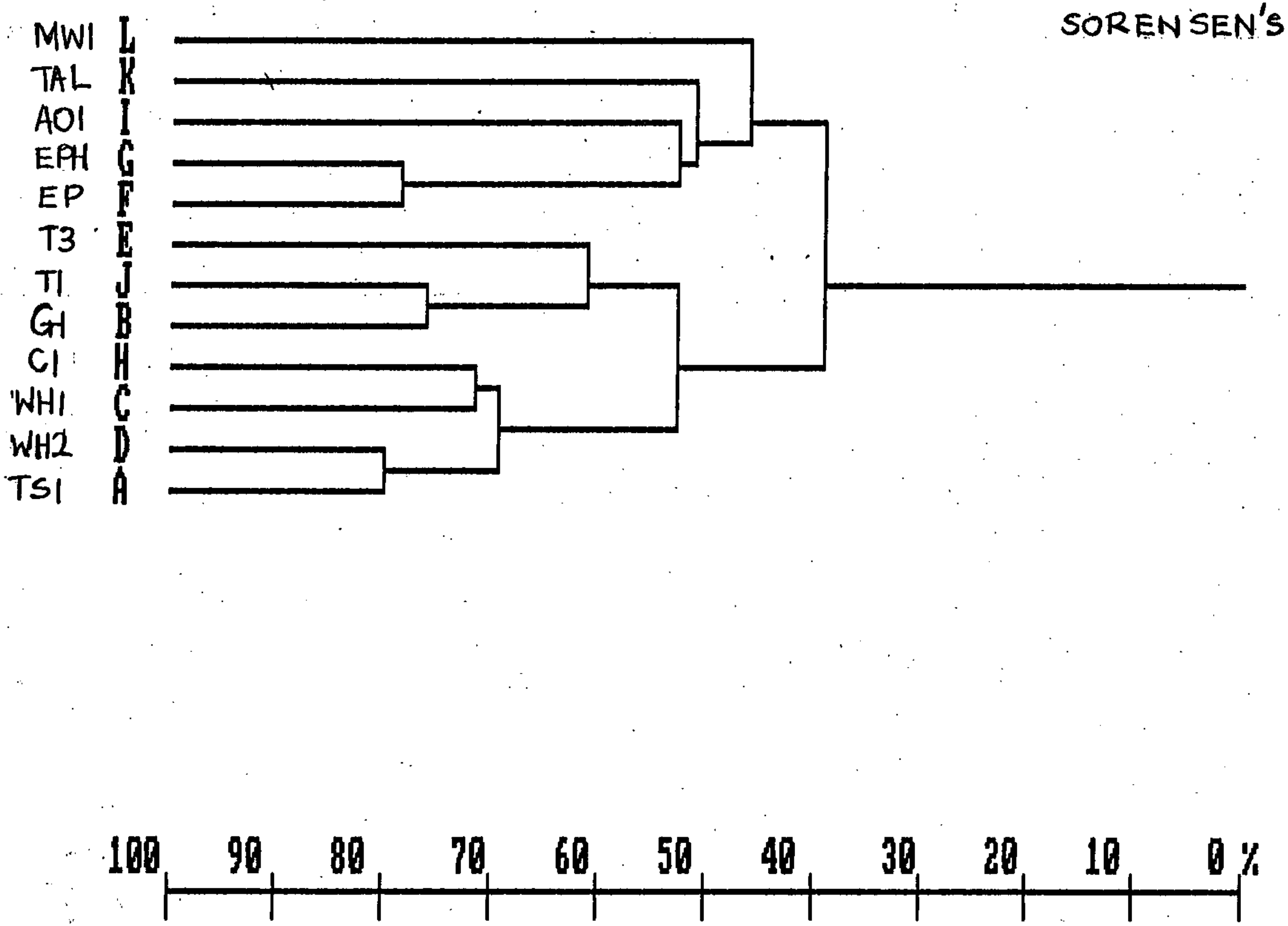
FIG 5.39



DURING REGIONAL FLOODING
NORTH-WEST BRANCH
NET POSITION
JAN 1987
Percentage of Catch
100
50
0
P<0·02
Mesh=28mm
P<0·001
Mesh=48mm
P<0·001
Mesh=75mm
P<0·02
Mesh=110mm
0-0.5
0.5-1.5
1.5-2.0
Depth in Net (m)
Other species
Silver catfish
Callop
Bony Bream

FIG 5.40

MAJOR SITES AGAINST MACROINVERTEBRATE FAMILIES



SITE DESCRIPTION

SITE NO__________ SITE TYPE__________ DATE__________

TIME__________ WEATHER____________________________________

VEGETATION:

TERRESTRIAL					
adjacent	1	2	3	4	5
submerged	1	2	3	4	5
AQUATIC					
emergent	1	2	3	4	5
submergent	1	2	3	4	5
floating unattached	1	2	3	4	5
TOTAL SURFACE COVER	1	2	3	4	5
TOTAL UNDERWATER COVER	1	2	3	4	5
WAVE ACTION	1	2	3	4	5
FLOW	1	2	3	4	5
SUBMERGENCE FREQUENCY	1	2	3	4	5

SUBSTRATE : rock gravel sand mud clay leaflitter

BANK INCLINE: undercut vertical acute shallow flat

DEPTH: max.______________ min______________

PROFILE SKETCH

ENVIRONMENT PARAMETERS

SITE NO__________ SITE TYPE_________ DATE __________ TIME __________

WEATHER ____

DEPTH

	0	0.2	0.4	0.6	0.8	1.0	1.2	1.4
TEMP								
DO								

	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0
TEMP								
DO								

COND _________________ PH _________________ SECCHI _________________

MACROINVERTEBRATES - METHODS CHECKLIST

hard parts stranded / baited traps / benthic tube / snags / dipnet /

kick sample / vegetation / 2m seine / light trap / artif. substrates

ENVIRONMENT PARAMETERS PER HAUL

SITE NO ________ DATE ________ NET TYPE ________ MESH ________

HAUL	VEGETATION (1-5)								(1-5)			OTHER					
	TERREST		AQUATIC				TOTAL		WA	FL	SF	TMP	DO	BI	SUBS	DEPTH	
	ADJ	SUB	EM	SUB	FLU	FLA	SC	UC								MAX	MIN
1																	
2																	
3																	
4																	
5																	
6																	
7																	
8																	
9																	
10																	

APP 5.4

CATCH/HAUL SEINES AND TRAWLS

DATE: SITE: GEAR:

HAUL	Bb			Sm			Mf			Rf			Wcg			Gf			Sc			Lc			C			Wg			Sp			Other
	A	J	L	A	J	L	A	J	L	A	J	L	A	J	L	A	J	L	A	J	L	A	J	L	A	J	L	A	J	L	A	J	L	
1																																		
2																																		
3																																		
4																																		
5																																		
6																																		
7																																		
8																																		
9																																		
10																																		
Σ																																		
$\bar{x}$																																		
S_x																																		

APP 5.5

FISHING EFFORT

SITE NO ______________ SITE TYPE ______________ DATE ______________

NET TYPE	MESH	NET IN	NET OUT	NET WET	ANGLE	HAUL NO.	TIME

APP 5.E

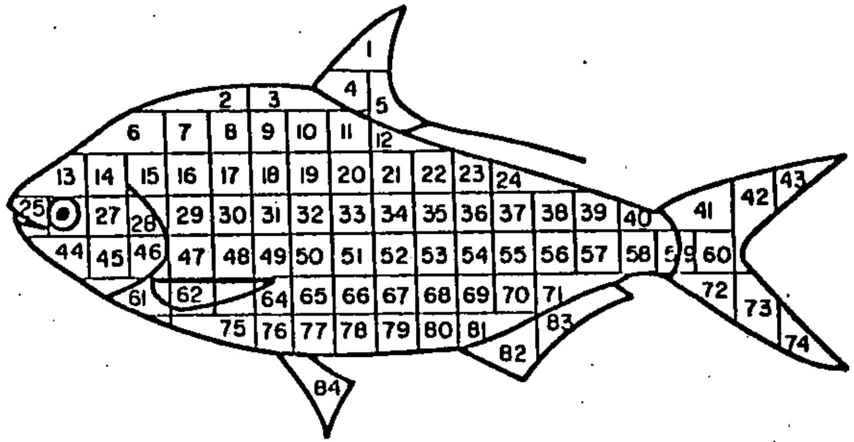
DATE: SITE:

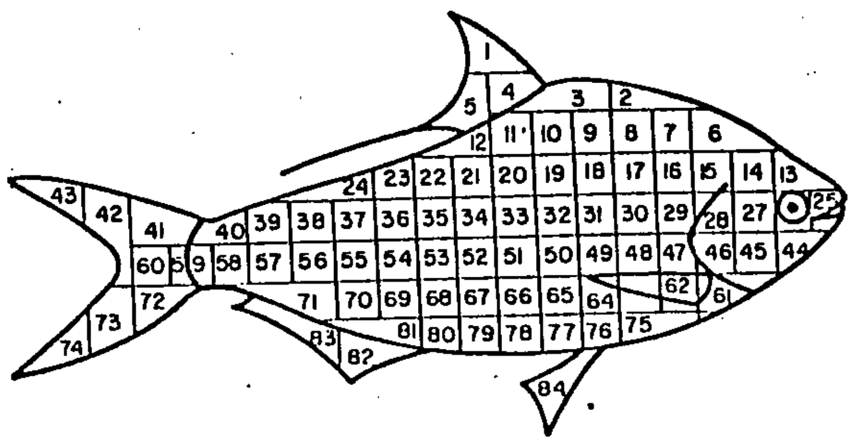
FISH NO.	SP.	GEAR TYPE	MESH	METHOD	HAUL NO.	TL	FL	CLIP SITE	GUT FULNESS	GUT CONTENTS	SEX	GONAD STATE	PATHOLOGY	CAPTURE TIME	PHOTO	PRESERVED Y	PRESERVED N	UNMEASURED FISH SP.	UNMEASURED FISH NO.

APP 5.7

DATE: ____________ SITE: ____________ FISH NO.: ______ SP.: ______________________

COMMENTS: ____





APP 5.8

DATE:

SITE:

FISH NO.	SP.	GEAR TYPE	MESH	METHOD	HAUL No.	TL	BODY DEPTH	CLIP SITE	DIRECTION IN NET US/DS	DEPTH IN NET T/M/B	SEX	GONAD STATE	PATHOLOGY	CAPTURE TIME	PHOTO	PRESERVED Y/N	UNMEASURED FISH SP.	UNMEASURED FISH NO.

Principal Components Analysis (HABITAT PARAMETERS)

Using centered correlation matrix

2M SEINE SITES – ALLTRIPS

EIGENVALUE 1 = 5.305 (35.36 % of total variance)
EIGENVALUE 2 = 2.071 (13.81 % of total variance)
EIGENVALUE 3 = 1.794 (11.96 % of total variance)
EIGENVALUE 4 = 1.230 (8.20 % of total variance)
EIGENVALUE 5 = 1.078 (7.19 % of total variance)

EIGENVECTORS (COMPONENT LOADINGS)

	PC 1	PC 2	PC 3	PC 4	PC 5
TA	0.40	-0.01	-0.04	0.07	0.03
TS	0.20	0.36	-0.19	-0.27	-0.10
AE	-0.26	0.28	0.29	0.21	-0.08
AS	0.29	0.18	0.09	0.26	0.06
FU	0.33	0.06	-0.24	-0.00	-0.40
FA	0.38	0.00	0.06	0.08	-0.05
WA	-0.38	0.01	0.13	0.15	-0.16
F	0.12	-0.06	0.23	-0.53	0.60
SF	0.28	-0.19	0.21	0.23	-0.09
T	0.05	-0.46	0.46	0.18	0.05
DO	-0.24	0.21	-0.38	0.08	0.31
BI	0.21	0.31	0.31	-0.24	0.09
AD	-0.16	0.40	0.43	-0.04	-0.11
CON	-0.14	-0.42	-0.19	-0.17	0.02
SEC	0.10	0.15	-0.14	0.57	0.56

20 M SEINE SITES – ALLTRIPS

EIGENVALUE 1 = 5.727 (38.18 % of total variance)
EIGENVALUE 2 = 2.191 (14.61 % of total variance)
EIGENVALUE 3 = 1.605 (10.70 % of total variance)
EIGENVALUE 4 = 1.188 (7.92 % of total variance)

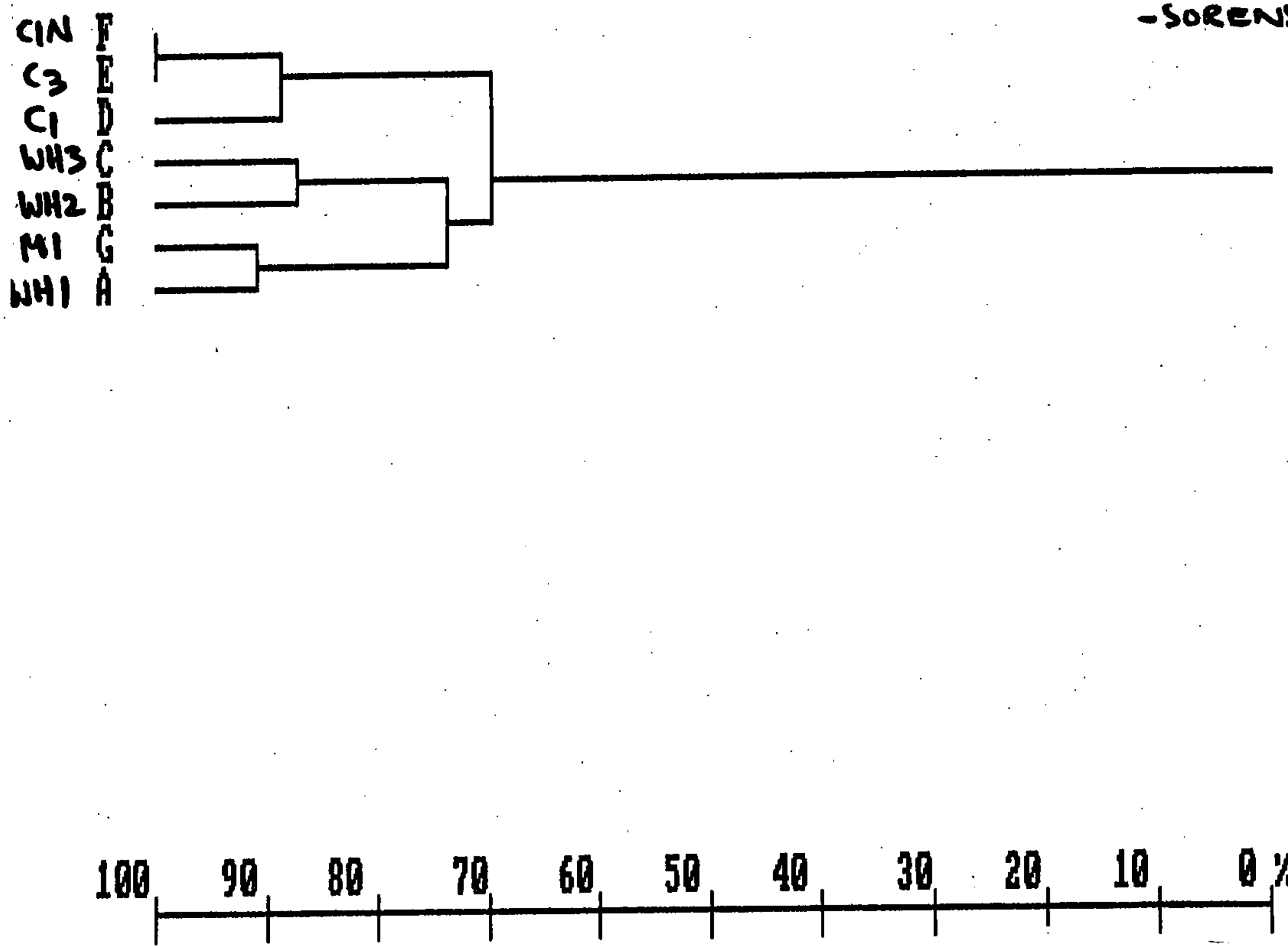
EIGENVECTORS (COMPONENT LOADINGS)

	PC 1	PC 2	PC 3	PC 4
TA	0.38	0.01	0.01	0.03
TS	0.25	-0.37	-0.01	-0.05
AE	-0.23	-0.12	0.36	0.47
AS	0.13	0.23	0.46	0.23
FU	0.32	-0.02	0.06	-0.31
FA	0.36	0.10	-0.00	0.08
WA	-0.35	0.11	0.06	0.22
F	0.25	-0.24	-0.27	0.31
SF	0.16	0.50	-0.04	0.05
T	0.01	0.54	-0.20	0.27
DO	-0.23	-0.39	-0.07	0.21
BI	0.35	-0.11	-0.11	0.25
AD	0.27	-0.09	0.18	0.20
CON	-0.18	0.07	-0.52	-0.18
SEC	-0.04	0.01	0.46	-0.48

APP 5.10A

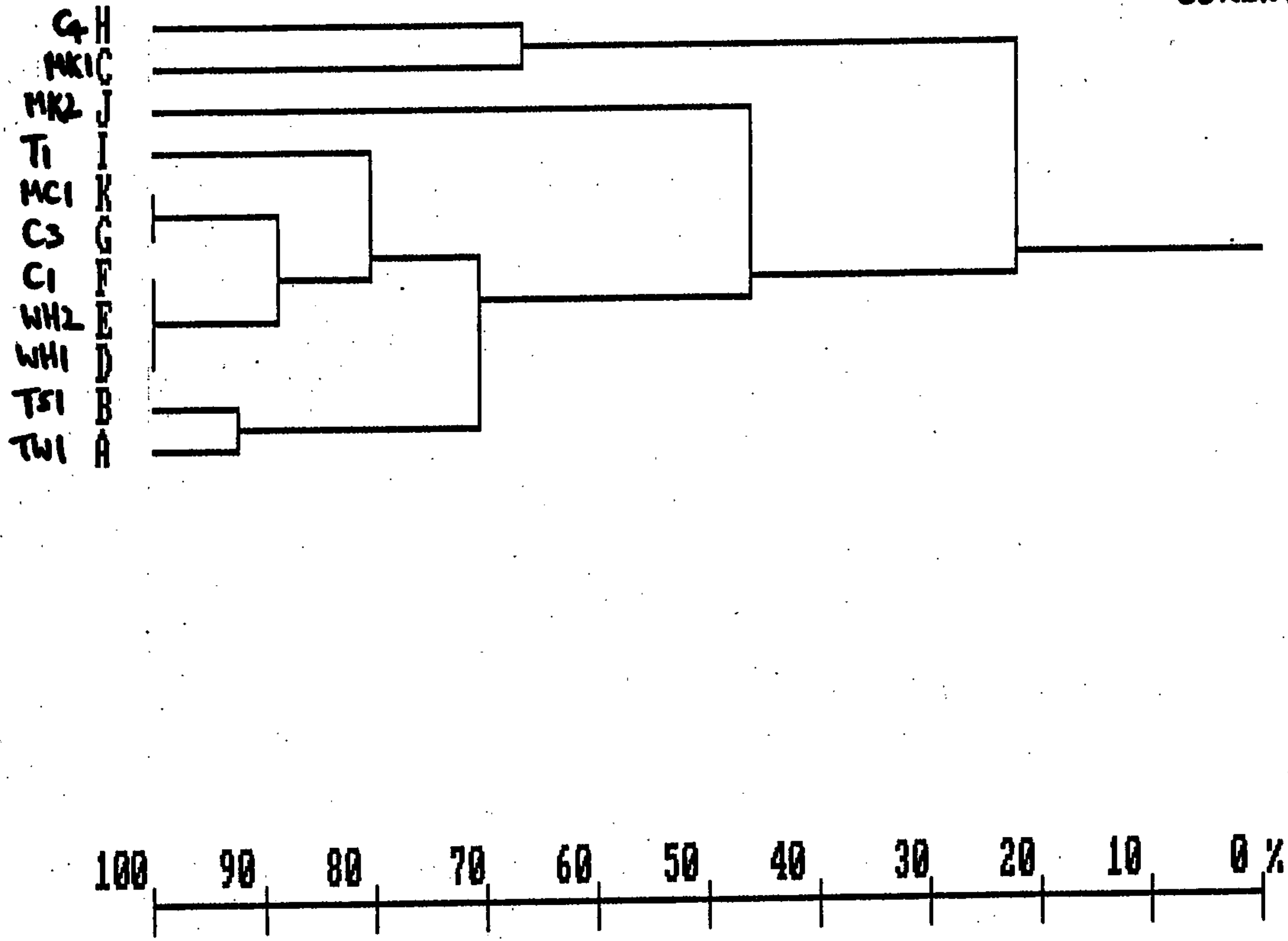
DEC. 1986 SITES AGAINST CATCH IN 2M S INE

-SORENSEN'S



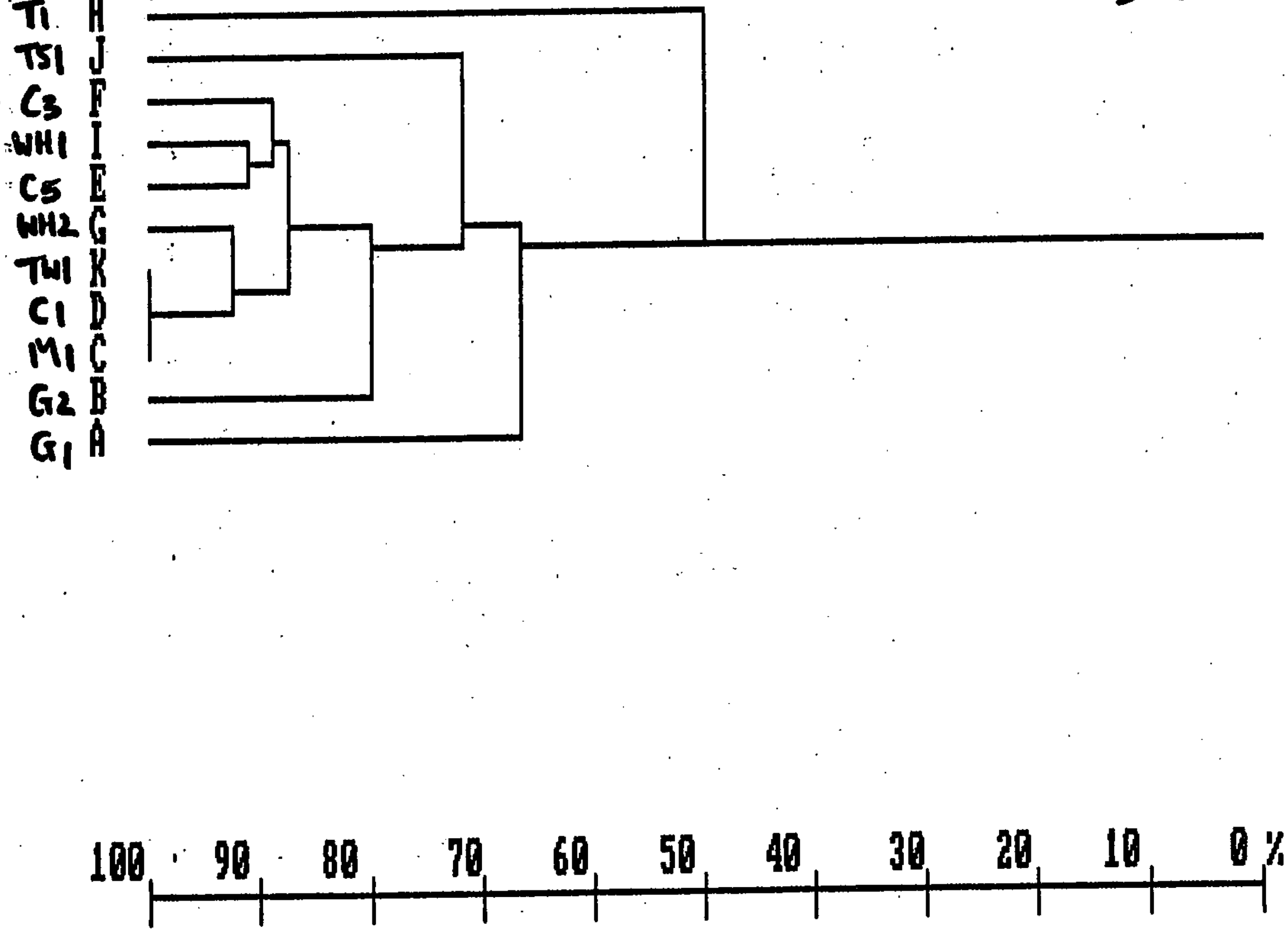
APP 5.10B

JAN. 1987 SITES AGAINST CATCH IN 2M SEINE - SORENSEN'S



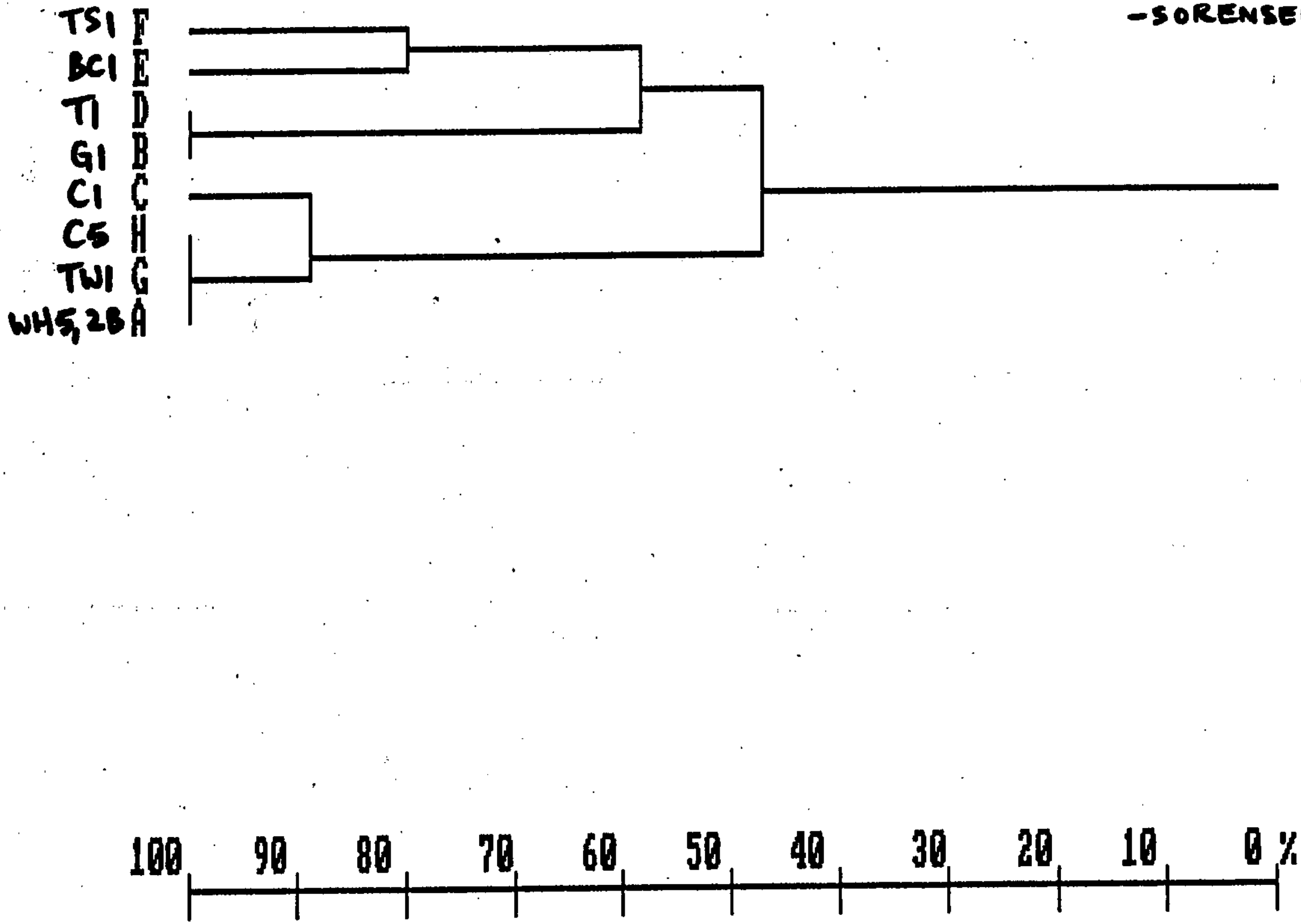
APP 5.10C

MAR-APR. 1987 SITES AGAINST CATCH IN 2M SEIN
—SORENSEN'S

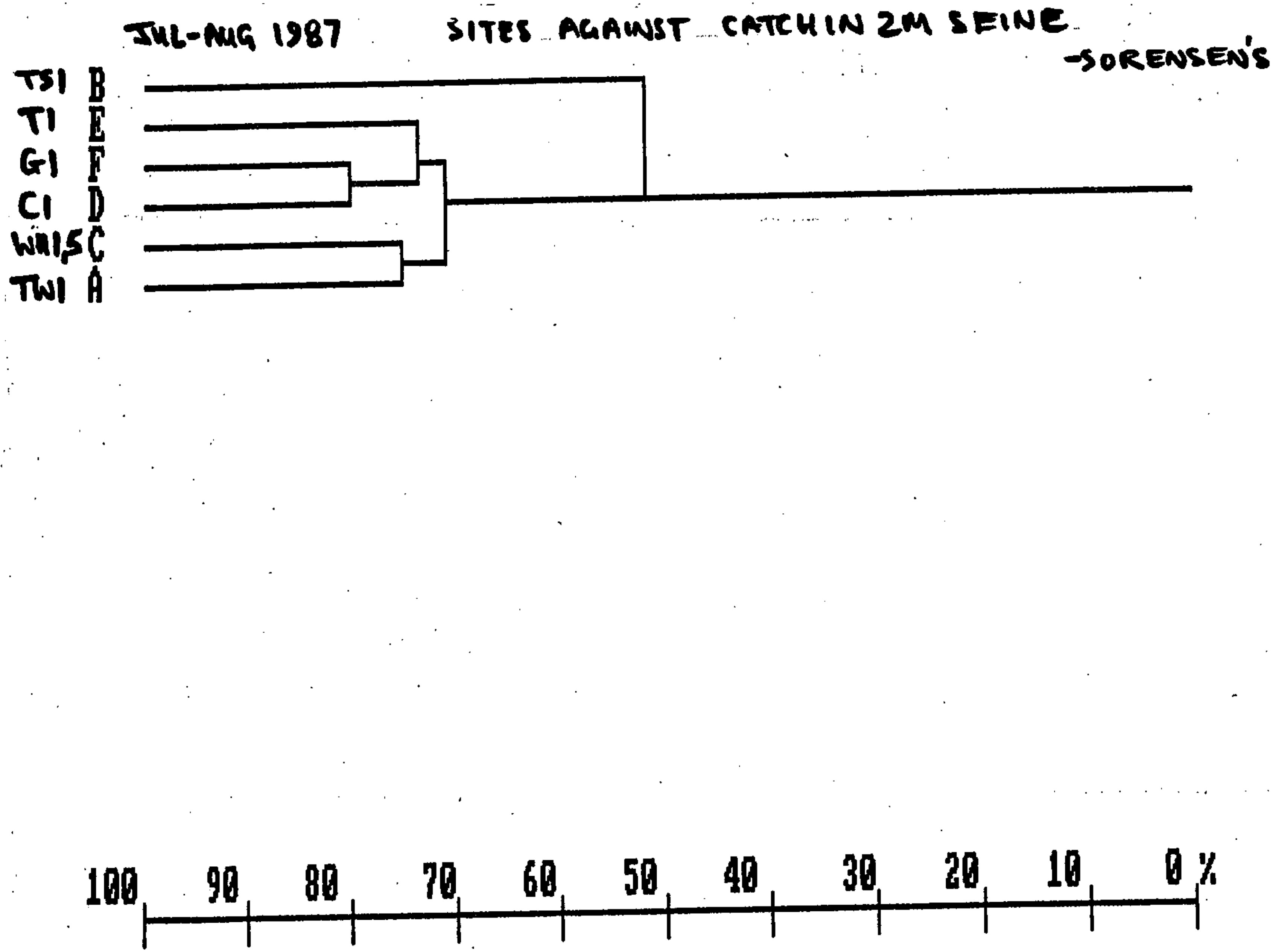


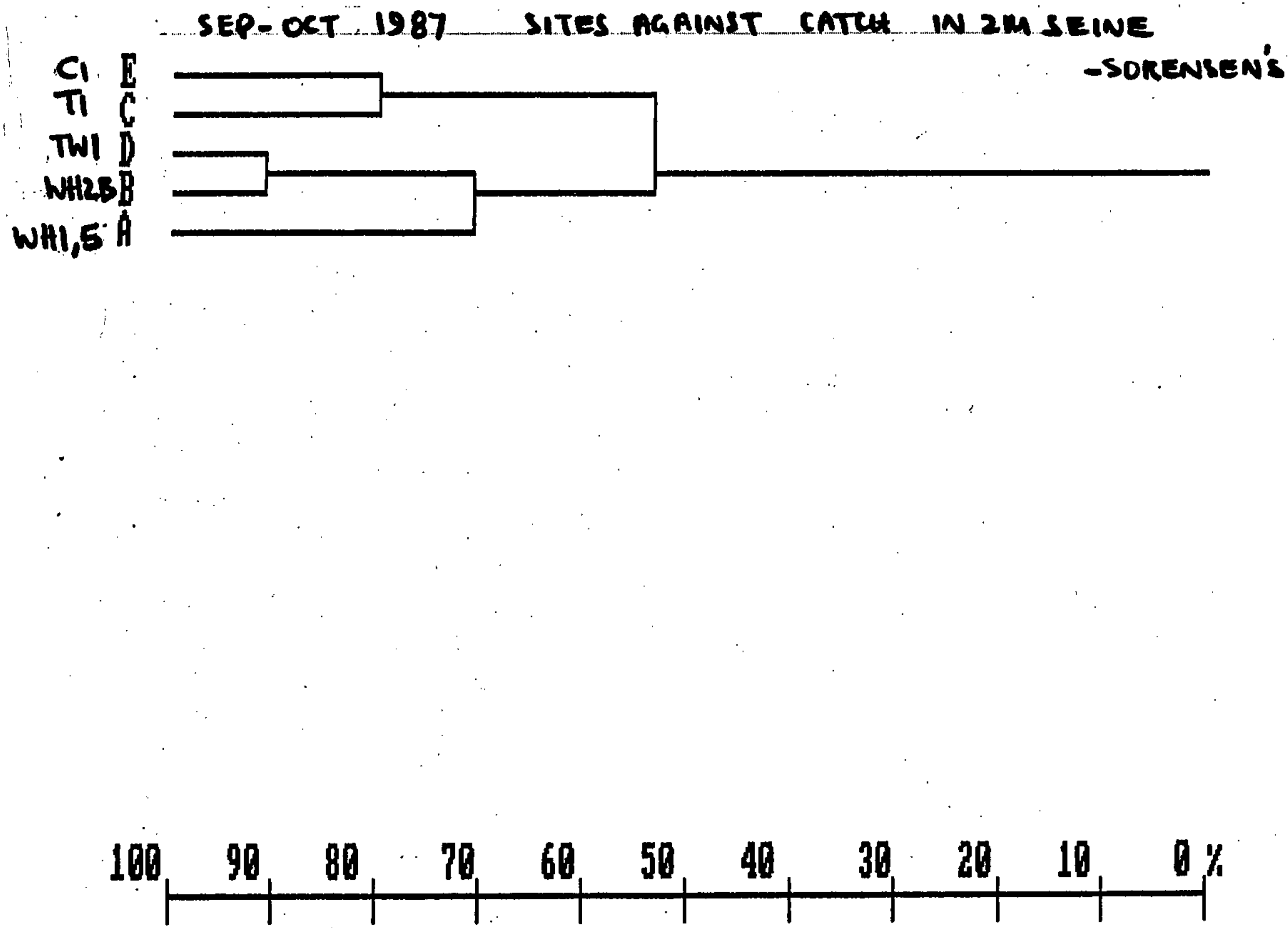
MAY–JUN 1987 SITES AGAINST CATCH IN 2M SEINE

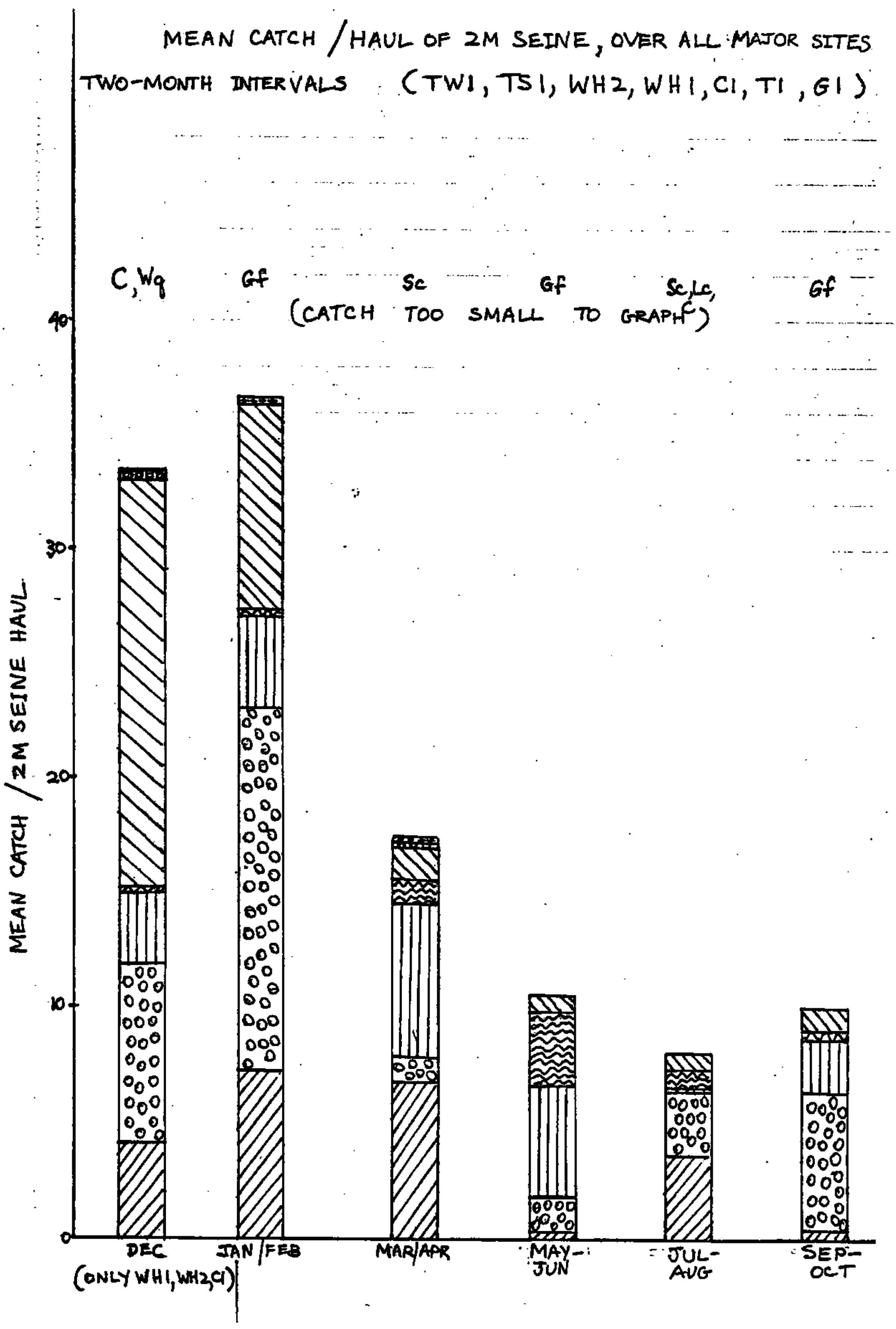
–SORENSEN'S



APP 5.10E

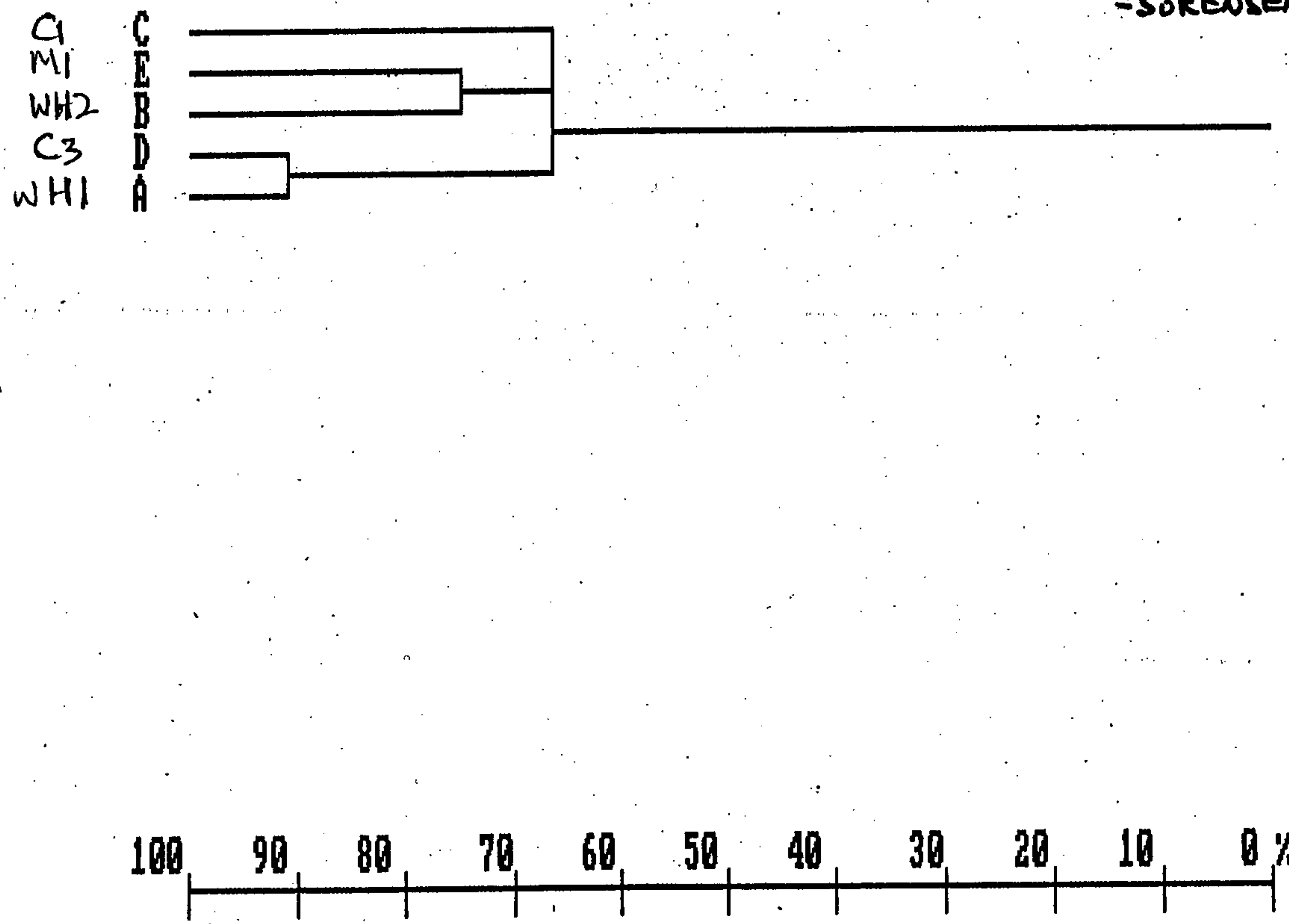

JUL-AUG 1987
SITES AGAINST CATCH IN 2M SEINE
-SORENSEN'S
TSI B
TI E
GI F
CI D
WH1,5 C
TWI A
100
90
80
70
60
50
40
30
20
10
0 %


SEP-OCT 1987 SITES AGAINST CATCH IN 2M SEINE
-SORENSEN'S
C1 E
T1 C
TW1 D
WH2B B
WH1,5 A
100 90 80 70 60 50 40 30 20 10 0 %

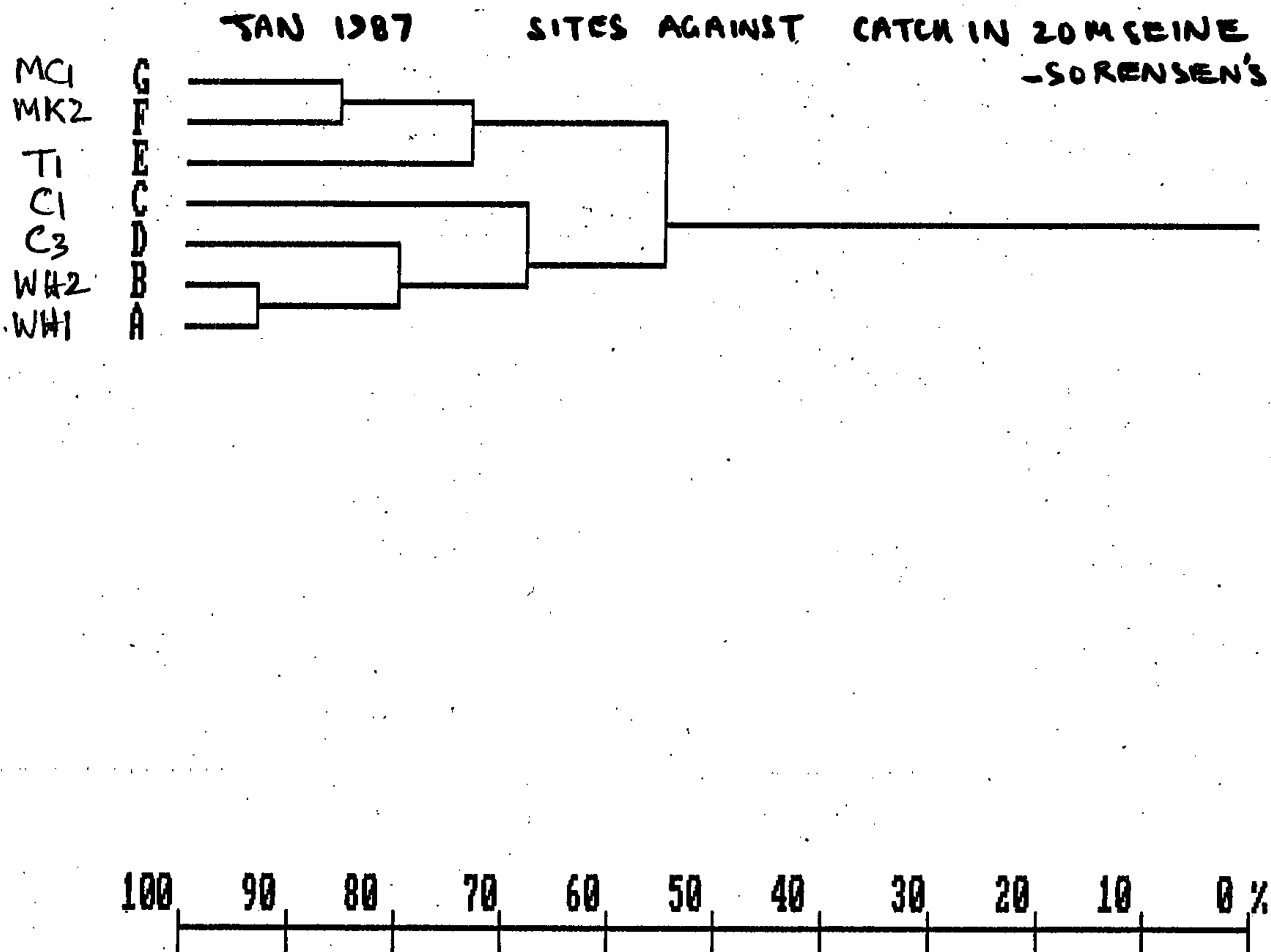

MEAN CATCH / HAUL OF 2M SEINE, OVER ALL MAJOR SITES
TWO-MONTH INTERVALS (TW1, TS1, WH2, WH1, C1, T1, G1)
C, Wq
Gf
Sc
Gf
Sc, Lc, Gf
Gf
(CATCH TOO SMALL TO GRAPH)
MEAN CATCH / 2M SEINE HAUL
40
30
20
10
0
DEC
(ONLY WH1, WH2, C1)
JAN/FEB
MAR/APR
MAY-JUN
JUL-AUG
SEP-OCT

APP 5.12A

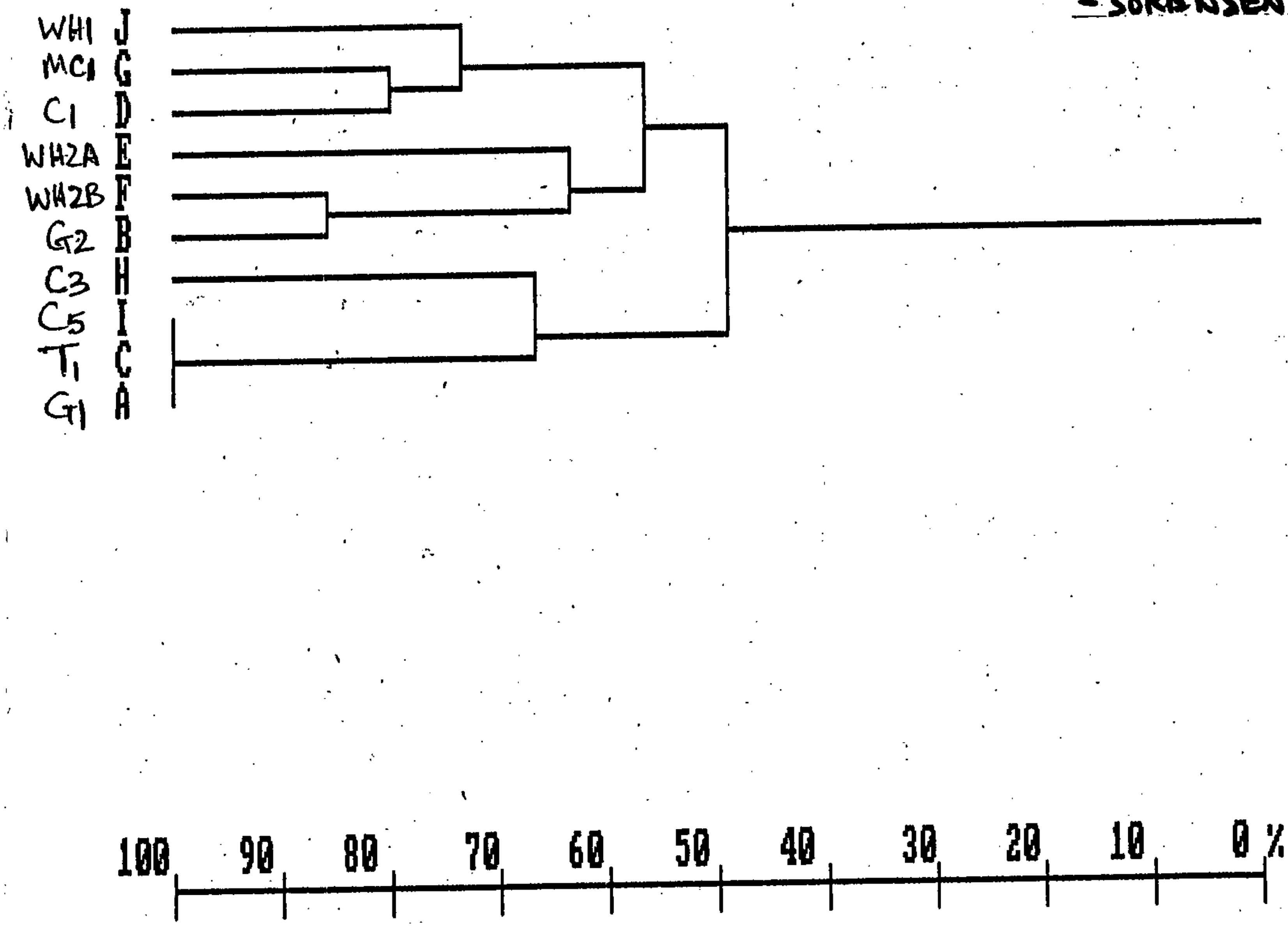
DEC 1986 SITES AGAINST CATCH IN 20M SEINE
-SORENSEN'S

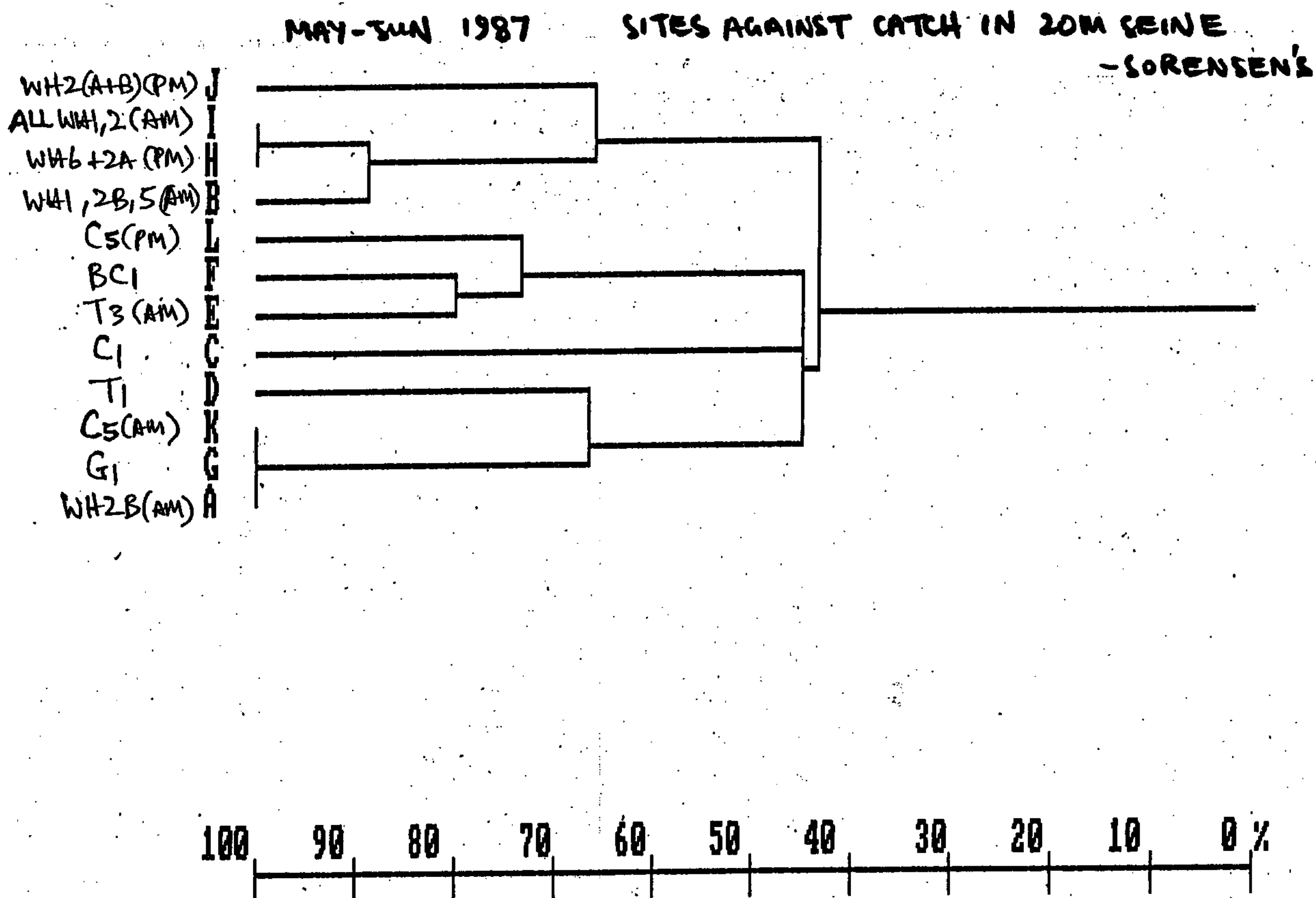


APP 5.12B

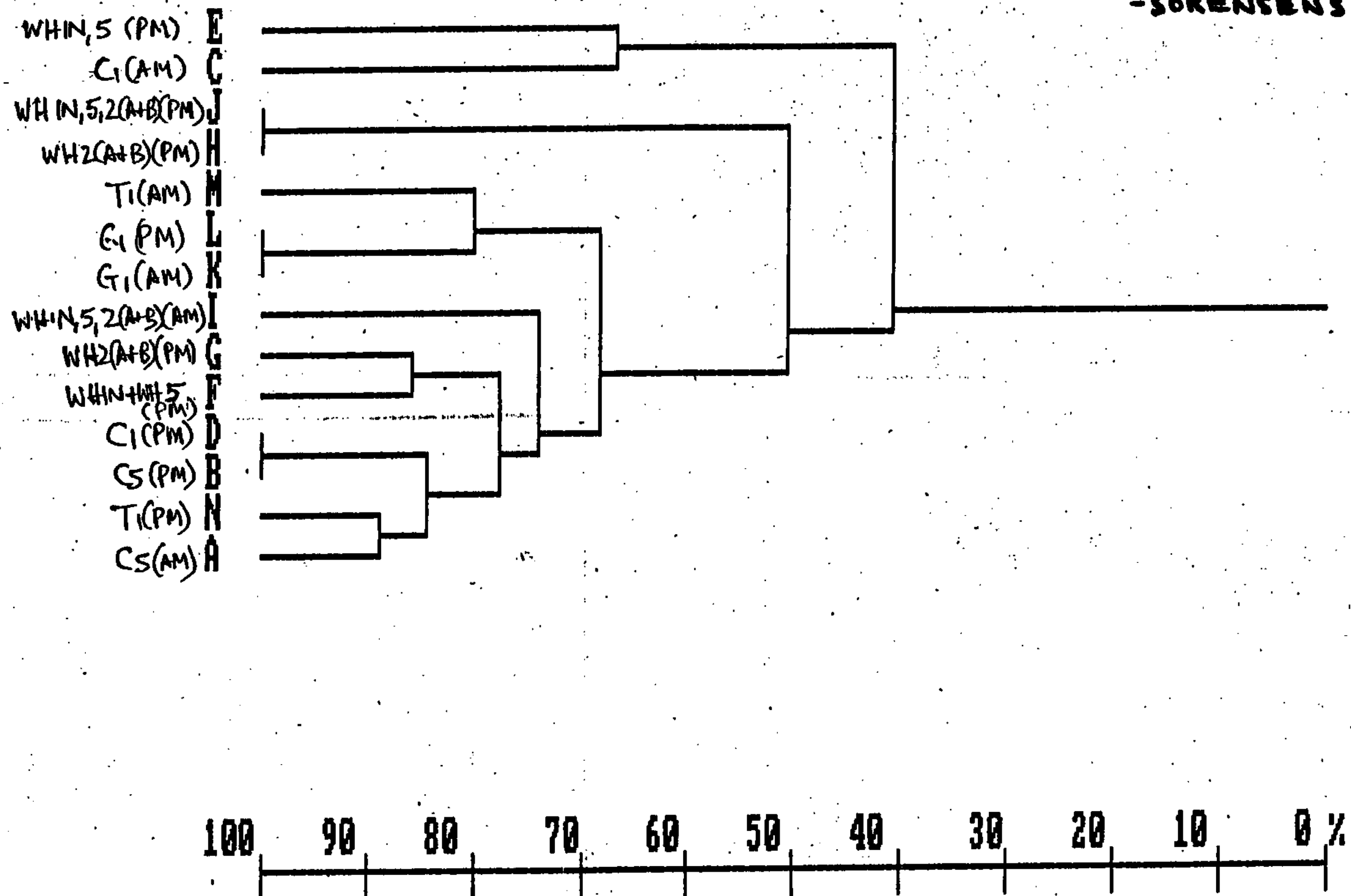

JAN 1987 SITES AGAINST CATCH IN 20M SEINE
-SORENSEN'S
MC1 G
MK2 F
T1 E
C1 C
C3 D
WH2 B
WH1 A
100
90
80
70
60
50
40
30
20
10
0 %

MAR-APR. 1987 SITES AGAINST CATCH IN 20M SEINE
- SORENSEN'S

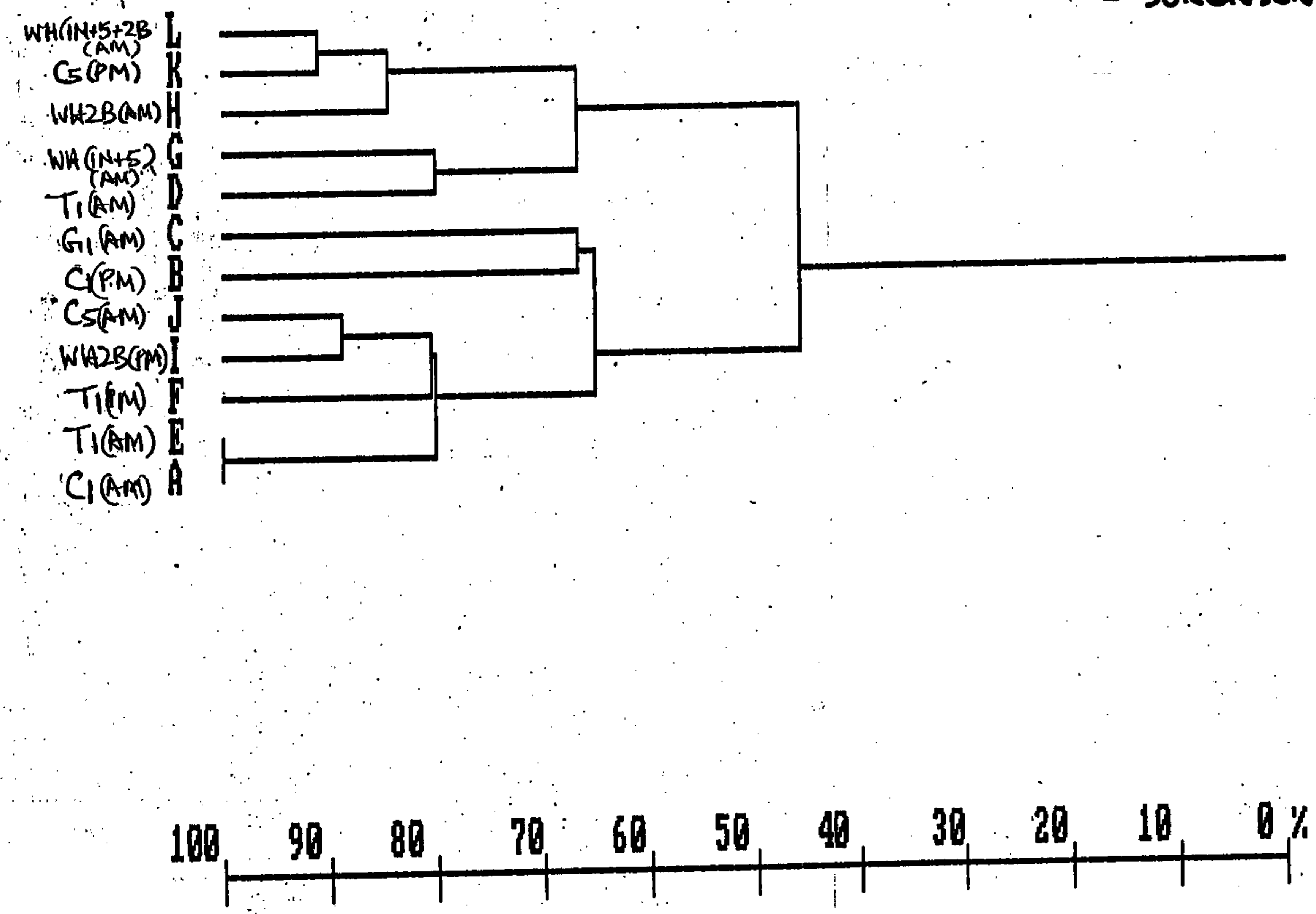


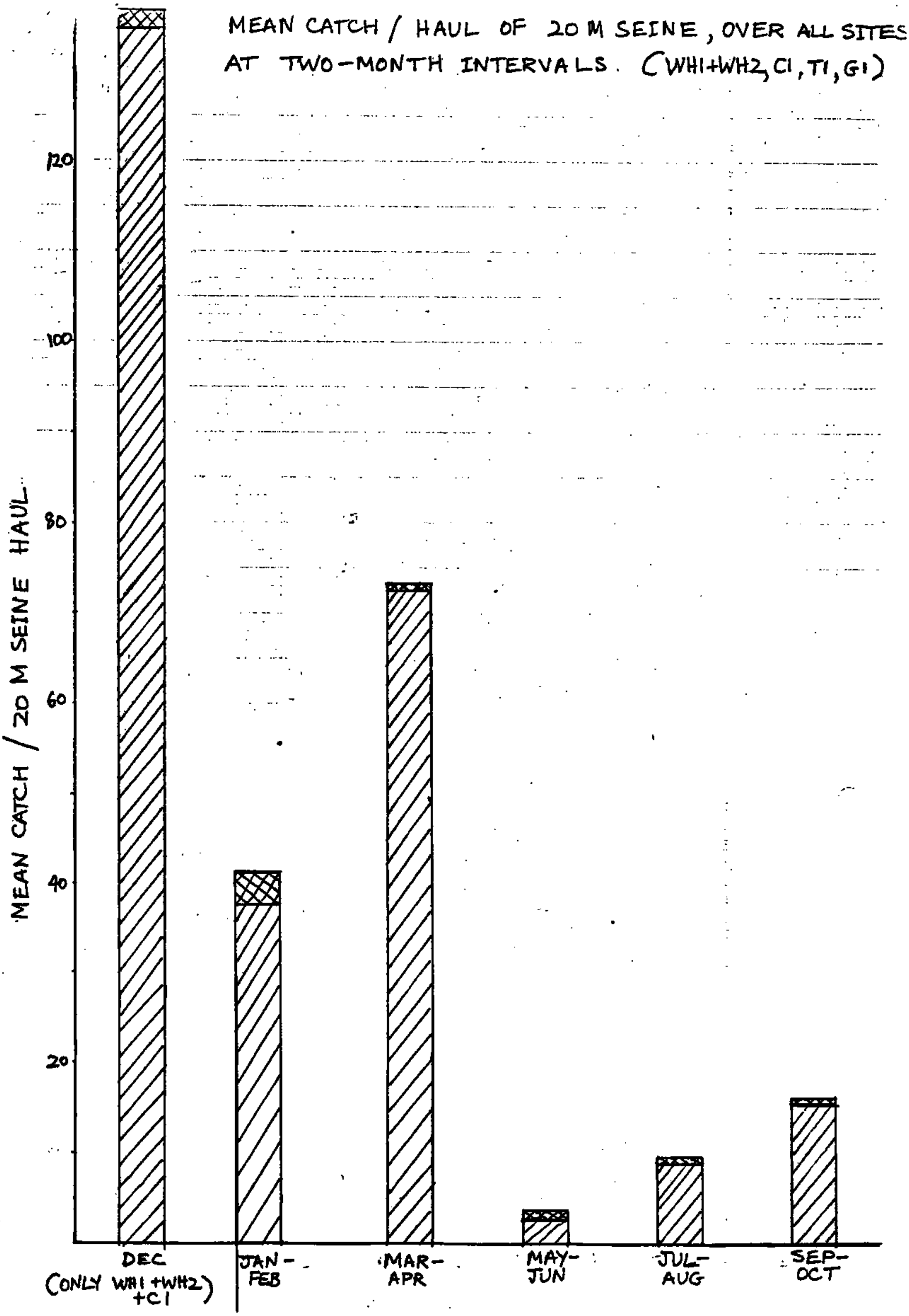

MAY-JUN 1987 SITES AGAINST CATCH IN 20M SEINE
-SORENSEN'S
WH2(A+B)(PM) J
ALL WH1,2(AM) I
WH6+2A (PM) H
WH1,2B,5(AM) B
C5(PM) L
BC1 F
T3 (AM) E
C1 C
T1 D
C5(AM) K
G1 G
WH2B(AM) A
100
90
80
70
60
50
40
30
20
10
0 %

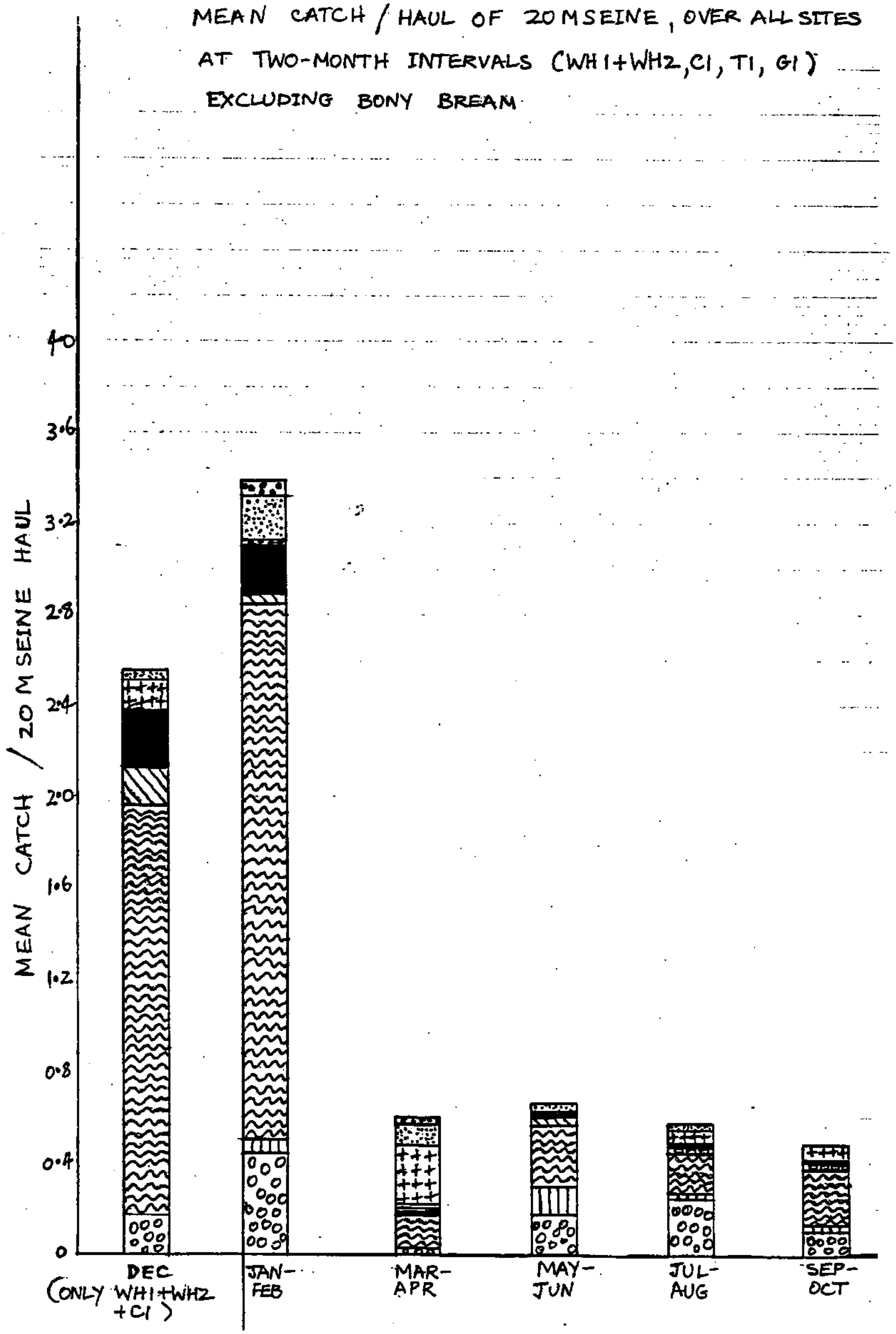
JUL-AUG 1987 SITES AGAINST CATCH IN 20M SEINE
-SORENSEN'S

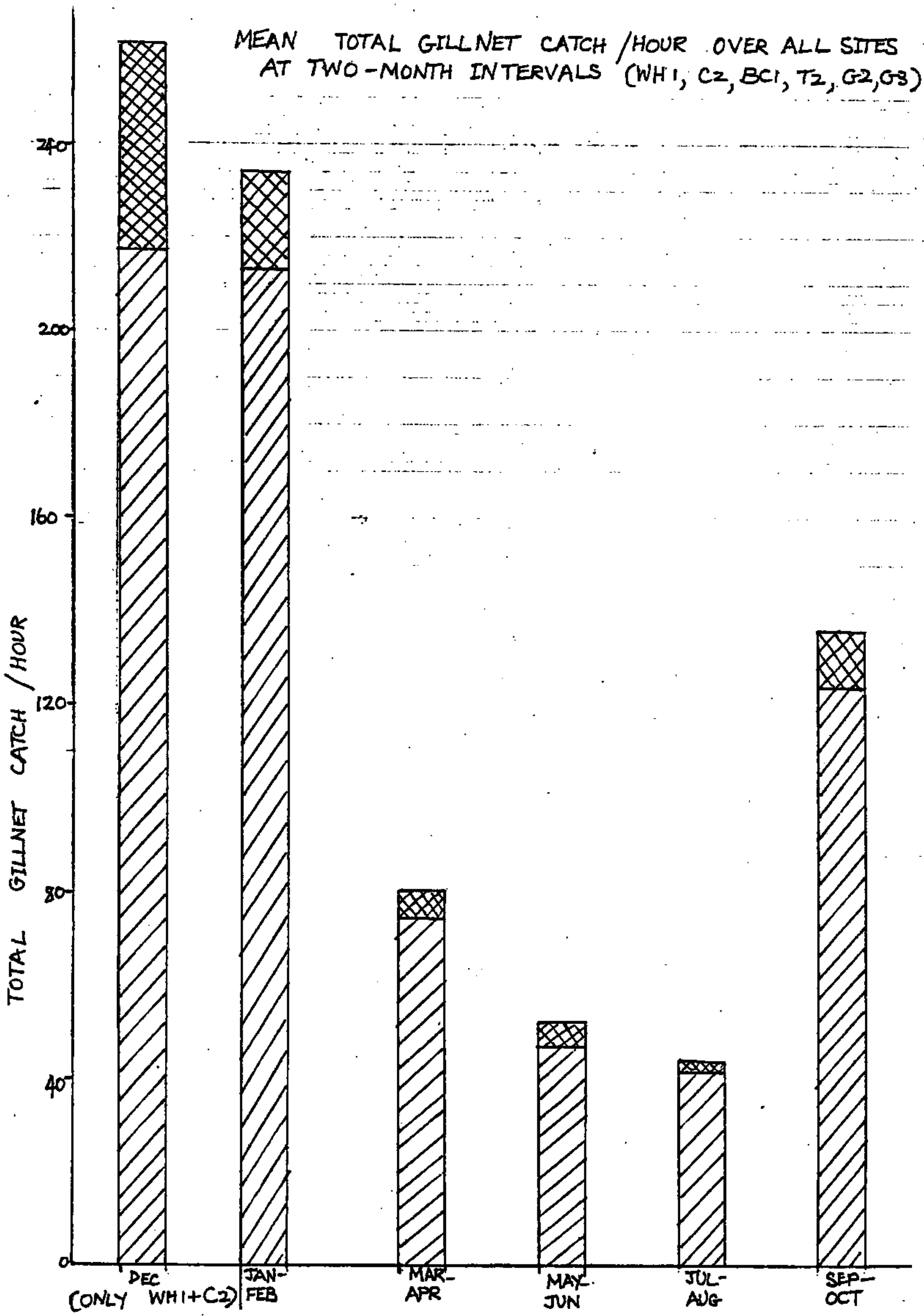


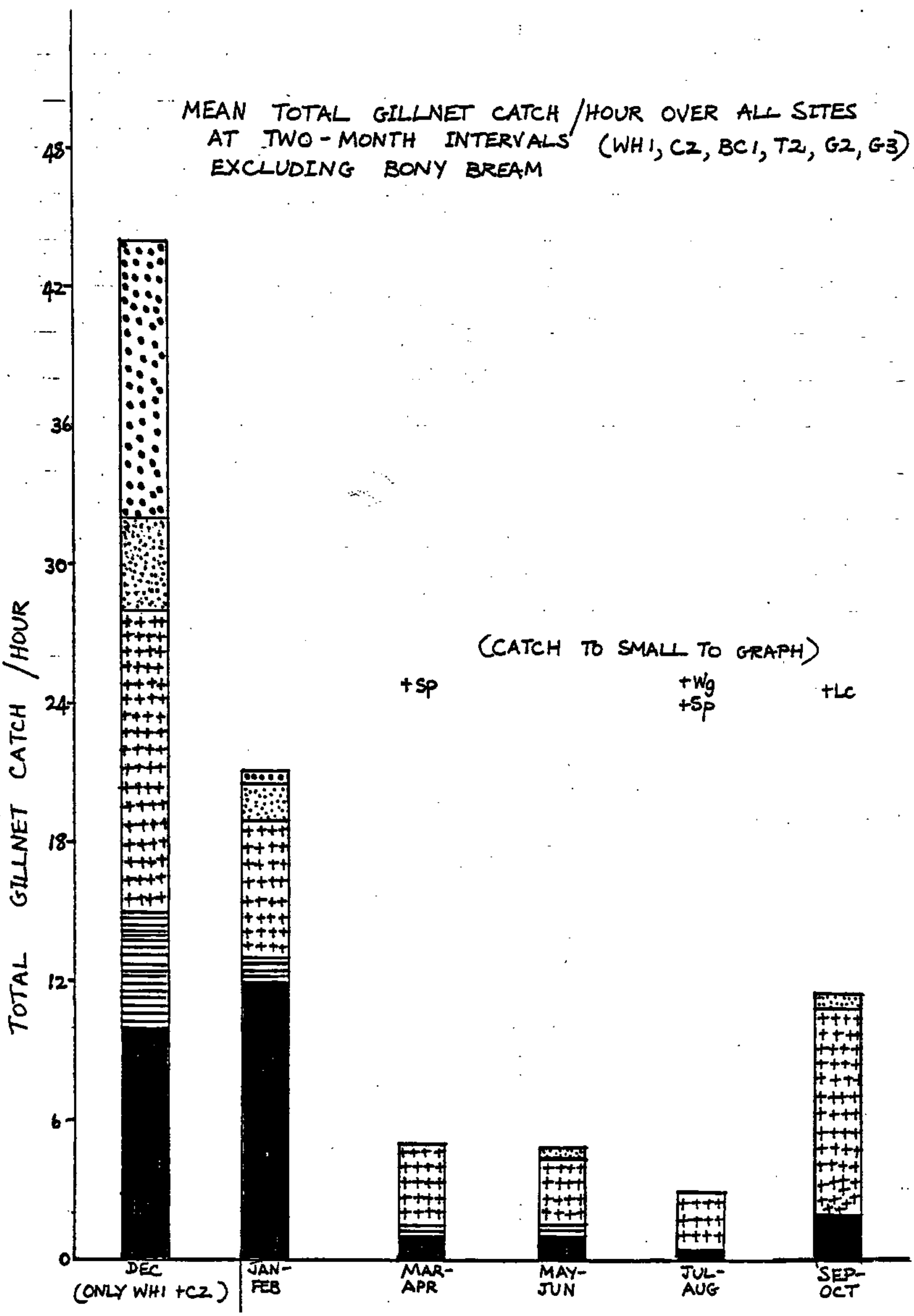
SEP-OCT 1987 SITES AGAINST CATCH IN 20M SEIN
– SORENSEN'S



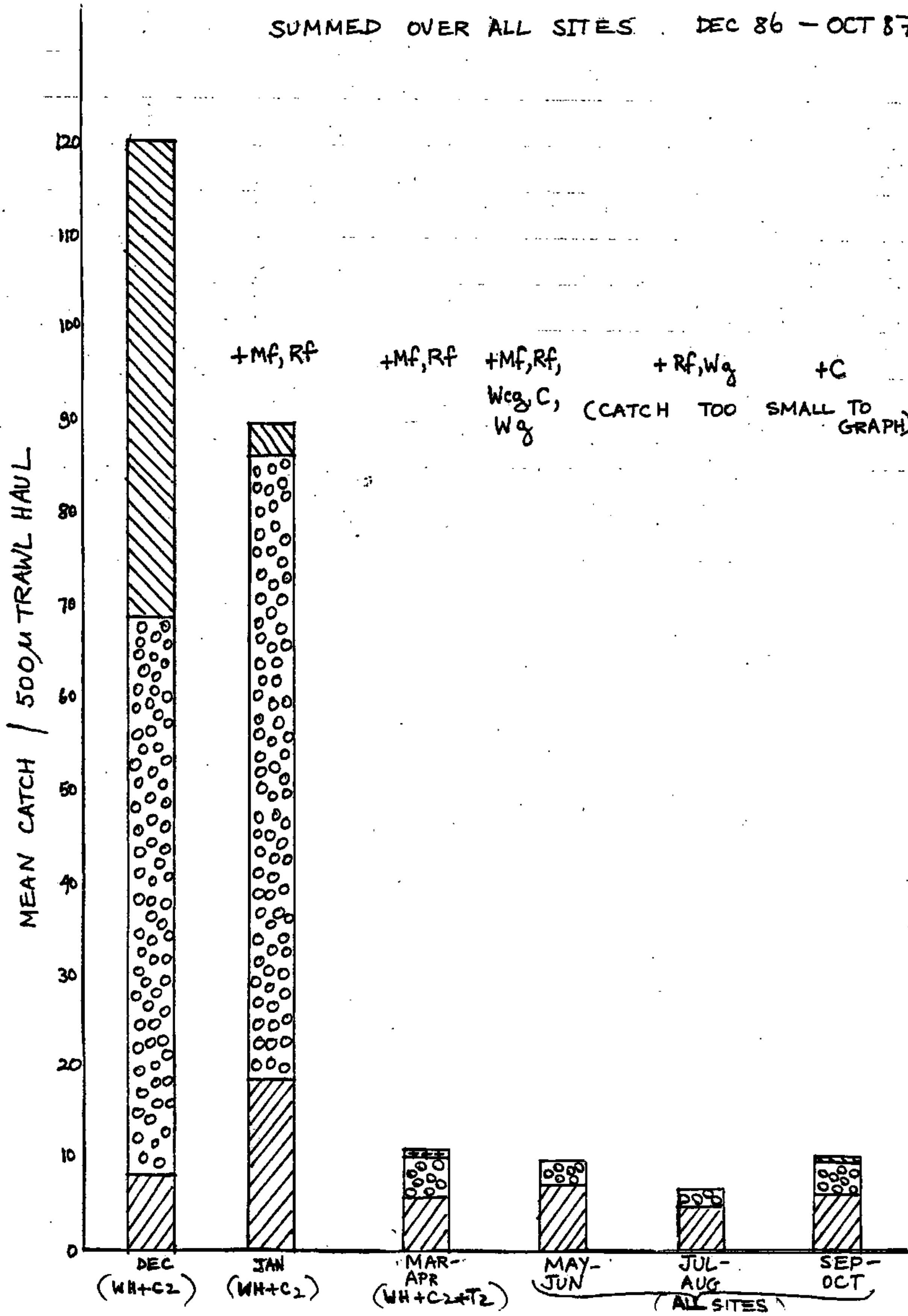

MEAN CATCH / HAUL OF 20 M SEINE, OVER ALL SITES
AT TWO-MONTH INTERVALS. (WH1+WH2, C1, T1, G1)
MEAN CATCH / 20 M SEINE HAUL
120
100
80
60
40
20
DEC
(ONLY WH1+WH2 +C1)
JAN-FEB
MAR-APR
MAY-JUN
JUL-AUG
SEP-OCT

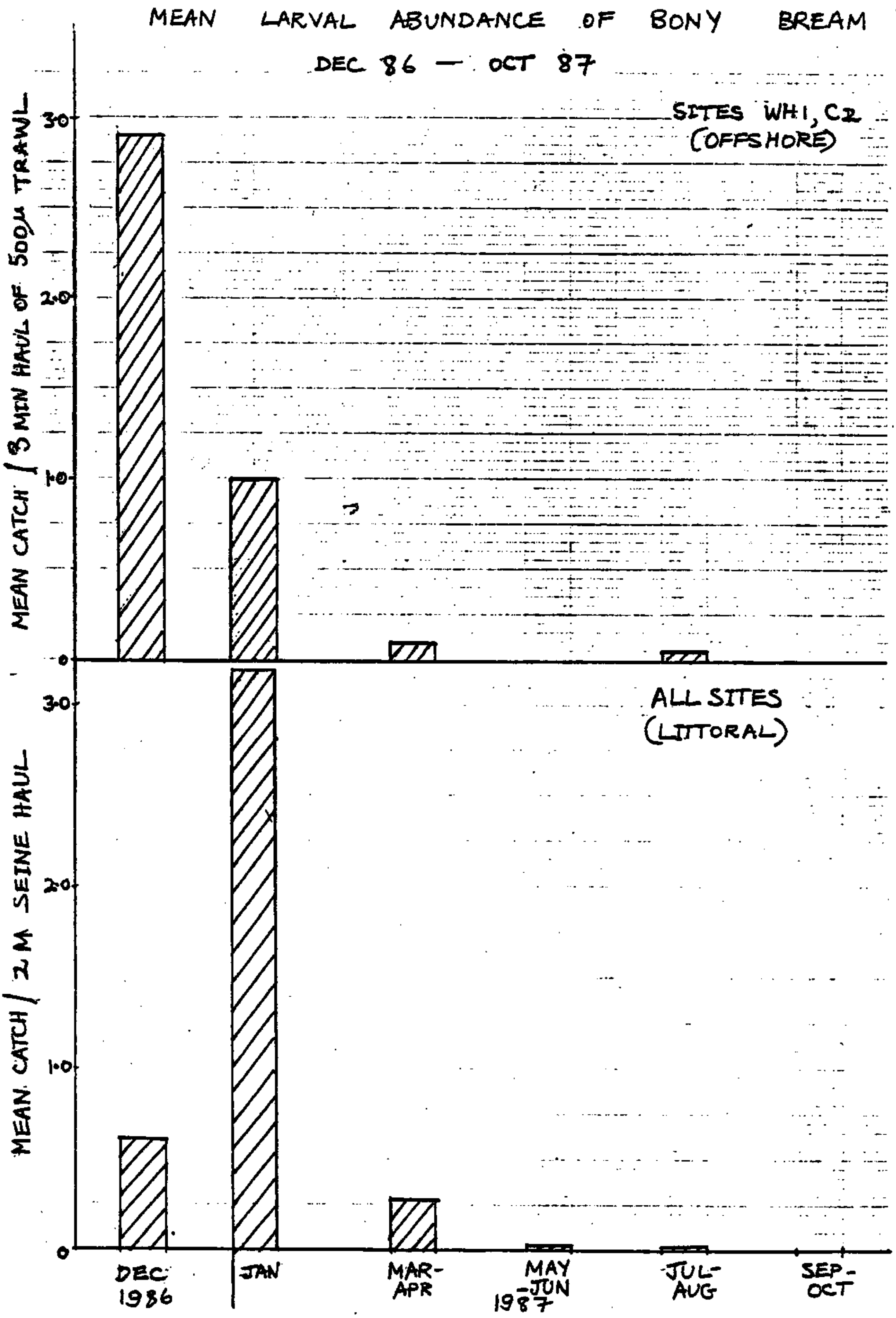

MEAN CATCH / HAUL OF 20 M SEINE, OVER ALL SITES
AT TWO-MONTH INTERVALS (WH1+WH2, C1, T1, G1)
EXCLUDING BONY BREAM
MEAN CATCH / 20 M SEINE HAUL
4.0
3.6
3.2
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0
DEC
(ONLY WH1+WH2
+C1)
JAN-
FEB
MAR-
APR
MAY-
JUN
JUL-
AUG
SEP-
OCT

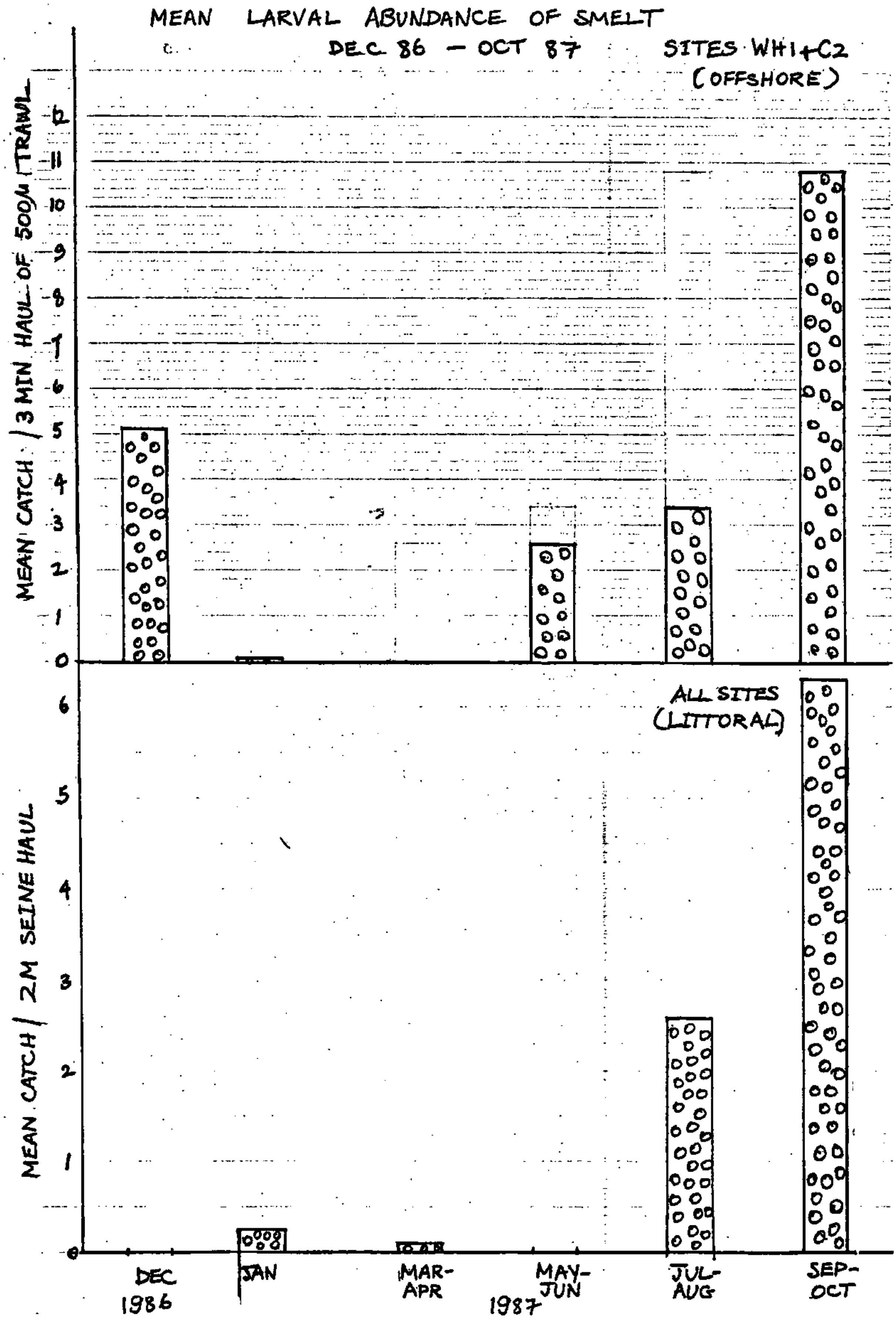

MEAN TOTAL GILLNET CATCH /HOUR OVER ALL SITES
AT TWO-MONTH INTERVALS (WH1, C2, BC1, T2, G2, G3)
TOTAL GILLNET CATCH /HOUR
0
40
80
120
160
200
240
DEC
(ONLY WH1+C2)
JAN-
FEB
MAR-
APR
MAY
JUN
JUL-
AUG
SEP-
OCT


MEAN TOTAL GILLNET CATCH /HOUR OVER ALL SITES
AT TWO-MONTH INTERVALS (WH1, C2, BC1, T2, G2, G3)
EXCLUDING BONY BREAM
TOTAL GILLNET CATCH /HOUR
0
6
12
18
24
30
36
42
48
(CATCH TO SMALL TO GRAPH)
+Sp
+Wg
+Sp
+Lc
DEC
(ONLY WH1 +C2)
JAN-
FEB
MAR-
APR
MAY-
JUN
JUL-
AUG
SEP-
OCT

MEAN TRAWL CATCH OF ADULTS + JUVENILES SUMMED OVER ALL SITES. DEC 86 – OCT 87

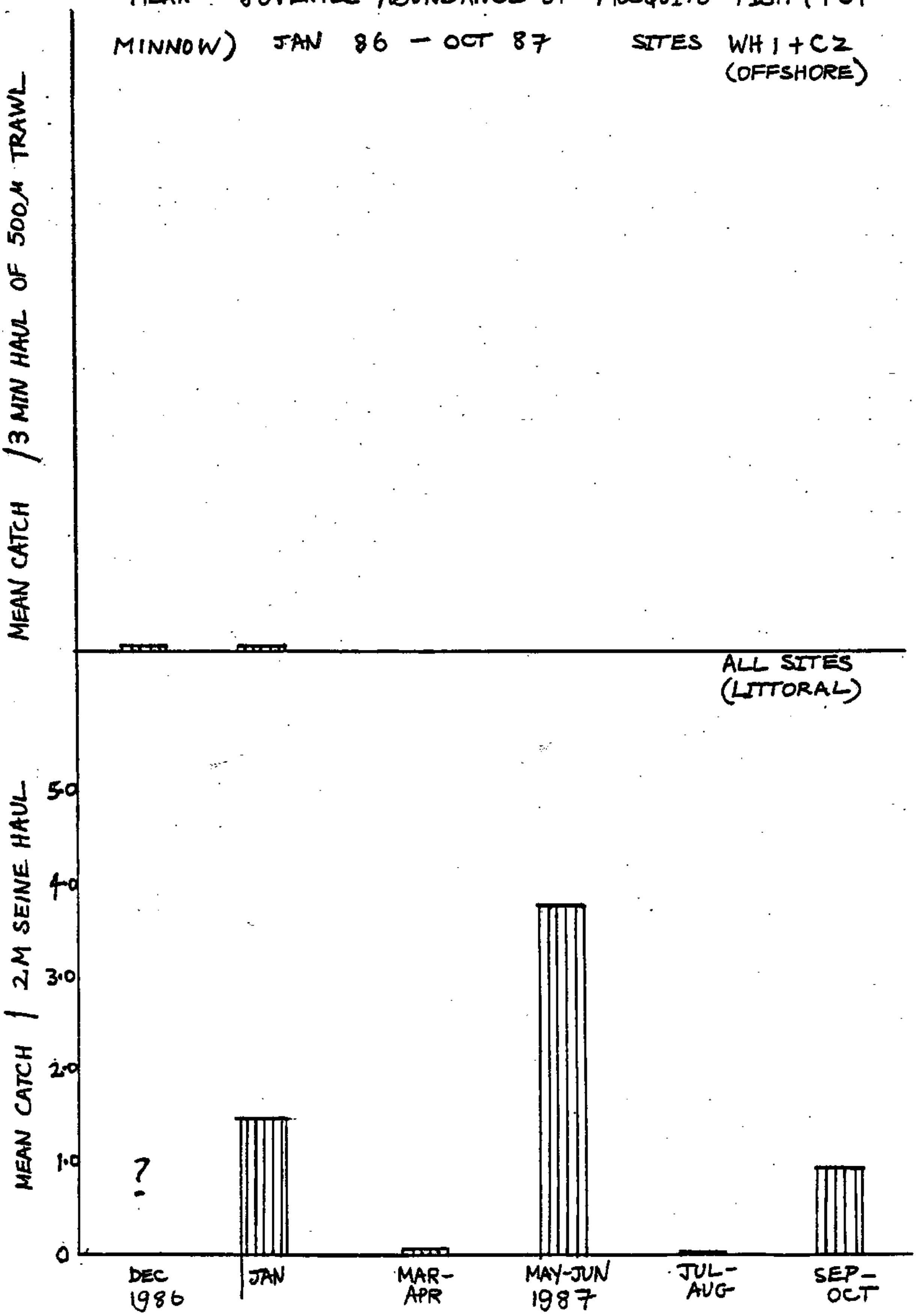


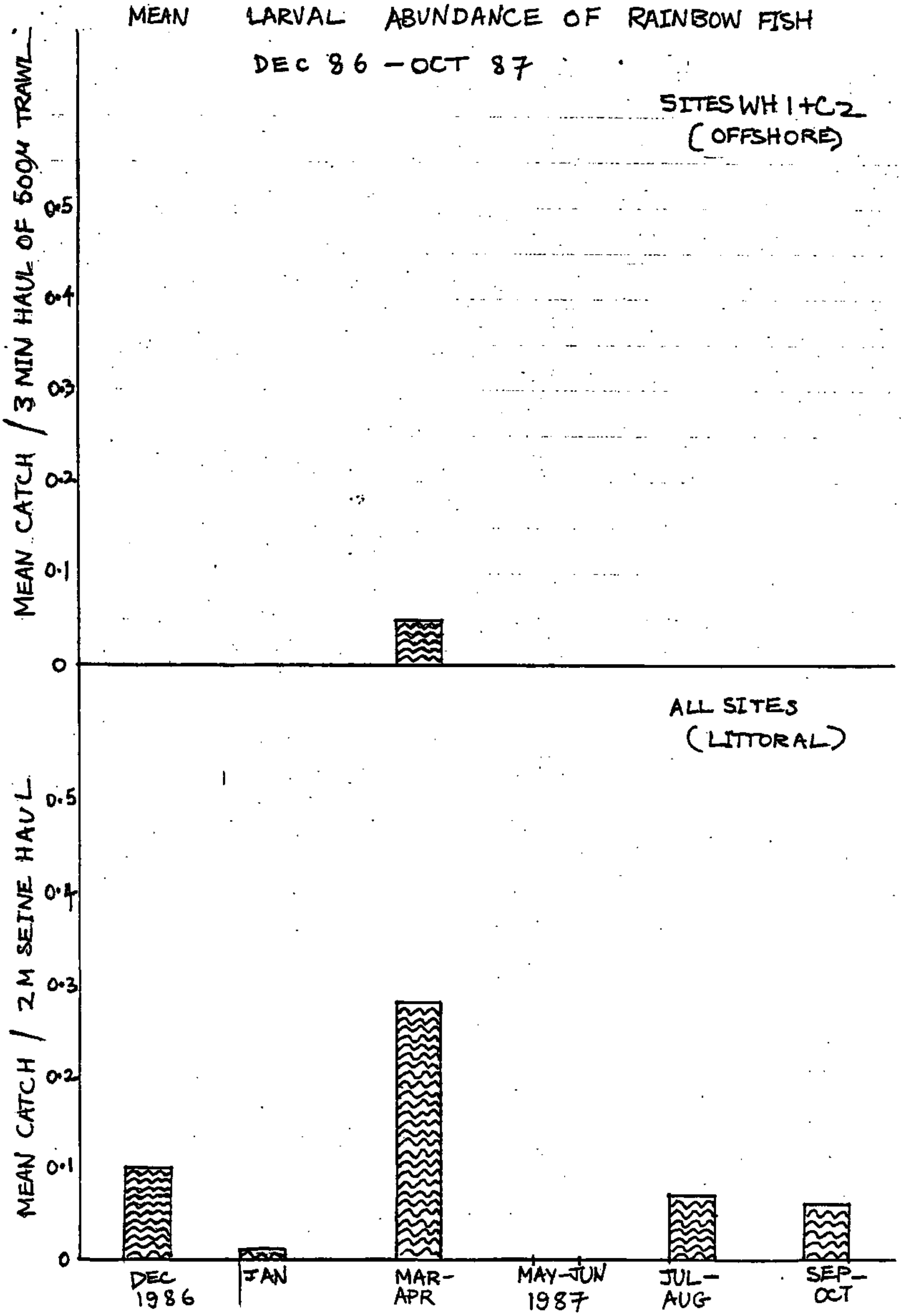

MEAN LARVAL ABUNDANCE OF BONY BREAM
DEC 86 — OCT 87
SITES WH1, C2
(OFFSHORE)
MEAN CATCH / 3 MIN HAUL OF 500µ TRAWL
3·0
2·0
1·0
0
ALL SITES
(LITTORAL)
MEAN CATCH / 2 M SEINE HAUL
3·0
2·0
1·0
0
DEC
1986
JAN
MAR-
APR
MAY
-JUN
1987
JUL-
AUG
SEP-
OCT

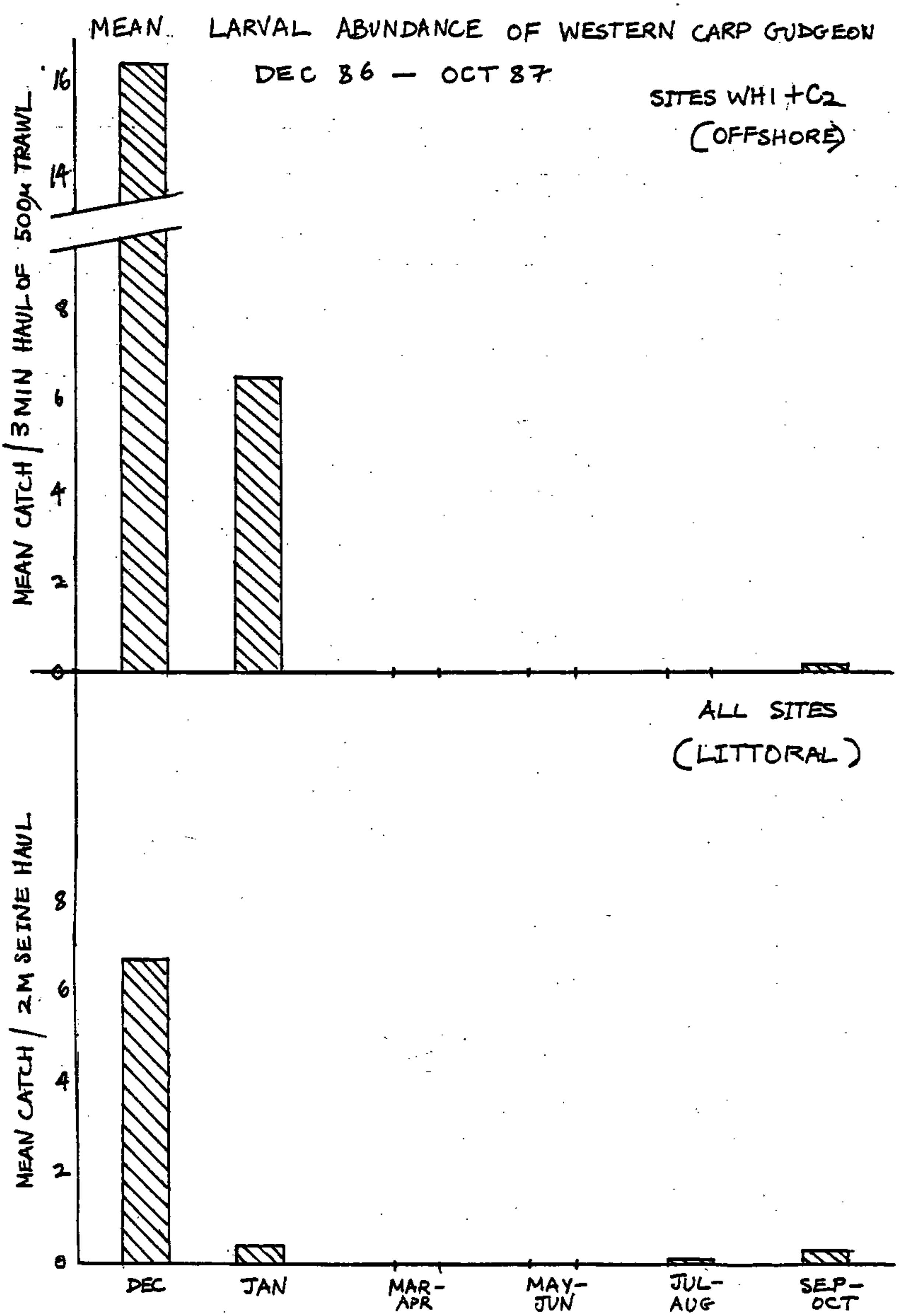


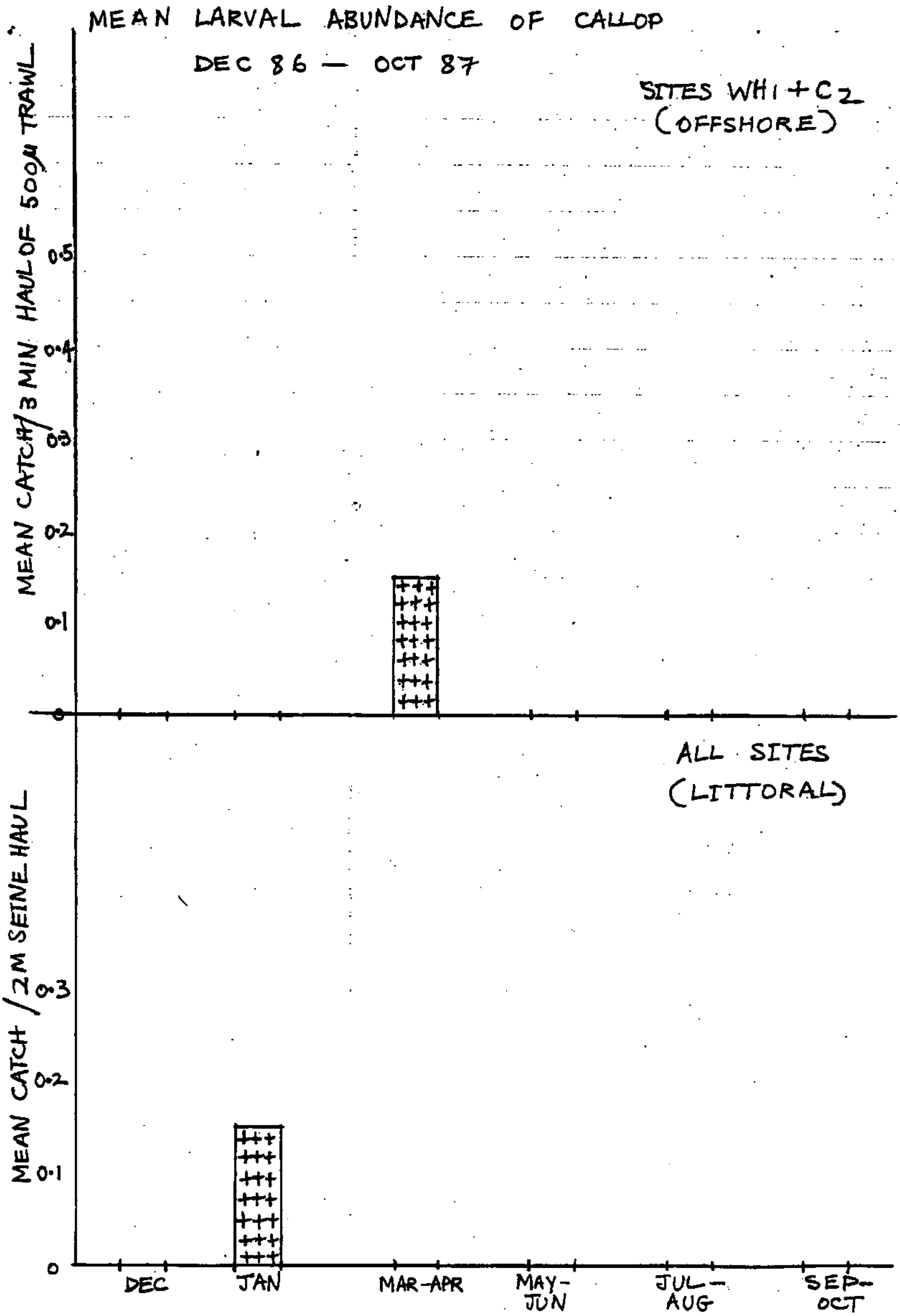
MEAN LARVAL ABUNDANCE OF SMELT
DEC 86 — OCT 87
SITES WH1+C2
(OFFSHORE)
MEAN CATCH / 3 MIN HAUL OF 500μ TRAWL
0
1
2
3
4
5
6
7
8
9
10
11
12
ALL SITES
(LITTORAL)
MEAN CATCH / 2M SEINE HAUL
0
1
2
3
4
5
6
DEC
1986
JAN
MAR-
APR
1987
MAY-
JUN
JUL-
AUG
SEP-
OCT

MEAN JUVENILE ABUNDANCE OF MOSQUITO FISH (TOP MINNOW) JAN 86 – OCT 87 SITES WH1 + C2 (OFFSHORE)

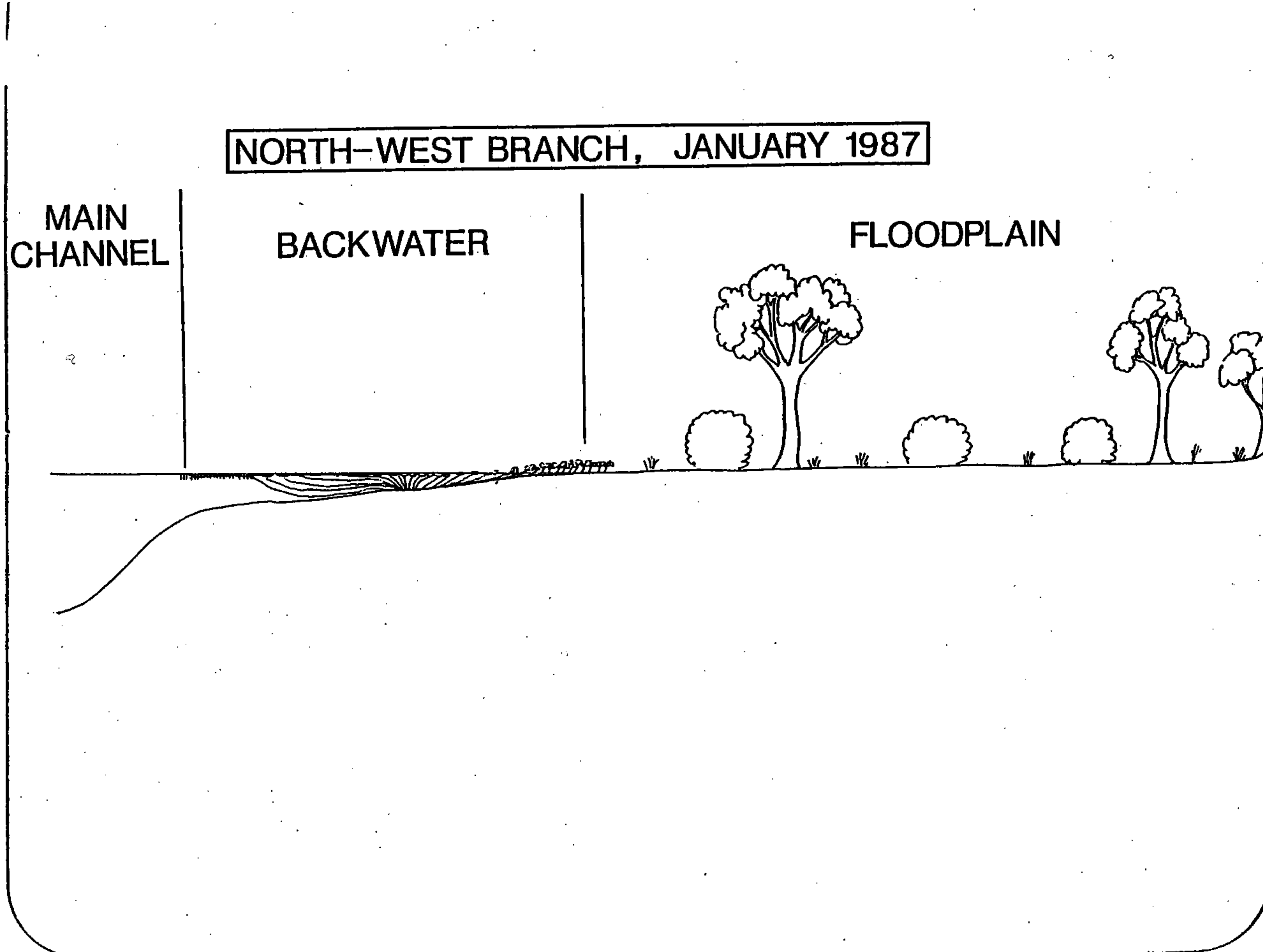



MEAN LARVAL ABUNDANCE OF RAINBOW FISH
DEC 86 – OCT 87
SITES WH 1 + C2
(OFFSHORE)
MEAN CATCH / 3 MIN HAUL OF 500M TRAWL
0
0·1
0·2
0·3
0·4
0·5
ALL SITES
(LITTORAL)
MEAN CATCH / 2 M SEINE HAUL
0
0·1
0·2
0·3
0·4
0·5
DEC
1986
JAN
MAR-
APR
MAY-JUN
1987
JUL-
AUG
SEP-
OCT

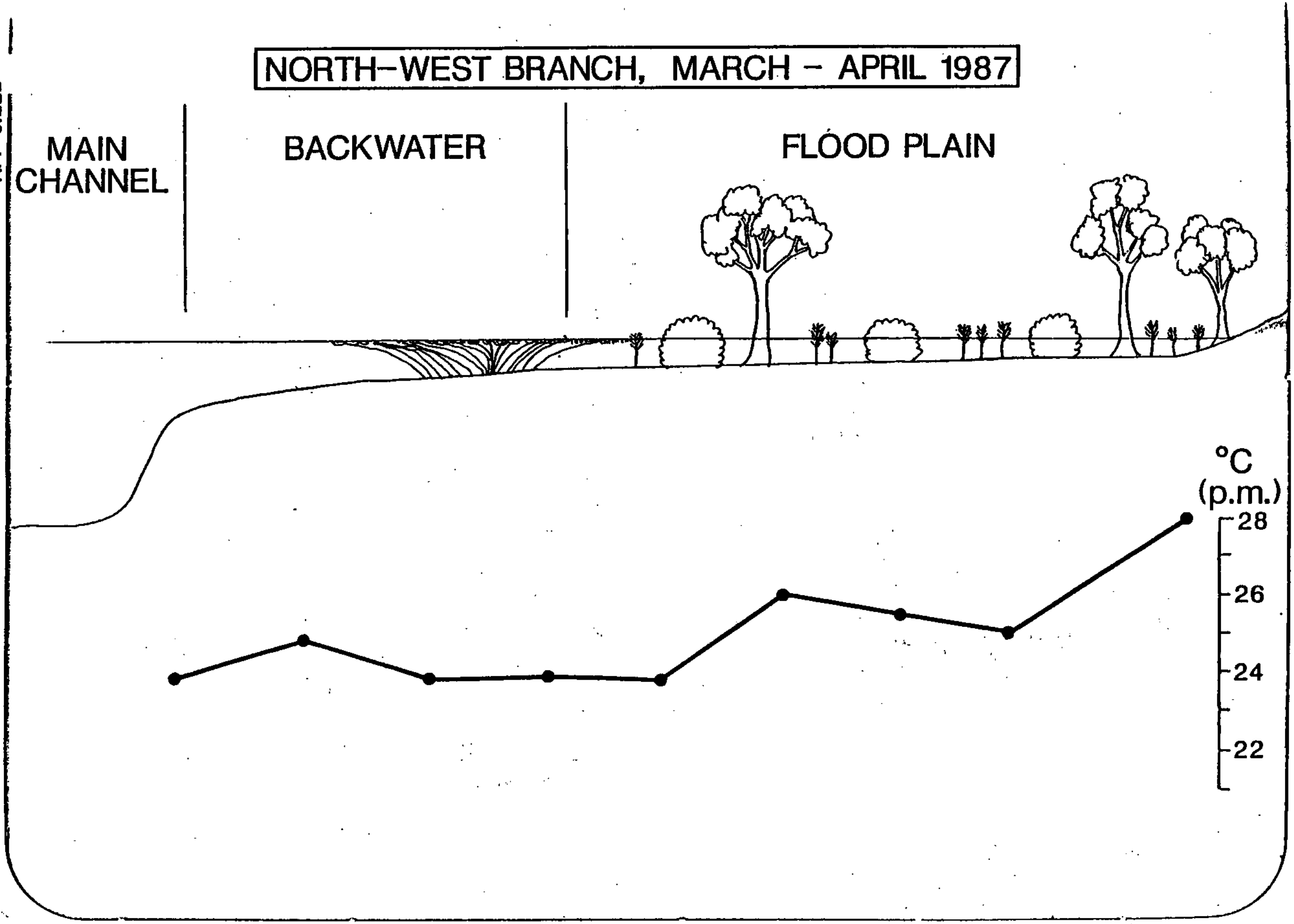

MEAN LARVAL ABUNDANCE OF WESTERN CARP GUDGEON
DEC 86 — OCT 87
SITES WH1 + C2
(OFFSHORE)
MEAN CATCH / 3 MIN HAUL OF 500μ TRAWL
16
14
8
6
4
2
0
ALL SITES
(LITTORAL)
MEAN CATCH / 2 M SEINE HAUL
8
6
4
2
0
DEC
JAN
MAR-APR
MAY-JUN
JUL-AUG
SEP-OCT

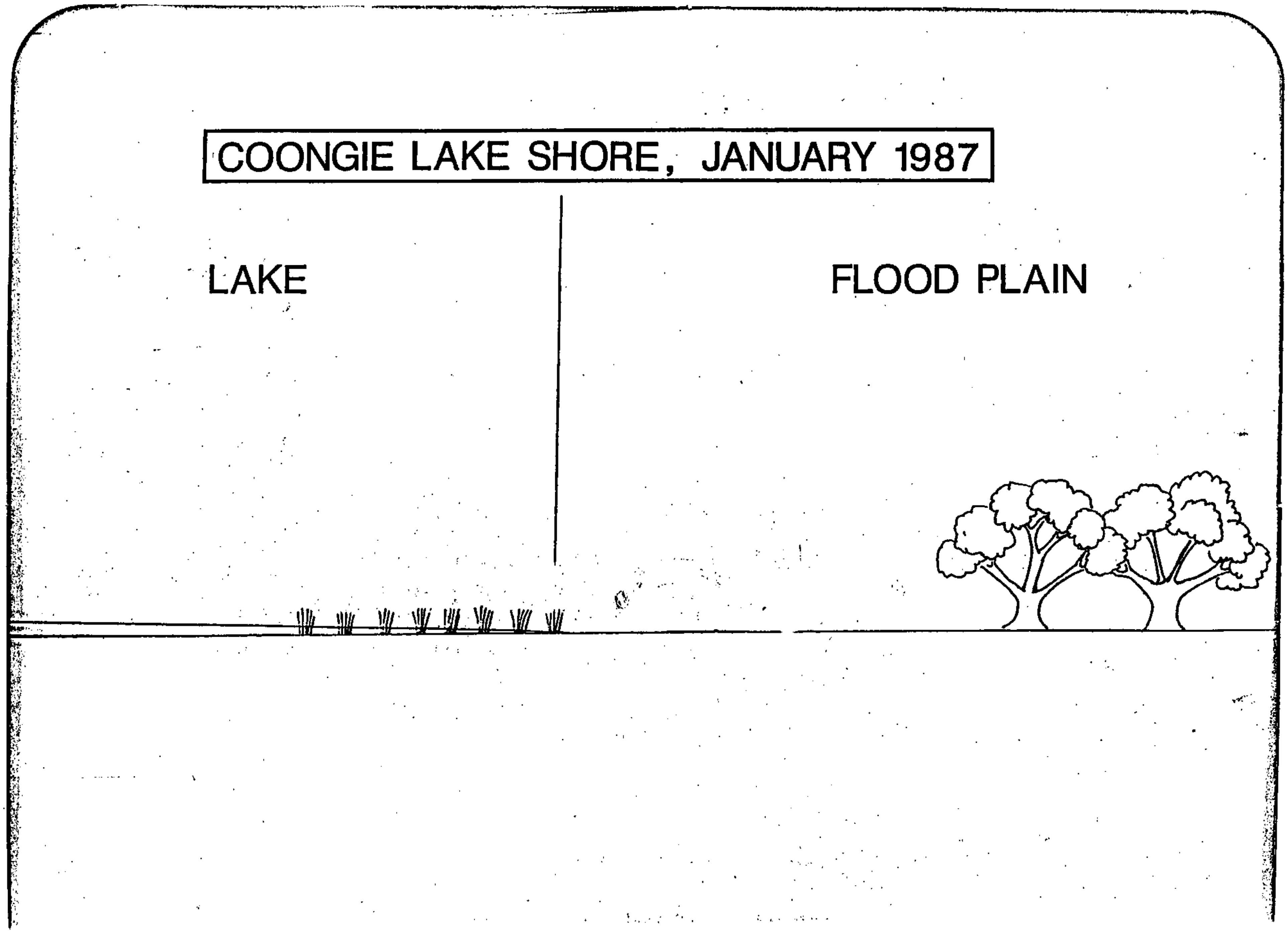

MEAN LARVAL ABUNDANCE OF CALLOP
DEC 86 — OCT 87
SITES WH1 + C2
(OFFSHORE)
MEAN CATCH/3 MIN HAUL OF 500µ TRAWL
0.5
0.4
0.3
0.2
0.1
0
ALL SITES
(LITTORAL)
MEAN CATCH /2M SEINE HAUL
0.3
0.2
0.1
0
DEC
JAN
MAR-APR
MAY-JUN
JUL-AUG
SEP-OCT

APP 5.22A

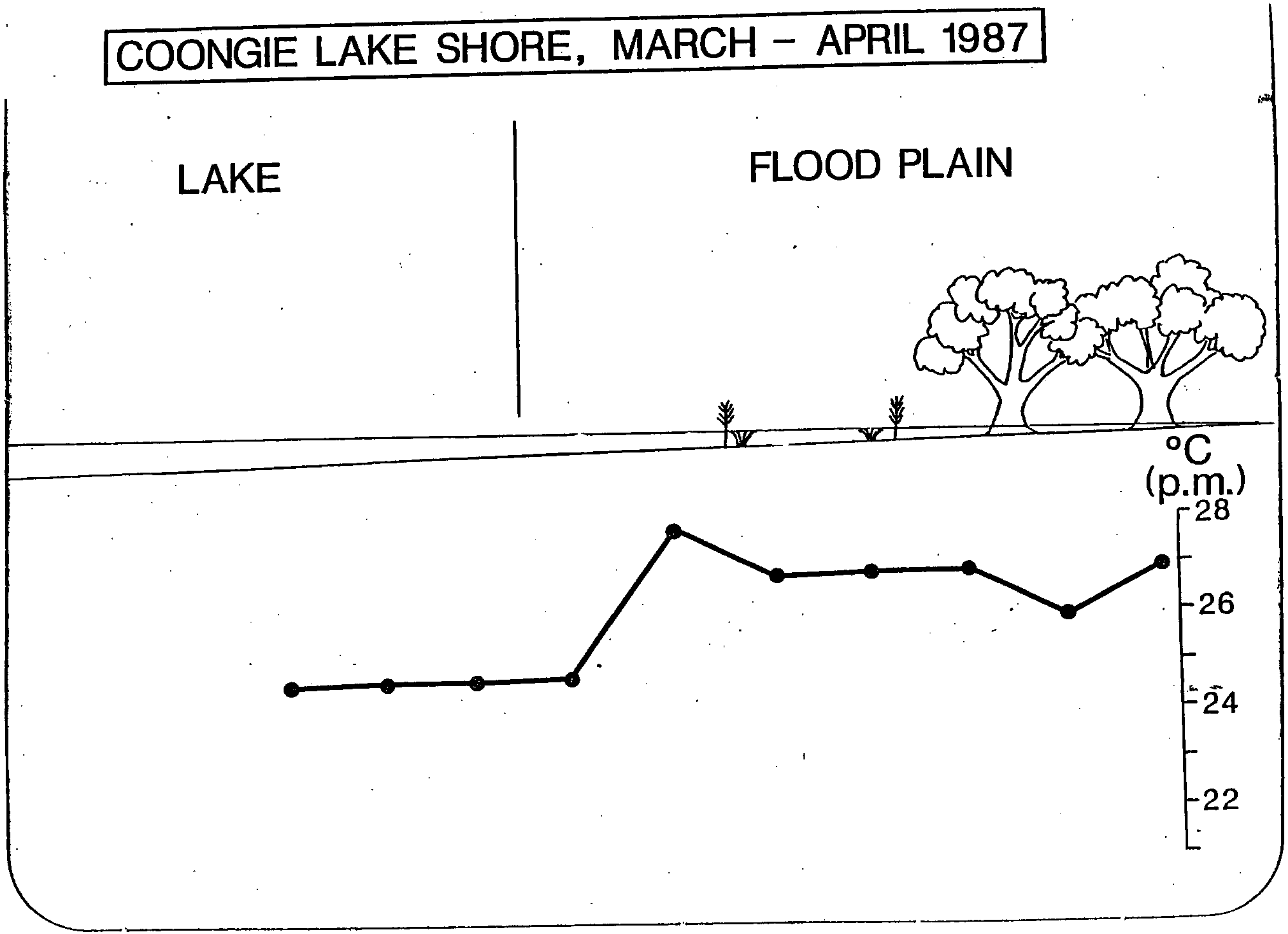


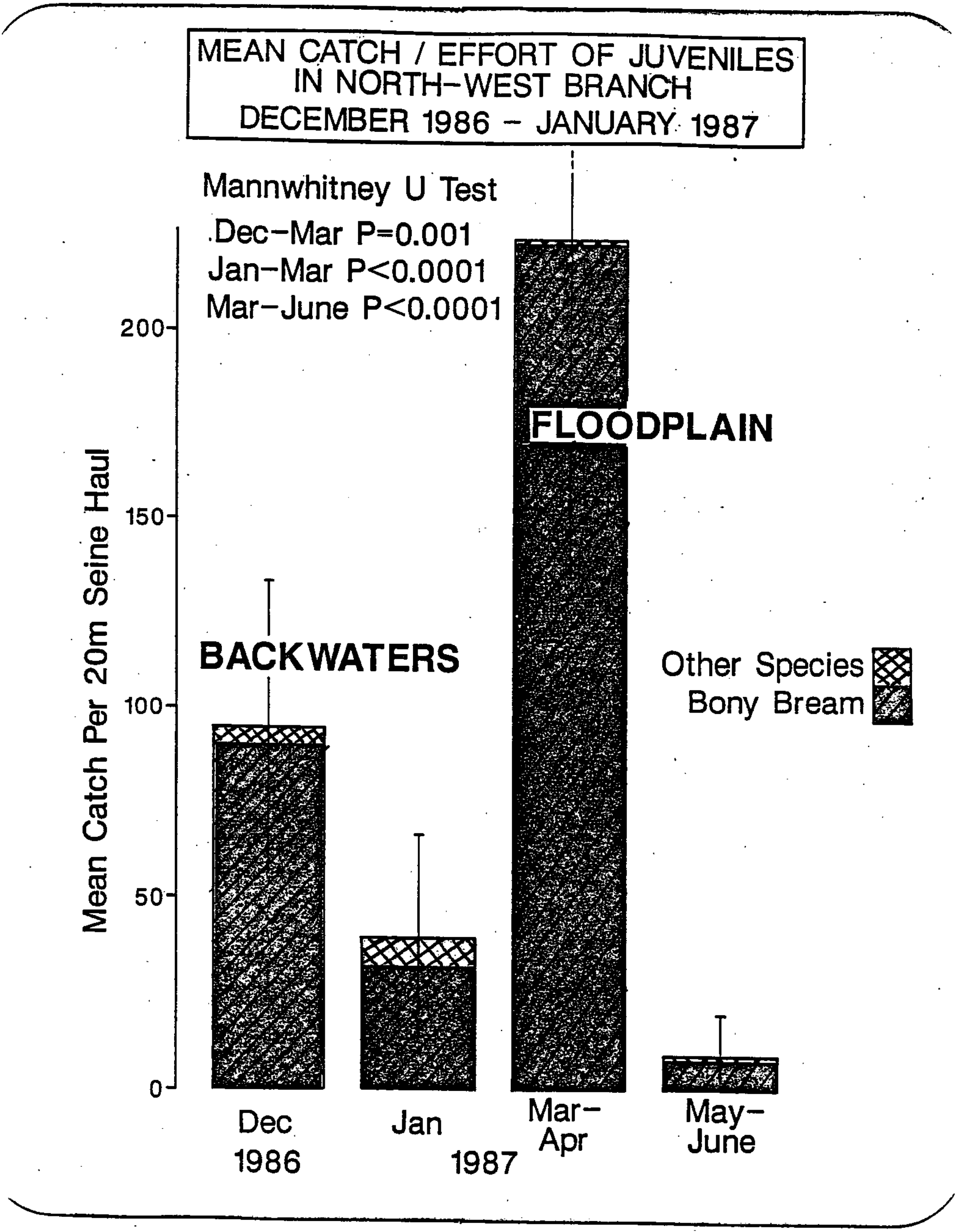
NORTH-WEST BRANCH, JANUARY 1987


NORTH-WEST BRANCH, MARCH - APRIL 1987
MAIN CHANNEL
BACKWATER
FLOOD PLAIN
°C (p.m.)
28
26
24
22


COONGIE LAKE SHORE, JANUARY 1987
LAKE
FLOOD PLAIN

APP 5.23B


COONGIE LAKE SHORE, MARCH - APRIL 1987
LAKE
FLOOD PLAIN
°C
(p.m.)
28
26
24
22


MEAN CATCH / EFFORT OF JUVENILES IN NORTH-WEST BRANCH DECEMBER 1986 - JANUARY 1987
Mannwhitney U Test
Dec-Mar P=0.001
Jan-Mar P<0.0001
Mar-June P<0.0001
Mean Catch Per 20m Seine Haul
0
50
100
150
200
BACKWATERS
FLOODPLAIN
Other Species
Bony Bream
Dec 1986
Jan
1987
Mar-Apr
May-June

APPENDIX 5.25

AQUATIC MACROINVERTEBRATES

PHYLUM	CLASS/ SUB-CLASS	ORDER/ SUB-ORDER	FAMILY/ SUB-FAMILY	GENUS	SPECIES
PORIFERA					
MOLLUSCA	BIVALVIA		CORBICULIDAE	Corbiculina	australis
			VELESUNIONINAE	Velesunio	wilsonii
	GASTROPODA		THIARIDAE	Plotiopsis	balonnensis
			ANCYLIDAE	Ferrissia	petterdi
			VIVIPARIDAE	Vivipara	sublineata
			LYNMNAEIDAE	Austropeplea	lessoni
			SUCCINEIDAE	Succinea	australis
			BITHYNIIDAE	Gabbia	australis
			PLANORBIDAE	Physastra	gibbosa
				Glyptophysa	aliciae
				Isidorella	hainesii
ANNELIDA	OLIGOCHAETA				
	POLYCHAETA		TUBIFICIDAE		
	HIRUDINEA		GLOSSIPHONIIDAE		
			ORNITHOBDELLIDAE		
ARTHROPODA	ARACHNIDA	ACARINA			
	CRUSTACEA	ANOSTRACA	BRANCHIPODIDAE	Branchinella	sp.
		NOTOSTRACA		Triops	australiense
		CONCHOSTRACA	CYCLESTHERIIDAE	Cyclestheria	sp.
			LIMNADIIDAE	Eulimnadia	sp.
			CYZICIDAE	Cyzicus	sp.
		DECAPODA	PALAEMONIDAE	Machrobrachium	australiense
			PARASTACIDAE	Cherax	destructor
			SUNDATELPHUSIDAE	Holthuisiana	transversa
	INSECTA	ODONATA	AESHNIDAE	Hemianax	papuensis
			GOMPHIDAE	Austrogomphus	australis
			CORDULIIDAE	Hemicordulia	tau
		(ANISOPTERA)	LIBELLULIDAE	Trapezostigma	loewi
				Diplacodes	melanopsis
				Orthetrum	caledonicum
		(ZYGOPTERA)	LESTIDAE	Austrolestes	aridus
		COLEOPTERA	DYTISCIDAE	Cybister	tripunctatus
				Homoeodytes	scutellaris
				Platynectes	decempunctatus
				Eretes	australis
				Necterosoma	wollastoni
			GYRINIDAE	Dineutus	australis
			HYDROPHILIDAE		
			(HYDROBIINAE)	Limnoxenus	sp.
				Sternolophus	marginicollis
			(HYDROPHILINAE)	Hydrophilus	sp.
			HALIPLIDAE	Haliplus	sp.

APPENDIX 5.25

AQUATIC MACROINVERTEBRATES

PHYLUM	CLASS/ SUB-CLASS	ORDER SUB-ORDER	FAMILY/ SUB-FAMILY	GENUS	SPECIES
		EPHEMEROPTERA	BAETIDAE	Cloeon	sp.
			CAENIDAE	Tasmanocoenis	sp.
		HEMIPTERA	NEPIDAE	Laccotrephes	tristis
			CORIXIDAE	Agraptocorixa	eurynome

DISTRIBUTION OF MACROINVERTEBRATE FAMILIES

FAMILIES	FLOOD-FILLED SITES (SOUTH TO NORTH)																RAIN-FILLED SITES (© One EPH site briefly connected to WH2)				
	TW1	TS1	WH3	WH2	WH1	WH1MC	C1	C2	C5	C3	MC1	MK1	BC	T3	T1	G1	AO1	TAL	MW1	EP	EPH
Notonectidae	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Hydrophilidae	*	*	-	*	-	-	*	-	*	*	-	*	-	*	*	*	-	*	-	*	*
Dytiscidae	*	*	*	*	*	-	*	-	*	-	*	*	-	*	*	*	-	*	*	*	*
Pyralidae	-	*	-	*	*	-	*	-	-	-	*	-	-	-	*	-	-	-	-	-	-
Stratiomyidae	*	*	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chironomidae	-	*	*	*	*	-	*	-	*	-	*	*	-	*	*	*	*	-	*	*	*
Corixidae	*	*	*	*	*	*	*	-	*	*	*	*	-	*	*	*	*	*	*	*	*
Mesoveliidae	*	*	-	*	*	-	*	-	-	-	-	*	-	-	-	-	-	-	-	-	-
Leptoceridae	-	*	-	*	*	-	*	-	-	*	-	*	-	*	*	*	-	-	-	-	-
Baetidae	-	*	-	*	*	-	*	-	*	-	*	-	-	*	-	-	-	-	-	-	-
Ephydridae	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Libellulidae	-	*	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Corduliidae	-	*	-	*	*	-	-	-	-	*	-	-	-	*	-	-	-	-	-	-	-
Aeshnidae	-	*	*	*	*	-	-	-	*	-	-	-	-	*	-	-	-	-	-	-	-
Caenidae	-	-	-	*	*	*	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Curculionidae	-	-	-	-	*	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	*
Culicidae	-	-	-	*	*	-	-	-	-	-	-	-	-	*	-	-	-	-	-	*	-
Gomphidae	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Haliplidae	-	-	-	-	-	-	*	-	-	-	-	-	-	*	-	-	-	-	-	-	-
Hydroptilidae	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-
Nepidae	-	-	-	-	*	-	*	-	-	-	-	-	-	-	-	-	-	*	-	-	-
Ecnomidae	-	-	-	-	-	-	*	-	*	-	-	*	-	-	-	-	-	-	-	-	-
Veliidae	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lestidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-
Gryllotalpidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-	-
Parastacidae	-	*	-	-	*	-	*	-	-	-	-	*	-	-	-	*	-	-	-	-	*
Palaemonidae	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	-	-	-	-	*©
Tubificidae	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Branchipodidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	*	-	*	*
Glossiphoniidae	-	-	-	-	*	-	*	-	-	-	-	*	-	-	-	*	-	-	-	-	-
Ornithobdellidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-	-
Sundatelphusidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-
Triops	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	*
Succineidae	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bithyniidae	*	*	-	*	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	*	*
Planorbidae	*	-	*	*	*	*	*	-	*	*	*	-	*	-	*	*	*	*	-	*	*
Velesunioninae	-	-	-	*	*	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Corbiculidae	-	-	-	*	*	*	*	-	*	-	-	-	*	-	-	-	-	-	-	-	-
Thiaridae	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ancylidae	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Viviparidae	-	*	*	*	*	-	*	-	-	*	*	*	*	*	*	-	-	-	-	-	*
Lymnaeidae	*	*	*	*	*	-	*	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Cyclestheriidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	*
Limnadiidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	*
Cyzicidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-	*	-
Syrphidae	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-

6. VEGETATION

Jake Gillen and Julian Reid

6.1 Aims

The following aims were derived from the broader objectives of the original project brief for the Coongie Lakes survey.

1) The observation, collection and identification of plants within the Coongie Lakes District and the greater region.

2) The documentation of the vegetation associations occuring within the study area.

3) The observation and documentation of the seasonal changes that occur to the flora within the study area over the period of the survey.

4) The identification and documentation of various noticeable impacts upon the flora.

Background

"There have been few intensive studies of a biological nature in the Cooper Creek Environmental Association" (Mollenmans et al. 1984). In fact the most comprehensive study of this area to date has been that conducted by the Mollenmans team. Previous botanical work could be considered to range from the collection of plants as a prime objective to the examination and documentation of vegetation associations, or perhaps a combination of the two. For example early plant collections were made by R. Tate (1889), S.A. White (in Black 1977) and J.B. Cleland, J.M. Black and L. Reese (1925), while more recent collections have been compiled and/or reviewed by J.P. Jessop (1982) and F.H. Mollenmans et al. (1984). Other botanical investigations of a broader nature, examining vegetation associations in the north-east of South Australia include, R.L. Specht (1972), South Australian Pastoral Board (1973), M.M. Lewis (1982), Environmental Research and Planning Group (1980) and Social and Ecological Assessment (1982). More recently the

Land Assessments Branch of the Department of Lands has been attempting to map the various vegetation associations occuring on Innamincka Station within various defined land systems (LAB 1986).

This present survey has benefited greatly from the detailed study and findings reported by the Mollenmans team.

However their achievements like others mentioned previously have been limited by time spent in the field. Typically, botanical fieldtrips into this area have only been of limited duration. Hence their findings, particularly with respect to the ephemeral flora, have been subject to the time of visitation (e.g. summer vs winter) and the type of season encountered (drought vs good local rains).

It was fortunate that the present survey was conducted over an 11 month period, which enabled the observation of summer and winter ephemerals following episodic rainfall events and local flooding in the Coongie Lakes system. In addition, within the time available between other biological studies, it was possible to collect plants further afield to provide a more comprehensive picture of the floristic composition of the greater region.

However to realistically view the results of this present survey within a wider ecological context it is important to bear in mind that, "ecological systems are not static entities, and they cannot be understood by simply finding out what is where over a short survey period. Assessment must be selective and monitoring (repeated assessment) maintained over a time scale that is appropriate to the response rate of the natural system......Arid systems cannot thus be sensibly described by one vegetation survey at one particular time" (Pech and Graetz 1982).

6.2 Methodology

6.2.1 Preliminary Preparations

During November 1986 a reconnaissance trip was made to the study area to select both animal trapping and vegetation survey sites. Using a combination of aerial photographs, topographic map (Innamincka 1:250,000) and ground truthing, thirty sites were selected. In terms of efficiency, as well as their obvious interdependency, a decision was made to integrate both plant and animal assessments at each site. As many readily identifiable vegetation/habitat types as possible were included in the sites selected. The need for rapid access to these sites (particularly during the trapping sessions) determined their proximity to each other and to roads and seismic tracks. This allowed an efficient assessment of the sites on a six weekly interval enabling other aspects of the biological programme to be conducted within the time frame of the study. Eventually fifteen sites were located on each of the west and east sides of the North-West Branch of the Cooper Creek (see Fig. 2.1) to cover as broad an area as practically possible.

During this selection process, photo-points were established at each of the sites and initial photographs taken to allow visual monitoring of vegetation types throughout the study.

Plant specimens were collected and those that could not be identified in the field were later presented to the State Herbarium for indentification.

6.2.2 Initial Assessment

From December 1986 to February 1987 the initial assessment of each of the sites was conducted in order to describe their vegetation types and to establish a permanent transect to enable regular monitoring of seasonal change over the period of the study.

6.2.3 Vegetation Description

Using prepared data sheets (Appendix 6.1), the structure and floristics of the dominant species of the tallest, mid and lower strata were described. The vegetation associations were classified according to the dominant stratum (the one with the most biomass), and described using the structural formation classes shown in Appendix 6.2. In addition quantitative information was collected for the perennial species at the site. Species density and cover were estimated using quadrats large enough to include the most sparsely distributed perennials. Progessively smaller quadrats (nested) were used to sample the more frequent perennials. This quantitative information was eventually combined with data from 118 random sites sampled during the year. The combined data were later computer-analysed to obtain a broader description of the vegetation associations occuring in the Coongie Lakes District.

6.2.4 Monitoring Programme

At each site a fifty metre transect with one hundred consecutive quadrats (50cm x 50cm = 0.25 m^2) was established. At each subsequent monitoring session the composition, frequency and life cycle stages of all annual/ground layer species found within the transect was documented using an appropriate data sheet (Appendix 6.1). For each species found in the transect a subjective estimate of its relative abundance over the greater site was recorded. Within the transect, subjective estimates were also made of percentage bare earth, vegetative litter and rabbit scats. During the monitoring procedure the floristic composition of each site was assessed (for perennials and annuals), documenting life cycle stages for each species and describing the structure and floristics of any annual layers present. At the previously established photopoints, photographs were also retaken at this time.

Over the period of the study, sites on the east side of the Channel were re-assessed a total of five times and those on the west side, six times.

The resulting data for all those sessions were then subjected to computer-analysis to examine the seasonal nature of the annual flora in the Coongie Lakes District.

During January 1987 two metereological stations, supplied by Flinders University, were erected in the area allowing correlation of periods of local rainfall with resulting germination events.

6.2.5 Analysis of Quantitative Data - Associations and Seasonality

The quantitative data collected at the 30 permanent and 118 random sites (Fig. 2.1) for perennial plants (percent cover) were analysed by Mr Ashley Sparrow (Univ. of Adelaide) to reveal patterns of association between the perennial species and to examine the likely environmental parameters which determine such associations. Clustering of sites with similar species composition (and densities) was performed using dissimilarity values between sites to generate a dendrogram (UPGMA) showing the grouping of similar sites. The sites were then plotted on a scattergram (DCA - Detrended Correspondence Analysis) with the distance between sites being proportional to their dissimilarity. This two dimensional representation of the sites reveals the gradational nature of vegetation associations, thus allowing an interpretation of important environmental influences responsible for this gradation to be made.

The seasonality of occurrence and abundance (based on frequency data) of ground layer and sub-shrub species at the 30 permanent sites was examined in two ways. Firstly, the six and five series of observations made at the western and eastern sites respectively were treated independently and subjected to Cluster (UPGMA) and Detrended Correspondence Analyses as described above. Any seasonal shifts in species composition and abundance common to a number of sites would result in clustering of those sites on a temporal rather than geographical basis. These analyses were thus used to investigate patterns of seasonality on the basis of each site's overall floristic composition. The second method allowed the seasonality of individual species at sites to be investigated, using chi-squared tests. The abundance of each species at each site was compared over the five or six sampling events, and significant deviations from the theoretically expected frequency figures (assuming no change in abundance over the sampling period) were interpreted as evidence for seasonality. Graphs for those species which gave significant results at a particular site were plotted to examine the pattern of changing frequency over the year.

6.3 **Findings**

6.3.1 Plant Species Collected

Over the survey period, from November 1986 to September 1987, a total of 1,204 plant specimens were collected and lodged for identification with the State Herbarium of South Australia. The majority of specimens were collected from the Coongie Lakes District. However, in accordance with the study's aims opportunistic collections were made whenever possible within the greater region (see Fig 6.1). During these opportunistic "forays", the objective was not to determine the floristic composition of these areas visited but rather "to highlight the diversity of the flora of the Region" (Project Brief). This meant the collection of plants other than those represented in the Coongie Lakes District. Certainly when viewed *in toto*, the number of species collected (see below) clearly provides an indication of the rich botanical diversity of the region. It is perhaps pertinant also, to view the list in the light of the following statement; "Even if we had the objective of providing a detailed list of species it would not have been possible from just one visit to the desert. A complete species list can only result from repeated collecting visits spread over many seasons (years)." (Graetz *et al*. 1982).

In order to meet the deadline for this report, all plant indentifications received from the State Herborium have been accepted. However certain determinations may need to be re-checked for future verification of the plant list.

The regional collection has representatives from 62 families, 203 genera and includes 458 species. The most prominent of the 62 families in the region were Chenopodiaceae (16 genera, 63 species) Graminae (31 genera, 55 species) and Asteraceae (23 genera and 49 species). Plants collected from the Coongie Lakes District represent 58 families, 179 genera and 326 species. Refer to Table 6.1.

It is informative to compare the above results with those obtained in previous surveys, for example:
"The total number of species recorded on these two trips was 277. To these can be added about 100 species which were recorded in Spechts, "Conservation supplement to the Australian Journal of Botany (1974)", as rare and endangered, but not collected on those trips, to bring the total to around 400. The total number of species ever recorded from the Far North East is not known, but it is unlikely that it would exceed 500" (Jessop 1982).

Later work by Mollenmans et al. (1984) revealed that:

"68 families, 241 genera and 556 species, sub-species and varieties of plant have been recorded in the study area [Cooper Creek Association 8.4.4] since the land was taken up last century (Appendix R). At least 50 of these are possibly misidentified so the true number may be in the order of 500. An additional 125 species are included on the species list for the Far North East (Jessop 1982) that have not been collected in 8.4.4. Hence the total number of species to have occupied the Far North East may be in the order of 625, contradicting Jessop who considered it unlikely that the total number would exceed 500."

The Mollenmans survey collected 49 families, 145 genera and 279 species which "represents over half the total number recorded in the study area since the first collections were reported last century by Professor R. Tate (Tate 1889)."

An additional 111 plants to the 556, species, subspecies and varieties listed by Mollenmans were collected during the survey, and of these 15 were introduced species (Table 6.1a). However, 185 of those species listed by Mollenmans were not detected during the survey. Of these plants, 99 were classified by Mollenmans as being either VR (Very rare, not encountered since 1924) or VR/E (Very rare if not locally extinct, not encountered since last century), highlighting and possibly verifying their accorded status (Tables 6.1b&c).

Although 52 species of the 458 collected this survey were cited by Mollenmans as being VR or VR/E, several species were found to be very common (e.g. *Myriophyllum verrucosum*, *Sesbania cannabina* and *Portulaca oleracea*), indicating a possible lack of prior collection of these relatively common species (although refer to Robert's comments of *M. verrucosum* and its changing status in the arid zone - Chapter 3). Time constraints preclude a detailed comparison of the Mollenmans' findings with those of the present survey. However this would certainly be a valuable exercise in the future in order to substantiate or refute some of the assertions in his important base-line contribution.

The collections of Mollenmans *et al*. (1984) and Jessop (1982) resulted from relatively short field trips to the region. The greater number of species collected during the present survey is an obvious indication of the advantage of an extended collecting period in contributing to the knowledge of the floristic composition of an area. This prolonged time enabled the collection of short lived annuals following sporadic local rainfall events throughout the region during the year.

6.3.2 Rare or Threatened Australian Plants

With reference to "Rare or threatened Australian plants" (Leigh *et al*. 1981), "Extinct and endangered plants of Australia" (Leigh *et al*. 1984) and a forthcoming revision of the above list (J. Briggs pers. comm.), the following rare or threatened plants were collected during this survey;

PLANT SPECIES	STATUS	AREAS
Echinochloa inundata	3KC	1,6
Frankenia cupularis	3K	1,5
Frankenia plicata	3E	3
Goodenia lobata	3K	1,9
Phlegmatospermum eremaeum	3KC	9

KEY TO STATUS

E Endangered and in serious risk of disappearing from the wild

R Rare, not considered endangered or vulnerable.

K Poorly known species, suspected of being rare, endangered or vulnerable.

1 Species known only from type collection

2 Species with very restricted distributions (less than 100 km)

3 Species with range greater than 100km but occuring in only small populations.

C Species known to occur in a conservation reserve.

KEY TO AREAS OF COLLECTION (See Fig 1.1)

1 Coongie Lakes District

3 Marqualpie

5 Embarka District

6 Koonchera Dune

9 Northern Strzelecki Creek

Notes on Species

1) Echinochloa inundata, although found at differing localities in the wider region, was sparse whenever encountered. Apparently a highly palatable grass species it appears to be recovering in the Coongie Lakes-Tirrawarra Swamp district. A major contributing factor to this recovery is thought to be the absence of cattle grazing from the Coongie Paddock for over 5 years.

2) Frankenia cupularis; found in light cracking clay soils on floodplains in the Coongie district - however it was locally sparse when collected.

3) Frankenia plicata; again a rare plant, collected only once during the survey from an interdune area in an un-coordinated red sand dune system in the Marqualpie Paddock in the north east corner of Innamincka Station. (This is a particularly interesting area which yielded several significant species).

4) Goodenia lobata; occurring within low ephemeral forblands in the Coongie Lakes District, was locally sparse when collected.

5) Phlegmatospermum eremaeum was collected only once during the survey, occurring with other low ephemeral herbs on a claypan in the northern Strzelecki Creek area.

Undescribed species, Brachycome sp. novum

One of the most significant and exciting finds during the survey was the collection of a previously undiscovered Brachycome species, to be described by A. Munir (pers. comm.) in a forthcoming edition of "The journal of the Adelaide Botanic Gardens". First collected in January by C. O'Malley at one of the permanent trapsites at Coongie (Site 3W) it was encountered again during September at Embarka Swamp and Coongie. Further research may show this plant to be endemic to the area, and it is believed that the species will take its name from the Coongie locality.

Other significant collections

The following plants collected during the survey are described by Mollenmans et al. (1984) as not having been collected from the area since last century by Professor R. Tate (1889).

	Areas Collected
Calostemma luteum	1
Brachycome linearloba	4
Maireana eriantha	2
Maireana sedifolia	7
Arabidella trisecta	2
Harmsiodoxa brevipes var. brevipes	1,4
Cassia pruinosa	2,3
Abutilon halophilum	2
Abutilon theophrasti	1
Hibiscus trionum var. vesicarius	1

KEY TO AREAS OF COLLECTION

1 Coongie Lakes District
2 Oonabrinta Creek District
3 Marqualipie
4 Moomba District
7 Gibber to the north-west of Coongie

As shown, four of these plants were collected from the Coongie lakes district. Other plants such as Maireana eriantha, Arabidella trisecta, Cassia pruinosa and Abutilon halophilum, were found in the Oonabrinta Creek area, in gibber country north of Innamincka. These finds indicate that this area has been little studied botanically since Tate (1889), and this deficiency needs to be rectified when Innamincka Station becomes a Regional Reserve (i.e. steps should be taken to assess this area). According to Symon (in Jessop and Toelken 1986), Cassia pruniosa is rare in South Australia and limited to the Far North East of the State (LE Region).

Other significant finds included 18 species not previously recorded in the LE Region. Again, these determinations should be checked. However if verified, the collections signficantly extend the known range of these plants in South Australia. It is rather disconcerting that six (33%) of these 18 species are naturalized (exotic) species.

6.3.3 Naturalised Species

A total of 28 (6%) of the 458 species collected are naturalised (or introduced) plants, (see plant list, Table 6.1). Six of these are not recorded in "The Flora of South Australia" as occuring in this region (LE). Of the 279 species collected by Mollenmans *et al.* (1984), 3% are naturalised plants. The apparent doubling in recorded number of naturalized species could be due to a number of factors. The most obvious is the extended period of collection, so that more naturalised species were encountered. Increased visitation to the region in recent years with the concurrent introduction of naturalised species (e.g. propagules carried in clothing or on vehicles) could be another possible contributing factor. However, because many exotic species tend to be found on floodplains, water-borne introductions are indicated. As well, "the practice of not cleaning exploration vehicles and drilling rigs before entering and leaving field localities is considered to be one of the major reasons for the spread of naturalized species in Association 8.4.4. and such lack of foresight encourages weed contamination of formerly weed free areas" (Mollenmans *et al.* 1984).

6.3.4 Vegetation Patterns

The quantitative data collected at the permanent and random sites over the year were analysed to reveal patterns of plant association and seasonality.

Vegetation Associations

The cluster analysis (described above) was performed using 84 perennial and biennial species (listed in Table 6.2), and the dendrogram displayed as Fig. 6.2 was generated. At the 0.85 dissimilarity level, the sites are grouped into four major clusters (here termed "complexes"), designated as the Riverine, Floodplain, Sand Dune Crest and Interdune Complexes, with two sites comprising a fifth "Barren Claypan" Complex (refer to Table 6.3 and Fig. 6.2). At the 0.65 level, there are 28 groups, from which the 28 vegetation associations listed in Table 6.3 were defined. Permanent sites were included in 15 of these groups (and in all four major complexes) and are thus thought to be fairly representative of the range of habitats within the district (a description of the vegetation at the permanent sites is given in App. 6.3).

Several comments are required in relation to these groupings. The Riverine Complex includes sites located well away from the margins of channels and lakes in the district, which are therefore not strictly riparian. Any sites that had a moderate cover of coolibah were placed in Associations 1-3 and areas of coolibah woodland were a feature of many dry lake beds in the district, as well as occurring occasionally near the junction of floodplain and dunefield systems. On the basis of landform analysis, such areas would be classified as floodplain rather than riverine, and so it is interesting that floristically they are linked with the true riparian vegetation associations. The Interdune Complex is again not truly representative of the range of interdune sites within the district, but contains only those sites where the influence of a sandy substrate is exerted, with base-level interdune sites (such as 8E and 13E) being grouped with the Floodplain Complex instead. The exclusion of the interdune lows (including sites which have no hydrological contact with the floodplain i.e. they receive water only as a result of rainfall events and not from floodings of the Cooper e.g. Site 13E) from the dunefield complexes reflects the influence that heavy soils subject to inundation have in determining the floristic composition of plant communities, to the point where these communities are linked with true floodplain sites regardless of whether they are hydrologically linked or not.

Examination of the dendrogram and scattergram (from DCA - Fig. 6.3) reveals the extensive intergradation between the defined vegetation associations, with the major distinction being the separation of dunefield ("sand dune crest", and "interdune" or sandy slopes) associations from floodplain ("riverine", "floodplain", and interdune low) associations, although as can be imagined close field observation of sites along the boundary of these two landform groups similarly reveals a gradation in vegetation types.

The scattergram or ordination figure allows interpretation of environmental influences that are most likely to account for the ordering of the sequence of vegetation associations depicted in Figure 6.3. The most obvious pattern is the placement of dune crest associations at the far right of the diagram and of riverine and other frequently inundated associations at the far left, with the various intergrades between. The corresponding environmental gradient is the frequency of inundation (through rain or flooding) or distance/height from flooding effects, termed water relations on the long (horizontal) axis shown in Figure 6.3. The other environmental gradient shown (vertical) is not as readily interpretable, at least not for the dunefield associations.

Within the dunefield complexes, it is pointed out that associations 17 & 20 (with Zygochloa paradoxa dominant) are most typical of crests of taller dunes in the district, and the adjacent association 22 is most typical of crests of small, white dunes found on the floodplain. To the right of these, lies association 21 (Triodia dominant) characteristic of long, upper slopes or raised interdune saddles in the older, more richly coloured dune systems. To the left lie seven dune slope associations (18, 19, 23-27), with a nuclei of three associations (each with Gunniopsis quadrifida prominent) being indicative of eroding "clay aprons", typical of long slopes where the heavier core of older dunes is exposed at the surface, and association 26 (Sclerolaena diacantha and Eragrostis dielsii) representing the lowest, shallow slopes of dunes bearing a thin layer of white sand

The vertical gradient is possibly a reflection of gradual change in soil type from heavy clay at the bottom to lighter sand at the top, as is indicated by the arrangement of floodplain associations on the left hand side of the scattergram. Certainly the isolated group at the top (with Eragrostis dielsii dominant) consists of sites located on sandier parts of the floodplain, and the presence of Morgania floribunda (e.g. association 12) is usually indicative of sandy alluvium. At the other extreme, Sporobolus mitchellii (15), Halosarcia indica (4), Eragrostis australassica (6) and the riverine associations generally indicate a heavier substrate. However this perceived influence is not pronounced nor consistent, because for instance, the co-dominance of Atriplex velutinella (generally indicative of sandier substrates) in association 5 should have caused this group to be placed further along the axis in the direction of the arrow. Instead the affinity of this species for sand is expressed in the placement of group 5 adjacent to the dunefield complexes, and the more obvious trend along the horizontal gradient is again shown.

The dominating influence of water in determining patterns of association has been stated by Beadle (1981) - "In the semi arid and arid zones, soil nutrients are of relatively minor importance in determining vegetation patterns, water availability being the most important factor controlling the communities."

Both analyses have indicated the subtle complexity of changing vegetation associations, and in the field the observer is struck by the small scale heterogeneity of the district's plant communities - the more regular patterning of associations of the sand dune system grades into a mosaic of associations on floodplains, channels, floodouts and lake shores.

Seasonality

Over the year, the changing seasonal expression of the plant life at Coongie was quite striking with the dominance of the annual component of the forb layer shifting from grasses (and ephemeral chenopods to a lesser degree) following the summer rains to daisies and brassicas in the winter-spring period. Exceptions to these trends within these dominant families were noted of course, with Setaria dielsii and Atriplex holocarpa achieving prominence in winter rather than summer-autumn for instance. Striking examples of seasonal expression in other families were provided by Portulaca, Trianthema and Boerhavia spp over summer-autumn, and by Tetragonia teragonioides, Trigonella suavissima and parakelia Calandrinia spp in winter-spring.

Cluster analysis performed on the total of 165 observations made at the 30 permanent sites over the year (15 X 6 = 90 for the western side and 15 X 5 = 75 for the eastern side sites) did not reflect the strong impression gained of a highly seasonal flora at Coongie. The dendrogram (Fig. 6.4) revealed that in the vast majority of cases, the different observations made at the same site clustered closely together. This result indicates little change in floristic composition at sites over the year, and that the change that did occur was less than the difference in floristic composition between sites. Moreover, the dendrogram shows clearly the separation of sites according to the broad landform categories, correlating the annual or ground layer composition with the respective perennial vegetation complexes and associations described previously. The scattergram (from DCA) also illustrates these same points (Fig. 6.5).

The reason for the lack of seasonality indicated by the cluster analyses and ordination is thought to be the overriding influence of the biennial and perennial components of the ground layer stratum, and further analysis, which excludes the non-annual species, might well reveal stronger patterns of seasonality.

In contrast to the above results, an examination of individual species at each site provided an indication of their seasonal variability in expression. The results of the chi-squared tests are presented in Table 6.4, and the list of the 137 species subjected to this analysis is presented in Table 6.5. As can be seen many species exhibited a significant deviation from an even (non-seasonal) frequency of occurrence through the year, and in the majority of cases this deviation was seasonally expressed.

Photopoints

In order to provide a qualitative indication of seasonal change, photographs were taken at the permanent sites each time the sites were assessed. The visual impression created by the photographs contrasts with the more analytical approach described above. Three photographs taken in November 1986, March and September 1987 at Sites 5W and 13W are presented (Plates 9 -16). Site 5W (Emu Flat), a low open Sporobolus mitchellii grassland, is a floodout of Lake Toontoowaranie near the inlet of Browne Creek. The effect of rainfall and inundation can be seen in the sequence of photographs, and Figure 6.6 shows the rainfall data over the survey period as well as the seasonal expression of the dominant annual plants at both sites. During November the site was composed almost entirely of dormant grass tussocks. However, following good rains in December, January and February, the flush of new, green growth is readily apparent. When viewed in September, flooding of the area transformed the site into an ephemeral forbland, composed predominantly of Senecio lautus (yellow flower) but with Cooper clover Trigonella suavissima prominent as well.

Site 13W, on the other hand, reflects the vegetative response to local rainfall only. This low ephemeral forbland is part of the ephemeral bed of Lake Apachirie, which receives water from the Cooper only in bigger floods. The March photograph shows the flush of *Panicum decompositum*, *Atriplex muelleri* and *A. crassipes* following the summer rains. In September, the demise of the *Atriplex* spp is revealed as is the surge of *Senecio lautus*.

Spatial variability in the local and regional pattern of rainfall events (see Fig. 6.6) was responsible for the mosaic of areas of pronounced ephemeral growth, and both spatial and temporal patterns were generated. For example, it was noted that the flush of ephemeral growth occurring in the area between Innamincka and Moomba following rains in February and June preceded the local response in the Coongie Lakes District by several weeks.

6.4 Significance

One view of the significance of the Coongie Lakes District is attributable to its enigmatic existence as an "island" of comparative vegetative luxuriance within a rippling sea of sand dunes. Certainly the richness of the flora has been shown in earlier sections, while the entire Cooper system within the region is similarly a humid and productive strand placed incongruously in a desert setting. Graetz *et al*. state "Above all the functioning of arid ecosystems is determined by the input and redistribution of water and that particularly within an arid environment, habitat and hence species diversity is determined by the heterogeneity of the landscape."

The wetland system with its associated flooding events provides an alternative source of water in an area in which the vegetation would otherwise be dependent solely on the distribution of the local meagre rainfall (the biological response to flooding is clearly indicated in the photographs of Site 5W - Plates 9-11).

The juxtaposition of wetland and desert can be expressed at a very small scale, and within a walk of only meters, the observer can encounter the channel edge aquatics, shade-only plants as well as the drought tolerant species of the dunes.

The mosaic of channels, floodplains, floodouts, swamps and terminal lakes has generated a complex array of vegetation associations, in turn providing myriad habitat types contributing to the diversity and therefore significance of the ecosystem. Mollenmans et al. (1984) concluded "The Cooper Creek Environmental Association 8.4.4 is one of the most heterogeneous environmental associations in the Lake Eyre Environmental Region 8.4." The ensuing diversity of plant species is a measure of the significance of this heterogeneity. Of most significance is the thin riparian strand of vegetation (in all its varied associations) and it is considered to be highly sensitive, requiring special protection and management.

As well as the rare and/or threatened plants identified in earlier sections, a number of plant associations which occur in the Coongie lakes District are considered by Davies (1982) to be inadequately conserved in South Australia, and in some cases, Australia.

1) *Atriplex nummularia* low shrubland
2) *Chenopodium auricomum* low shrubland
3) *Eragrostis australasica* tussock grassland
4) *Erodium*, *Helichrysum*, *Brachycome*, *Calocephalus*, *Calotis* spp ephemeral communities
5) *Atriplex spongiosa* +/- *A. holocarpa*, *Sclerolaena* spp ephemeral communities
6) Ephemeral grass and herb communities of floodplains of Diamantina and Warburton Rivers and ephemeral lake basins
7) *Eucalyptus microtheca* woodland
8) *Atriplex angulata* - *A. velutinella* - *A. leptocarpa* - *Sclerolaena intricata* - *S. limbata*, *Frankenia serpyllifolia* low shrubland.

These associations are all expressed (at least seasonally) in varying abundance in the Tirrawarra Swamp to Lake Goyder district. Some occur as discrete patches in contrast to the more extensive distribution of E. microtheca woodland.

At the regional level, there are at lest two other associations on Innamincka Station considered to be inadequately conserved (Davies 1982). They are the Astrebla pectinata open tussock grassland on the stony country north of Innamincka HS, and the Eucalyptus terminalis association on the sandplains in the extreme north-east corner of Innamincka Station.

6.5 Impacts

"A century of white settlement has left visible scars on the environment at many levels" (Tolcher 1986).

Today the results of past and present human related impacts are reflected in the state of the region's vegetation. There is no doubt that the "Vegetation has changed significantly since the land was first settled" (Mollenmans et al. 1984).

"Hard hooved beasts have broken up the soil surface and accelerated erosion, and grazed some varieties of herbage almost to extinction while rabbits have contributed to a marked decline in small shrubs and have permanently destroyed much of the ephemeral plant population and many perennials" (Tolcher 1986).

Human impact on vegetation in the area can be attributed largely to the following factors, acting independently and at times in concert with each other.

1) Rabbits
2) Pastoralism
3) Mineral exploration and mining
4) Tourism/Recreation

6.5.1 Rabbits

"Rabbits were very numerous on the Cooper by 1891; they were thick at the Misson Station at Kopperamana and in Innamincka, and had been seen as far north as Cowarie, 80 kilometres south of Birdsville" (Tolcher 1986).

During this survey the effects of rabbits were observed at virtually all the permanent sites periodically assessed. This was particular so at those sites located on dune systems in which burrows or warrens are easily established. The effects ranged from the obvious soil/sand disturbance caused by surface scratchings and extensive warren systems to the grazing or denudation of perennials, annuals and emerging ephemeral seedlings after local rains. Browse lines could be observed in Acacia ligutata, and even the less palatable species such as Sclerolaena intricata on the floodplains and Cynanchun floribundum in the dunes were in some instances subject to grazing pressure. There is no doubt that the vegetation composition on some of the dunes observed had been altered by selective grazing of rabbits to a structure of less palatable species such as Nicotiana velutina, Crotalaria cunninghamii and Salsola kali. The most obvious conclusions based on the observations of this survey and others is that, "Rabbits pose the greatest present day threat to the floodplain and dunefield vegetation (LAB 1986).

The implications of present rabbit pressure in the area are several. The continued level of grazing could lead to the loss of recruitment of various perennial trees and shrubs that presently contribute to soil stability by reducing wind velocity at the ground surface thereby decreasing the effects of wind erosion. The loss of more palatable species will continue to change the floristic composition of most vegetation associations and may threaten the existence of particular species.

The grazing of emerging seedlings prevents many annuals and ephemerals from completing their life cycles and setting seed, leading to a decrease in numbers of individuals and species. The consequence of this may be reflected in a poor response by this flora after local rains. The overall effect is denudation with the exposure of dunes and floodplains to the vectors of wind and water erosion.

Over the year, rabbit activity was observed to be most pronounced along the dunes adjacent to or on (semi) permanent water bodies i.e. the main channels and lakes. These dunes were thus particularly degraded, while it was also noticeable, that the rabbits in these areas preferentially grazed the adjacent floodplain - each evening upon leaving their burrows, most would rapidly descend the dune slopes. In particular, the lake shore was a preferred grazing habitat, and rabbit excreta deposited in thick rings around the lake margin was a notable feature of the lake shores.

Grazing pressure appeared to decrease in the dunefields with distance from the main water bodies, while floodplain features more than several hundred metres from a sandy substrate were also less heavily grazed (e.g. limited grazing activity on Lake Apachirie).

6.5.2 Pastoralism

"The Cooper Creek floodplain has had a long history of domestic stock grazing since the Innamincka lease was taken up in 1864. Periods of heavy stocking combined with droughts, when cattle herds of up to 15,000 head perished, have been noted, along with widely fluctuating rabbit populations. The combined impact of these herbivores, and also large numbers of horses, has undoubtedly resulted in significant floristic changes since European settlement, such that it is likely that no areas remain unaffected" (LAB 1986).

The evidence from the past indicates that the Coongie Lakes area has suffered severely from the effects of cattle and feral horses. For example consider the following statements:

"During the period 1957 to 1959, 6,000 horses were shot in Innamincka station........Most of these animals were taken from the Coongie Lakes and the stony hills structure of the station" (LAB 1986).

"When the river frontage and Coongie Lakes are eaten out the cattle are put onto the bores south and north of the River, on the outside country of the run" (Vickery in Litchfield 1983).

"Cattle numbers in the Innamincka area have been largely confined to the floodplain of the Cooper where permanent water supplies are available, consequently grazing and trampling together with rabbit impact have severely restricted the vegetation cover fringing the channels" (LAB 1986).

Currently the Coongie Paddock, has been destocked for over five years, as part of the Brucellosis/tuberculosis eradication programme. As mentioned previously (see findings) the recovery of Echinochloa inundata especially in the Tirrawarra Swamp system, is an indication of the relaxed stocking pressure.

The effect of restocking the Coongie paddock would only compound the present rabbit problem and be expressed in the following ways.

"The linear nature of the watercourse results in heavy grazing pressure paralleling the creek banks. The passage of stock to and fro results in the trampling of vegetation surrounding the waterholes; soil disturbance of the steep banks, along with browsing of shrubs and trees and a loss of vegetation cover. A decline in condition is evidenced by a reduction in perennial shrubs (possible old man saltbush) and an increase in the proportion of unpalatable species in the understorey e.g. lignum ".... "A poor vegetation response following rainfall may indicate a decline of resilience especially in the ephemeral species, with perennials exhibiting signs of stress" (LAB 1986).

6.5.3 Mineral exploration and Mining

Within the Coongie Lakes District the most obvious effect of this activity is the network of seismic tracks cutting across dunefield and floodplain. The obvious primary impact that these tracks impose is the localised denudation of vegetation in their path. These affect a relatively small area of land and in the majority of cases vegetation regeneration is evident.

However it is the secondary impact associated with these seismic lines that is of more concern. Regeneration is only possible if these tracks remain unused. Today they form a network of access routes for vehicles in the area preventing recovery of the vegetation.

The continued use of seismic lines by vehicles increases erosion which is especially obvious where tracks cross dune crests around Coongie. An additional concern is that these tracks could become the foci for the inadvertant introduction of exotic plants into the area.

"Buckley (1982a) considers the" introduction and spread of weeds "......to be one of the secondary disturbances associated with "the extensive track cutting required for geophysical survey and drilling programmes" (Mollenmans *et al*. 1984).

Often during the construction of clayed surface roads, large borrow pits are created, to supply clay to cap the sandy roads. These pits later fill with runoff from local rainfall which leads to the possibility that...." the provision of these water supplies would prolong the duration of high rabbit populations and of their very damaging overgrazing" (Pech and Graetz 1982).

Of additional concern is the possibility of any activity leading to an alteration in the flow characteristics of the North-West Branch of the Cooper or in the Tirrawarra Swamp system. The vegetation associations occuring in these land units such as the woodland fringes could suffer as a result. An impact of unknown risk but with catastrophic potential for damage to the vegetating fringing swamp, channel and lake is hydrocarbon contamination of the North-West Branch. This possibility is highlighted by a present proposal to build a pipeline across the North-West Branch from the Bookabourdie field to the Tirrawarra Satellite Station, which will be the first development of this nature along the length of the North-West Branch.

6.5.4 Tourism and Recreation

The impact of increased visitation to the Coongie Lakes District is being expressed in several forms. The most obvious effect is the loss of ground layer species and leaf litter in the immediate vicinity of Coongie Lake and the river channel. Increased camping pressure combined with the effects of off-road vehicles have led to the creation of large scalded areas free of vegetation and leaf litter.

"Any impact which reduces the naturally occurring erosion resistant cover of arid soils, for example, mechanical disturbance, fire or grazing, will promote accelerated erosion of that landscape and erosion is a self reinforcing process - erosion causes a loss or redistribution of water and nutrients which results in reduced plant production and cover - which further predisposes that surface to further erosion and so the cycle is perpetuated. If it is not broken the ultimate ecosystem end point is a bare eroded landscape" (Graetz and Pech 1982).

The above effects will only be compounded if equivalent pressures are maintained especially in the situation of a future poor season being followed immediately by another or several poor seasons.

"Arid ecosystems are labelled 'unstable' or fragile because they can show great variability and turnover in biomass and populations over short periods of time or remain inert for far greater periods of time. Irregularity rather than equilibrium is characteristic" (Graetz and Pech 1982).

One need only visit the Innamincka town environs to observe the effects of longer term visitation and camping pressure along the Cooper's banks to extrapolate such a situation to Coongie in the future. It is precisely the uniqueness of a luxuriant fringe of channel and lake woodland, incongruously imposed on an otherwise arid dunefield ecosystem, that draws visitors to this area. However the compaction of soils of these areas and the removal of plant litter could threaten the vegetation both aesthetically and environmentally. For example: "The fragile topsoil provides conditions favourable for seedling establishment, e.g. ease of root penetration, and in undisturbed soils the overlying plant litter provides a useful protective layer that:

- protects soil from direct raindrop impact
- reduces surface run-off
- provides habitat for micro fauna and burrowing fauna
- returns nutrients and organic matter to soil.

The removal of the overlying plant litter occurs as a result of various land uses, e.g. grazing (including feral animals) mining and recreation and also through the natural agents of fire and heavy rainfall" (LAB 1986).

The riparian woodland is considered to be biologically important by fulfilling a vital role in nutrient recycling within the aquatic ecosystems of the district. The litter dropped directly or subsequently washed into the water after rain provides carbon, energy and nutrients (refer to Roberts, Chapter 4, and Briggs and Maher 1983).

The impact of fire on the disctict's vegetation both directly and indirectly is of major concern. During the survey period, one camping group's fire was observed to get out of control and burn the fringing channel vegetation. Fortunately it was noticed and contained, but not before burning an area of about $30m^2$. Recreational use of fire has depleted sources of firewood in the Coongie Lakes District with some groups now travelling further afield to collect, leading to a proliferation of tracks, compounding the existing destruction of vegetation by off-road vehicles. The situation has progressed to the stage where standing dead wood and even live timber is being cut, resulting in the loss of animal habitat and possibly affecting the recycling of nutrients.

Impact of another form, although not directly damaging the vegetation but aesthetically degrading the area has been the localised (as yet) appearance of graffiti carved upon several river red gums along the Cooper. Finally, the passage of boats to and from the channel or lake margin has resulted in the denudation of vegetation in these immediate areas and may need to be addressed before other areas are affected.

6.6 Recommendations

Rabbits

The impact imposed by rabbits is undoubtedly, at present, the most serious threat to the vegetation of the Coongie Lakes District. The importance of continued support of current research to find a vector of the myxoma virus effective in the arid zone of Australia is emphasized. Certainly virus affected rabbits were observed in the district, particularly in the summer months after periods of local rainfall and consequent mosquito activity.

The sheer numbers of the rabbits and their presence throughout the district prohibit any effective economic control in the short term. The establishment of appropriately planned rabbit-proof exclosures located in various vegetation associations would provide a positive contribution to the future monitoring and assessment of the rabbit's impact, and this action is strongly recommended.

Pastoralism

It is recommended that the evident but partial recovery of the Coongie Paddock not be jeopardized by the reintroduction of cattle. Their continued exclusion would also contribute to a better understanding of the effects of cattle grazing in such an ecosystem, and these sentiments were expressed in Foale (1982).

According to LAB (1986), Goonaburoo Paddock, immediately adjoining Coongie Paddock and in the same Cooper Creek land system, was deemed to be in poor condition. This paddock is currently stocked and contrasts with the "fair to good" condition accorded to the destocked Coongie Paddock.

At the time of the study only a few cattle and several groups of horses were observed in the Coongie Paddock. It is recommended that these animals be removed or eradicated now and in any future instance.

Mining

Due to the problem of uncontrolled access and its accompanying vegetative damage, present seismic tracks in the district should be closed to the public to prevent further degradation and to allow rehabilitation.

A fairly large area around the Coongie Lakes system should be free of all exploratory and extraction activities to protect this highly significant section of the Cooper and its floodplain. This exclusion area should extend south to the Tirrawarra Swamp complex. In terms of the total area of the Cooper Basin, this district's area is insignificant, and exclusion of mining activities would allow future visitors to realize their expectations of an aesthetically unspoilt environment.

Tourism

Recommendations include:

- controlled access to a limited number of established camping areas;

- rehabilitation (including closure) of currently degraded camping sites;

- prohibition of fires within the district;

- prohibition of the use of chainsaws within the district;

- regular monitoring of camp-sites and visitor activities to assess impact on vegetation (e.g. establishment of photopoints);

- regular revision of the visitor carrying capacity of the district in light of monitoring of visitor impact, and the reduction of visitor numbers as required;

- the production of interpretive material for the district's visitors, including a guide to the local flora.

Research

In addition to the establishment of rabbit exclosures recommended above, it is recommended that the monitoring of the permanent sites established over the year in the Coongie district be continued for a minimum of three years to enable the documentation of the longer term variability of the district's vegetative responses to differing environmental conditions.

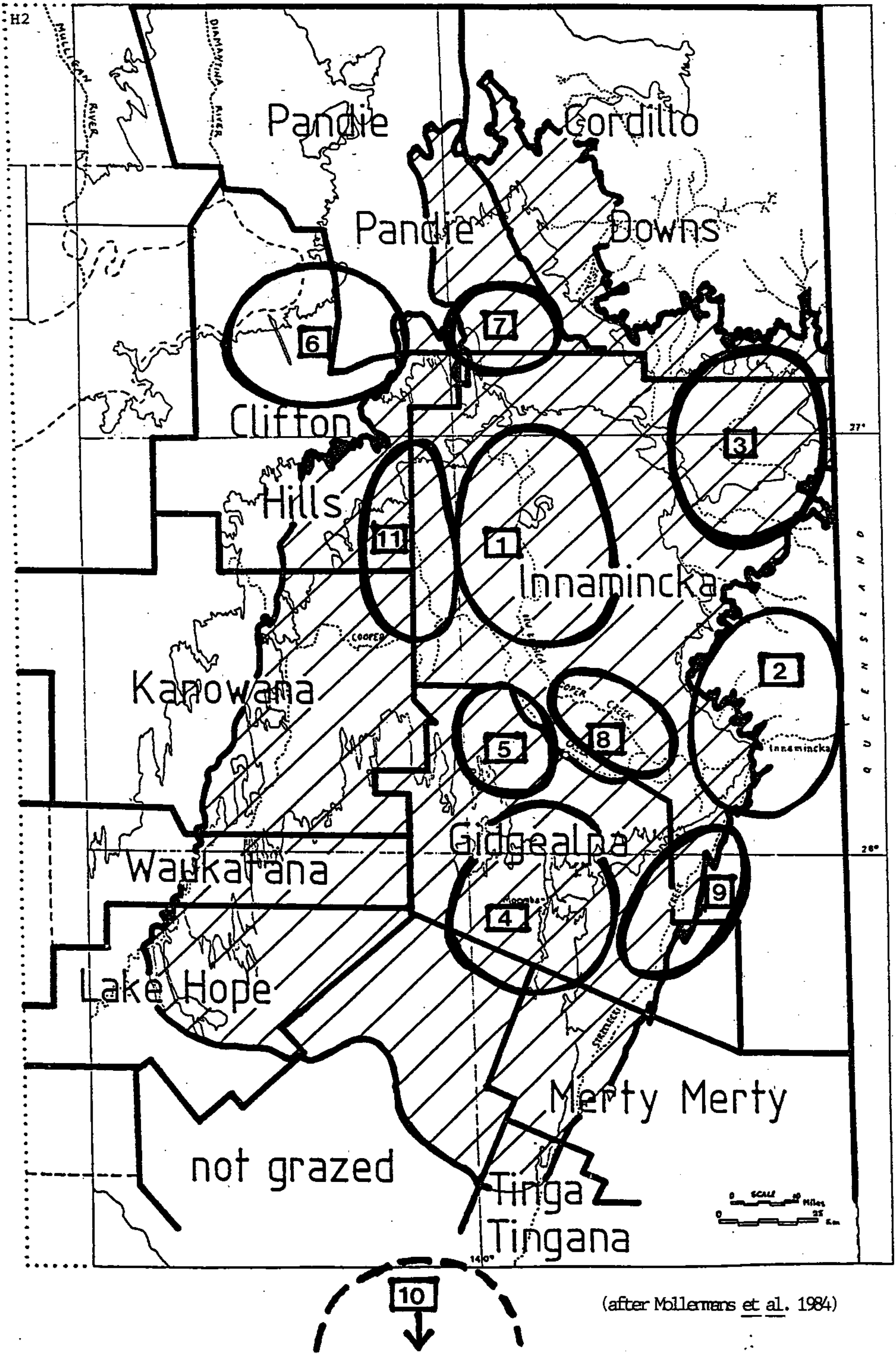
In terms of the regional reserve proposal for Innamincka Station a more detailed examination of the regional flora is required to enable the more thorough documentation of species present on the station, and to define more clearly the biologically significant areas in the wider region, so that appropriate action can be taken to protect or manage such areas.

KEY TO SYMBOLS (SEE ACCOMPANYING MAP)

1 COONGIE LAKES DISTRICT
2 INNAMINCKA DISTRICT
3 MARQUALPIE DISTRICT
4 MOOMBA DISTRICT
5 EMBARKA DISTRICT
6 KOONCHERA DISTRICT
7 SOUTHERN PANDIE PANDIE DISTRICT
8 SCRUBBY CAMP DISTRICT
9 NORTHERN STRZELECKI CREEK DISTRICT
10 COBBLERS DESERT DISTRICT
11 CHRISTMAS CREEK DISTRICT

Figure 6.1 (facing page)

Cooper Creek region showing districts where majority of botanical collections were made (and pastoral leases).



(after Mollemans et al. 1984)

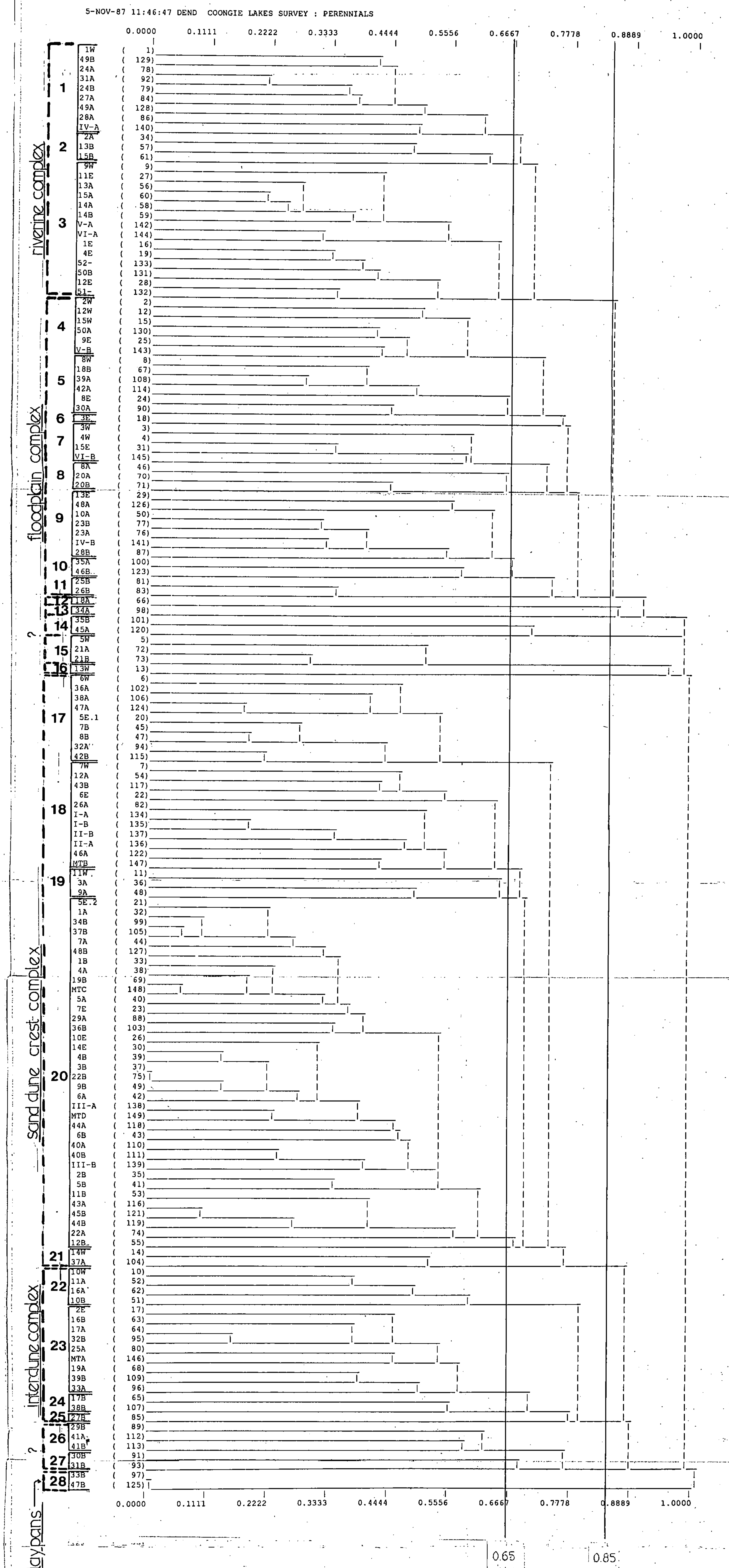


Figure 6.2

Dendrogam showing clustering of the 30 permanent and 118 random sites in the Coongie Lakes District. Perennial species only used for analysis (UPGMA).

COONGIE PERENNIALS FULL DENDROGRAM

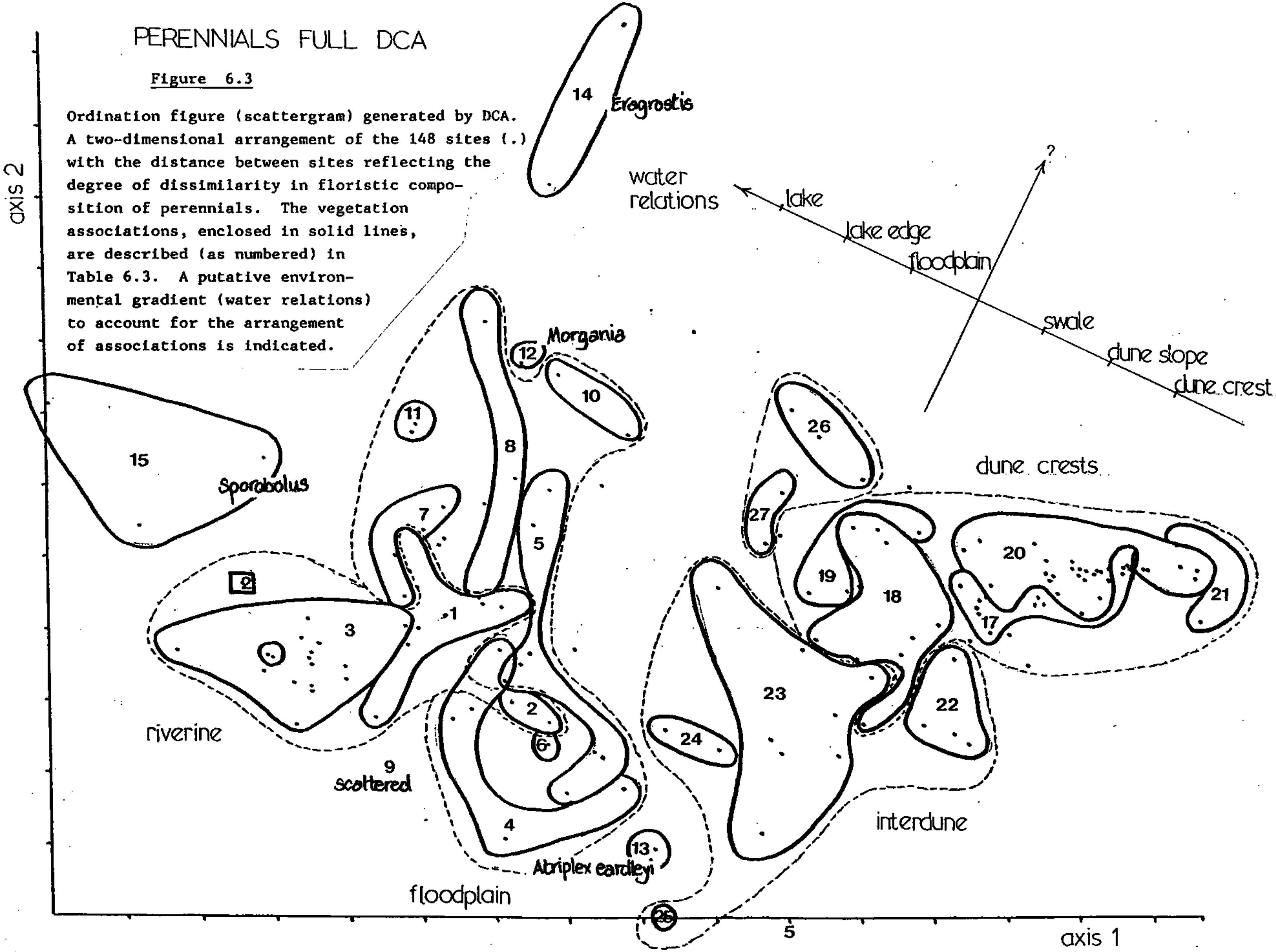


Figure 6.3

Ordination figure (scattergram) generated by DCA. A two-dimensional arrangement of the 148 sites (.) with the distance between sites reflecting the degree of dissimilarity in floristic composition of perennials. The vegetation associations, enclosed in solid lines, are described (as numbered) in Table 6.3. A putative environmental gradient (water relations) to account for the arrangement of associations is indicated.

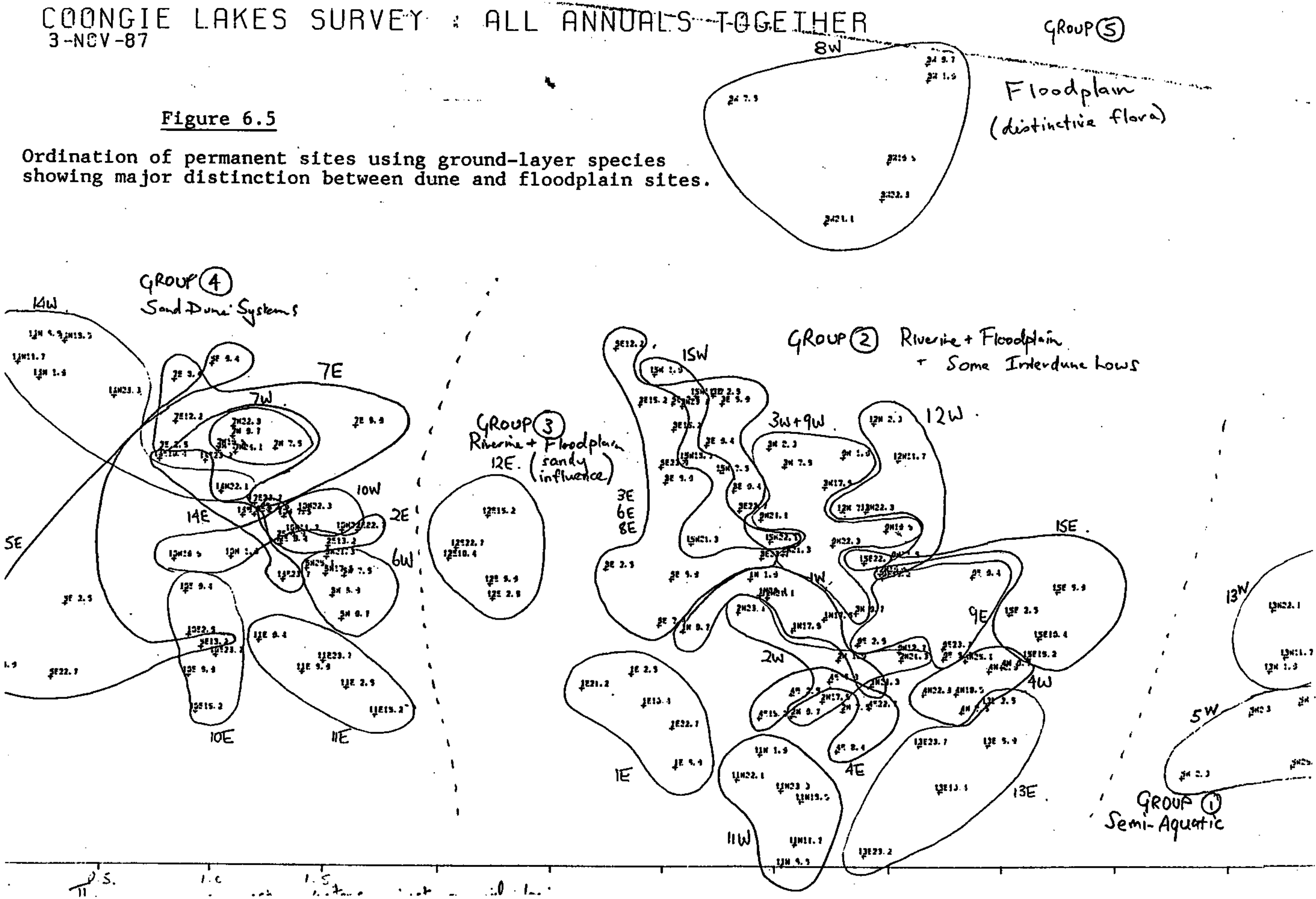


Figure 6.5

Ordination of permanent sites using ground-layer species showing major distinction between dune and floodplain sites.

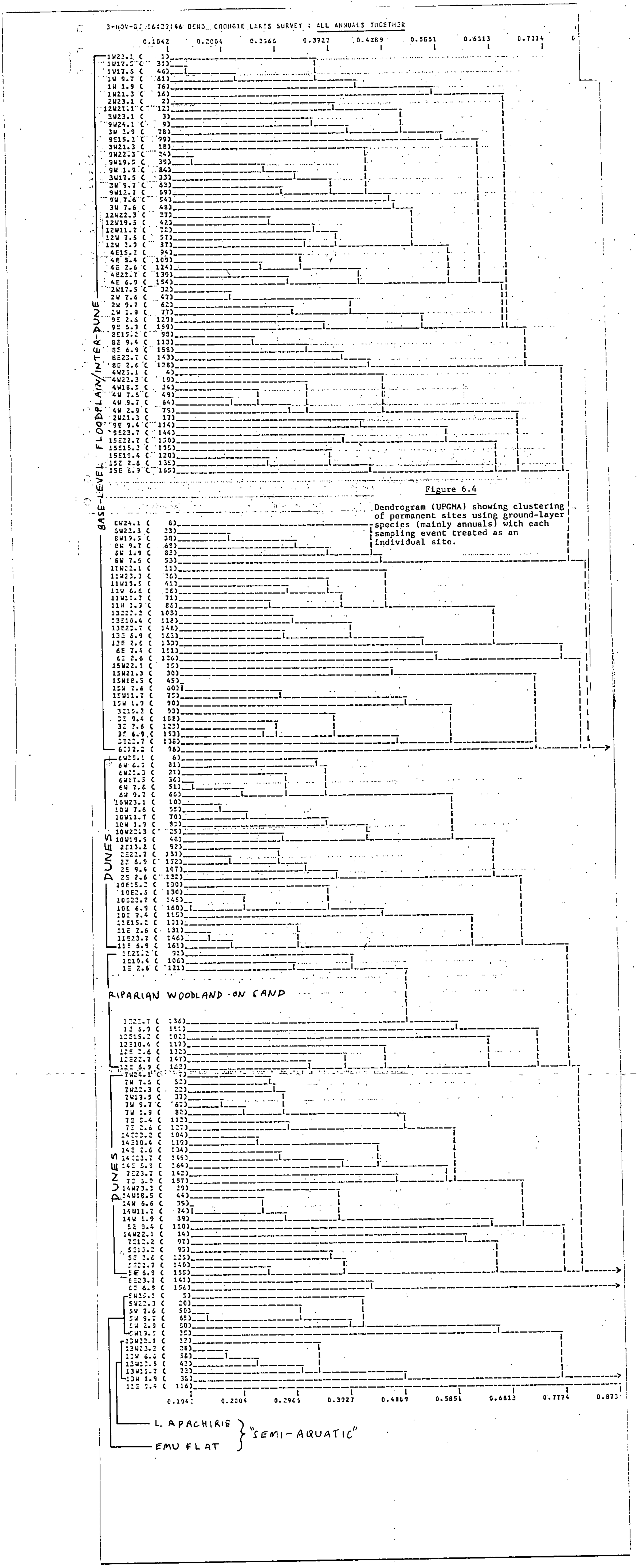


Figure 6.4

Dendrogram (UPGMA) showing clustering of permanent sites using ground-layer species (mainly annuals) with each sampling event treated as an individual site.

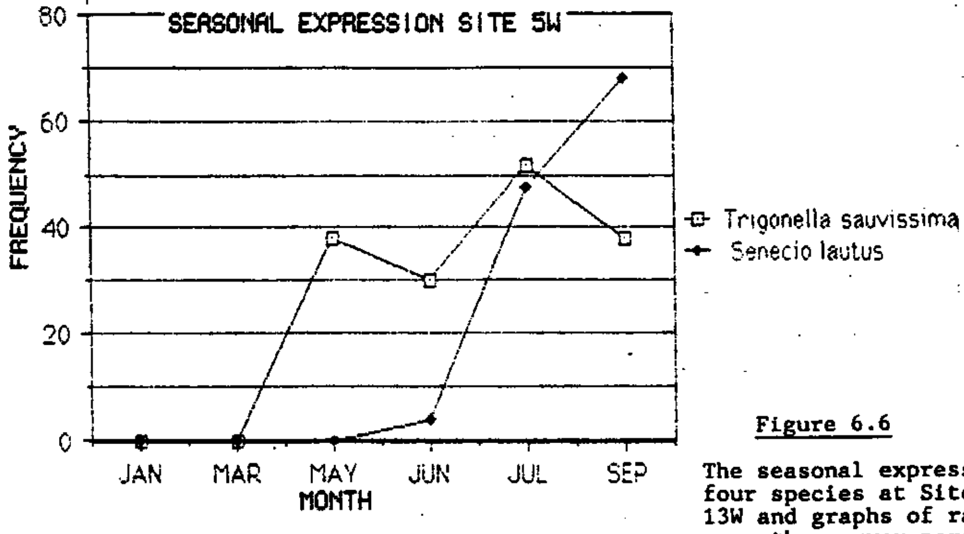
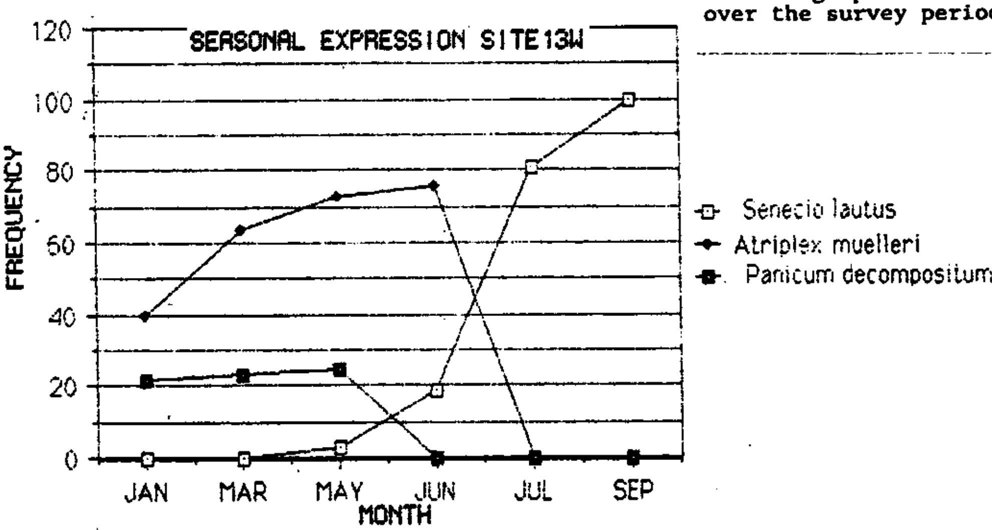
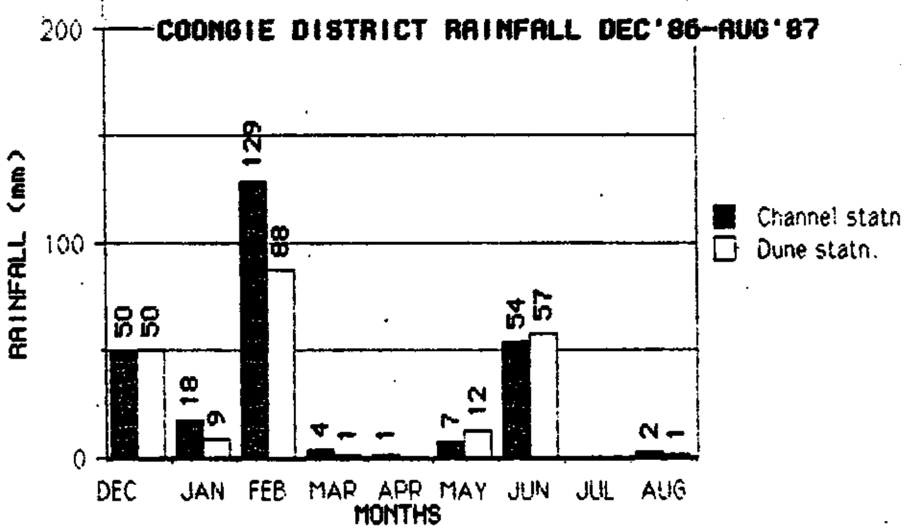


Figure 6.6

The seasonal expression of four species at Sites 5W & 13W and graphs of rainfall over the survey period.





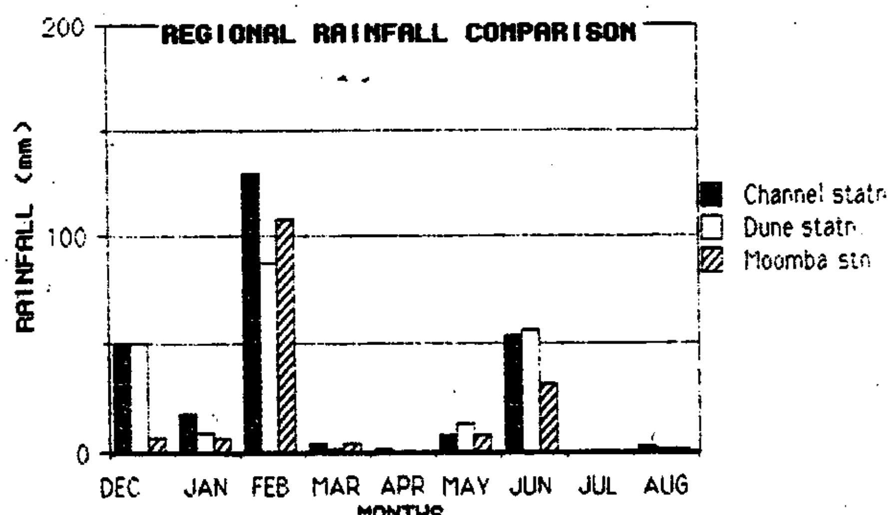


Table 6.1a

List of plants collected over the survey period, showing localities where collected, and indicating introduced species and species not recorded in the LE Region previously.

KEY TO SYMBOLS (SEE ACCOMPANYING MAP - FIG. 6.1)

1 COONGIE LAKES DISTRICT
2 INNAMINCKA DISTRICT
3 MARQUALPIE DISTRICT
4 MOOMBA DISTRICT
5 EMBARKA DISTRICT
6 KOONCHERA DISTRICT
7 SOUTHERN PANDIE PANDIE DISTRICT
8 SCRUBBY CAMP DISTRICT
9 NORTHERN STRZELECKI CREEK DISTRICT
10 COBBLERS DESERT DISTRICT
11 CHRISTMAS CREEK DISTRICT

* INTRODUCED/ NATURALISED SPECIES

□ NOT LISTED IN THE FLORA OF S.A. AS OCCURRING IN THE LE REGION.

COMBINED PLANT LIST FOR COONGIE LAKES AND		
WIDER REGION	AREA(S)	STATUS
	COLLECTED	VR OR VR/E
ACANTHACEAE		
Dipteracanthus australasicus ssp glabratus R.M.Barker		
Rostellularia adscendens (R.Br) R.M.Barker ssp adscendens var	2;	
pogonanthera (F.Muell) R.M.Barker		
AIZOACEAE	2;	
Glinus lotoides L.		
Glinus oppositifolia L.	1;	
Gunniopsus quadrifida F.Muell.	3;	
Gunniopsus septifriga F.Muell.	1;	
Mollugo cerviana L.	1;	
Trianthema pilosa F.Muell.	1;	
Trianthema triquetra Willd.	1;	VR
Zaleya galericulata (Melville) H.Eichler	1;	
AMARANTHACEAE	1;	
Alternanthera angustifolia R.Br.		
Alternanthera denticulata R.Br.	1;	
Alternanthera nodiflora R.Br.	1;	
Amaranthus grandiflorus J.Black	1;	
Amaranthus mitchellii S.Watson	10;	
Ptilotus atriplicifolius (Cunn ex Moq) Benl var atriplicifolius	1;	
Ptilotus latifolius R.Br.	1;	
Ptilotus macrocephalus (R.Br.) Poiret	1;	
Ptilotus nobilis (Lindley) F.Muell var nobilis	2;	
Ptilotus obovatus (Gaudich) F.Muell var obovatus	2;	
Ptilotus polystachus (Gaudich) F.Muell var polystachus	2;	
Ptilotus polystachus (Gaudich) F.Muell forma rubriflorus	1;	
(J.Black) Benl.		
AMARYLLIDACEAE		
Calostemma luteum Sims.		
Crinum flaccidum Herbert	1;	VR/E
ASCLEPEDIACEAE	1;	
Cynanchum floribundum R.Br.		
Sarcostemma australe R.Br.	1;	
ASTERACEAE	2;	
Angianthus tomentosus Wendl.		
Brachycome basaltica F.Muell var gracilis Benth.	7;	
Brachycome campylocarpa J.Black	□;1	
Brachycome ciliaris (Labill) Less var languginosa (Steetz) Benth.	1;	
Brachycome linearloba (D.C.) Druce	1;	
Brachycome sp. novum	4;	VR/E
Calocephalus knappii (F.Muell.) Ewart & J.White	1;5	
Calocephalus platycephalus F.Muell	1;	
Calotis ancyrocarpa J.Black	1;3	
Calotis erinacea Steetz.	1;4	
Calotis hispidula (F.Muell) F.Muell	2;3	
Calotis latiuscula F.Muell & Tate	1;9	
Calotis multicaulis (Turcz) Druce	1;	
Calotis plumulifera F.Muell	1;4	
Calotis porphyroglossa F.Muell ex Benth.	1;4	

Centipeda cunninghamii (D.C.)A.Br. & Aschers	1;9	
Centipeda minima (L)A.Braun & Asch	1;	
Centipeda thespidiodes F.Muell	1;	
Craspedia chrysantha(Schldl)Benth	1;	
Dichromochlamys dentatifolia (F.Muell)Dunlop	1;	
Epaltes australis Less.	5;	
Epaltes cunninghamii (Hook)Benth.	1;	
Gnaphalium polycaulon Pers.	1;	
Gnephosis arachnoidea Turcz.	*;1	
Gnephosis eriocarpa (F.Muell)Benth.	3;7	
Helichrysum podolepidium F.Muell	2;3;10	
Helichrysum semifertile F.Muell	2;7	
Helipterum floribundum D.C.	4;	VR
Helipterum microglossum (F.Muell ex Benth)Maiden & Betche	1;2	
Helipterum moschatum (Cunn ex D.C.)Benth.	2;	
Helipterum pterochaetum (F.Muell)Benth.	1;	
Helipterum strictum (Lindley)Benth.	2;	
Ixiolaena brevicompta F.Muell	1;9	
ixiolaena chloroleuca Haegi.	1;2	
Ixiolaena leptolepis (D.C.)Benth.	1;2	
Minuria cunninghamii (D.C.)Benth	1;2	VR
Minuria denticulata (D.C.)Benth.	7;	
Minuria integerrima (D.C.)Benth.	1;	
Minuria leptophylla D.C.	1;	
Minuria rigida J.Black	2;7	
Myriocephalus rudallii (F.Muell)Benth.	1;	
Myriocephalus stuartii (F.Muell &Sonder ex Sonder)Benth.	1;	
Pentzia suffructicosa (L)Hutch ex Merxm.	1;	
Pluchea tetranthera F.Muell	*;□;9	
Psuedognaphalium luteoalbum (L)Hilliard & B.L.Burtt.	1;4	
Pterocaulon sphacelatum (Labill)Benth	1;	
& Hook ex F.Muell		
Rutidosis helichrysoides D.C.	1;	
Senecio cunninghamii D.C. var serratus M.laur.	1;2;7	
Senecio gregorii F.Muell	1;	
Senecio lautus Forster.f. ex Willd.	1;4;9;10	
Sonchus asper (L)Hill ssp glaucescens (Jordan)Ball	1;	
Sonchus oleraceus L.	*;1	
Streptoglossa adscendens (Benth)Dunlop	*;1	
AZOLLACEAE	1;3	
Azolla filiculoides Lam.		
BORAGINACEAE	1;	
Halganea cyanea Lindley		
Heliotropium curassavicum L.	3;	
Heliotropium supinum L.	*;1	
Heliotropium tenuifolium R.Br.	*;1	
Omphalolappula concava (F.Muell)Brand	2;	
Plagiobothrys plurisepaleus (F.Muell)I.M.Johnston	4;	
Trichodesma zeylanicum (Burman f.)R.Br.	1;	
CALLITRICHACEAE	1;	
Callitriche sonderi Hegelm.		
CAMPANULACEAE	1;	
Isotoma petraea F.Muell		

Wahlenbergia aridicola P.J.Smith	2;	VR
Wahlenbergia communis Carolin.	1;	
Wahlenbergia gracilenta Loth.	1;	
Wahlenbergia tumidifructa P.J.Smith	4;	
CAPPARACEAE	1;	
Capparis mitchellii Lindley		
Cleome viscosa L.	2;	
CARYOPHYLLACEAE	2;	
Polycarpa arida Pedley		
Spergularia diandra (Guss.) Boiss	2;	
CENTROLEPIDIACEAE	*;1	
Centrolepis eremica D.Cooke		
CHENOPODIACEAE	1;	
Atriplex angulata Benth.		
Atriplex crassipes J.Black	1;	
Atriplex eardleyae Aellen	1;	
Atriplex fissivalvis F.Muell.	1;	
Atriplex holocarpa F.Muell.	2;	
Atriplex leptocarpa F.Muell	1;9	
Atriplex limbata Benth.	1;	
Atriplex lindleyi Moq. ssp conduplicata (F.Muell) Paul G.Wilson	1;	
Atriplex lindleyi Moq. ssp inflata (F.Muell) Paul G. Wilson	2;	
Atriplex lobativalvis F.Muell.	1;	
Atriplex muelleri Benth.	1;	
Atriplex nummalaria Lindley	1;	
Atriplex pseudocampanulata Aellen	1;	
Atriplex aff. pumilio R.Br.	1;	
Atriplex quinii F.Muell.	5;	
Atriplex spongiosa F.Muell.	2;	
Atriplex velutinella F.Muell.	1;	
Atriplex vesicaria Heward ex Benth.	1;	
Chenopodium auricomum Lindley	2;7	
Chenopodium cristatum (F.Muell) F.Muell.	1;	
Chenopodium nitrariaceum (F.Muell) F.Muell ex Benth.	1;	
Chenopodium pumilio R.Br.	1;	
Dissocarpus biflorus F.Muell. var biflorus	1;	
Dissocarpus paradoxus (R.Br.) F.Muell. ex Ulbr.	2;4;7	
Dysphania platycarpa Paul G. Wilson	3;	
Einadia nutans (R.Br.) A.J.Scott ssp eremaea Paul G. Wilson	1;2	
Enchylaena tomentosa (R.Br.) var tomentosa	1;	
Halosarcia indica (Willd.) Paul G. Wilson ssp leiostachya (Benth.)	1;	
Paul G. Wilson		
Maireana aphylla (R.Br.) Paul G. Wilson	1;	
Maireana appressa Paul G.Wilson	7;	
Maireana astrotricha (L.Johnson) Paul G. Wilson	7;	
Maireana ciliata (F.Muell) Paul G. Wilson	7;	
Maireana coronanta (J.Black) Paul G. Wilson	2;4	VR/E
Maireana erianthа (F.Muell.) Paul G. Wilson	1;	
Maireana georgei (Diels.) Paul G. Wilson	2;	VR/E
Maireana integra (Paul G. Wilson) Paul G. Wilson	2;7	
Maireana microcarpa (Benth.) Paul G. Wilson)	2;	
Maireana pyramidata (Benth.) Paul G. Wilson	1;	
Maireana radiata (Paul G. Wilson) Paul G. Wilson	7;	

Maireana sedifolia (F.Muell) Paul G.Wilson	0;3	
Maireana spongiocarpa (F.Muell) Paul G. Wilson	0;7	VR/E
Malacocera albolanata (Ising)Chinn.	7;	
Malacocera tricornis (Benth.) R.Anderson	1;	
Neobassia proceriflora (F.Muell.)A.J.Scott	1;	
Osteocarpum acropterum (F.Muell & Tate)Volkens	1;2	
Osteocarpum dipterocarpum (F.Muell.)Volkens	1;	
Rhagodia spinescens R.Br.	1;2;7	
Salsola kali L.	2;7	
Schlerochlamys brachyptera F.Muell.	*;1	
Sclerolaena bicornis Lindley	2;7	
Sclerolaena calcarata (Ising)A.J.Scott	1;	
Sclerolaena convexula (R.Anderson)A.J.Scott	1;	
Scleroleena decurrens (J.Black) A.J.Scott	3;	
Sclerolaena diacantha (Nees.) Benth.	1;	
Sclerolaena divaricarta (R.Br.)Smith	1;	
Sclerolaena eriacantha (F.Muell) Ulbr.	1;	VR
Sclerolaena glabra (F.Muell.)Domin.	1;	
Sclerolaena intricata (R.Anderson) A.J.Scott	2;	
Sclerolaena johnsonii (Ising) A.J.Scott	1;	
Sclerolaena lanicuspis (F.Muell) Benth.	3;	
Sclerolaena muricata (Moq) Domin. var	1;7	
muricata		
Sclerolaena parallelicuspis (R.Anderson)A.J.Scott	1;	
Sclerolaena patenticuspis (R.Anderson)Ulbr.	2;	
Sclerolaena ventricosa (J.Black) A.J.Scott	1;	
Sclerostegia tenuis (Benth.) Paul G. Wilson	1;7	
CONVOLVULACEAE	1;2;4	
Convulvulus erubescens Sims.		
convolvulus remotus R.Br.	1;	
Cressa cretica L.	1;3	
Cuscuta victoriana Yuncker	1;	
Evolvulus alsinoides (L.) var villosicalyx Ooststr.	2;7	
Ipomoea muelleri Benth.	1;	
Ipomoea polymorpha Roemer & Schultes	3;	VR
Ipomoea racemigera F.Muell.& Tate	1;	
CRASSULACEAE	1;	VR
Crassula sieberana (Schultes & Schultes) Druce. ssp tetramera		
Toelken		
CRUCIFERAE	1;	
Arabidella erimigena (F.Muell.)E.Shaw		
Aribadella procumbens (Tate)E.Shaw	1;9	
Arabidella trisecta (F.Muell.)O.Schulz	1;	
Blennodia canescens R.Br.	2;	VR/E
Blennodia pterosperma (J.Black)J.Black	1;	
Brassica tournefortii Gouan.	4;10	
Harmsiodoxa blennodioides (F.Muell)O.Schulz	*;1	
Harmsiodoxa brevipes (F.Muell.)O.Shulz var brevipes	9;	VR
Lepidium muelleriferdinandi Thell.	1;4	VR/E
Lepidium phlebopetalum (F.Muell.) F.Muell	1;9	
Lepidium cf. pseudoruderale Thell.	1;4	
Menkea crassa E.Shaw	1;	
Phlegmatospermum cochlearinum (F.Muell.)O.Shulz	1;	

Phlegmatospermum eremaeum (J.Black) E.Shaw	4;	
CUCURBITACEAE	9;	
Citrullus colocynthis (L) Schrader		
Citrullus lanatus (Thunb.) Mansf.	*;1	
Cucumis melo L. ssp agrestis (Naudin) Grebensc.	*;1	
Mukia maderaspatana (L.) M.Roemer	1;	
Mukia micrantha (F.Muell.) F.Muell	1;	
CYPERACEAE	7;	
Bolboschoenus cardwellii (V.Cook) Sojak		
Cyperus bifax C.B.Clarke	7;	
Cyperus bulbosus Vahl.	1;	
Cyperus difformis L.	1;	
Cyperus exaltus Retz.	1;	VR
Cyperus gymnocaulus Steudel.	2;	
Cyperus iria L.	1;	
Cyperus laevigatus L.	1;	
Cyperus pygmaeus Rottb.	7;	
Cyperus rigidellus (Benth.) J.Black	1;	VR
Cyperus squarrosus L.	1;	
Eleocharis acuta R.Br.	1;2	R/VR
Eleocharis pallens (Benth) S.T.Blake	1;	
Fimbristylis dichotoma (L.) Vohl.	1;	
Fimbristylis velata R.Br.	1;	VR
Isolepis australiensis (Maiden & Betche) K.L.Wilson	□;1	
Isolepis sp. aff. congrua Nees.	1;	
Isolepis hookerana Boeckeler	□;1	
Schoenoplectus dissachanthus (S.T.Blake) Raynal	1;	
Scnoenoplectus litoralis (Schrader) Palla	1;	
DROCERACEAE	7;	
Drosera indica L.		
ELATINACEAE	7;	
Bergia ammaniodes Heyne ex Roth		
Bergia trimera Fischer & C.Meyer	1;	VR
EUPHORBIACEAE	2;3	
Euphorbia coghlanii Bailey		
Euphorbia drummondii Boiss.	1;2	
Euphorbia c.f. tannensis Sprengel ssp eremophila (Cunn. ex Hook)	1;2	
Hassall		
Euphorbia wheeleri Baillon	1;	
Phyllanthus fuernrohrii F.Muell	1;	
Phyllanthus lacunarius F.Muell.	1;	
Sauropus trachyspermus (F.Muell) Airy Shaw	1;	
FRANKENIACEAE	1;	
Frankenia cordata J.Black		
Frankenia crispa J.Black	4;	
Frankenia cupalaris Summerh.	□;2	
Frankenia plicata Melville	1;5	
Frankenia pulverulenta L.	3;	
Frankenia serpyllifolia Lindley	□;*;1	
GENTIACEAE	2;7	
Centaurium tenuiflorum (Hoffsgg & Link) Fritsch.		
GERANIACEAE	□;*1	
Erodium cicutarium (L.) L.Her.ex Aiton		

Erodium crinitum Carolin.	*;1	
Erodium cygnorum Nees ssp glandulosum Carolin.	9;	
GOODENIACEAE	10;	
Goodenia cycloptera R.Br.		
Goodenia fasicularis F.Muell. & Tate	1;	
Goodenia glauca F.Muell.	2;	VR
Goodenia heterochila F.Muell.	1;	
Goodenia lobata Ising	1;	
Goodenia lunata J.Black	9;	
Goodenia triodiophila Carolin.	2;7	
Lechenaultia divaricata F.Muell.	10;	
Scaevola collaris F.Muell.	1;	
Scaevola depauperata R.Br.	10;	VR
Scaevola parvibarata Carolin.	1;	
Scaevola spinescens R.Br.	1;	
GRAMINEAE	2;	
Agrostis avenacea J.Gmelin var avenacea		
Agrostis avenacea J.Gmelin var perennis Vick.	□;1	
Aristida anthoxanoides (Domin) Henrard	1;	
Aristida contorta F.Muell.	1;2	
Aristida holathera Domin var holathera	1;2	
Aristida latifolia Domin.	□;1	
Astrebla lappacea (lindley) Domin	2;3	
Astrebla pectinata (Lindley) F.Muell.	2;	
Brachiaria gielsii (Benth.)Chase	2;7	
Brachiaria subquadripara (Trin) A.S.Hitchc.	2;	
Cenchrus ciliaris L.	1;	
Chloris pectinata Benth.	*;4	
Cynodon dactylon (L.)Pers.	1;	VR
Dactyloctenium radulans (R.Br.)P.Beauv.	*;1	
Dichanthium sericeum (R.Br.)A.Camus.	1;	
Digitaria brownii (Roemer & Schultes) Hughes	1;2;7	
Digitaria coenicola (F.Muell)Hughes var coenicola	2;	VR
Diplachne fusca (L.) P.Beauv ex Roemer & Schultes	1;	
Echinochloa inundata Michael & Vick.	1;	
Enneapogon avenaceus (Lindley) C.E.Hubb.	1;6	
Enneapogon nigricans (R.Br.) P.Beauv.	1;	
Enneapogon polyphyllus (Domin)N.Burb.	2;	VR
Enteropogon acicularis (Lindley) Lazarides	1;	
Eragrostis australasica (Steudel) C.E.Hubb.	1;	VR
Eragrostis basedowii Jedwabn	1;	
Eragrostis dielsii Pilger	1;	
Eragrostis elongata (Willd.) Jacq.F.	1;	
Eragrostis falcata (Gaudlich) Benth.	1;	
Eragrostis lanifolia Benth.	10;	VR
Eragrostis leptocarpa Benth.	1;2	
Eragrostis parviflora (R.Br.) Trin.	2;	
Eragrostis setifolia Nees.	1;	VR
Eragrostis tenellula (Kunth.)Steudel	1;	
Eriachne aristidea F.Muell.	*;2	
Eriachne mucronata R.Br.	1;	
Eriochloa australiensis Stapf. ex Thell.	2;	
Eriochloa pseudoacrotricha (Stapf ex Thell)J.Black	1;	

Eulalia fulva (R.Br.) Kuntze	1;	
Iseilema membranaceum (Lindley) Domin.	1;2	
Iseilema vaginiflorum Domin.	1;	VR
Panicum decompositum R.Br.	1;	
Pannicum effusum R.Br. var effusum	1;	
Pannicum whitei J.Black	□;1	
Paractaenum novae-hollandiae P.Beauv.	1;	
Plagiosetum refractum (F.Muell.) Benth.	1;	
Pseudoraphis spinescens (R.Br.)Vick.	1;	
Setaria dielsii R.Herrm.	□;1	
Sporobolus actinocladus (F.Muell.) F.Muell	1;	
Sporobolus indicus (L.)R.Br. var africanus(Poiret)Jovet&Guedes	2;	
Sporobolus mitchellii (Trin.) C.E.Hubb ex S.T.Blake	□;*;9	
Themeda triandra Forsskal	1;	
Tragus australianus S.T.Blake	2;	VR
Triodia basedowii Pritzel	1;	
Tripogon loliiformis (F.Muell.) C.E.Hubb.	1;	
Triraphis mollis R.Br.	1;2	
Zygochloa paradoxa (R.Br.) S.T.Blake	1;	
HALORAGACEAE	1;	
Gonocarpus sp aff.tetragynus Labill.		
Haloragis aspera Lindley	□;1;2;9	
Haloragis gossei F.Muell.	1;	
Myriophyllum verrucosum Lindley	3;	
JUNCAGINACEAE	1;	VR?
Triglochin calcitrapum Hook.		
Triglochin hexagonum J.Black	1;	VR?
LABIATAE	1;	
Mentha australis R.Br.		
Teucrium albicaule Toelken	1;	
Teucrium racemosum R.Br.	1;	
LEGUMINOSAE	1;	
Acacia aneura F.Muell. ex Benth.		
Acacia cambagei R.Baker	4;9;11	
Acacia cyperophylla F.Muell. ex Benth.	3;7	VR?
Acacia dictyophleba F.Muell.	2;3	
Acacia farnesiana (L.) Willd.	7;	
Acacia ligulata Cunn. ex Benth.	2;	
Acacia murryana F.Muell. ex Benth.	1;	
Acacia oswaldii F.Muell.	1;3	
Acacia salicina Lindley.	1;	
Acacia stenophylla Cunn ex Benth.	1;	
Acacia tetragonophylla F.Muell.	1;	
Acacia victoriae Benth. ssp victoriae	1;	
Aeschynomene indica L.	1;	
Cassia artemisiodes Gaudich.	1;	
Cassia desolata F.Muell.	3;	VR
Cassia helmsii Symon	2;	VR
Cassia nemophila Cunn. ex J.Vogel var nemophila	2;7	
Cassia nemophila Cunn ex J.Vogel var zygophylla (Benth.) Benth.	1;	
Cassia oligophylla F.Muell.	1;	
Cassia phyllodinea R.Br.	2;3;7	
Cassia pleurocarpa F.Muell. var pleurocarpa	2;7	

Cassia pruinosa F.Muell.	1;3	
Cassia sturtii R.Br.	2;3	VR/E
Crotalaria cunninghamii R.Br.	1;	VR
Crotalaria eremaea F.Muell. ssp eremaea	1;	
Crotalaria eremaea F.Muell. ssp strehlowii (Pritze) A.Lee	1;	
Crotalaria smithiana A.Lee	1;	
Glycine canescens F.J.Herm.	1;	
Indigofera brevidens Benth. var brevidens	1;	
Indigofera colutea (Burman f.) Merr.	1;	
Indigofera linifolia (L.f.) Retz	4;	
Indigofera linnaei Ali.	3;	
Isotropis wheeleri F.Muell. ex Benth.	1;3	VR
Lotus cruentus Court.	1;	
Lysiphyllum gilvum (Bailey) Pedley	1;	
Neptunia dimorphantha Domin	1;	
Psoralea australasica Schldl.	2;	
Psoralea cineria Lindley	1;2	
Psoralea pallida N.Burb.	1;	
Psoralea patens Lindley	1;	
Rhynchosia minima L.	1;	
Sesbania cannabina (Retz) Poiret var cannabina	□;1;3	
Swainsona campylantha F.Muell.	1;	R/VR?
Swainsona flavicarinata J.Black	11;	VR
Swainsona microphylla A.Gray ssp affinis A.Lee	3;	
Swainsona oligophylla F.Muell. ex Benth.	3;	VR
Swainsona oroboides F.Muell. ex Benth.	1;4	VR
Swainsona phacoides Benth. ssp phacoides	1;	
Swainsona rigida (Benth.) J.Black	1;4	
Tephrosia sphaerospora F.Meull.	1;10	
Trigonella suavissima Lindley	1;	
Vigna lanceolata Benth.	1;9	
LEMNACEAE	3;	VR
Lemna disperma Hegelm.		
LILIACEAE	1;	
Bulbine alata Baijnath		
LORANTHACEAE	1;	
Amyema maidenii (Blakely) Barlow ssp maidenii		
Amyema preissii (Miq) Tieghem.	2;	
Diplatia grandibractea (F.Muell.) Tieghem.	1;	
Lysiana exocarpi (Behr) Tieghem ssp exocarpi	1;	
LYTHRACEAE	1;	
Ammania multiflora Roxb. var multiflora		
Lythrum hyssopifolia L.	2;	VR
MALVACEAE	1;	
Abutilon fraseri (Hook.) Hook ex Walp		
Abutilon halophilum F.Muell.	1;	
Abutilon leucopetalum (F.Muell.) F.Muell ex Benth.	2;	VR/E
Abutilon malvaefolium (Benth.) J.Black	2;	VR
Abutilon otocarpum F.Muell.	1;	
Abutilon theophrasti Medik	1;	
Hibiscus brachysiphonius F.Muell.	□;*;1	VR/E
Hibiscus krichauffianus F.Muell.	1;	
Hibiscus trionum L. var vesicarius (Cav) Hochr.	1;11	

Lavatera plebeia Sims.	1;	VR/E
Malvastrum americanum(L) Torreq	1;	
Sida ammophila F.Muell. ex J.H.Willis	*;1;2	
Sida calyxhymenia Gay ex D.C.	1;	
Sida cunninghamii C.White	2;	
Sida fibulifera Lindley	1;	
Sida trichopoda F.Muell.	1;	
MARSILIACEAE	1;2	
Marsilea drummondii A.Brown		
Marsilea hirsuta R.Br.	1;	
MELIACEAE	1;	VR
Owenia acidula F. Muell.		
MYOPORACEAE	1;	
Eremophila bignoniiflora (Benth.) F.Muell.		
Eremophila dalyana F.Muell.	1;	
Eremophila freelingii F.Muell.	2;	
Eremophila latrobei F.Muell.	2;	
Eremophila longifolia (R.Br.) F.Muell.	2;7	
Eremophila macdonnellii F.Muell.	1;	
Eremophila maculata (Ker Gawler) F.Muell. var maculata	1;	
Eremophila obovata L.S.Smith var obovata	1;3	
MYRTACEAE	3;	
Eucalyptus camaldulensis Dehnh var obtusa Blakely		
Eucalyptus microtheca F.Muell.	1;	
Eucalyptus terminalis F.Muell.	1;	
Melaleuca lineariifolia Smith var trichostachya (Lindley) Benth.	3;	
NYCTAGINACEAE	2;	
Boerhavia dominii Meikle & Hewson		
Boerhavia schomburgkiana Oliver	1;	
ONAGRACEAE	1;	
Ludwigia peploides (Kunth.) Raven ssp montevidensis		
(Sprengel) Raven		
PEDALIACEAE	*;1	
Josephinia eugeniae F.Muell.		
PITTOSPORACEAE	1;	
Pittosporum phylliraeoides D.C. var microcarpa S.Moore		
PLANTAGINACEAE	1;	
Plantago drummondii Decne.		
Plantago turrifera B.Briggs, Carolin & Pulley	1;	
POLYGONACEAE	1;	
Muehlenbeckia cunninghamii (Meissner) F.Muell.		
Polygonum lapathifolium L.	1;	
Polygonum plebeium R.Br.	1;2	
Rumex crystallinus Lange	1;	
Rumex vesicarius L.	1;	
PORTULACACEAE	*;9;10	
Calandrinia eremaea Ewart		
Calandrinia pumila (Benth.) F.Muell.	1;	
Calandrinia polyandra Benth.	2;	
Calandrinia ptychosperma F.Muell.	3;	
Calandrinia remota J.Black	1;3	
Calandrinia stagnensis J.Black	3;	
Portulaca intraterranea J.Black	1;7	

Portulaca oleracea L.	1;	
PROTEACEAE	1;	YR?
Grevillea stenobotrya F.Muell.		
Grevillea striata R.Br.	7;	
Hakea eyreana (S.Moore) D.McGillivray	1;	
Hakea leucoptera R.Br.	2;3;7	
RANUNCULACEAE	1;	
Myosurus minimus L. var australis (F.Muell) Huth.		
Ranunculus pentandrus J.Black var platycarpus (F.Muell.)	*;1	
H.Eichler	1;	
Ranunculus pumilio R.Br. ex D.C. var pumilio		
RUBIACEAE	1;	
Asperula gemella Airy Shaw & Turrill		
Dentella pulvinata Airy Shaw	1;	
Synaptantha tillaecea (F.Muell.) Hook.f.	1;	
SANTALACEAE	1;	
Santalum lanceolatum R.Br.		
SAPINDACEAE	1;	
Atalaya hemiglauca (F.Muell.) F.Muell ex Benth.		
Dodonaea viscosa Jacq ssp angustissima (D.C.) J.G.West	1;	
SCROPHULARIACEAE	2;	
Glossostigma diandrum (L.) Kuntze		
Glossostigma drummondii Benth.	1;	YR
Mimulus prostratus Benth.	1;	
Morgania floribunda Benth.	1;9	
Morgania glabra R.Br.	1;	
Peplidium sp D	1;7	
Veronica peregrina L. ssp xalapensis (Kunth.) Pennell	1;	
SOLONACEAE	□;*;1	
Nicotiana glauca Graham		
Nicotiana velutina H.Wheeler	*;10	
Solanum ellipticum R.Br.	1;	
Solanum esuriale Lindley	2;	
Solanum nigrum L.	1;	YR
Solanum oligacanthum F.Muell.	*;1	
STERCULIACEAE	1;	
Gilesia biniflora F.Muell.		
Keraudrinia integrifolia Steudel	4;	
Melhania oblongifolia F.Muell.	3;	
Rulingia loxophylla F.Muell.	2;	
TETRAGONIACEAE	3;	
Tetragonia tetragoniodes (Pallas) Kuntz		
THYMELAEACEAE	1;	
Pimelea trichostachya Lindley		
TYPHACEAE	1;	
Typha domingensis (Pers) Steudel		
UMBELLIFERAE	1;	
Daucus glochidiatus (Labill.) Fischer C.Meyer & Ave Lall		
Eryngium plantagineum F.Muell	1;9	
Eryngium supinum J.Black	9;	YR
Trachymene glaucifolia (F.Muell.) Benth.	1;2	
URTIACEAE	1;	
Parietaria debilis Forster f.		

VERBENACEAE	1;	
Verbena officinalis L.		
ZYGOPHYLLACEAE	*;1	
Nitraria billardieri D.C.		
Tribulus hystrix R.Br.	9;10	
Tribulus occidentalis R.Br.	1;	
Tribulus terrestris L.	1;	
Zygophyllum ammophilum F.Muell.	*;1	
Zygophyllum howittii F.Muell.	1;2;3;4	
Zygophyllum iodocarpum F.Muell.	1;10	
	1;	

Table 6.1b

PLANTS COLLECTED DURING COONGIE SURVEY WHICH ARE NOT LISTED BY MOLLENMANS

ACANTHACEAE
Dipteracanthus australasicus ssp glabratus
AIZOACEAE
Glinus oppositifolia
Gunniopsis septifraga
AMARANTHACEAE
Alternanthera angustifolia
A. denticulata
Ptilotus macrocephalus
P. nobilis
ASTERACEAE
Angianthus tomentosus
Brachycome basaltica var gracilis
Brachycome sp. novum
Calotis latiuscula
C. plumulifera
Dichromochlamys dentatifolia
Gnaphosis arachnoides
Ixiolaena chloroleuca
* Pentzia suffruticosa
BORAGINACEAE
* Heliotropium supinum
H. tenuifolium
Plagiobothrys plurisepaleus
CALLITRICHACEAE
Callitriche sondri
CAMPANULACEAE
Wahlenbergia aridicola
W. communis
W. gracilenta
W. tumidifructa
CARYOPHYLLACEAE
* Spergularia diandra
CHENOPODIACEAE
Atriplex fissivalvis
A. pseudocampanulata
A. sp. aff. pumilio
A. quinii
Chenopodium pumilio
Dysphania platycarpa
Maireana appressa
M. integra
M. radiata
M. spongiocarpa
Malacocera albolanata
Sclerolaena convexula
S. decurrens
S. eriacantha
S. johnsonii
S. patenticuspis
CONVOLVULACEAE
Convolvulus remotus
Cuscuta victoriana
Ipomoea polymorpha
CRASSULACEAE
Crassula sieberana ssp. tetramera
CRUCIFERAE
Lepidium phlebopetalum
L. cf. pseudoruderale
Phlegmatospermum cochlearinum
P. eremaeum
CUCURBITACEAE
* Citrullus colocynthis
* C. lanatus
Mukia micrantha
CYPERACEAE
Bolboschoenus cardwellii
Cyperus bifax
C. bulbosus
C. laevigatus
C. rigidellus
Fimbristylis velata
Isolepis sp. aff. congrua
I. hookerana
Schoenoplectus dissachanthus
DROCERACEAE
Drosera indica
EUPHORBIACEAE
Euphorbia coghlanii
FRANKENIACEAE
Frankenia crispa
F. plicata
* F. pulverulenta
GENTIACEAE
* Centaurium tenuiflorum
GERANIACEAE
* Erodium cicutarium
GOODENIACEAE
Goodenia triodiophila
Scaevola parvibarbata
GRAMINAE
Aristida latifolia
Brachiaria subquadripara
B. gilesii
* Cenchrus ciliaris
Dichanthium sericeum
Digitaria coenicola var coenicola
Eragrostis laniflora
Eriachne mucronata.
Eriochloa australiensis
Iseilema vaginiflorum
Panicum effusum var effusum
Psuedoraphis spinescens
Setaria dielsii
* Sporobolus indicus var africanus
HALORAGACEAE
Gonocarpus sp. aff. tetragynus
JUNCAGINACEAE
Triglochin hexagonum
LABIATAE
Teucrium albicaule
LEGUMINOSAE
Crotalaria eremaea ssp. strehlowii
Indigofera linifolia
LEMNACEAE
Lemna disperma
MALVACEAE
Abutilon malvaefolium
Hibiscus brachysiphonius
Sida calyxhymenia
NYCTAGINACEAE
Boerhavia dominii
B. schomburgkiana
PEDALIACEAE
Josephinia eugeniae
PLANTAGINACEAE
Plantago drummondii
POLYGONACEAE
Polygonum lapathifolium
* Rumex vesicarius
PORTULACACAEA
Calandrinia pumila
C. stagnensis
RANUNCULACEAE
* Myosurus minimus var australis
Ranunculus pentandrus var platycarpus
R. pumilio var pumilio
SCROPHULARIACEAE
Glossostigma drummondii
* Veronica peregrina ssp. xalapensis
SOLONACEAE
* Nicotiana glauca
* Solanum nigrum
STERCULIACEAE
Gilesia biniflora
TYPHACEAE
Typha domingensis
URTIACEAE
Parietaria debilis

* INTRODUCED SPECIES

Table 6.1c

PLANTS NOT COLLECTED DURING COONGIE SURVEY ALTHOUGH LISTED BY MOLLENMANS

ADIANTACEAE
Chielanthes tenuifolia VR/E*
C. vellea VR/E
AIZOACEAE
Glinus orygioides VR/E
AMARANTHACEAE
Ptilotus murrayi VR
AMARYLLIDACEAE
Crinum luteolum VR*
ASCLEPIDIACEAE
Rhyncharrhena linearis V
ASPLENIACEAE
Pleurosorus rutifolius VR/E
ASTERACEAE
Brachycome melanocarpaVR\E
Calotis cymbacantha VR
Chrysocoryne pusilla VR
Crespedia pleiocephala VR
Erodiophyllum elderi VR/E
Gnaphalium indutum FC*
Helichrysum ambiguum R
H. apiculatum VR
H. basedowii VR/E
Helipterum corymbiflorumVR
H. demissum VR/E*
H. hyalospermum VR/E*
H. troedelii VR
H. uniflorum R
Leptorhychos tetrachaetusVR/E*
Millotia greevesii VR/E
Pluchea rubelliflora R
Podolepis arachnoidesVR/E
P. canescens VR/E
P. capillaris VR/E
P. muelleri VR
Pterocaulon serrulatum R
Senecio glossanthus VR/E
S. odoratus R
Sonchus megalocarpus R
Vittedinia dissecta R
V. pterochaeta R*
V. sp. unknown U
BORAGINACEA
Colandenia procumbensVR/E
Cynoglossum australe VR/E
Heliotropium europaeum FC
H. filaginoides VR/E
H. ovalifolium VR/E
H. undulatum R
CRUCIFERAE
Alyssum linifolium VR
Arabidella glaucescens R
Lepidium papillosum VR*
L. rotundum R
Pachymites cardminoidesVR*
Scambopus curvipesVR*
Stenopetalum lineare R
S. nutans VR/E
S. velutinumVR/E

CALLITRICHACEAE
Callitriche stagnalis VR*
CAMPANULACEAE
Pratia puberula VR/E
Wahlenbergia gracilisVR
W. stebert R
CARYOPHYLLACEAE
Polycarpaea arida R
P. indica
P. spirostylis ssp. glabra R
CHENOPODIACEAE
Atriplex sp. aff. hiocarpa U
A. incrassata U*
A. inflata R*
A. rhagodioides R*
Dysphania littoralis VR
Halosarcia halocnemoides R
Rhagodia gaudichaudiana U
Sclerolaena costata U
S. holtiana U*
S. sp. aff. tatei U
S. tricuspis R
S. uniflora R
CHLOANTHACEAE
Dicrastylis costelloi U
D. lewellinii R
Newcastelia cephalantha R
CONVULVULACEAE
Bonamia media VR/E
Polymera longifolia VR/E*
CYPERACEAE
Bulbostylis turbinata VR
Cyperus cunninghamii U
C. sp. aff. cunninghamii U
C. dactylotes VR
C. eragrostis VR/E*
C. gilesii R
C. rotundus ssp. retzii VR
C. vaginatus VR
Isolepis maginata VR/E*
Scirpus maritimus R
EUPHORBIACEAE
Adriana hookeri U
Euphorbia australis U
E. boophthona R
E. parvicaruncula U
E. stevenii R*
Phyllanthus maderaspatensis var angustifolius R
FRANKENIACEAE
Frankenia angustipetala U
F. cinerea U
F. foliosa R*
F. gracilis R
F. psuedo-flabellata U
F. uncinata FC
GENTIACEAE
Erodium aureum U
GOODENIACEAE
Goodenia sp. aff. havilandii U
Scaevola aemula U
S. parvibarata
GRAMINAE
Alopecurus geniculatus VR
Aristida ramosa VR*
A. strigosa VR
Bothriochloa bladhii VR*
Brachiaria notochthone VR
Brachyachne ciliaris VR
Chloris pectinata VR
Chrysopogon fallax R/VR
Cymbopogon sp.(exaltus) R
Dichanthium affine R
Digitaria ammophila R*
Echinochloa crus-galli VR
Enneapogon cylindricus U
Eragrostis confertifolia VR
E. eriopoda FC
E. speciosa U
E. xerophila VR
Eriachne ovata VR
Leptochloa digitata FC
Panicum australiense VR/E*
Paspalidium gracile VR*
Perotis rara VR/E*
Sporobolus caroli VR
S. virginicus R*
Stipa semibarbata VR/E*
GUTTIFERAE
Hypericum gramineum U*
H. japonicum VR/E*
GYROSTEMONACEAE
Codonocarpus continifolius R
Gyrostemon ramulosus VR
HALORAGACEAE
Haloragis glauca V
Myriophyllum muelleri VR*
JUNCACEAE
Juncus planifolius VR/E*
LABIATAE
Prostanthera stiatifolia VR/E
LEGUMINOSAE
Acacia brachystachya R
A. ramulosa R
A.victoriae ssp arida FC
A. sp unknown R
Cassia desolata var planipes VR
Clianthus formosus VR
Glycine falcata VR/E
G. tomentosa VR/E
Medicago polymorpha U
Swainsona lessertiifolia R
S. stipularis VR/E
Templetonia egena U*
LILIACEAE
Thysanotus exiliflorus VR/E
Tricoryne elatior VR/E*
LORANTHACEAE
Amyema quandang VR/E
Lysiana linearifolia VR
MALVACEAE
Alogyne pinonana R*
Lawrencia glomerata VR
Sida corrugata U/R
S. intricata R
S. sp. D U
MARSILIACEAE
Marsilea mutica VR*
MENYANTHACEAE
Nymphoides crenata VR
MYOPORACEAE
Eremophila clarkei VR/E*
E. duttonii VR/E
E. glabra VR/E
E. macgillivrayi U
Myoporum acuminatum VR/E
MYTACEAE
Melaleuca glomerata VR/E*
NYCTAGINACEAE
Boerhavia diffusa VR
Commicarpus chinensis VR
ORCHIDACEAE
Caladenia deformis VR/E
Cymbidium canaliculatum VR/E
PLANTAGINACEAE
Plantago varia R*
POLYGONACEAE
Muehlenbeckia coccoloboides R
Polygonum attenuatum VR/E
PORTULACACEAE
Calandrinia balonensis VR
PROTEACEAE
Grevillea pterosperma VR/E*
Hakea ivoryi VR
SAPINDACEAE
Dodonaea microzyga VR/E
Heterodendrum oleaefolium VR
SCROPHULARIACEAE
Mimulus gracilis R
SOLONACEAE
Nicotiana exelsior VR*
Solanum chenopodium VR/E
S. sturtianum VR/E
THYMELIACEAE
Pimelea microcephala VR
P. simplex ssp. simplex VR
VERBENIACEAE
Verbena bonariensis R*
V. macrostachya
VIOLACEAE
Hybanthus monopetalus VR
ZYGOPHYLLACEAE
Zygophyllum aurantiacum R
Z. billardieri VR/E*
Z. crenatum VR/E

KEY TO SYMBOLS
FC ENCOUNTERED AT 2-5 LOCALITIES ,MOLLENMANS SURVEY
U ENCOUNTERED AT 1-2 LOCALITIES ,MOLLENMANS SURVEY
VR NOT ENCOUNTERED SINCE 1925
VR/E NOT ENCOUNTERED SINCE LAST CENTURY

* INTRODUCED SPECIES

Table 6.2

Perennial species used in vegetation association analyses.

1 Acacia ligulata
2 Acacia murrayana
3 Acacia oswaldii
4 Acacia salicina
5 Acacia stenophylla
6 Atalaya hemiglauca
7 Atriplex leptocarpa
8 Atriplex limbata
9 Atriplex nummularia
10 Atriplex velutinella
11 Cassia nemophila nemophila
12 Chenopodium auricomum
13 Crinum flaccidum
14 Crotalaria cunninghamii
15 Crotalaria eremaea
16 Cynandrum floribundum
17 Cyperus gymnocaulis
18 Einadia nutans
19 Enchylaena tomentosa
20 Eragrostis australasica
21 Eremophila bignoniflora
22 Eremophila longifolia
23 Eucalyptus camaldulensis
24 Eucalyptus microtheca
25 Gunniopsis quadrifida
26 Hakea leucoptera
27 Halosarcia indica
28 Lavatera plebeia
29 Lechenaultia divaricata
30 Lotus cruentus
31 Lysiphyllum gilvum
32 Maireana coronata
33 Maireana microcarpa
34 Malacocera albolanata
35 Marsilea drummondii
36 Marsilea hirsuta
37 Morgania floribunda
38 Muehlenbeckia cunninghamii
39 Osteocarpum acropterum
40 Phyllanthus fuernrohrii
41 Psoralea pallida
42 Ptilotus latifolius
43 Santalum lanceolatum
44 Sauropus trachyspermus
45 Sclerolaena bicornis
46 Sclerolaena calcarata
47 Sclerolaena diacantha
48 Sclerolaena intricata
49 Sclerolaena patenticuspis
50 Sida ammophila
51 Solanum oligacanthum
52 Sporobolus mitchellii
53 Teucrium racemosum
54 Trichodesma zeylanicum
55 Triodia basedowii
56 Zygochloa paradoxa
57 Frankenia cupularis
58 Atriplex pseudocampanulata
59 Sclerolaena lanicuspis
60 Eragrostis leptocarpa
61 Diplatia grandibractea
62 Atriplex lindleyi
63 Atriplex muelleri
64 Dentella pulvinata
65 Atriplex angulata
66 Eragrostis setifolia
67 Eragrostis dielsii
68 Scaevola parvibarbata
69 Aristida holathera
70 Agrostis avenaceus
71 Enneapogon avenaceus
72 Triraphis mollis
73 Haloragis aspera
74 Eriachne aristidea
75 Acacia victoriae
76 Setaria dielsii
77 Atriplex eardleyi
78 Ptilotus atriplicifolius
79 Fimbristylis velata
80 Aristida contorta
81 Sclerochlamys brachyptera
82 Owenia acidula
83 Atriplex crassipes
84 Sida cunninghamii

Table 6.3

Vegetation associations in the Coongie Lakes District, based on cluster analysis of random and permanent sites, as defined by perennial species (see Figs 6.2&3).

RIVERINE COMPLEX	1. Eucalyptus microtheca- Sclerolaena intricata +/- Atriplex velutinella
	2. Depauperate version of the above
	3. Eucalyptus microtheca - Muehlenbeckia cunninghamii +/- Eucalyptus camaldulensis + Acacia stenophylla / Acacia salicina
FLOODPLAIN COMPLEX	4. Halosarcia indica - Sclerolaena intricata
	5. Muehlenbeckia cunninghamii - Sclerolaena intricata - Atriplex velutinella
	6. Eragrostis australasica
	7. Muehlenbeckia cunninghamii -Chenopodium auricomum - Sclerolaena patenticuspis
	8. Intergrade
	9. Sclerolaena intricata / S. bicornis - Muehlenbeckia cunninghamii
	10. As above with Maireana coronata
	11. Sclerolaena calcarata / S. intricata
	12. Morgania floribunda- Crinum flaccidum - Osteocarpum acropterum
	13. Atriplex eardleyi - Sclerolaena intricata .
	14. Eragrostis dielsii +/- Sclerolaena lanicuspis - Malacocera albolanata
	15. Sporobolus mitchellii
	16. Marsilea drummondii
SAND DUNE CREST COMPLEX	17. Zygochloa paradoxa +/- Acacia ligulata
	18. Acacia ligulata +/- Atriplex velutinella - Aristida holathera
	19. Acacia ligulata +/- Zygochloa paradoxa - Sclerolaena intricata - Gunniopsis quadrifida
	20. Acacia ligulata - Triodia basedowii - Zygochloa paradoxa
	21. Triodia basedowii
INTERDUNE COMPLEX	22. Crotalaria cunninghamii - Atriplex velutinella - Trichodesma zeylanicum
	23. Atriplex velutinella - Gunniopsis quadrifida +/- Acacia ligulata
	24. Atriplex velutinella - Sclerolaena intricata - Gunniopsis quadrifida
	25. Acacia oswaldii - Atriplex velutinella
	26. Sclerolaena diacantha - Eragrostis dielsii +/- acacia ligulata
	27. Aristida holathera - Acacia ligulata
CLAYPANS	28. Barren clay pans

TEST OF SEASONALITY OF ANNUAL SPECIES
AT PERMAMENT SITES DURING 1987.

Table 6.4

. -> not significant   * -> P < 0.05   ** -> P < 0.01   *** -> P < 0.001

SPECIES	SITE NO. -> 1W	2W	3W	4W	5W	6W	7W	8W	9W	10W	11W	12W	13W	14W	15W	1E	2E	3E	4E	5E	6E	7E	8E	9E	10E	11E	12E	13E	14E	15E
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Table 6.5

List of species (annuals and other ground-layer species) used in the cluster analysis performed on data gathered at the permanent sites during each sampling event.

1 Abutilon malvaefolium
2 Abutilon otocarpum
3 Alternanthera denticulata
4 Alternanthera nodiflora
5 Amaranthus mitchellii
6 Aristida contorta
7 Aristida holathera
8 Asperula gemella
9 Atriplex angulata
10 Atriplex crassipes
11 Atriplex leptocarpa
12 Atriplex limbata
13 Atriplex lindleyi
14 Atriplex muelleri
15 Atriplex nummularia
16 Atriplex pseudocampanulata
17 Atriplex spongiosa
18 Atriplex velutinella
19 Azolla filiculoides
20 Blennodia canescens
21 Blennodia pterosperma
22 Boerhavia dominii
23 Brachycome ciliaris
24 Brassica tournefortii
25 Bulbine alata
26 Calocephalus platycephalus
27 Calostemma luteum
28 Calotis hispidula
29 Calotis latiuscula
30 Calotis plumulifera
31 Centaurium tenuifolium
32 Centipeda minima
33 Convolvulus erubescens
34 Crassula sieberana
35 Cressa cretica
36 Crinum flaccidum
37 Crotalaria cunninghamii
38 Crotalaria eremea
39 Cynanchum floribundum
40 Dactyloctenium radulans
41 Daucus glochidiatus
42 Diplachne fusca
43 Einadia nutans
44 Enchylaena tomentosa
45 Enneapogon avenaceus
46 Epaltes cunninghamii
47 Eragrostis setifolia
48 Eragrostis australasica
49 Eragrostis basedowii
50 Eragrostis dielsii
51 Eriachne aristidea
52 Euphorbia drummondii
53 Euphorbia wheeleri
54 Evolvulus alsinoides
55 Frankenia cupalaris
56 Glycine canescens
57 Gunniopsis quadrifida
58 Haloragis aspera
59 Helipterum moschatum
60 Helipterum strictum
61 Ipomaea polymorpha
62 Ipomaea racemigera
63 Iseilema membranaceum
64 Ixiolaena brevicompta
65 Josephina eugeniae
66 Lavatera plebeia
67 Lepidium phlebopetalum
68 Lechenaultii divaricata
69 Lotus cruentus
70 Maireana coronata
71 Malacocera albolanata
72 Marsilea drummondii
73 Marsilea hirsuta
74 Minuria denticulata
75 Minuria integerrima
76 Mollugo sp.
77 Morgania floribunda
78 Myriocephalus stuartii
79 Myriophyllum verrucosum
80 Nicotiana velutina
81 Osteocarpum acropterum
82 Panicum decompositum
83 Paractaenum novae-hollandiae
84 Phyllanthus fuernrohrii
85 Phyllanthus lacunarius
86 Pimelea trichostachya
87 Plagiosetum refractum
88 Plantago drummondii
89 Plantago varia
90 Portulaca oleracea
91 Portulaca intraterranea
92 Pseudognaphalium luteoalbum
93 Pseudoraphis spinescens
94 Psoralea cinerea
95 Psoralea pallida
96 Psoralea patens
97 Ptilotus polystachus
98 Rumex crystallinus
99 Salsola kali
100 Sauropus trachyspermus
101 Scaevola parvibarbata
102 Sclerolaena bicornis
103 Sclerolaena calcatrata
104 Sclerolaena diacantha
105 Sclerolaena intricata
106 Sclerolaena patenticuspis
107 Senecio gregorii
108 Senecio lautus
109 Sida ammophila
110 Sida cunninghamii
111 Solanum oligacanthum
112 Streptoglossa adscendens
113 Tephrosia sphaerospora
114 Tetragonia tetragonoides
115 Teucrium racemosum
116 Trachymene glaucifolia
117 Tragis australianus
118 Trianthema pilosa
119 Trianthema triquetra
120 Tribulus hystrix
121 Tribulus occidentalis
122 Tribulus terrestris
123 Trichodesma zeylanicum
124 Triglochin calcitrapum
125 Trigonella suavissima
126 Sonchus oleraceus
127 Triraphis mollis
128 Verbena officinalis
129
130 Zygophyllum howittii
131 Zygophyllum iodocarpum
132 Sporobolus mitchellii
133 Senecio sp.
134 Crotalaria smithiana
135 Agrostis avenacea
136 Eriochloa australiensis
137 Myosurus minimus
138 Calandrinia sp.

COONGIE LAKES SURVEY

TRAPSITE / RANDOM SITE VEGETATION DATA SHEET, PAGE ____ OF ____ PAGES

App 6.1

OBSERVERS: ____________________ DATE: ____________________

RANDOM SITE NO.: ____________ /TRAPSITE NO.: ________

LANDFORM TYPE AND COMMENTS: ____________________

SOIL TYPE AND COMMENTS: 1) TEXTURE: ____________ 2) COLOUR: ____________

VEGETATION DESCRIPTION: E.G. STRUCTURE AND FLORISTICS OF DOMINANT SPECIES OF THE FOLLOWING STRATA :

TALLEST STRATUM ____________________

MID STRATUM ____________________

LOWEST STRATUM ____________________

ASSOCIATION DESCRIPTION ____________________

LIST OF EPHEMERALS PRESENT: ____________________

QUANTITATIVE INFO FOR PERENNIAL SPECIES

GENUS SPECIES	/VOUCH. NO.	QUAD. SIZE	NUMBERS INDIV.	DENSITY	AVE. RADIUS	% COVER	COMMENTS

COONGIE LAKES SURVEY

MONTHLY TRAPSITE VEGETATION DATA SHEET

OBSERVERS: ____________________ TRAPSITE #: ______ DATE: ________

ALL SPECIES

SPECIES	L.C STAGE	COMMENTS

DESCRIPTION OF STRUCTURE AND FLORISTICS OF ANNUALS.

LIFE CYCLE STAGES: N = New Growth, B = Budding, F = Flowering, S = Fruit/shedding, S(p) = Shed, Sd = Seedling, G = Badly Grazed, D = Dead, DO = Dormant, V = None of the above!

COONGIE LAKES SURVEY

SITE NO.:__________ OBSERVER:___

ANNUALS SAMPLING

DATE:________________ PAGE___OF___PAGES

SUMMARY

ABUNDANCE: t= 1%, 1=1-5%, 2=6-25%, 3=26-50%, 4=51-75%, 5=76-100%

LIFE CYCLES: V=VEGETATIVE, B=BUDS, F=FLOWERS, S=SEED, D=DEAD.

SPECIES	NEM	A	LC	FREQ.	SPECIES	NEM	A	LC	FREQ.

HEIGHT CLASSES

App 6.2

HEIGHT(M)	TREES	SHRUBS	GRASSES/FORBS/SEDGES
20-35	VERY TALL	N.A.	N.A.
12-20	TALL	N.A.	N.A
6-12	MID-HIGH	N.A.	N.A
3-6	LOW	VERY TALL	EXTREMELY TALL
1.01-3	DWARF	TALL	VERY TALL
0.51-1.00	N.A.	MID-HIGH	TALL
0.26-0.50	N.A.	LOW	MID-HIGH
≤0.25	N.A.	DWARF	LOW

CROWN COVERAGE (SEPARATIONS)

CLOSED (C)	MODERATELY OPEN (M)	OPEN (O)	VERY OPEN (V)	SPARSE (S)	ISOLATED PLANTS (I)	ISOLATED CLUMPS (IC)
CROWNS	TOUCHING SLIGHTLY	CLEARLY SEPARATED	WELL SEPARATED	VERY GOOD SEPARATION	ISOLATED	ISOLATED
OVERLAP	<1/4 DIAM.SEP.	1/4≤D.S≤1	1<D.S.≤10	10<D.S.≤20	>20 D.S.	>20 D.S.

STRUCTURAL FORMATION CLASSES

	C	M	O	V	S	I(C)
TALL TREE (12-35M)	CLOSED FOREST	OPEN FOREST	WOODLAND	OPEN WOODLAND	SPARSE WOODLAND	ISOLATED TREES (CLUMP)
LOW-MID TREE (3-12M)	LOW CLOSED FOREST	LOW OPEN FOREST	LOW WOODLAND	LOW OPEN WOODLAND	LOW SPARSE WOODLAND	LOW ISOLATED TREES (CLUMPS)
SHRUBS	CLOSED SHRUBLAND	SHRUBLAND	OPEN SHRUBLAND	VERY OPEN SHRUBLAND	SPARSE SHRUBLAND	ISOLATED SHRUBS (C)
CHENOPOD SHRUBS	CLOSED CHENO. SHRUBLAND	CHENOPOD SHRUBLAND	OPEN	VERY OPEN	SPARSE	ISOLATED
HUMMOCK GRASS	CLOSED HUMM GRASSLAND	HUMMOCK GRASSLAND	-	-	-	-
GRASS	CLOSED GRASSLAND	GRASSLAND	-	-	-	-
FORB	CLOSED FORBLAND	FORBLAND	-	-	-	-
SEDGE	CLOSED SEDGELAND	SEDGELAND	-	-	-	-

(EXAMPLE: FORBS 70cm TALL, D.S.=8 ⟶ TALL, VERY OPEN FORBLAND (70 cm, D.S.=8))

LIFE CYCLE STAGES: B=BUDS, D=DEAD, Do=DORMANT, F=FLOWERS, G=BADLY GRAZED, N=NEW GROWTH, S=FRUIT/SHEDDING, Sd=SEEDLING, S(p)=PAST EVENT FRUITING, R=REGENERATING, OLD STOCK, V=NO NEW GROWTH BUT GREEN.

PLANTS QUALITATIVE ABUNDANCE

t = TRACE ≤1% COVER
1 ——— 1-5%
2 ——— 6-25%
3 ——— 26-50%
4 ——— 51-75%
5 ——— 76-100%

— JULIAN REIDS "BUMP UP CLASSES"
BY 1, IF SPECIES COMMON, WIDESPREAD OR PATCHILY, LOCALLY DOMINANT.
BY 2, IF SPECIES VERY COMMON, ABUNDANT OR MONOSPECIFIC OVER LARGE AREAS.
NO BUMPING UP BELOW THIS LINE

D.S.	0.7	1.0	5	10
≏ COVER	50%	25%	5%	1%

ROUGH CORRELATION OF DIAM. SEPNS TO COVER.

VEGETATION DESCRIPTIONS FOR PERMANENT SITES

SITE	VEGETATION
1E	Low open Eucalyptus camaldulensis / E. microtheca woodland
2E	Low sparse Gunniopsis quadrifida , Atriplex velutinella shrubland
3E	Very tall sparse Eragrostis australasica grassland
4E	Low open E. camaldulensis / E. microtheca woodland
5E	Dune crest : Tall sparse hummock Zygochloa paradoxa grassland Midslope : Sparse hummock Triodia basedowii gassland
6E	Tall sparse Acacia ligulata / Atalaya hemiglauca shrubland
7E	Sparse hummock Triodia basedowii grassland
8E	Tall sparse Atriplex nummalaria shrubland
9E	Sparse Halosarcia indica / Sclerolaena intricata shrubland
10E	Sparse hummock Zygochloa prardoxa grassland
11E	Dune: Low open Eucalyptus microtheca woodland Floodout : Tall sparse Muehlenbeckia cunninghamii shrubland
12E	Low open Eucalyptus microtheca / Lysiphyllum gilvum woodland
13E	Mid-high sparse Sclerolaena intricata, Solanum oligacanthum shrubland
14E	Tall sparse Acacia ligulata shrubland
15E	Tall sparse Muehlenbeckia cunninghamii shrubland
1W	Low open Eucalyptus microtheca woodland grading into a very open Mid-high Cyprus gymnocaulus sedgeland
2W	Open Mid-high Halosarcia indica shrubland
3W	Tall open Chenopodium auricomum shrubland
4W	Tall sparse Muehlenbeckia cunninghamii shrubland
5W	Low open Sporobolus mitchellii grassland
6W	Tall open hummock Zygochloa paradoxa grassland
7W	Tall sparse Acacia ligulata shrubland
8W	Low open Sclerolaena intricata, S. calcarata shrubland
9W	Low open Eucalyptus microtheca woodland
10W	Mid-high open Crotalaria cunninghamii / Salsola kali shrubland
11W	Low open Atalaya hemiglauca woodland
12W	Low open Eucalyptus microtheca woodland
13W	Tall moderately open Atriplex crassipes, A muelleri forbland
14W	Tall sparse Acacia ligulata / Atalaya hemiglauca shrubland
15W	Mid-high open Halosarcia indica shrubland

COLOUR PLATES SECTION

A series of 48 colour plates follows - four per page. Captions and credits for each photograph are given on the facing (left-hand) page.

Plate 1 Jake Gillen

Aerial view of Coongie Lake from the west, looking over the biologically rich delta of the North-West Branch, Cooper Creek.

Plate 2 Jake Gillen

Two Brolga and scattered waterfowl feeding along the recently inundated northern shore of Lake Goyder in August 1987.

Plate 3 Jake Gillen

River Red Gums fringing the North-West Branch near the base camp.

Plate 4 Peter Canty

Lake Talinnie (salt lake) with samphire and rat's tail couch in foreground.




Plate 5 V. Kotwicki

Flow guaging station (E&WS) at Callyamurra WH, east of Innamincka.

Plate 6 Jake Gillen

Aerial view of Tirrawarra Swamp showing the dense vegetation, lignum mainly, and myriad small channels - a biological powerhouse.

Plate 7 Jake Gillen

A drift-fence and pitfall line through spinifex-clad sand-dune habitat, used to trap small mammals and reptiles at the permanent sites over the year.

Plate 8 Jake Gillen

Echinochloa inundata, channel millet, a nationally threatened plant, confined to the margins of the main Cooper Creek system in the region. Native millets are particularly favoured by cattle for grazing.

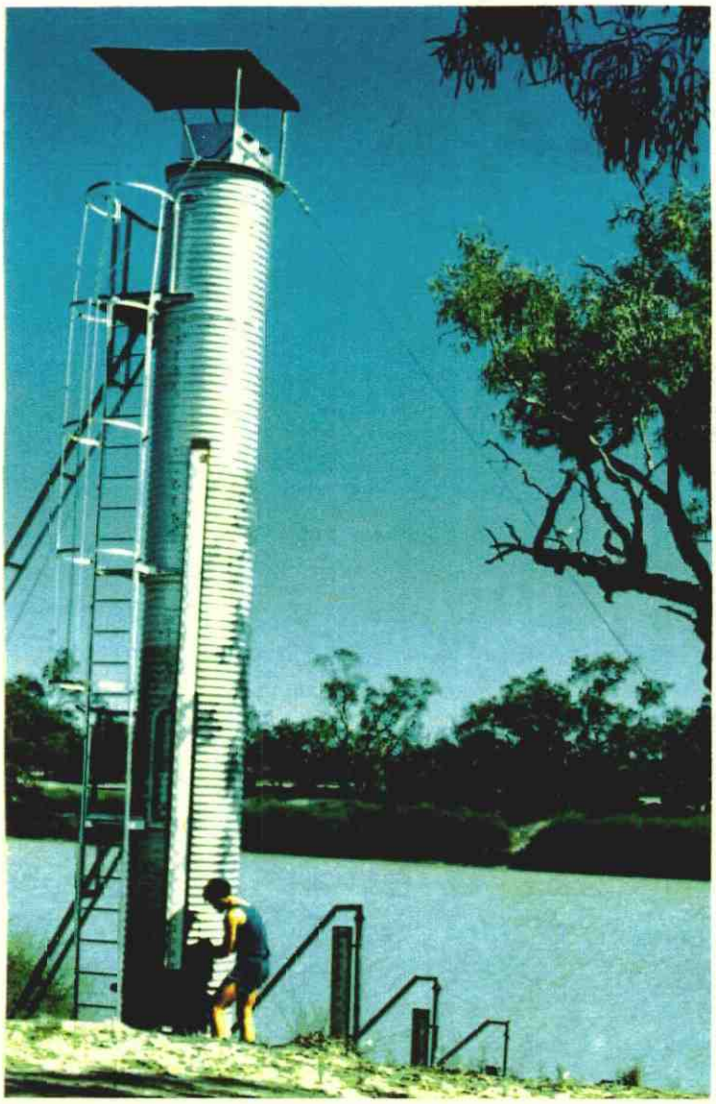
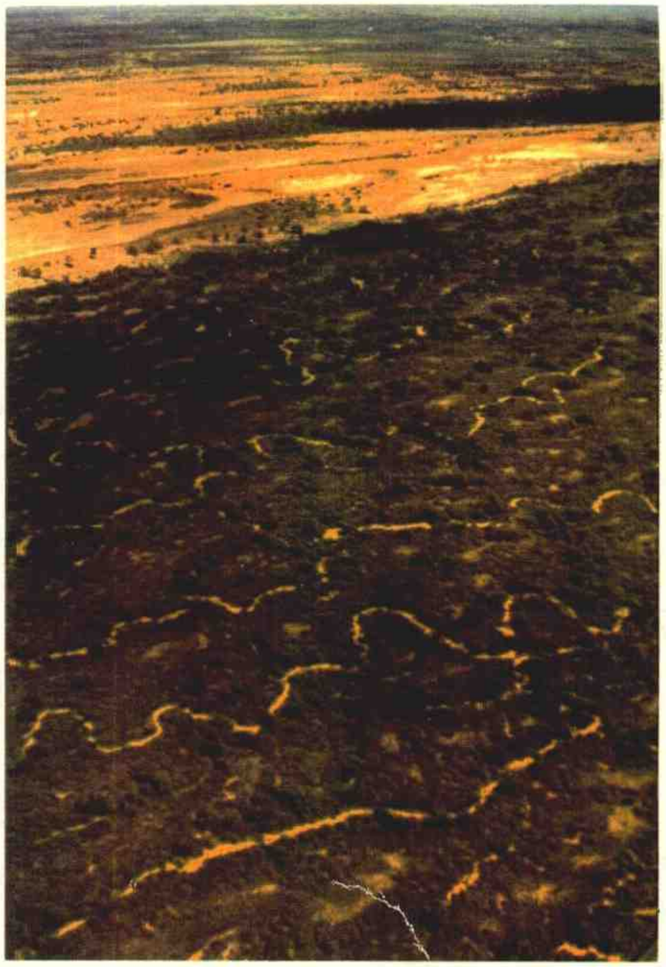



Plate 9 Julian Reid

Photopoint at Permanent Site 5W on Emu Flat, taken in November 1986.

Plate 10 Jake Gillen

Same photopoint, March 1987, showing the new (green) growth of the dominant plant, rat's tail couch *Sporobolus mitchellii*, after heavy summer rains.

Plate 11 Jake Gillen

Same photopoint, September 1987, after inundation (floodout of Lake Toontoowaranie), with the yellow flowered daisy *Senecio lautus*, variable groundsel, prominent.

Plate 12 Peter Canty

Planigale tenuirostris, narrow-nosed planigale. This tiny animal (weight 4g) was captured in a few floodplain habitats, including Emu Flat.

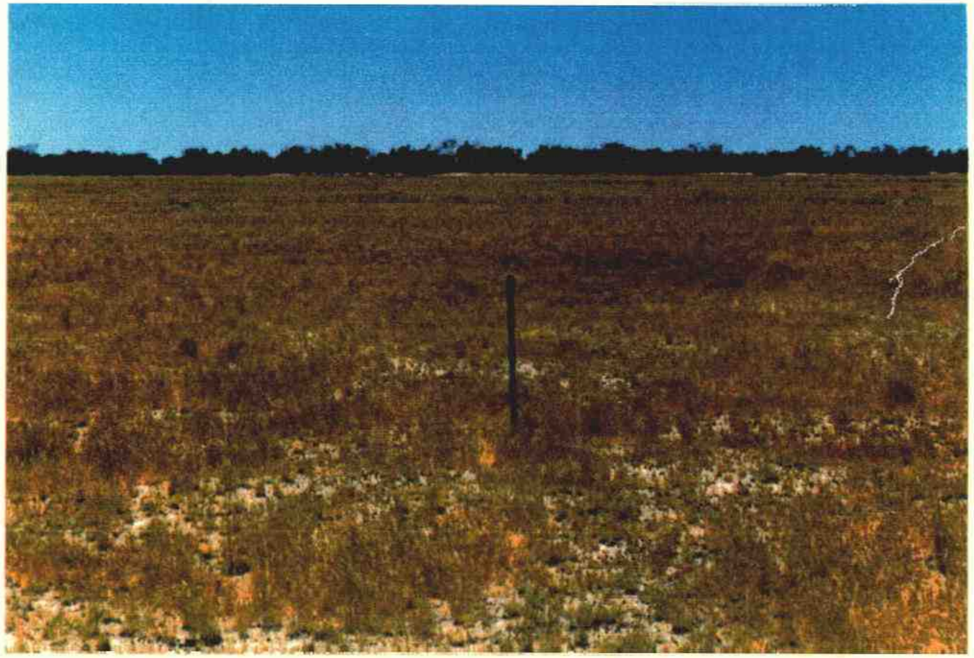



Plate 13 Julian Reid

Photopoint at Permanent Site 13W on Lake Apachirie, taken in November 1986. Note patches of dry grass to left of marker stake.

Plate 14 Jake Gillen

Same photopoint, March 1987, showing new, green growth of annual chenopods after summer rains, and patches of dry grass gone.

Plate 15 Jake Gillen

Same photopoint, September 1987, showing decline of the annual chenopods and the eruption of *Senecio lautus* (variable groundsel).

Plate 16 Jake Gillen

Suta suta, curl snake, a fairly plentiful small snake which favours base-level floodplain habitats, such as L. Apachirie and Emu Flat.

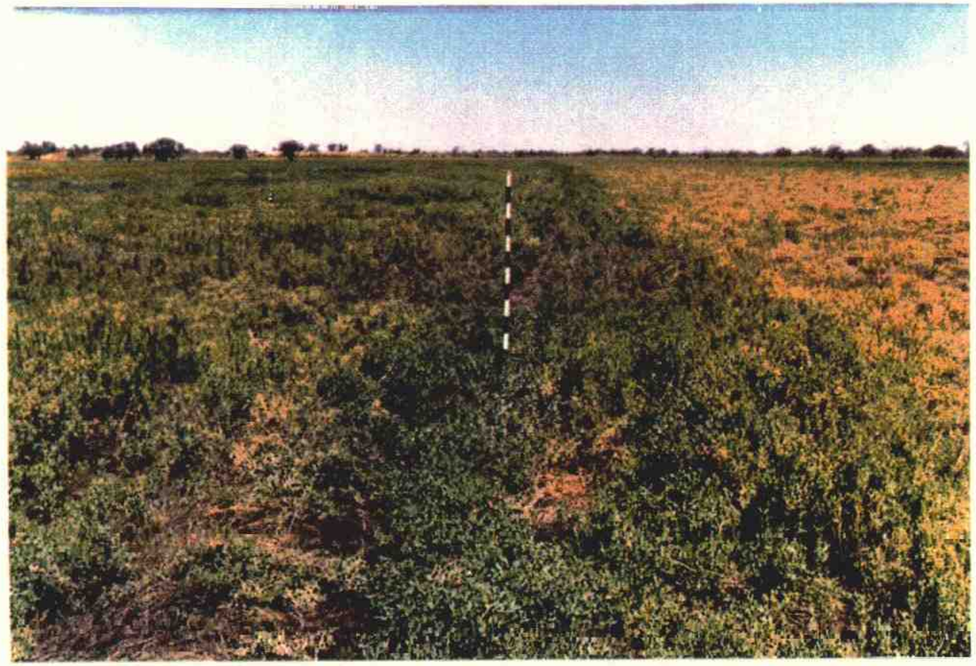



Plate 17 Julian Reid

North-western margin of Coongie Lake at dusk - an important feeding and breeding site for waterbirds.

Plate 18 Jake Gillen

A grassy claypan after heavy summer rains. Prolific grass growth in response to these summer rains was a feature of the district.

Plate 19 Peter Canty

Lysiana exocarpi, harlequin mistletoe - flowers and fruits, an important food source for birds in the region over winter.

Plate 20 Peter Canty

Morgania floribunda, blue rod, a common plant of sandy shores of lakes and ephemeral water bodies in the district.

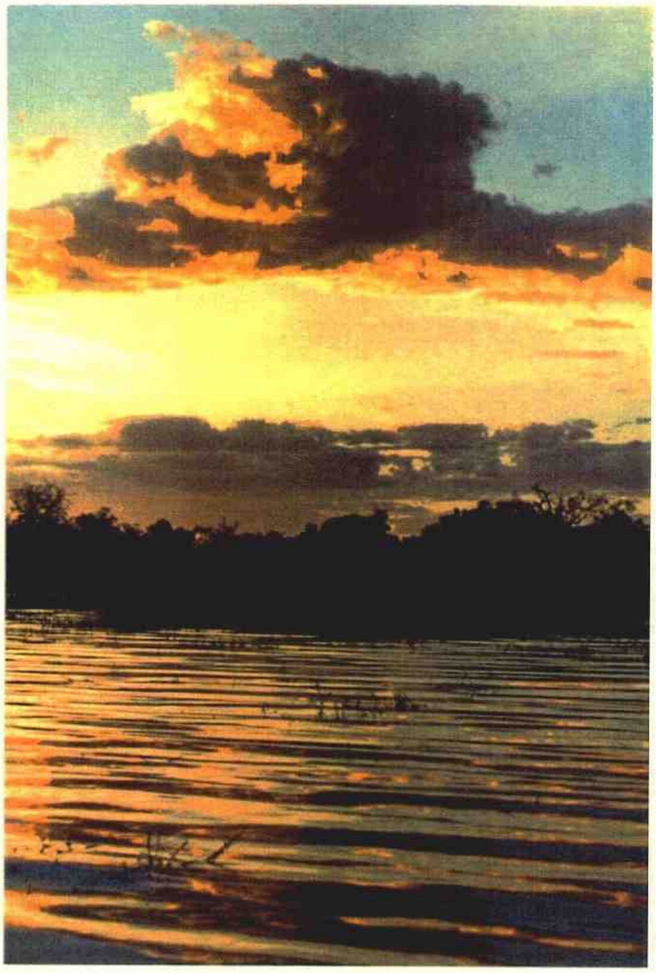
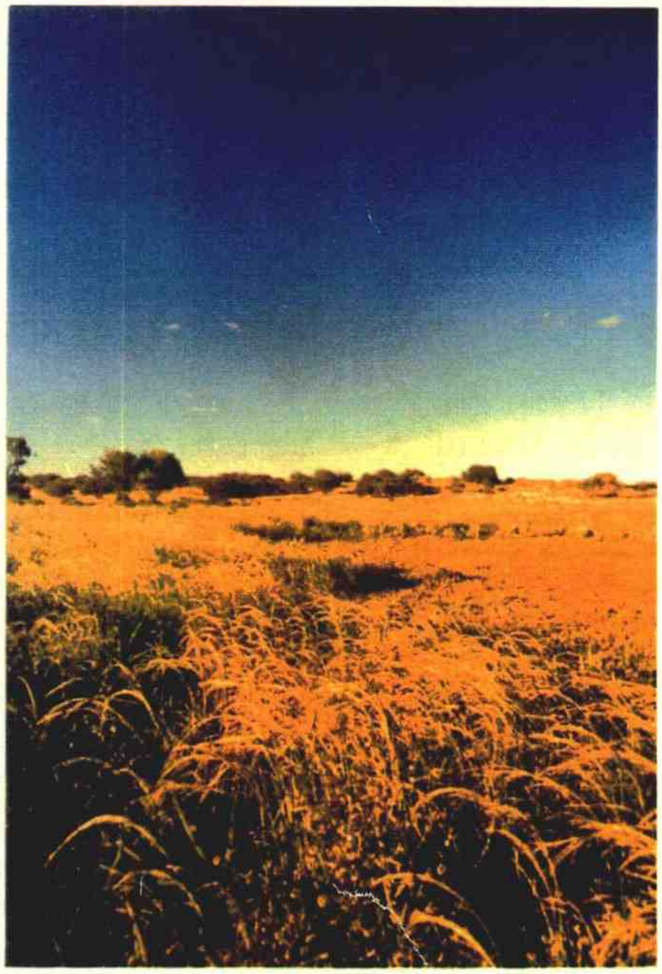



Plate 21 Jacquie Gillen

Vehicle tracks through an Aboriginal midden atop a dune - a typical example of the frequent damage to archaeological sites caused by unthinking visitors as they drive over dunes to gain access to lakes. This (unwitting) vandalism is a consequence of lack of information and management.

Plate 22 Jacquie Gillen

An example of an area that has become devoid of vegetation through heavy cattle activity in the vicinity of Leap Year Bore.

Plate 23 Jake Gillen

A cluster of nests of the Fairy Martin attached to the trunk of a coolibah. The nests are made of mud, collected by the beakfull, which the birds then daub on bit by bit - see Plate 27.

Plate 24 Peter Canty

The pupa case of the Lesser Wanderer butterfly attached to a sandhill canegrass stem - see Plates 25 & 26 for other life-cycle stages.

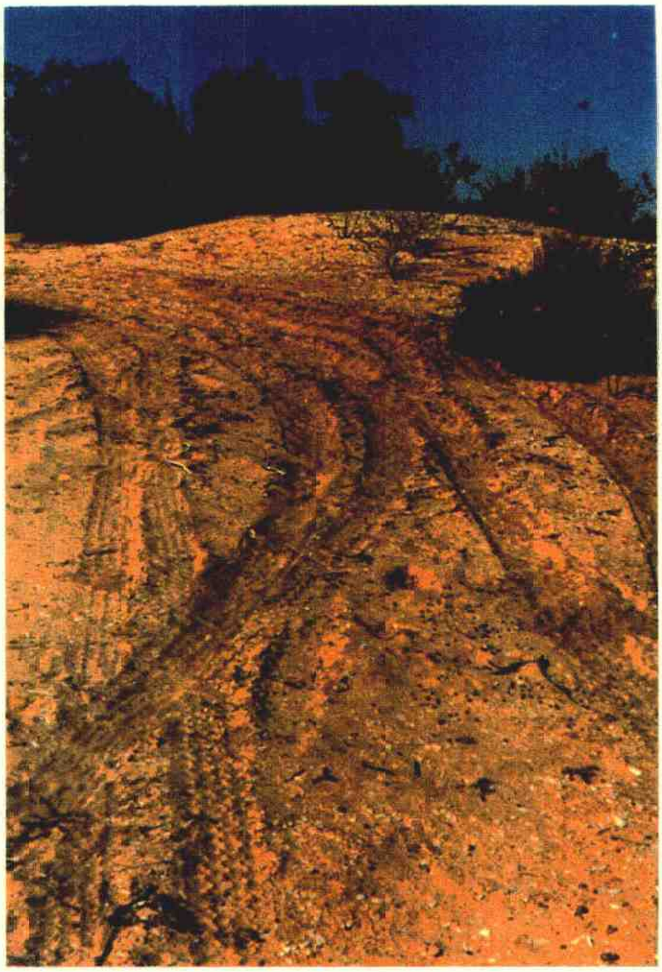
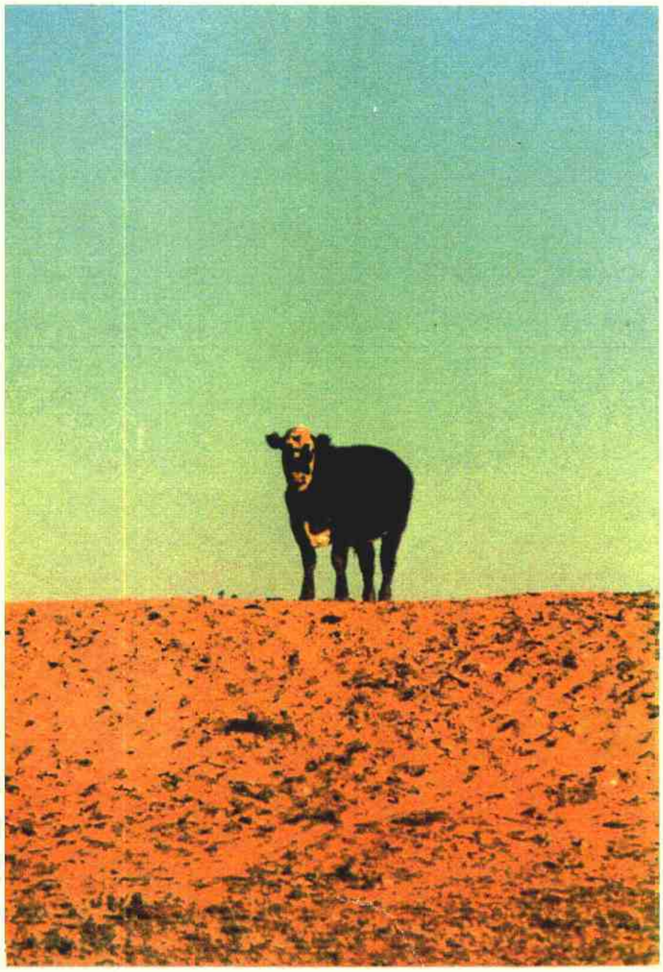
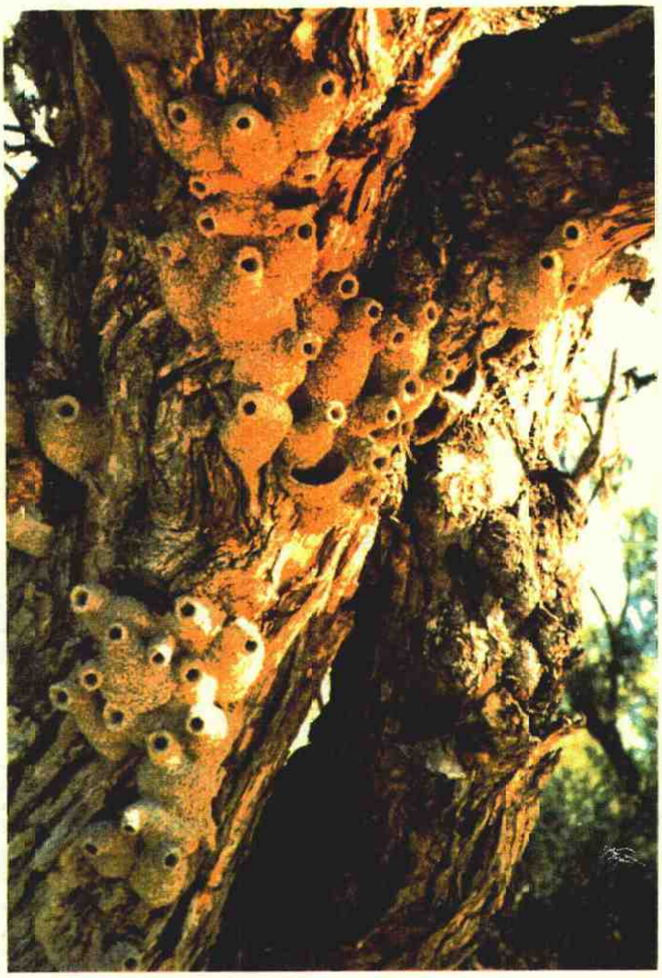
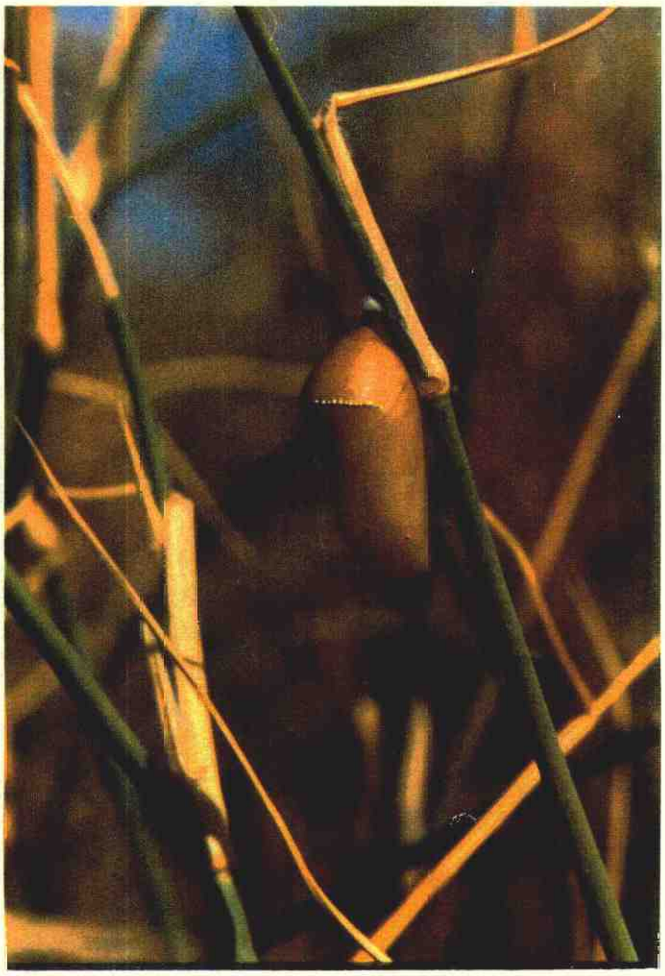





Plate 25   Peter Canty

Larval stage (caterpillar) of the Lesser Wanderer on the fruit of its principal food-plant *Cynanchum floribundum*, a native pear, a common plant of degraded dunes close to water.

Plate 26   Peter Canty

Adult Lesser Wanderer on flower of *Cynanchum*.

Plate 27   Jake Gillen

Fairy Martins collecting mud at the water's edge of Lake Toontoowaranie. They were building their colonial nests nearby in a coolibah (see Plate 23).

Plate 28   Jake Gillen

An Australian Bustard, an easy prey for the "sportsman", as the species is reluctant to fly at the approach of a vehicle. The species was seen in good numbers only along the Upper Strzelecki floodplain, with a few scattered individuals seen in the Coongie Lakes District.

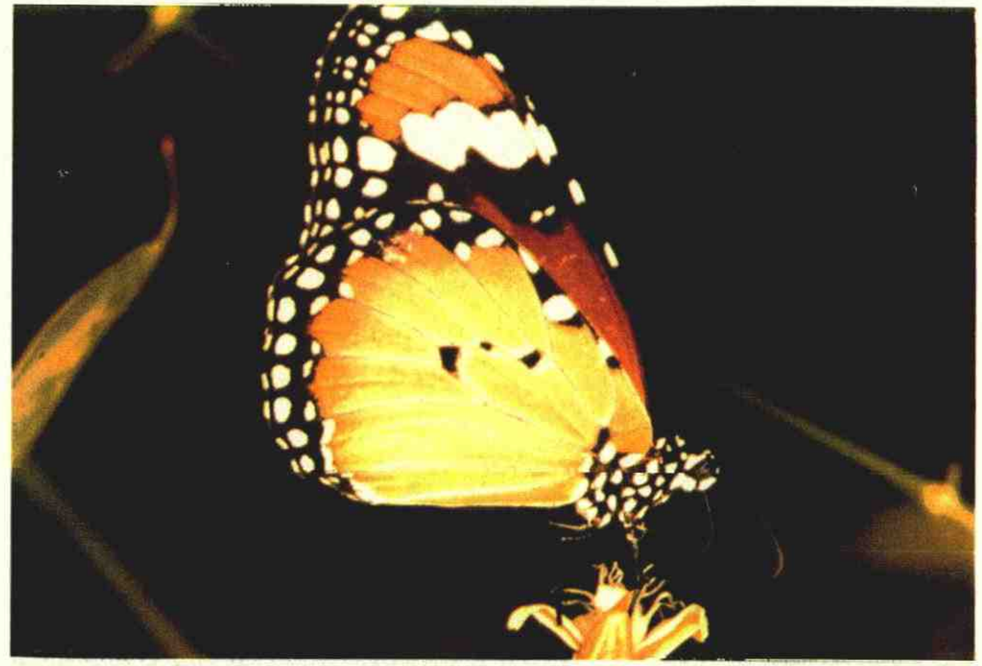


Plate 29 Peter Canty

Ningaui sp. aff. *ridei*, ningaui, in its customary habitat of *Triodia* or spinifex. This species had not previously been found in the north-east of South Australia.

Plate 30 Peter Canty

Antechinomys laniger, kultarr, a rare marsupial-mouse, which was encountered only on gibber plains. The long hind feet and tufted tail are characteristics of the species.

Plate 31 Peter Canty

Litoria rubella, desert tree-frog, perched on lignum branchlets along the bank of the North-West Branch.

Plate 32 Peter Canty

Male *Ctenophorus pictus*, painted dragon - a common lizard in sandy habitats throughout the region.

Plate 33 Jake Gillen

An aerial view of Embarka Swamp, a highly significant wetland along the Main Branch of Coopers Creek, which is a major gas producing field. SANTOS has constructed a network of raised embankments to provide year-round access to well-heads, with unknown effects on the Swamp's hydrology and ecology.

Plate 34 Jacquie Gillen

A typical unsightly scene along Coopers Creek around Innamincka after a busy tourist period. The Creek's frontage in the Innamincka District has been highly degraded through a combination of heavy camping and a long history of stock grazing.

Plate 35 Jacquie Gillen

Chainsaw cuts are now a common sight in the Coongie District. The use of fire has led to a severe depletion of the district's timber resources, causing habitat loss and visual degradation.

Plate 36 Peter Canty

The use of outboards along the North-West Branch and in the lakes, as shown by these irresponsible visitors, is causing multiple problems for wildlife and the environment in general e.g. bank erosion, disturbance of breeding birds, as well as unsettling other people in the district.


EXPORT

Plate 37 Lee Heard

The camel, an exotic herbivore is present in small numbers in the district. This animal was found on a low dune fringing the western shore of Lake Goyder. Feral horses and camels are having an impact on the district's flora.

Plate 38

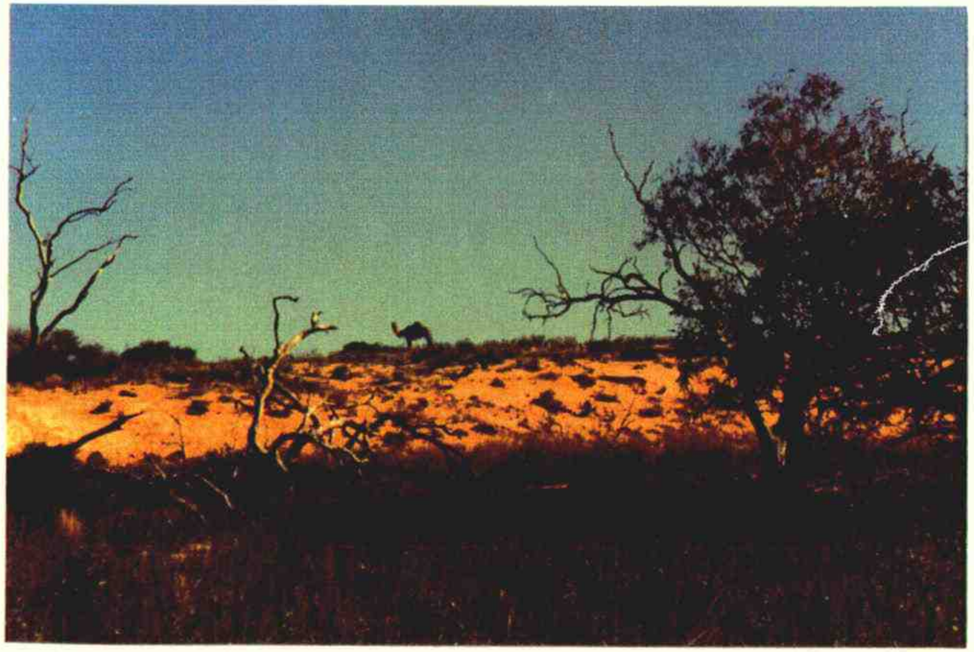
Emydura sp. - an undescribed species of river tortoise confined (endemic) to the Cooper Creek system of South Australia and adjacent Queensland, was found to be common in the Coongie Lakes.

Plate 39 Jake Gillen

Calostemma luteum, the beautiful yellow garland lily, had not been collected in the region since 1888. It sprang up (from bulbs) in some profusion following the heavy summer rains. These lilies are growing on the south-western shore of Coongie Lake amidst coolibahs.

Plate 40 Jake Gillen

A parakeelya, *Calandrinia* ?*remota* growing on red sands in the Marqualpie District.



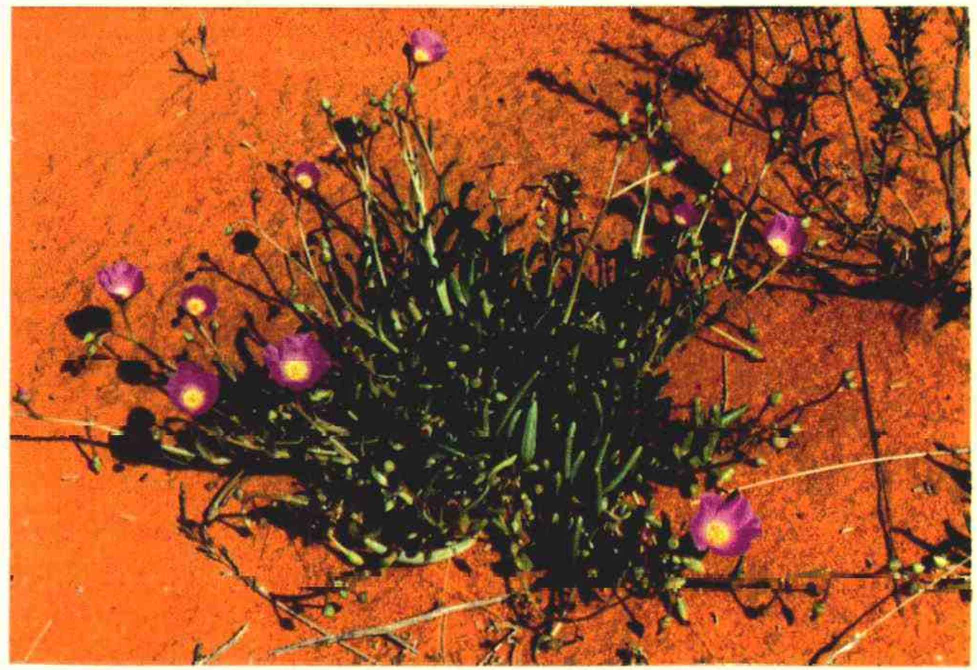


Plate 41 Lee Heard

A family party of Brolga (pair with last season's young) in a flooded samphire claypan adjacent to Lake Toontoowaranie.

Plate 42 Peter Canty

A dingo surveying her domain atop of Koonchera Sandhill in the Goyders Lagoon District (Diamantina River).

Plate 43 Peter Canty

A typical gibber landscape after good rains with a moderate cover of grasses and forbs - some 20 km. north-west of Lake Goyder. Habitat for several distinctive animals including the kultarr (Plate 30).

Plate 44 Jake Gillen

Wild Dog Hill, north of Innamincka. Stony tableland landscape, a habitat which has only been scantily surveyed, biologically.

Plate 45 Jacquie Gillen

The North-West Branch near the campsite early one morning.

Plate 46 Jake Gillen

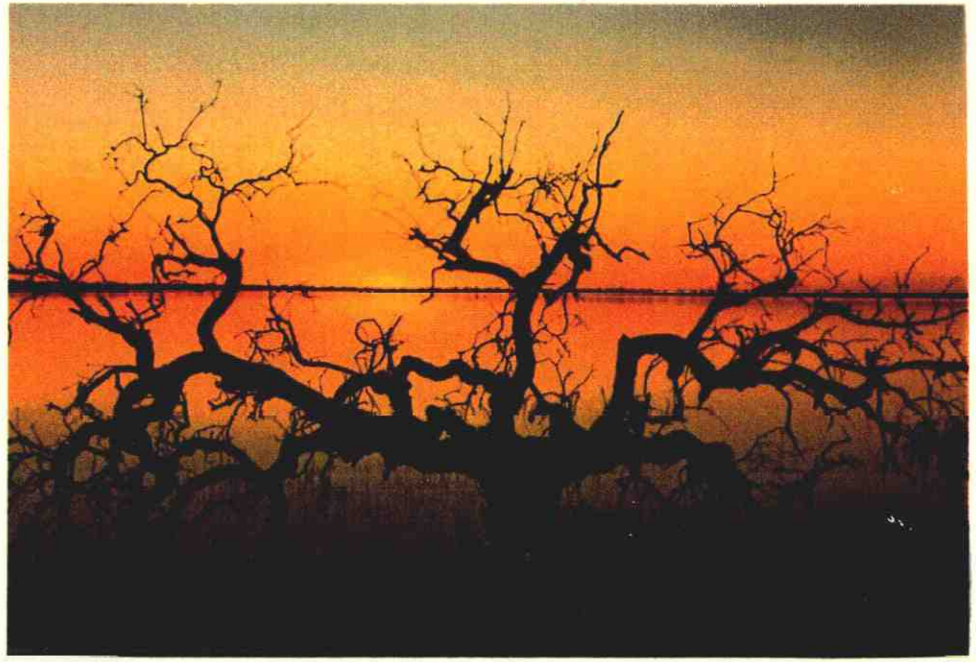
A backwater off the main channel of the North-West Branch near Coongie with fringing coolibah and lignum. Upon flooding, this habitat is important for fish and waterbird breeding events.

Plate 47 Jake Gillen

The North-West Branch near the campsite in winter upon cessation of flow along the river - quickly the mats of duck-weed, *Azolla* spread and cover the channel.

Plate 48 Lee Heard

Sunset on Coongie Lake.



7. MAMMALS, REPTILES AND FROGS

Julian Reid

7.1 Background and Aims

The studies of Thompson (in Mollenmans *et al*. 1984), in conjunction with the lists and reviews presented in ERPG (1980), Forrest (1982), James (1982) and Turner (1982), had revealed the range of mammals, reptiles and frogs occurring in the region, and therefore likely to be encountered in the Coongie Lakes District. As these animals had been studied only casually in the Coongie district, the first aim of this component of the study was to establish the presence of species in the district.

Because of the longer period of this survey, compared with previous biological surveys in the region, the unique opportunity of studying the patterns of activity of the animals and how the patterns of activity, distribution and abundance change through time was afforded (the hallmark of a truly ecological survey - Braithwaite 1985). A related aim was to gather basic ecological data, on abundance, habitat preferences, breeding periods, and relate the information to environmental changes or events over the year (e.g. temperature, rainfall and hydrology).

An overall project goal was the documentation of those features of the Coongie Lakes Environment that made the area biologically significant or "unique" (refer to project brief - Appendix 1.1). Therefore it was considered necessary to undertake short surveys in the wider region for comparative purposes. It was realized, however, that because the majority of research would be undertaken in the Coongie district, comparisons would have to rely substantially on previously published information.

7.2 Methods

A variety of standard techniques, available to detect the presence of mammals, reptiles and frogs, was employed over the year at Coongie, including pitfalling, Elliott box and wire cage trapping, spotlighting, active search (in litter, under bark and rocks, in hollow or fallen timber, digging up burrows), mist-netting and harp-trapping (for bats), examination of tracks, scats and owl pellets, and general observation/listening. Pitfalling was considered to be the only suitable technique for both trapping a wide range of the smaller mammals, reptiles and frogs, and gathering comparable, quantitative information through the year to enable seasonal patterns to be discerned.

Pitfalling is recognized to be the most effective way of sampling, in a standardized manner, the small, terrestrial mammals and reptiles in the arid zone (e.g. Howe et al. 1984). Pitfall lines consist of a series of cylindrical containers (open at the top), dug into the ground so that the top of the trap or pot lies flush with the ground surface, which are joined by a length of "drift-fence" (flywire to a height of c. 25 cm), which passes over the middle of each pot (Plate 7).

Two pitfall lines, each comprising five pots spaced 10 m apart, were established at 28 of the 30 permanent sites (see Chapter 2) in December 1986 (eastern sites) and January 1987 (western). At Site 1E, three lines (4,3 and 3 pots) were established, while Site 3E was inundated in the early stages of the project and could not be established. Thus 10 pitfall traps were used at 29 sites, enabling trapping results to be directly compared between sites and between trapping events.

Two sized pots were used. Their depth was c. 45 cm, with the larger pots having a diameter of 22 cm and the smaller pots 16 cm. With two exceptions, each site had an equal complement of pot sizes.

As detailed in Chapters 2 & 6, the permanent sites were selected to encompass the range of habitats within the district, with the major or especially significant habitats being represented at a number of sites. Site selection was therefore subjective, and their location reflected ease of access, while sites considered to be in "good" condition or intrinsically "rich" (by virtue of structural/floristic complexity, or presence and vigour of Triodia or Zygochloa say, or presence of deep cracks in the ground) were searched for and chosen, and a disproportionately large number of sites were in vegetation types with a cover of perennial plants greater than customary in the district. The sites were trapped six times during the year, and the following details were generally recorded for each animal captured : species, sex, age (adult, sub-adult or juvenile), weight of mammals, snout-vent length of reptiles, reproductive state, and any other pertinent details. A unique number was assigned to individuals of most species, by clipping the terminal joint of one or two digits, allowing a trapping history to be constructed for each individual over the study. The year's capture data were pooled at each site and cluster analysis (UPGMA) performed by A. Sparrow (Adel. Univ.) to reveal patterns of animal distribution and community composition.

The larger terrestrial animals were not trapped in pitfalls, and were consequently not studied in the same detail. General notes on their abundance and behaviour were made as opportunities arose e.g. while spotlighting, on the basis of vocalizations, or observations during the day. Because it was conceivable that certain smaller terrestrial mammals may also have eluded capture in pitfall traps through behavioural or locomotory traits (e.g. hopping-mice Notomys spp.), the other trapping or search techniques were employed. In particular, lines of baited Elliott traps were set in dunes, in an attempt to catch hopping-mice or mulgaras Dasycercus cristicauda.

An intensive bat-trapping survey was carried out by C. Kemper and W. Head of the S.A. Museum in early May. Spotlighting, use of mist-nets and harp-traps and opportunistic methods were used during and prior to this period.

The (semi)aquatic water rat Hydromys chrysogaster and tortoise Emydura sp. were observed and/or trapped casually or when appropriate conditions prevailed. Frogs were occasionally trapped in pitfalls, but their presence and relative abundance was readily assessed after periods of heavy rain or flooding by listening to their chorus and actively searching for them.

Voucher specimens of most species were collected over the course of the study and lodged with the museum, with identifications made or verified by C. Kemper (mammals), G. Armstrong (reptiles) and M. Tyler (frogs).

7.3 **Findings**

7.3.1 Species Recorded

Twenty native mammals, eight introduced mammals, 36 species of reptile and eight frogs were positively recorded by the study team over the survey period. For the Coongie Lakes District, the figures are 17, 8, 32 and 7 (probably 8) respectively (see Table 7.1). Specimen evidence exists for all but the larger species, and the specimens have been deposited with the S.A. Museum (details in Vol. II). In addition to these definite records, a number of additional observations were made (either by the contractors or reported to them) which require comment or qualification (see Table 7.2).

Mammals

A number of the species recorded are highly significant and they are discussed below.

1. The eight individuals of Ningaui sp. aff. ridei constitute the first records of the genus from the State's North East region. They were all captured in pitfall traps at Site 14W on a spinifex-clad dune. Spinifex communities comprise the customary habitat for the genus (from Strahan

1983). Preliminary examination of the three collected specimens lead Dr Kemper (Curator of Mammals, S.A. Museum, pers. comm.) to believe that they belong to a morphologically distinct and as yet undescribed population of Ningaui, but further material (including tissues and blood for biochemical analyses) is required. Dr Kemper is continuing her investigations. N. ridei is classified as rare in South Australia (Kemper 1985).

2. The 10 individuals of Planigale tenuirostris captured are the first recorded in the Cooper Creek region in South Australia, although the species is known from adjacent regions in this State (P. Bird pers. comm.), N.S.W. (Read 1982) and Qld (Morton 1982). The species occupies floodplain, lake shore and channel edge habitats in the Coongie district, including areas with only a limited extent of cracking clay. The larger Planigale gilesi, which has previously been recorded in the region by Thompson (in Mollenmans et al. 1984), was not as widespread, and more restricted to deeply cracking clay habitats such as Lakes Apachirie (13W) and Mundooroounie (15E). At the former site, the species was locally common at some times of the year, with nine individuals being caught there over three nights in early May. Both species of planigale are considered to be rare in the Cooper Basin region (ERPG 1980).

3. Of the six species of bat encountered, the Yellow-bellied Sheath-tail Saccolaimus flaviventris is rare in South Australia (Kemper 1985). One specimen was collected and others spotlit at Coongie in May, and this date is consistent with Reardon and Flavel's (1987) observation that the species is an autumn visitor to the State (presumably from northern Australia?). Based on aural clues - the species is one of the few South Australian bats to emit echo-location sounds that are readily detectable by humans - the species was present around the base-camp through to July.

4. The four captures of Forrest's Mouse Leggadina forresti were made in a variety of habitats, namely upper dune slope (5E), sandy plain/interdune at the margin of a saltlake (15W), an ephemeral lake-bed (15E) and a floodplain with a cover of low chenopods (8W). It is rare in the district, and wider region (Thompson in Mollenmans et al. 1984), and is classified as rare in the State (Kemper 1985).

5. A single female long-haired or plague rat Rattus villosissimus (a native species) was caught in a pitfall at Site 8E. Redhead (in Strahan 1983) considers the species to be usually rare in Australia as a whole, but after exceptionally wet periods in the Centre, can plague in great numbers (Watts and Aslin 1981), and was found to be common at Coongie in 1975 (Forrest 1982). Somewhat surprisingly, a plague did not eventuate in the region in 1986/87, after an eighteen month period of very high rainfall (e.g. 462 mm at Innamincka Store between May 1986 and October 1987, M. Steel pers. comm.). Between plagues, the species distribution shrinks to small pockets in perennially damp locations within the Channel Country, and it is surmised that the Coongie Lakes may be such a refuge for the species. Since the last great plague of the mid 70's, a small irruption is known to have occurred around the northern shores of Lake Goyder in c. 1985 (personal communication from a professional rabbiter in the district), while a similarly localized population build-up was observed in the Koonchera - Pandiburra Bore district in June 1984 (unpub. data).

Another four native species (Notomys alexis, Pseudomys hermannsburgensis, Sminthopsis crassicaudata and S. macroura) and the introduced House Mouse Mus musculus were caught, and the Coongie Lakes District was thus shown to have a rich small mammal fauna. Their patterns of distribution and abundance are treated in a subsequent section.

Table 7.1

List of mammals, reptiles and frogs recorded in the Coongie Lakes District and wider region

A: C- Coongie Lakes District
X- not recorded in the district

B: Districts from which species recorded in the wider region.
K- Koonchera District
I- Innamincka District
G- an area of Gibber c. 25 km NW Lake Goyder
W- widespread

C: Mammals classified as rare (R) in South Australia by Kemper (1985)

*: exotic species

Mammals	A	B	C
Antechinomys laniger	X	K,G	R
Dasyuroides byrnei	X	K	R
Ningaui sp. aff. ridei	C		R
Planigale gilesi	C		
Planigale tenuirostris	C		
Sminthopsis crassicaudata	C	W	
Sminthopsis macroura	C	W	
Macropus rufus	C	W	
Hydromys chrsogaster	C		
Leggadina forresti	C		R
*Mus musculus	C	W	
Notomys alexis	C		
Notomys cervinus	X	K	R
Pseudomys hermannsburgensis	C	G	
Rattus villosissimus	C		
Saccolaimus flaviventris	C		R
Mormopterus planiceps	C		
Tadarida australis	C	W	
Chalinolobus gouldii	C		
Nyctophilus geoffroyi	C		
Scotorepens greyii	C		
*Oryctolagus cuniculus	C	W	
*Canis familiaris dingo	C	W	
*Vulpes vulpes	C	W	
*Felis catus	C	W	
*Equus caballus	C		
*Bos taurus	C		
*Camelus dromedarius	C		

Reptiles	A	B
Emydura sp. (undescribed species)	C	I
Ctenophorus nuchalis	C	
Ctenophorus pictus	C	
Diporiphora winneckei	C	
Gemmatophora gilberti	C	I
Pogona vitticeps	C	W
Tympanocryptis intima	X	G
Tympanocryptis lineata	C	K
Tympanocryptis tetraporophora	X	I
Diplodactylus byrnei	X	K
Diplodactylus intermedius	C	
Diplodactylus tessellatus	C	
Gehyra variegata	C	W
Heteronotia binoei	C	
Lucasium damaeum	C	
Nephrurus levis	C	
Rhynchoedura ornata	C	
Delma tincta	C	
Cryptoblepharus plagiocephalus	C	
Ctenotus brooksi	C	
Ctenotus leae	C	
Ctenotus regius	C	
Egernia stokesii	X	I
Eremiacsincus fasciolatus	C	
Lerista aericeps	C	
Lerista labialis	C	
Menetia greyii	C	
Morethia adelaidensis	C	
Morethia boulengeri	C	
Tiliqua multifasciatus	C	
**Varanus gouldii	C	W
Aspidites ramsayi	C	
Pseudechis australis	C	
Pseudonaja nuchalis	C	I
Suta suta	C	W
Ramphotyphlops endoterus	C	

Frogs	A	B
Cyclorana platycephalus	C	G
Cyclorana sp. (undescribed sp.)	C	
Litoria caerulea	?C	I
Litoria latopalmata	C	I
Litoria rubella	C	I
Limnodynastes tasmaniensis	C	I
Neobatrachus centralis	C	W
Ranidella deserticola	C	

** a second species, V. tristis, considered rare in S.A. (G. Armstrong pers. comm.) was located at Lake Toontoowaranie in February 1988.

Table 7.2

Species possibly observed by or reported to the study team during the survey period. The mammal records in particular are speculative.

Mammals	A	B
Dasycercus cristicauda	?C	
Macropus robustus	X	?I
Pseudomys australis	X	?I

Reptiles	A	B
Ctenotus strauchii	X	I
Liasis childreni	X	I (M. Steel pers. comm.)
Acanthophis pyrrhus	X	Moomba (R. Kidd pers. comm.)

P. australis is classified as rare in the State (Kemper 1985). Of "Indeterminate" status are D. cristicauda (Kemper 1985) and L. childreni (Schwaner and Tyler 1985).

6. In the wider region which was investigated, a further three small mammals were captured - all rare in South Australia (Kemper 1985), and all found on the gibber plains to the north-west of Coongie. Three individuals of Kowari Dasyuroides byrnei, one fawn hopping-mouse Notomys cervinus, and about 10 Kultarr Antechinomys laniger were spotlit at Koonchera (the three species), and c. 35 km south-east of Koonchera and c. 20 km north-west of Lake Goyder (Kultarr only). Additionally, Ian May (NPWS, pers. comm.) reported seeing three Kowaris at the second locality in late 1986.

Larger mammals recorded were:

red kangaroo - sparse generally in the region, and only two individuals were sighted in the Coongie Lakes District (coolibah woodland on a dry lake-bed, c. 3 km west of Coongie Yards in August);

water rat - a moderately common animal in the main lakes and three main channels of the district, although its presence was not confirmed in Lake Goyder or beyond;

seven exotic animals, of which the rabbit was the most abundant. Dingos were consequently common, and cats and wild horses were fairly plentiful. Foxes, feral cattle and camels were all scarce.

Another seven species are known from either within the region (in recent years) or closely adjacent regions, while it is not improbable that the brush-tailed possum and Mulgara will be rediscovered and the marsupial mole discovered in the region.

In the past 20 years, the echidna, plains rat Pseudomys australis, inland eptesicus Eptesicus baverstocki and dusky hopping-mouse Notomys fuscus have been recorded in the Far North East, while the euro, hairy-footed dunnart Sminthopsis youngsoni and bilby Macrotis lagotis are known from adjacent Queensland districts. The bilby and dusky hopping-mouse are endangered in Australia (Burbidge and Jenkins 1984). Although the bilby is probably locally extinct in the Cooper Creek region (indeed it is considered to be extinct over the whole State - Kemper 1985), the hopping-mouse has been recorded at several localities along the Strzelecki Creek (Aitken 1968), with another exciting discovery having recently been made there (B. Luxton pers. comm.). With similar habitat occurring along the Cooper (and within the Coongie district), further research may reveal its presence. As the bilby occurs just across the border in the vicinity of Birdsville, it is hoped that the species may yet be rediscovered in suitable habitat on Pandie Pandie or Cordillo Downs Stations to the north of the Cooper Creek Environmental Association.

The Mulgara (status indeterminate in S.A. - Kemper 1985) inhabits sandplain and dunefield country in the Northern Territory where the species is moderately common (Gibson and Cole 1987). It was recorded from the eastern margin of the Simpson Desert in South Australia earlier this century (Wood Jones 1923), and the last specimen deposited in the S.A. Museum was taken in 1965 from Lake Eyre South (C. Kemper pers. comm.). Woolley (in Strahan 1984) states the species was last recorded in the State in 1969, although the provenance of this record is unknown. The hairy-footed dunnart, with similar habitat preferences, has yet to be found in South Australia. However, Dr Kemper (pers. comm.) has recently handled a specimen from the vicinity of Birdsville, while Gibson and Cole (1987) encountered the species in their N.T. Simpson Desert survey. Both species may occur in the Cooper Creek region, and sandy areas having a good cover of spinifex should be investigated further. Although no solid evidence of either species existence was gathered during the survey, the occasional tracks of a mammal considered to be larger than a dunnart were seen in the dunes around Coongie. The tracks' size was consistent with a Mulgara sized animal. The highly cryptic marsupial mole, another inhabitant of central Australian sandy environments, may also occur within the region, but the chances of detecting the animal will always be remote.

The echidna, plains rat and euro are perhaps unlikely to be encountered in the Coongie Lakes District or the Cooper Creek Environmental Association area, because of their preferences for stony or hilly habitats within the arid zone. Suitable habitat exists in the wider region, and the first two species have been found at Innamincka - Mike Steel recalls (pers. comm.) seeing a couple of echidnas along the Cooper there in the early 70's, while there are specimen records of the plains rat (SAM, unpub. data). The plains rat is rare in South Australia (Kemper 1985) and Dr W. Breed (pers. comm.) has expressed grave concern for the species survival in the wild, as the last known record dates from 1974 (Corbett <u>et</u>

al. 1975). The species habitat preference is gibber plain of the Lake Eyre Basin (Watts and Aslin 1981). An observation of interest, therefore, made at the end of the December fieldtrip, as the convoy of four vehicles and trailers was pulling out of Innamincka, is recounted. A small "rat" (estimated to be half the size of a common rat, with sleek-haired appearance) bounded across the road in rolling gibber habitat in front of the vehicle, and then crouched behind a road-side rock as the vehicle passed. Regrettably, the author did not stop to investigate the animal further (not wishing to halt the progress of the convey on its homeward leg), but he is certainly left wondering!

The echidna is likely to remain in the region, despite the absence of records in the last 15 years, and the small caves and overhangs which occur on some of the larger hills in the country north of Innamincka (e.g. Table Hill) are logical places to search. During the study, Jake Gillen observed kangaroo dung in such a cave near the summit of Table Hill, and although the euro has apparently never been recorded in the Far North East, it is a more likely occupant of such habitat than the plains dwelling red kangaroo. ERPG (1980) raised the possibility of the euro's occurrence in the Cooper Basin.

The brush-tailed possum was formerly common along Coopers Creek and Tolcher (1986) reveals that many thousands were trapped there in the early half of the century. However, there are no recent sightings or specimens from the region, and Aslin (1984) has described how the central Australian form has vanished from much of its former range. Gibson and Cole (1987) regard it as having become recently extinct (last 15 years) in the greater Simpson Desert region. Its rediscovery, some five years ago, in the Tanami Desert (Gibson 1985) affords some hope for the species survival in other parts of its central Australian range. Certainly no signs of the species presence was detected over the year, its dung was looked for in the Cooper's riparian woodlands without success, while no sounds, that could be attributable to the generally vocal possum, were heard.

A number of other species have become extinct in the region - animals of a similar size to the possum and bilby. The early historical record is too sketchy to be sure which species originally occupied the Cooper Creek region, but the demise of two or more rat-kangaroos, bandicoots and small wallabies is thought to be involved (see James 1982).

Reptiles

Of the 36 reptile species recorded in the region (probably 37 - the identification of a specimen of Ctenotus strauchii from Innamincka is awaiting confirmation), 32 species occur in the Coongie Lakes District (see Table 7.1). Thirty-seven species were identified during the NPWS survey of the Cooper Creek Environmental Association in 1983 (Thompson in Mollenmans et al. 1984), while Thompson listed another 10 species which occurred in the region, or closely adjacent, on the basis of S.A. Museum records. In fact an additional seven species have been recorded from the Cooper Creek region (upstream of the Birdsville Track) in South Australia (Houston 1978, ERPG 1980, Turner 1982, this survey), bringing the tally to 54 species, while there is a specimen of the collared whip-snake Demansia torquata from Coopers Creek, just the Queensland side of the border (Longmore 1986). These additional species and the more significant finds of the study are discussed below.

The records of Gilbert's Water Dragon Gemmatophora gilberti from the Coongie district (December, February and June) establish the species presence within the Environmental Association 8.4.4. It has a very restricted South Australian range (Houston 1978), being confined to the more permanently watered portions of the Cooper. The records of the smooth earless dragon Tympanocryptis intima (gibber, 25 km north-west of Lake Goyder), lined earless dragon Tympanocryptis lineata (Coongie and Koonchera) and gidgee skink Egernia stokesii (Innamincka) are additional to the earlier records from the region (reviewed by Houston 1978, ERPG 1980) - these species were not presented in the list compiled by Thompson (in Mollenmans et al. 1984). ERPG (1980) had also indicated the presence of red-naped snake Furina diadema and Ctenotus helenae (and see Turner 1982) within the Cooper Basin. The specimen of red-naped snake was collected (G. Armstrong pers. comm.) along the Cooper, c. 5 km west of Innamincka.

Mike Steel (pers. comm.) reported a children's python Liasis childreni at Innamincka in December 1986 (and see ERPG 1980), while a desert death-adder Acanthophis pyrrhus was found at Moomba by SANTOS personnel in August 1987 (R. Kidd pers. comm.). Regrettably the specimen was not retained, as there have been few South Australian records, and none from the region under study, although there is a locality record from the adjacent part of south-west Queensland - c. 50 km north of Cadelga Outstation (Longmore 1986).

Two other reptiles of interest recorded during the survey were the undescribed species of Cooper Creek tortoise (considered endemic to the region), and the Centralian blue-tongue Tiliqua multifasciata, the single individual at Coongie in December apparently being only the third State specimen record (see Thompson in Mollenmans et al. 1984).

Thompson (in Mollenmans et al. 1984) referred to an unidentified species of Ctenotus collected by him in 1983. This record (or specimen) has not been investigated, but interestingly, an unidentified Ctenotus (a stout skink of similar appearance to robustus) was seen in gibber habitat (with dense ephemeral cover), c. 15 km south-east of Koonchera in February. Although it was viewed at close quarters, it eluded capture.

The composition of the reptile fauna occurring in the Far North East (east of the Diamantina River) differs significantly from that recorded for the northern Simpson Desert by Gibson and Cole (1987). Both regions have been surveyed reasonably comprehensively in recent years, and it is interesting that the northern Simpson Desert (with less survey effort) has a richer fauna - 60 species. As observed earlier, the two regions have a similar array of habitats in terms of the land zones (after Purdie 1984) which can be recognized. Gibson and Cole (1987) list 20 species not recorded for the Cooper Creek region in South Australia. With respect to composition by family (see below), the greater richness of the Simpson Desert fauna is accounted for by the number of skinks and varanids, but note the respective numbers of elapid snakes. Examination of the Atlas of Australian Elapid Snakes (Longmore 1986) reveals the likelihood of several of the snakes recorded in the Cooper region, but not in the northern Simpson, actually occurring in the latter region.

	Northern Simpson NT	Cooper Creek SA	Species in Common
Chelidae	0	1	0
Gekkonidae	9	10	9
Agamidae	9	9	6
Varanidae	5	2	1
Scincidae	22	17	13
Pygopodidae	5	3	3
Typhlopidae	2	2	1
Boidae	2	2	2
Elapidae	6	8(9)	5
TOTAL	60	54(55)	40

The degree of dissimilarity (c. 35%) between the two faunas, given their virtual adjacentness is surprising, and warrants further study. In particular the South Australian portion of the Simpson Desert requires survey, and the range limits of the pertinent species should be determined. It is likely that a consistent pattern would emerge, indicative of an effective barrier between the Simpson and Strzelecki Deserts (along the present day course of the Diamantina River and spur of Sturts Stony Desert), which could be tested for other animal groups and plants as well. Separate evolutionary histories (biological but therefore physical) may be involved for these structurally very similar dunefield deserts (often mapped as a single physiognomic entity), and Wasson (1983) has presented geomorphologic evidence to support the case for convergence (e.g. different sediment sources).

Frogs

At least seven and probably eight frogs were present at Coongie. This number of species occurring together is significant in itself, constituting the richest frog fauna known within central Australia (M. Tyler pers. comm.). The green tree-frog Litoria caerulea was observed twice (November and July) at Innamincka, but not collected in the Coongie district, but was reliably reported to be there by G. Armstrong, on the basis of calls heard in December. However, of more significance was the collection of an undescribed species of water-holding frog Cyclorana from ephemeral pools at Coongie after heavy summer rains. The species had not previously been found in South Australia (M. Tyler pers. comm.). On the basis of calling activity and of a large number of frogs handled over summer, this species was rare, in contrast to the abundance of the other six species. The species' combined chorus was deafening immediately following the heavy rains in December and February, and this chorus was a feature of the humid nights over the summer period generally.

The collections of *Litoria latopalmata* and *Ranidella deserticolor* were significant, as few previous records in the State existed (Thompson in Mollenmans *et al*. 1984).

7.3.2 Patterns of Activity

Trapping Success

Ten species of small mammal, 27 species of reptile and four species of frog were captured in pitfalls at the permanent sites. The only individual of Centralian blue-tongue encountered was found next to the drift-fence at Site 7E, and is included in subsequent analyses of the pitfalling data. The occasional capture of small rabbits have been ignored for the analysis, as have captures of four species of frog, although the patterns of frog activity are described qualitatively later in this section.

The permanent sites were trapped six times over the year, with the pots open for two to three nights per event. Emu Flat (Site 5W) was not trapped after March, because of flooding of Lake Toontoowaranie, one line at 11E was used only once (December) for the same reason (Lake Coongie), while rarely lines could not be opened through the year as a consequence of localized flooding after heavy rain. Total pitfalling effort over the year at Coongie was 4 515 pot-nights (the sum of all occasions on which any pot was open for a night/day).

Elliott (and cage) traps were not used systematically, but were deployed casually at permanent sites and in other areas/habitats. Their use was not rewarding, with two species of mammal being caught (a large number of house mice and three sandy inland mice). Neither the use of Elliotts nor pitfalls (240 pot-nights) in other parts of the Coongie Lakes District, or the wider region, yielded species of reptile or mammal additional to those trapped in pitfalls at the 29 permanent sites. This is largely a reflection of the greater trapping effort invested at the permanent sites. Likewise the examination of owl pellet material from Coongie did not reveal the presence of additional mammal species (C. Kemper pers. comm.). However, an additional three species of small mammal, and (probably) five reptiles were detected away from Coongie, using active search techniques, and serves to illustrate the importance of using a range of techniques.

The return, from 4 515 pot-nights at the permanent sites was the capture of 876 reptiles and 691 mammals (including some captures of the same individual between but not within trapping sessions), i.e. a 19.4% and 15.3% success rate respectively. By comparison, the 740 Elliott-nights yielded 40 mammal captures (and two reptiles) at the permanent sites for a 5.4% success rate. These figures can be compared with the results gained by Thompson (in Mollenmans et al. 1984) in the Cooper Creek region for mammals, and with those of Kemper et al. (1985) in the Mabel Creek district for reptiles - neither report gives the appropriate data for the other animal group. Thompson recorded a 4.3% success rate for pitfalls (and 1.0% for baited box-traps), and so it would appear that mammals were far more abundant in the Coongie district in 1987 than they were in the wider Cooper Creek region in the latter half of 1983, when conditions were generally dry after a severe drought (Badman 1988). The success rate for reptiles in pitfall traps at Mabel Creek was a staggering 68% (calculated from data presented in Kemper et al. 1985), a figure which is almost double that of the maximum reptile capture rates obtained at Coongie in December 1986 (38% for all eastern sites) and February 1987 (39% for all western sites) - refer to Table 7.3. This difference is perhaps attributable to the much richer reptile fauna of the western arid region of Australia (illustrated by Cogger 1984), and it would be ecologically interesting to know if this trend is persistent in the longer-term, with regard to species packing - niche theory and associated increased productivity/standing crop (i.e. abundance of reptiles).

Alternatively, the highly successful pitfalling event at Mabel Creek may have been more a function of particularly favourable local conditions, propitious trapsite selection (e.g. greater effort in richer dunefield habitats), or the dimensions and spacing of pitfall traps.

The mammal capture rates can also be compared with those of recent surveys in the Nullarbor, Eastern Goldfields and Great Sandy Desert regions (data presented in McKenzie and Robinson (1987), and the Simpson Desert (Gibson and Cole 1987). For the three former surveys, the figures are 2.9%, 10.9% and 11.6% respectively, while although Gibson and Cole do not give an overall survey average, figures for each of their four fieldtrips are presented viz 5.0%, 8.0%, 14.2% and 20.8%. These figures can be compared with the Coongie data presented in Table 7.3, where trap success varied between 8.4% and 26.7% for the average of 15.3%.

Table 7.4

Total captures and capture rates (expressed as percentage of no. of pot-nights) of mammals (M) and reptiles (R) for east (E) and west (W) permanent sites over all sessions on successive nights of trapping (three nights).

		E		W		All Sites	
		R	M	R	M	R	M
FIRST NIGHT	Pot-nights	670		825		1495	
	No. Caught	98	116	119	166	217	282
	% Success	15	17	14	20	15	19
SECOND NIGHT	Pot-nights	670		825		1495	
	No. Caught	124	74	159	112	283	186
	% Success	19	11	19	14	19	12
THIRD NIGHT	Pot-nights	445		610		1055	
	No. Caught	104	30	95	85	199	115
	% Success	23	7	16	14	19	11
ALL NIGHTS	Pot-nights	2255		2260		4515	
	No. Caught	503	328	373	363	876	691
	% Success	22	15	17	16	19	15

Table 7.5

Number of individuals of small mammals trapped at east and west permanent sites during each trapping session (first two letters of the generic and specific names used to denote the species)

	EAST (9 spp)							WEST (8 spp)						
Species	Dec	Mar	Apr	Jun	Jul	Sep	Tot	Jan	Mar	May	Jun	Jul	Sep	Tot
Le fo	1	1					2		1		1			2
Mu mu	26	18	8	18	16	17	103	20	26	42	16	17	15	136
Ni ri							0	1		2	3		2	8
No al				3			3							0
Pl gi		1	1				2	1	1	9	1			12
Pl te						2	2	1	0	3	2	1	1	8
Ps he	55	23	18	11	11	6	124	4	2	20	5	7	12	50
Ra vi			1				1							0
Sm cr	4	2	3	7	4	4	24	11	10	21	5	12	5	64
Sm ma	22	12	5	4	6	4	53	15	11	16	5	2	8	57
Total	108	57	36	43	37	33	314	53	51	113	38	39	43	337
No. Spp	5	6	6	5	4	5		7	6	7	8	5	6	

Table 7.6

Number of individuals of reptiles trapped at east and west permanent sites during each trapping session

	EAST (26 spp)							WEST (25 spp)						
Species	Dec	Mar	Apr	Jun	Jul	Sep	Tot	Jan	Mar	May	Jun	Jul	Sep	Tot
Cr pl	5	1				1	7						1	1
Ct nu	2		1				3	1					1	1
Ct pi	2	4	6		4	6	22	7	4	3	11	2	7	34
Ct br	20	10	6	5	2	8	51	16	9	8	9	2	10	54
Ct le				1	2	3	6							0
Ct re	11	10	13	4	2	21	61	7	5	5	3	2	10	32
De ti	4	2	2			1	9	1						1
Di wi	1		1		1	3	6						2	2
Di in	1						1							0
Di te							0	6	1					7
Er fa	24	18	12				54	17	15	9				41
Ge va	2						0							0
He bi	7	7	5	1		2	22	5	1	2	1			9
Le la	6	4	14	4	1	2	31	3	3	8		2		16
Le ae							0	1					1	2
Ge gi							0				1			1
Lu da	15	1	2				18	17	5	4	1			27
Me gr	2	6	2			4	14	14	14	4	2	4	14	54
Mo ad	7	4	3		2	14	30	5	3	10	4	10	10	42
Ne le	19	6	2				27	7						7
Po vi							0	2			1		1	4
Ra en		1					1							0
Rh or	12	19	2				33	3	4		1			8
Su su	1	1				1	3		3					3
Ti mu	1						1							0
Ty li				2		7	9			2			2	4
Va go	3	6					9	1	3					4
Total	163	109	84	22	17	100	495	120	71	59	38	24	63	375
No. Spp	21	17	15	7	8	14		18	14	11	11	7	11	

Table 7.7

No. of reptile individuals (and species) caught at each site over the year, with the no. of sites at which each species was recorded (bottom of table).

SITE	Crpl	Ctnu	Ctpi	Ctbr	Ctle	Cter	Deti	Dein	Dite	Diwi	Erfa	Geva	Hebi	Lela	Leae	Gegi	Luda	Megr	Moad	Mobo	Nele	Povi	Raen	Rhor	Susu	Timu	Tyli	Vago	TOT	SPP
W																														
1	0	0	1	0	0	2	0	0	1	0	0	0	0	0	0	0	0	2	0	3	0	0	0	0	0	0	0	0	9	5
2	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	2	0	5	4
3	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0	3	0	1	0	0	0	0	0	0	7	5
4	0	0	0	0	0	1	0	0	4	0	2	0	0	0	0	0	0	1	0	4	0	1	0	0	2	0	0	0	15	7
5	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	3	3
6	0	0	13	11	0	1	0	0	0	2	10	0	2	1	0	0	5	0	1	0	4	1	0	1	0	0	0	0	52	12
7	0	0	4	17	0	1	0	0	0	0	2	0	0	10	0	0	6	0	8	0	0	1	0	0	0	0	0	0	48	8
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	2	2
9	1	0	0	0	0	2	0	0	0	0	0	0	2	0	0	1	1	0	0	5	0	0	0	1	0	0	0	1	14	7
10	0	0	6	14	0	8	0	0	0	0	4	0	0	3	0	0	11	0	12	0	0	0	0	1	0	0	0	1	60	9
11	0	1	3	4	0	1	0	0	0	0	7	0	1	0	0	0	2	0	0	0	1	0	0	1	0	0	0	0	21	9
12	0	0	0	0	0	4	0	0	0	0	0	0	3	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	11	3
13	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	42	0	1	0	0	0	0	0	0	0	0	45	4
14	0	0	3	6	0	5	0	0	0	0	14	0	1	2	2	0	1	6	7	2	2	0	0	4	0	0	0	2	57	14
15	0	0	3	1	0	5	0	0	0	0	2	0	0	0	0	0	0	0	8	0	1	0	0	0	0	0	1	0	21	7
E																														
1	2	0	0	0	0	2	6	0	0	0	0	1	5	3	0	0	0	0	0	36	0	0	0	0	0	0	0	0	55	7
2	0	1	4	12	0	6	0	0	0	0	0	0	2	1	0	0	12	0	3	0	4	0	0	0	0	0	4	0	48	10
4	1	0	0	0	0	1	3	0	0	0	2	0	5	2	0	0	0	0	0	30	0	0	0	0	0	0	0	0	44	7
5	0	0	2	7	5	13	0	0	0	0	13	0	1	5	0	0	0	4	9	0	10	0	0	4	0	0	0	2	75	12
6	0	0	4	7	0	9	0	0	0	0	0	0	1	1	0	0	0	1	2	0	1	0	0	8	0	0	0	0	34	9
7	0	0	0	6	0	9	0	0	0	0	4	0	1	2	0	0	5	5	2	0	4	0	0	2	0	1	0	1	42	12
8	0	0	1	0	0	5	0	0	0	0	1	0	3	0	0	0	0	0	2	0	0	0	0	0	0	0	1	1	14	7
9	0	1	0	1	0	6	0	0	0	0	0	0	1	0	0	0	0	1	4	1	0	0	0	0	2	0	1	0	18	9
10	0	0	3	8	1	1	0	0	0	6	9	1	1	8	0	0	0	0	2	0	4	0	0	0	0	0	0	2	46	12
11	0	0	0	0	0	0	0	1	0	0	13	0	2	2	0	0	1	0	0	0	2	0	0	1	0	0	0	0	22	7
12	4	0	0	0	0	1	0	0	0	0	0	0	0	6	0	0	0	0	0	6	0	0	0	10	0	0	0	1	28	6
13	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	3	0	10	4
14	0	0	6	9	0	5	0	0	0	0	12	0	0	0	0	0	0	2	1	0	2	0	1	7	0	0	0	1	46	10
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	0	1	0	0	0	4	3
	4	4	14	14	2	24	3	1	4	2	14	2	15	13	1	1	10	11	15	12	11	5	1	11	4	1	7	9		

Table 7.8

No. of mammal individuals (and species) caught at each site over the year, with the no. of sites at which each species was recorded (bottom of table).

SITE	Le fo	Mu mu	Ni ri	No al	Pl gi	Pl te	Ps he	Ra vi	Sm cr	Sm ma	TOT	SPP
W												
1						1				1	2	2
2		4							12	4	20	3
3		8				2			3	12	25	4
4		10				2	1		2	6	21	5
5		3			1				1		5	3
6		23					14		3	1	41	4
7		10					5		2	2	19	4
8	1	8							14	14	37	4
9		4				1					5	2
10		23					8			1	32	3
11		4					4		1		9	3
12		3				1			7		11	3
13		14			11					4	29	3
14		12	8				13				33	3
15	1	7					5		19	13	45	5
E												
1		13					2				15	2
2		8					2		6	4	20	4
4		2					3			1	6	3
5	1	12					27			6	46	4
6		5					14		1	1	21	4
7		6		3			30		1	1	41	5
8		2					11	1	1	5	20	5
9		8			1		1		13	8	31	5
10		16					9				25	2
11		3					1		1	4	9	4
12		3					9			1	13	3
13		4					2			7	13	3
14		12					15		1	4	32	4
15	1	7			1	2				11	22	5
	4	28	1	1	4	6	20	1	17	22		

Table 7.9

Captures and capture rates (percentage of total pot-nights) of four reptile guilds at the east (E) and west (W) permanent sites through the year. Note that the two diurnal guilds (agamid lizards or dragons, and diurnal skinks) maintain higher levels of activity during the winter than the nocturnal guilds (burrowing or sand-swimming skinks, and geckos). The percentages in the "Tot" column are the number of reptiles in that guild expressed as a percentage of the number of all reptiles trapped (i.e. not of pot-nights).

	E	W	E	W	E	W	E	W	W	E	W	E	Tot
Date	5/12	2/2	5/3	13/3	10/4	6/5	2/6	8/6	10/7	23/7	2/9	7/9	
Dragons	5	10	4	4	8	5	2	13	2	5	12	16	86
(6 spp)	1%	3%	1%	1%	2%	1%	1%	3%	1%	1%	3%	4%	10%
Diurnal	63	49	40	32	37	31	15	22	20	11	50	78	448
Skink (7)	13%	16%	12%	11%	10%	6%	6%	5%	6%	3%	12%	19%	51%
Noct.	30	21	22	18	26	17	4	0	2	1	1	2	144
Skink (3)	6%	7%	7%	6%	7%	4%	1%	0	1%	0	0	0	16%
Geckos	56	38	33	11	11	6	1	3	0	0	0	2	161
(7 spp)	12%	12%	10%	4%	3%	1%	0	1%	0	0	0	0	18%

Trapping data are summarized in Tables 7.3 and 7.4 in terms of captures of all reptiles and all mammals per site per night and per side (east or west) per night. Certainly a feature of this study was the number of mammals caught - 651 individuals were trapped 691 times (i.e. disappointingly few recaptures obtained), of which house mouse captures constituted 36.7% of the tally (see Table 7.5 for full details). The number of reptile individuals trapped in each trapping session is presented for each species in Table 7.6. The number of individuals of each species caught at each site (summed over the whole year) is presented in Tables 7.7 (reptiles) and 7.8 (mammals).

Mammal Activity

Examination of Tables 7.3, 7.4 and 7.5 reveals how variable the capture of mammals was - between trapping sessions, between the east and west sides, and between successive nights of the one session. The only (generally) consistent pattern was the decline in capture rate (for all mammals combined) on successive nights of a trapping session (see Tables 7.3, 7.4). Over 10 of 11 of the trapping sessions, for which the appropriate data were recorded, the percentage capture rate declined on the second night (see Table 7.3). While this decline continued on the third night at the eastern sites, the trend was halted on the western side (Table 7.4). The decline on successive nights seems logical for three reasons - mammals could be expected to avoid the pitfall lines on nights following their initial capture (because of the absence of a "reward", unlike that involved with the use of baited traps) and the trapline is likely to be encountered by a majority of individuals in its vicinity on the first night; animals that died overnight could not be recaptured, nor could animals retained as voucher specimens - trap-deaths were minimal but significant, especially for the two common rodents, and the sandy inland mouse would often die if caught on successive nights; consequently individuals were released well away from the trapline, which further lessened their chance of recapture.

Another general trend was a decline in capture of mammals through the year (illustrated in Fig 1.1). Analysis of the data from the twelve trapping sessions reveals a weak but significant negative correlation between % trap rate and duration of study ($r = -0.63$, $P = 0.05$). The most significant deviation from this trend occurred in the May trapping session (western sites) which was the most successful for the year (27% trap rate), with both rodent and dasyurid numbers being the largest caught this side (Table 7.5). This peak could have several explanations e.g. random variation in trapping success (unsatisfactory), there were actually larger populations of these species present, or local conditions (weather, food availability etc.) or life cycle stage (onset of breeding season/territoriality inducing greater distance of nightly travel) stimulated greater levels of activity than usual.

The second explanation, although possibly applicable to the rodents, is not appropriate for the dasyurids. The *Sminthopsis* spp breed seasonally (Lee *et al*. 1982) finishing by February (i.e. progeny having attained independence), and so maximal numbers (as reflected in capture rates) would have been expected earlier in the year than May (and assuming no immigration of which there was no evidence). Therefore, the third explanation seems the most likely, at least for the dasyurids. The two common rodents were observed to breed throughout the year, and given the good rains experienced between May 1986 and February 1987, their populations could be expected to have peaked in the autumn of 1987, before declining over the ensuing cooler (and generally) drier period. However, as this pattern cannot be discerned in the results for the eastern sites, the third explanation is again favoured.

The general decline in capture rates over the year probably results from trap avoidance (which may be supported by the low incidence of recapture of marked individuals), as well as an actual decline in mammal populations over the latter half of the study. Throughout the survey, small mammal numbers were high (as shown above), which is assumed to have been a function (through breeding success and reduced competition for food) of the favourable (wet) conditions in the latter half of 1986 and early 1987 (e.g. see Morton 1982). Conditions were much drier from March onwards, and increased competition for food could have caused higher mortality rates as the year progressed. Certainly the average weights of adult rodents declined in the winter period and the concomitant increase in trap-death numbers lends support to this argument. The *Sminthopsis* spp prey largely on arthropods

(Morton 1982), and there was an obvious decline in arthropod availability over the cooler months (April - September), as indicated by their numbers in the bottom of pitfalls. Although the dasyurids did not show the overt signs of cold and hunger stress that the rodents did, a population crash could be expected to have occurred at the onset of winter (presumably mainly affecting second year adults at the end of their customary life span e.g. Morton 1982).

Sufficient captures of four species enable their breeding patterns to be described. The other six species of small mammal were caught too infrequently to allow any other than casual comment. The house mouse and sandy inland mouse bred throughout the year, although only a small proportion of the trapped population was actually breeding at any one time. Their breeding activity seemed to decline over the year, with least signs recorded in July (both sides). Rodents of inland Australia are known to be able to breed in any season when conditions are appropriate (Watts and Aslin 1981) - such was the case at Coongie over the survey period.

One of the two individuals of Leggadina forresti caught in March had bred recently, while the size of the three juvenile spinifex hopping-mice caught in June indicated a breeding event initiated shortly after the heavy February rains.

The two species of dunnart are known to breed seasonally over an extended spring-summer period (June - February), and they are capable of raising two litters in this long season (Lee et al. 1982). Both species had pouched young in December at Coongie 1986. By February 1987 only the stripe-faced dunnart was trapped with pouched young. Pouched young were then not observed again until July (one fat-tailed dunnart). In September two stripe-faced dunnarts with pouched young were trapped, while the pouch of one fat-tailed dunnart had recently been vacated. Although the data are too few to draw firm conclusions, certainly the seasonality of their breeding was confirmed, and it appears that the fat-tailed dunnart may start and finish breeding earlier than the stripe-faced species.

Reptile Activity

When Tables 7.3, 7.4 and 7.6 are examined, the marked seasonality of reptile captures is evident. If the total number of all reptile species captured per trapping session is considered, the rate peaks over summer, drops away steadily through the cooler months, before beginning to rise again in the final session (September). This pattern, depicted in Fig. 7.2, occurred on both sides, and is to be expected. Being cold-blooded (or poikilothermic), the body temperature and therefore activity of reptiles are regulated to a large degree by the temperature of the environment. Obviously at Coongie the great majority of species were most active in the warmer months - many species were not trapped at all in the coolest months. However, there were exceptions, and this topic will be returned to later in this section.

When capture rates are compared between successive nights, the patterns are not as well defined. The common trend shared by the east and west sides, is an increased capture rate on the second night (observed in 10 of the 11 data sets). A further increase in capture rates occurred on the third night of trapping in eight on the nine sessions, for which data are available (see Table 7.3), but because trapping effort on the third night over "summer" (December to March) was much less than for the remainder of the year (90 vs 965 pot-nights), this trend has been swamped when the totals for all trapping sessions are pooled (see Table 7.4) and expressed as a percentage of trapping effort. The increase in captures on the second night largely results from the diurnally active species (dragons and most skinks) not having been caught on the day that the traplines were established. The third night's increase (if real) may be attributable to fossorial or otherwise cryptic species (e.g. Menetia greyi, Morethia spp., Lerista spp and Eremiascincus) not having been detected in the pots until the final morning, when the pots were thoroughly examined prior to their closure.

Although the breeding cycles of reptiles were not studied in any great detail, breeding activity (as indicated by distended abdomens or visible eggs) was particularly evident during the December trapping session, and generally not evident over the remainder of the survey. However, recently hatched or born lizards of a range of species were trapped until June.

The seasonal trend of capture rate for all reptiles approximately matches change in temperature over the year (Fig. 7.2). However, if the data for individual species or groups of species are examined more closely, several trends become apparent.

Of the 26 lizards captured at Coongie in the pitfalls, all but the large sand goanna and Centralian blue-tongue can be considered to be a member of the following guilds:

1. diurnal dragons (6 spp - 10%)
2. small diurnal skinks (7 spp - 51%)
3. nocturnal fossorial skinks (3 spp - 16%)
4. nocturnal geckos (7 spp - 18%).

Together these reptiles account for 95% of all reptile captures during the year, with the percent contribution by the guilds shown above. The activity of members of these guilds (as reflected by capture rates) is graphed in Fig. 7.3. The two nocturnal suites of reptiles are shown to have been virtually inactive from June through to September, when night temperatures were cool to cold. By comparison, the diurnally active lizards both retained a level of activity through the year and took advantage of the warmer day-time temperatures in September, when captures increased dramatically. An explanation for the lag displayed by the nocturnal lizards, is ground (and therefore burrow) temperatures would have still been cool in September after the cold winter period, and being nocturnal the animals would have been unable to take direct advantage of the sun's rays, which the diurnal reptiles could. The sand goanna, which also hibernates underground over winter, exhibited a similar pattern of activity to the nocturnal reptiles, although it is active by day. Goannas were not seen from the end of April to the end of the survey period (mid September), and ground temperature is thought to be the proximate factor again. Interestingly, goannas were plentiful above ground two weeks later (late September - early October) at Coongie, when Jim Puckridge was conducting the last phase of the aquatic programme, and it is highly likely that the sand-swimming skinks and geckos had also reappeared by then.

Although the overall activity of the diurnal skink guild declined generally from mid-summer to the end of winter before increasing again in September, dragon activity ,while variable, did not follow this pattern (see Fig. 7.3). Painted dragons (and lined earless dragons) were equally active (or more so) in the cooler months, whereas there were more captures of bearded dragon, central netted dragon and Diporiphora winneckei in the warmer period. Observations of the first two species revealed that they were common on low lying ground in the district (although trapped infrequently), but were rarely seen, if at all, between June and August inclusive, while Diporiphora was most active in the spring - early summer months, becoming less conspicuous in late summer and autumn, when painted dragons became more active on the dunes (both species preferred habitat). The sparsely distributed water dragon Gemmatophora gilberti was observed/captured three times at Coongie (December, February and June), and so probably retains some activity through the year.

Of the skinks, captures of Ctenotus leae diverged the most from the general pattern depicted in Fig. 7.3 for the diurnal skink guild. Six individuals were trapped between June and September at two permanent sites, and several more were captured in August while pitfalling at opportunistic sites to the north of Lake Goyder and to the east of Marroocutchanie. These data, although few are indicative of a species primarily active over the winter - spring period and further trapping should confirm this trend. Morethia adelaidensis was trapped regularly throughout the survey period, and this skink may be more active in the three seasons other than summer. While capture rates of the nocturnal, burrowing skink Lerista labialis certainly declined in the last six trapping sessions (June to September inclusive), larger numbers were captured in autumn than summer.

Continued trapping at the permanent sites is required for several years, before some of these trends can be confirmed and described more clearly. However, it would be logical for species occupying similar habitat within the same guild to exhibit seasonal differences in activity (correlated with dietary preferences), as a way of reducing competition (temporal partitioning of habitat), thus enabling a relatively rich reptile fauna to be assembled, as was found at Coongie. This theme warrants further investigation.

Frog Activity

Frogs were particularly abundant and active over the summer period immediately following heavy rains. Thereafter activity declined, with only the marbled frog Limnodynastes tasmaniensis calling over winter and retaining moderate levels of activity in recently flooded ground (such as Emu Flat, when the level of Lake Toontoowaranie rose, or backwaters along the main channel as the Cooper's level rose). The tiny Ranidella deserticola remained vocal for a longer period than the other species, but ceased calling for 3½ months between late May and early September. The other five (or six) species were not heard to call after the end of March, when conditions became drier and cooler. These periods of vocal activity are of significance, as they are assumed to mark the limits of the breeding season, with only the male frog producing the calls (characteristic to each species) as advertisement to females in reproductive condition. However, apart from the locally rare undescribed species of Cyclorana, the remaining five species were all found (active, above ground) during the non-vocal "winter" period, but in low numbers and mainly after rain storms, and so it is concluded that the species did not actually hibernate over winter (or, at least, not all individuals).

The marbled frog is the only species with Bassian affinities (basically a south-eastern Australian distribution), and it is not surprising, therefore, to find it vocally active through the cool winter period. The other species are either truly Eyrean (central Australian distribution - Cyclorana spp, Litoria rubella, Neobatrachus centralis), Torresian (tropical northern and eastern Australia - L. latopalmata and L. caerulea) or broadly northern (R. deserticola) in origin, and apparently find conditions over the cooler half of the year unsatisfactory for breeding.

7.3.3 Habitat Preferences and Community Structure

All animals tend to spend more time in particular habitats than others, because of food preferences, shelter and breeding requirements etc. Small animals with limited mobility (non-flying) will generally have small home or foraging ranges, and can therefore be quite habitat specific. Often such animals evolve adaptations (in behaviour and body-form) that render them unable to live in other environments. The sand-swimming skinks at Coongie - Lerista labialis, L. aericeps and Eremiascincus fasciolatus - are virtually restricted through their specialization to areas of loose sand. Other similar sized skinks, such as *Ctenotus regius* and *Morethia adelaidensis*, are habitat generalists, occurring in dune and floodplain habitats within the Coongie district.

The larger animals at Coongie, having larger foraging areas, range widely through different habitats, and all the feral animals belong in this category, although they too exhibit preferences. For instance, rabbits centre their activity on the dunes (close to water), while cats were generally observed along the channels or closely adjacent floodplain.

The native herbivore, red kangaroo, although sparsely distributed within the region and seen only once in the actual Coongie district, definitely avoids the dunefields, but occurs in floodplain, gibber plain and stony tableland land zones.

The larger snakes (woma python, western and king brown snakes) were encountered rarely, but are assumed to wander widely through the district in all habitats in search of their favoured prey of small mammals, reptiles and nesting birds (and frogs when conditions are appropriate). Similarly, the sand goanna, abundant by comparison, occurs in all habitats seeking similar prey as well as fossicking for larger arthropods, but was most active in the dunes and woodlands fringing channels and lakes.

The number of captures of the 28 lizard and 10 small mammal species at each of the trapping sites is presented in Tables 7.7 and 7.8, which also indicate the relative richness of each site (the number of species trapped at each site over the year). Dendrograms, constructed from the dissimilarity matrix and clustering (by UPMGA), group sites with a similar trapping record for mammals (Figs 7.4a&b) and reptiles (Figs. 7.5a&b), and so reveal patterns of community structure and habitat preferences within the district.

Mammals

A maximum of five species of small mammal was captured at any one site over the year (see Table 7.9), and this result was obtained at one dune and five floodplain/interdune corridor sites. The maximum number of rodents and dasyurid marsupials caught at the same site was three (at three and four sites respectively). These statistics bear out the claims of Morton (1982), who concluded (from a limited data set) that any particular site (i.e. very small scale) within the arid zone is unlikely to support more than three co-habiting dasyurids, while at the district level, five (as found at Coongie) is the maximum number likely to occur.

The poorest catch of two species was obtained at one dune and three fringing woodland sites. Fringing woodland sites were also poor in terms of total numbers of individuals caught.

Over the year the largest capture of individuals was generally obtained at dune sites (19-46, avg = 34, n = 8), although some floodplain/interdune sites were equally as productive, but they yielded lower tallies on average (5-45, avg = 23, n = 13). The house mouse and sandy inland mouse contributed most to the numbers caught on dunes, while the two <u>Sminthopsis</u> species dominated floodplain habitats.

The introduced house mouse was trapped at all sites apart from 1W, and proved to be the most abundant small mammal over the year. It certainly displayed the most catholic habitat preferences, although strongly favouring dune sites, which was also the preferred habitat of the sandy inland mouse. This species was not entirely restricted to dune sites, but it did not stray far from them (i.e. where it was trapped on low ground, a dune was closely adjacent to that site). Also the species was trapped far more frequently in the dunefields on the east side than the west, which is perhaps indicative of a preference for older dune systems (i.e. the dunefield as opposed to the fringing dunefield land zone of Purdie 1984).

Kemper et al. (1985) suggested that trapping success of these two common rodents at their Mabel Creek sites was negatively correlated. Accordingly this study's results (for all sites) were plotted (Fig. 7.6) and subject to correlation/ regression analysis. A very weak, but insignificant (at the 5% level) positive correlation was obtained, which is unsurprising, given the preference of both species for sand dune habitat. Therefore the exercise was repeated using the data from the 13 sites (9 dunes and four sandy interdune sites) representative of the preferred habitat of the two species (Fig 7.7), and again virtually no correlation was apparent.

The eight captures of ningaui (14W) and three captures of Spinifex hopping-mouse (7E) were from spinifex-clad dune sites. These two species are thought to have patchy distributions within the district, probably being confined to some of the small, localized occurrences of Triodia in the older dunefields.

The four captures of Leggadina forresti were made in a range of habitats from a big dune through intermediate habitats to a base level floodplain site, and the species is thought to occur sparingly through the district, mainly in the floodplain and allied habitats.

The two dunnarts and two planigales all favour floodplain sites, with the planigales being virtually restricted to such sites. The dunnarts were occasionally trapped in the dunefield sites (dunes as well as interdunes). At no site were all four species trapped. While the two species of dunnarts were frequently trapped together (14 of the 24 sites where either species was recorded), at only one of the nine sites where either planigale was caught were both species recorded. This suggests that the two species of planigale have distinct habitat preferences within the general floodplain land system, with P. gilesi being confined to deeply cracking clay habitats of the floodout lakes

(Apachirie and Mundooroounie) and floodout extensions of the main lakes (Emu Flat and 9E), and P. tenuirostris being more widely distributed in floodplain habitats, in open and densely vegetated areas, with or without deeply cracking clay substrates. The only obvious trend apparent for the two dunnarts is the greater abundance of the fat-tailed dunnart on the west side, while this species showed a weak preference for more open habitats and the stripe-faced dunnart for more densely vegetated floodplain habitats. During times of major regional flooding, when all the district's floodplain habitats become inundated, these four species of dasyurid are likely to seek refuge in the adjacent dunefields. Certainly the dunnarts were occasionally encountered in the dunefields, while a specimen of P. gilesi was trapped atop of Koonchera Dune in June 1984 (unpub. data), after most of the surrounding floodplain had been inundated as a consequence of a strong flow down the Diamantina.

The cluster analysis (using species standardisation) reveals three main groups of sites at the 0.72 level (Fig. 7.4a), namely three "riparian" woodland sites (west side), a large group of dunefield (both sides) and three "riparian" woodland (east side) sites, and a large group of floodplain and a few interdune sites (both sides). The small "western riparian woodland" group is defined mainly by the presence of P. tenuirostris and captures of few individuals overall. The intermediate nature of interdune sites is revealed also, with some being grouped with dune sites and the others with the floodplain group. The eastern "riparian" sites are aligned with the dunefield group, because of the predominance of rodent captures (and because of the absence of P. tenuirostris). Further subdivision of these groups (0.53 level) splits off the two sandy interdune and two eastern "riparian" woodland sites from dune sites proper, while the large floodplain group is divided into several groups based on the capture of the rarer animals, Leggadina and two planigales, and does not support a distinction based on landform types. One interesting anomaly is the grouping of the dune site 5E with the floodplain group, because of the Leggadina capture.

Cluster analysis using logarithms reveals a similar pattern. Because less weighting is given to the capture of rare species by this method, Site 5E is grouped with the dune sites at both levels of resolution (0.49 and 0.33 - see Fig. 7.4b).

Reptiles

Reptile diversity was highest at dune sites (8-14 spp, avg = 11.1, n = 8), lowest on those floodplain (but not riparian woodland) and interdune sites located some distance from dunes (2-7 spp, avg = 4.2, n = 10), and intermediate in fringing woodland or at sites placed adjacent to dunes (5-10 spp, avg = 7.5, n = 10). Total numbers of individuals caught at each site followed this same trend, and so the sand-dune environment is the most productive for reptiles in the Coongie district. Nine species are virtually restricted to dune habitat, namely Ctenotus brooksi, C. leae, Diporiphora winneckei, Eremiascincus fasciolatus, Lerista labialis, L. aericeps, Nephrurus levis and Ramphotyphlops endoterus, and another eight species are regular inhabitants but occur in other habitats as well.

Four species are virtually confined to the denser woodlands usually associated with channels and lake margins in the district - the arboreal (tree dwelling) Cryptoblepharus plagiocephalus, and Delma tincta, Morethia boulengeri and Gemmatophora gilberti. The Delma and Morethia are tied to this habitat because of their requirement for a well developed litter layer. Additionally, another arboreal species, the tree dtella Gehyra variegata shows a strong preference for this habitat, but occurs in other habitats as well. Woodlands of this type occupy a very small fraction of the district's total land surface, and it is therefore significant that four species of reptile are restricted to this habitat. To amplify this point, a similarly restricted habitat, of interdune claypan, is frequented by very few species none of which are restricted to it (and claypans occupy a greater area overall than fringing woodland).

The variable floodplain and interdune habitats are occupied by some twelve species, of which three or four are virtually confined to them, namely Ctenophorus nuchalis, Diplodactylus tessellatus, Suta suta and perhaps Tympanocryptis lineata. Of these, the two dragons were frequently seen in sandy habitats (but not dunes), whereas the other two species were base level inhabitants. In particular, the lined earless dragon showed a preference for pale (sandy alluvium) substrates. The bearded dragon preferred floodplain habitats to those of the dunefield, but along with Ctenophorus pictus, Ctenotus regius, Heteronotia binoei, Lucasium damaeum, Menetia greyi, Morethia adelaidensis, Rhynchoedura ornata and Varanus gouldii occurred throughout the district. Most of these habitat generalists displayed certain preferences e.g. the painted dragon for sandy slopes.

Cluster analysis (using standardized scores) reveals a strong separation between dune sites and the other sites. The other sites did not cluster clearly, although four riverine sites (plus an interdune - 8E) comprise a group distinct from several other floodplain/interdune groups (at the 0.76 level - Fig. 7.5a). Patterning within the dune cluster is revealed at the 0.61 level, with a group of six sites in older dunes emerging (dominated by Menetia, Nephrurus, Rhynchoedura and Varanus), with Lucasium (and perhaps more C. pictus and M. adelaidensis) captures causing the separation of a smaller group of fringing dunes.

Frogs

All species occurred along the main North-West channel in the Coongie district and in ephemerally inundated pools on the closely adjacent floodplain after the heavy summer rains. Species richness declined sharply away from the Cooper, and in the dunefields, only Cyclorana platycephalus, Neobatrachus centralis and Ranidella deserticolor were found, and perhaps only Neobatrachus is widely distributed in the dunefields. Ranidella and Limnodynastes tasmaniensis were also found on peripheral lake beds in the district (e.g. Apachirie and Mundooroounie), and so are not as tied to the main system as the three species of Litoria.

In the wider region, Neobatrachus and C. platycephalus were found in gibber habitat after showers in early May.

7.4 Management Considerations

Significance

The terrestrial fauna of the Coongie Lakes District is shown to be rich, with the frog community considered (by Mike Tyler pers. comm.) to be the richest known to occur in the arid zone of Australia. The occurrence of mammals, reptiles and frogs which are rare or have restricted distributions within South Australia is also of significance.

In the wider region, the presence of additional rare and even endangered species (dusky hopping-mouse) is further evidence of the importance to wildlife of the diverse range of habitats represented in the Far North East.

The most significant habitats within the Coongie district are identified below, and these habitats will require careful management:

1. the aquatic channel and lake habitat, which supports populations of the water rat and endemic species of tortoise.

2. the fringing riparian woodland, which supports a distinctive reptile community, comprising some species restricted to the habitat. Also important for nesting sites for the water rat and tortoise.

3. adjacent floodplain habitats with their ephemeral pools, which are especially important for the rich frog community.

4. densely vegetated ephemeral lake-beds, which support populations of the rarer floodplain-inhabiting mammals, such as planigales and Forrest's Mouse.

5. dense lignum beds, adjacent to lakes or channels, which are considered to provide a refuge for the long-haired rat.

6. the patchily distributed areas of spinifex-clad dunes, which support localized, but highly important faunal communities, and populations of rare animals such as ningaui.

Other habitats important for fauna undoubtedly exist on Innamincka Station, and in particular, the stony tablelands to the north of Innamincka HS, the Upper Strzelecki district, and the red sand habitats in the Marqualpie district are likely to support significant populations.

<u>Impacts</u>

Currently, within the Coongie Lakes District, the aquatic environments and riparian woodland are receiving the most pressure from tourist activities. Trampling, vehicles, camping and use of fires are the main agents of scalding and general degradation of the riparian habitats.

Rabbits have had an enormous impact on the region's terrestrial fauna, but it is hoped that the damage that they have wrought (in terms of extinction of native mammals) may have run the full cycle.

Other exotic animals, such as foxes and cats, have also contributed to the decline of the Australian desert mammal fauna, while the impact of cattle grazing has been particularly severe in wetland and adjacent habitats.

Mining impacts are generally localized, in contrast to grazing activities, although the provision of artificial watering points in the form of borrow pits is seen as a problem, if it maintains higher populations of rabbits, as has been suggested.

<u>Recommendations</u>

1. that the faunal sampling programme be continued within the Coongie Lakes District to span a three year period, and that a thorough investigation be undertaken of other districts on Innamincka Station.

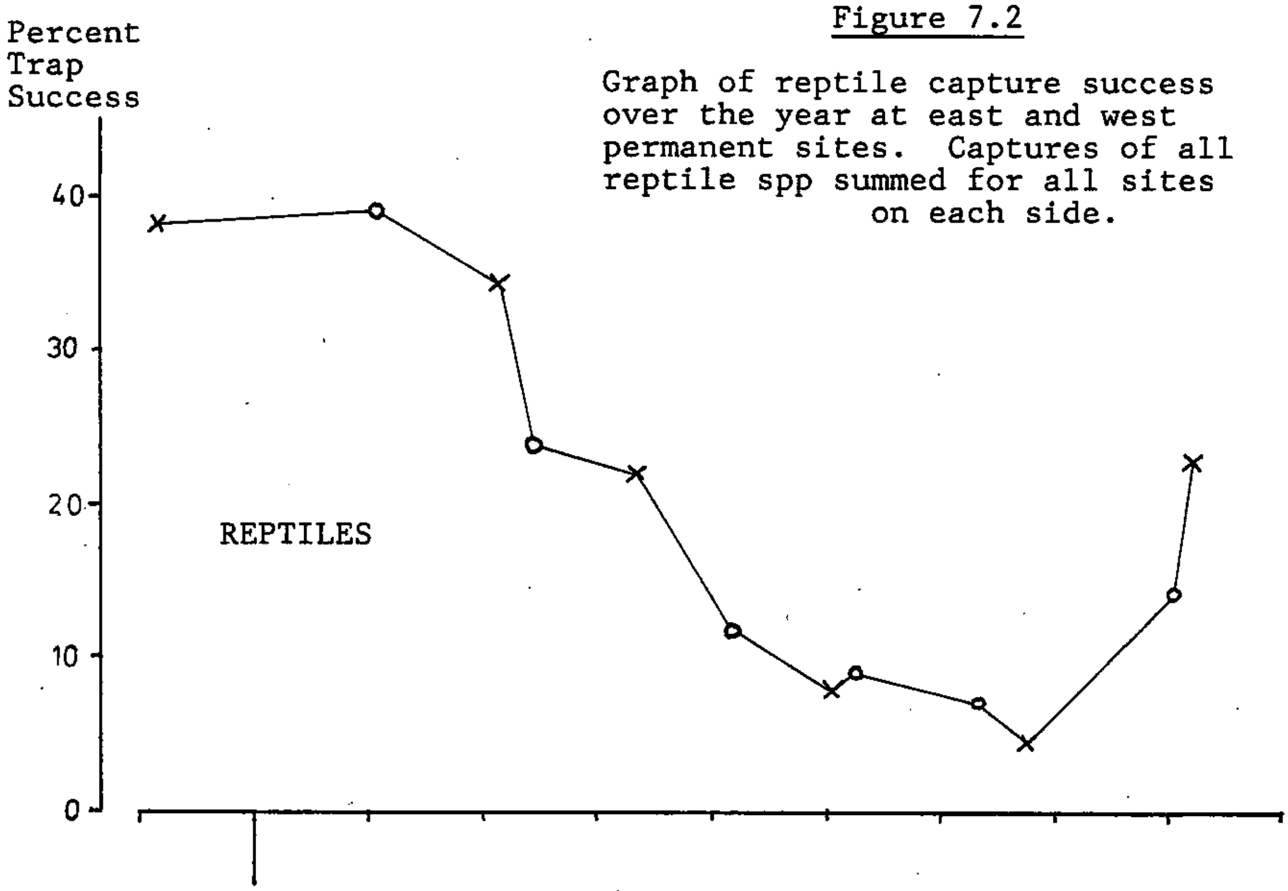
2. that the current degradation of riparian habitats within the Coongie Lakes District through unregulated visitor use be halted.

3. the exclusion of cattle from the Coongie Paddock and from river frontage elsewhere on Innamincka Station.

4. that mining activities be excluded from the Cooper Creek and immediately adjacent floodplain, and from the Coongie Lakes District entirely.

Figure 7.2

Graph of reptile capture success over the year at east and west permanent sites. Captures of all reptile spp summed for all sites on each side.



X Eastern Permanent Sites

O Western Permanent Sites

Figure 7.1

Mammal capture success (all species at all sites) at the eastern and western permanent sites over the year.

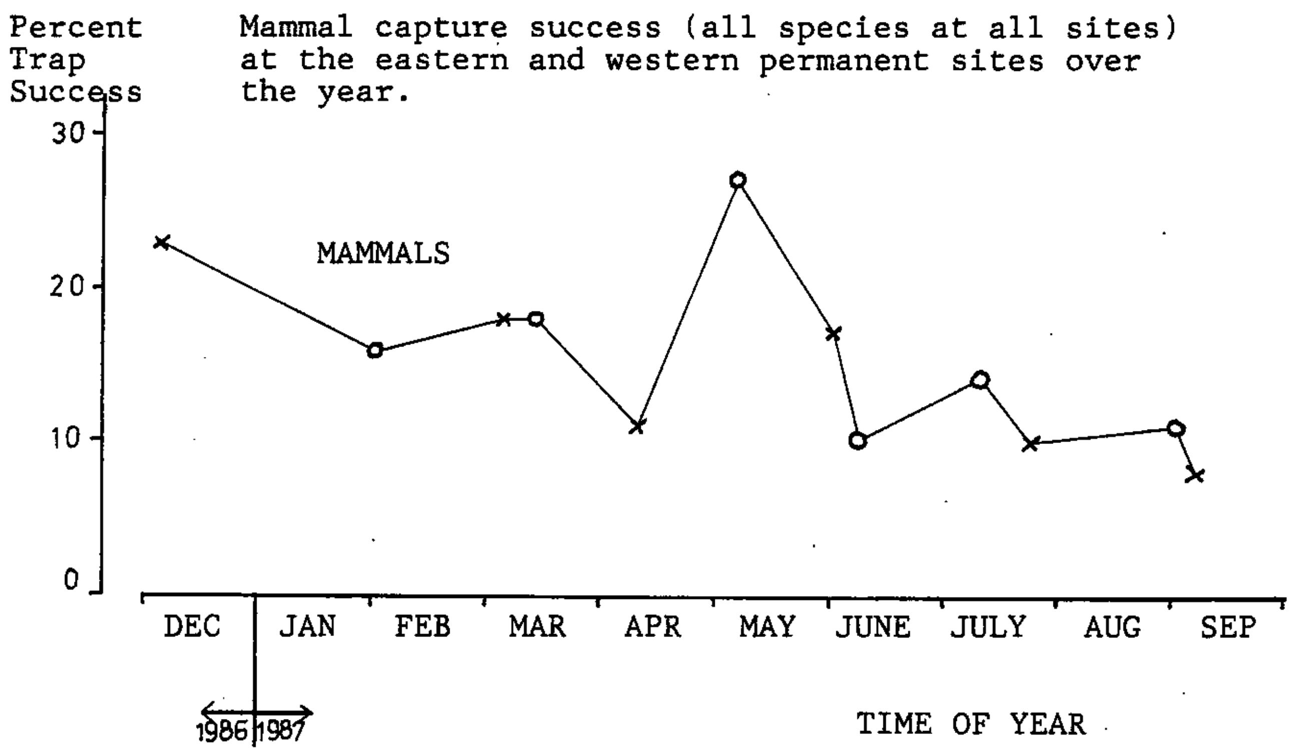
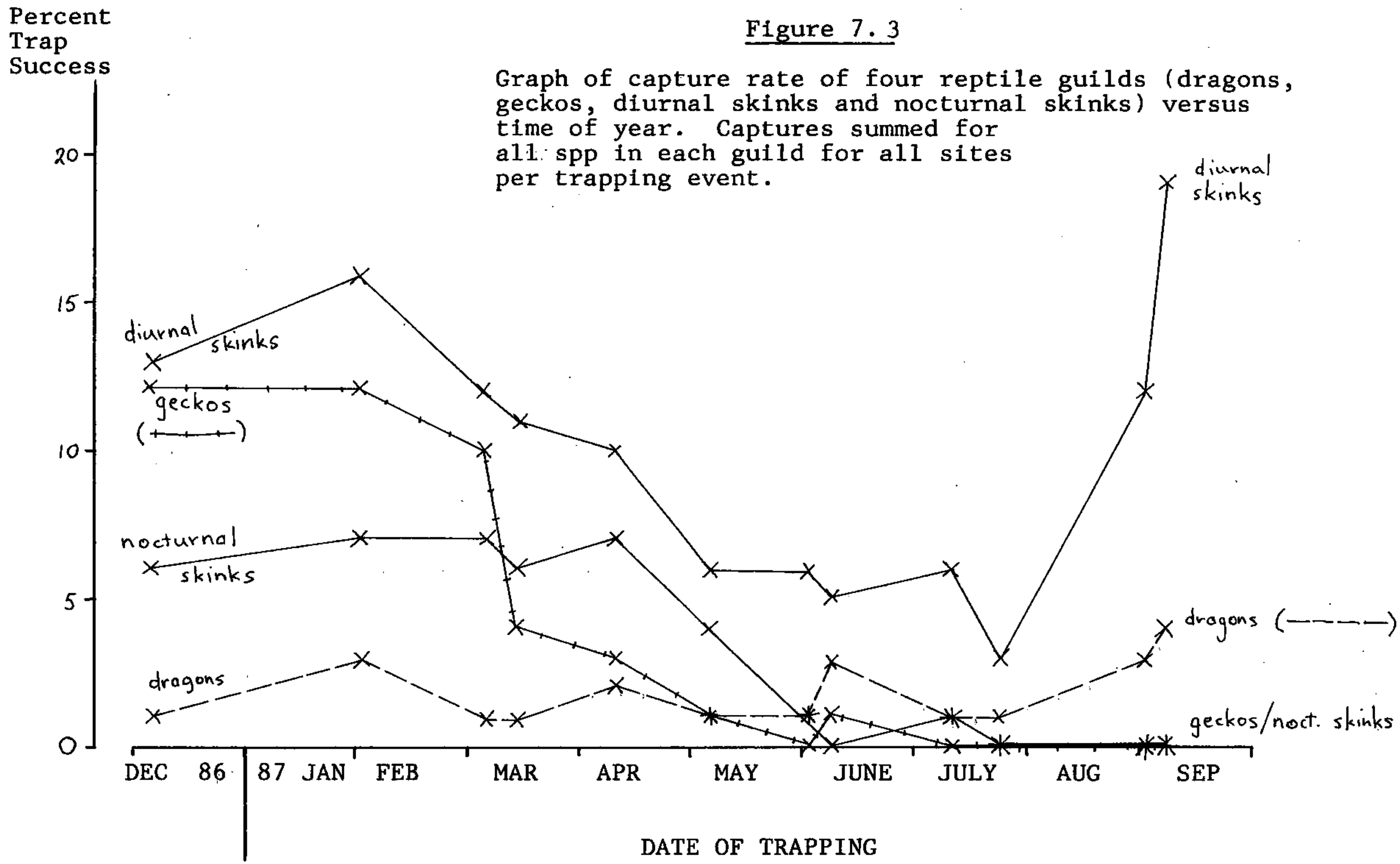
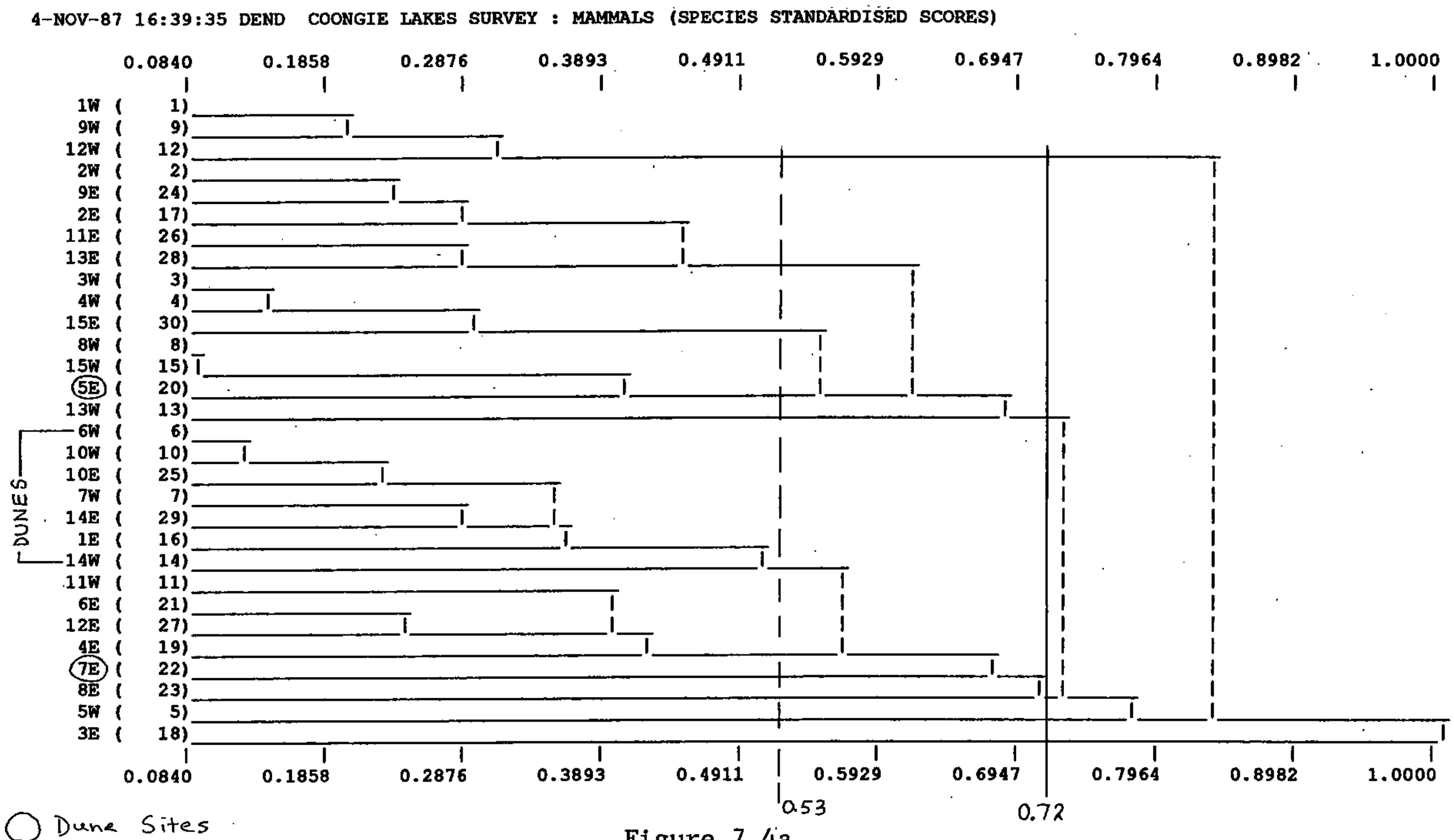


Figure 7.3

Graph of capture rate of four reptile guilds (dragons, geckos, diurnal skinks and nocturnal skinks) versus time of year. Captures summed for all spp in each guild for all sites per trapping event.





<u>Figure 7.4a</u>

Dendrogram showing clustering of permanent sites based on all mammal captures over the year. UPGMA - species standardised scores.

4-NOV-87 16:36:55 DEND COONGIE LAKES SURVEY : MAMMALS (LOG CAPTURE SCORES)

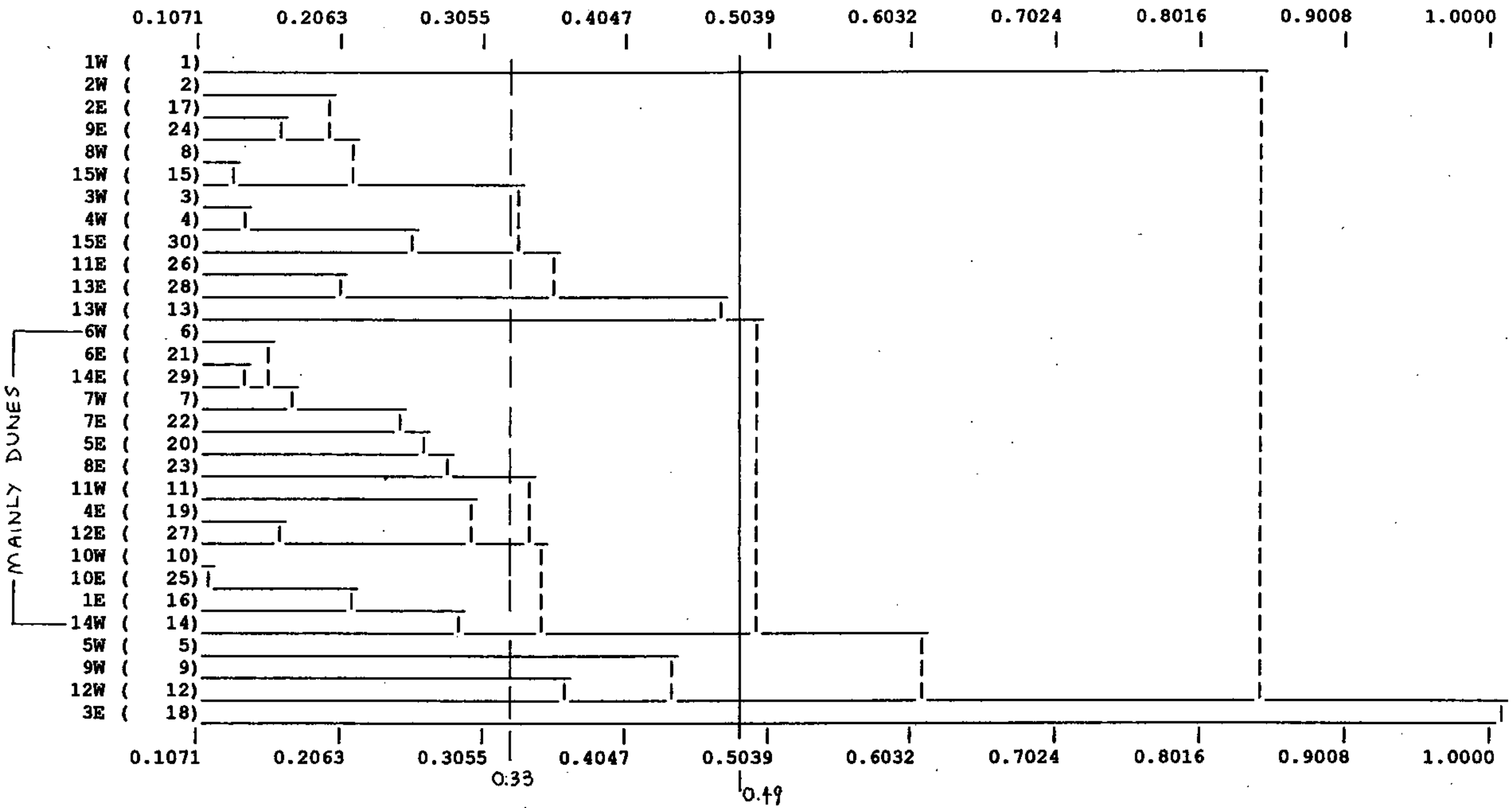
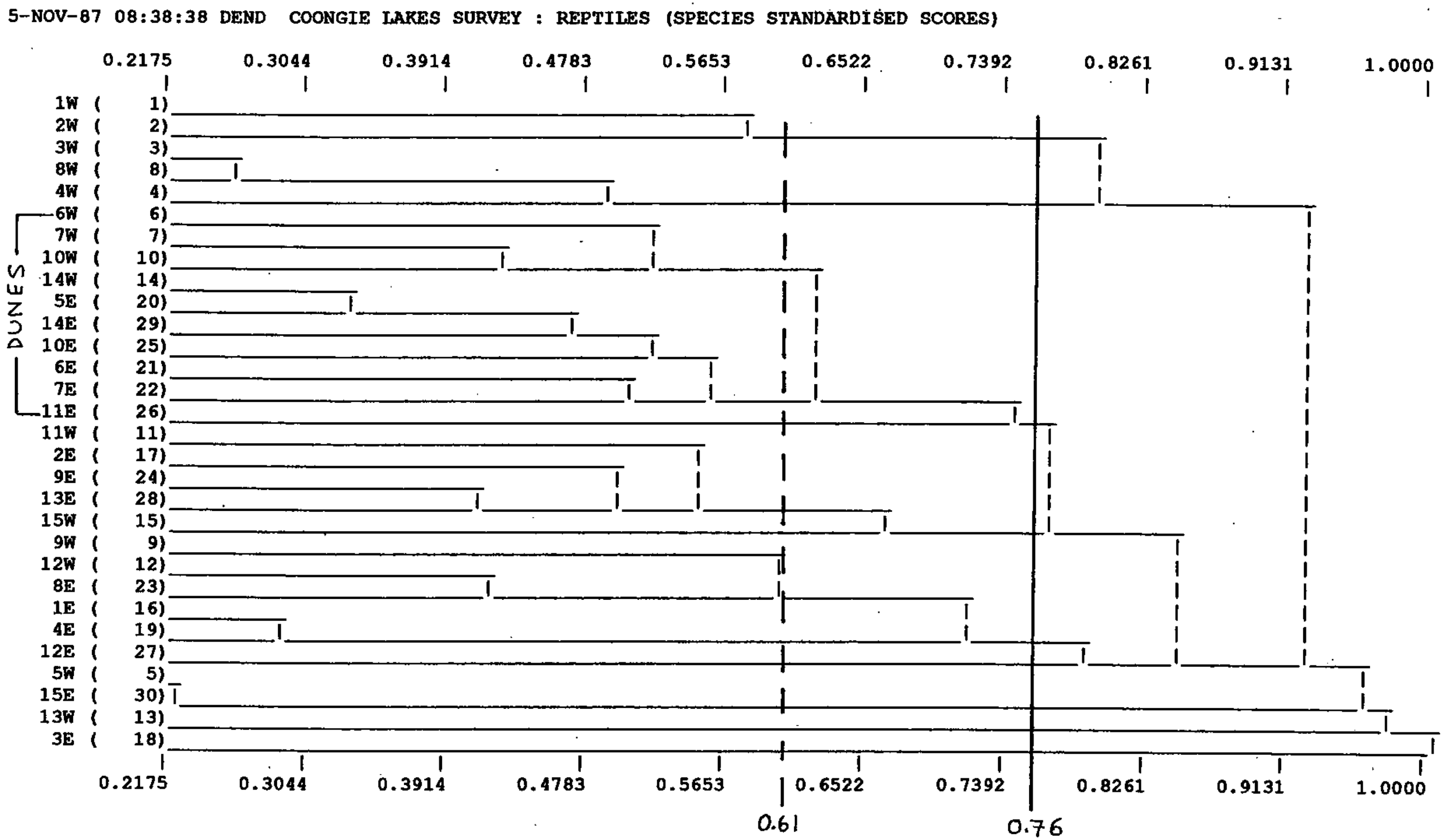


Figure 7.4b

Dendogram showing clustering of permanent sites based on log trasformed mammal capture data.



<u>Figure 7.5a</u>

Dendrogram showing clustering of permanent sites based on all reptiles captured at each site over the year (UPGMA - species standardised scores).

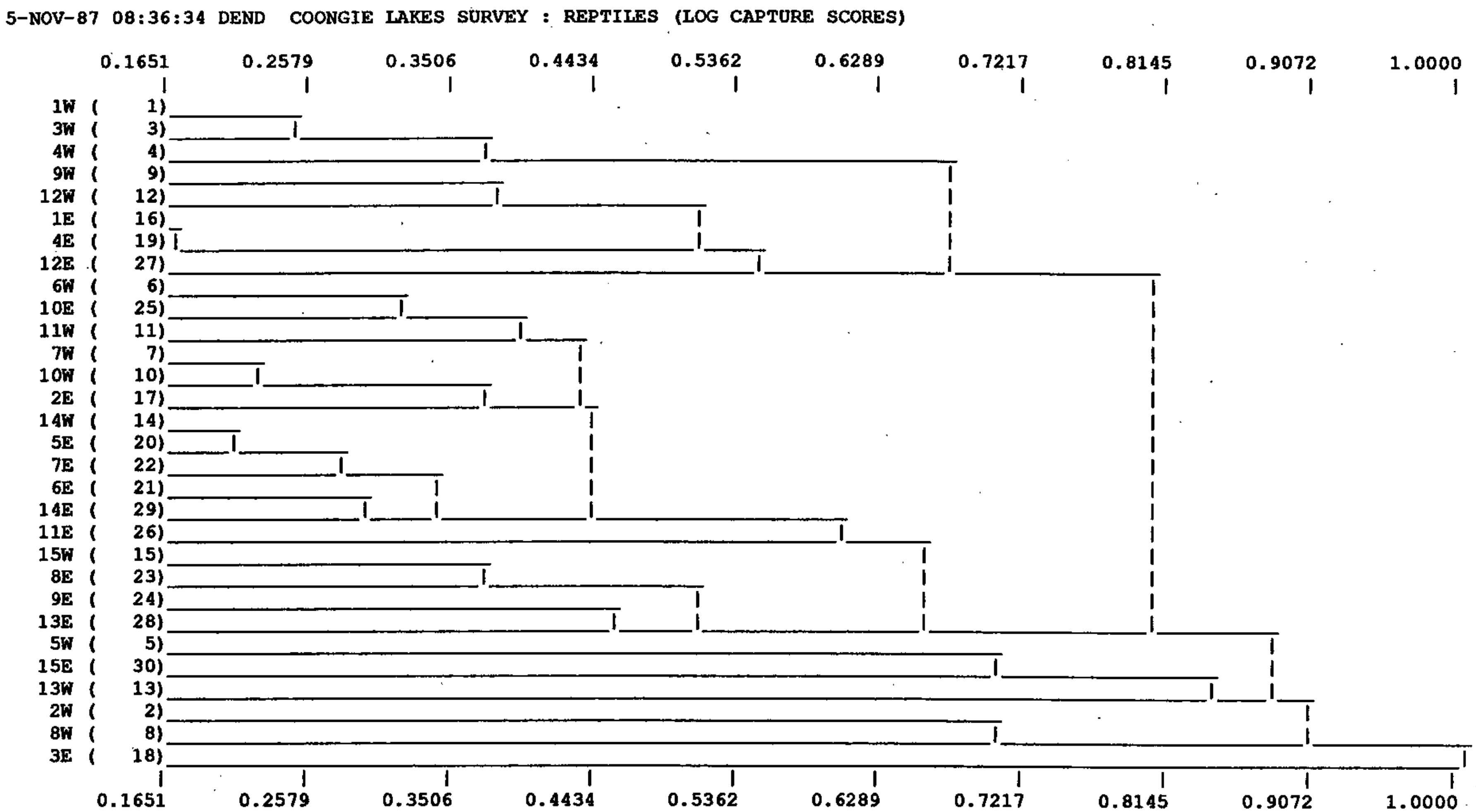
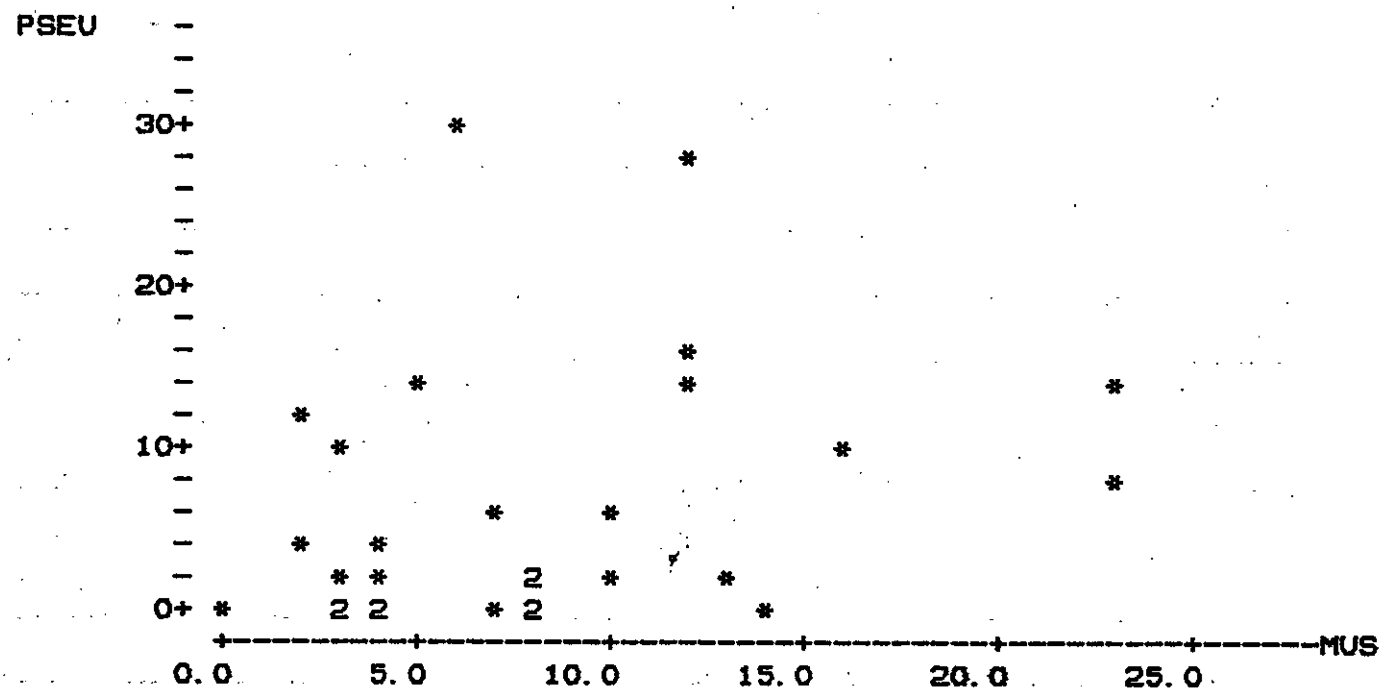


Figure 7.5b

Dendrogram showing clustering of permanent sites based on log transformed reptile capture data.

MTB > PLOT C2 C3



MTB > CORRELATION C2 C3

Correlation of PSEU and MUS = 0.282

MTB > REGRESS 'PSEU' ON 1 PREDICTOR 'MUS'

The regression equation is
PSEU = 2.94 + 0.388 MUS

Predictor	Coef	Stdev	t-ratio
Constant	2.939	2.506	1.17
MUS	0.3879	0.2535	1.53

s = 7.797   R-sq = 8.0%   R-sq(adj) = 4.6%

Analysis of Variance

SOURCE	DF	SS	MS
Regression	1	142.29	142.29
Error	27	1641.57	60.80
Total	28	1783.86	

Unusual Observations

Obs.	MUS	PSEU	Fit	Stdev.Fit	Residual	St.Resid
4	12.0	27.00	7.59	1.76	19.41	2.55R
6	6.0	30.00	5.27	1.54	24.73	3.24R
20	23.0	14.00	11.86	4.05	2.14	0.32 X

Figure 7.6

Plot of all captures of Mus musculus vs all captures of Pseudomys hermannsburgensis at each permanent site over the year. A very weak positive correlation shown.

Table 7.3

Trapping results for mammals and reptiles at the permanent sites for each sampling event. All mammal and all reptile captures for each night of the sampling event are summed over all sites on the east (E) and west (W) sides. M = mammal. R = reptile.

		5/12/86 E		2/2/87 W		5/3/87 E		13/3/87 W		10/4/87 E		6/5/87 W		2/6/87 E		8/6/87 W		10/7/87 W		23/7/87 E		2/9/87 W		7/9/87 E	
		R	M	R	M	R	M	R	M	R	M	R	M	R	M	R	M	R	M	R	M	R	M	R	M
FIRST NIGHT	pot-nights			145		130		150		135		140		135		140		110		135		140		135	
	No caught			54	28	41	28	33	29	22	20	14	45	5	28	3	15	5	23	7	17	10	26	23	23
	% trap success			37	19	32	22	22	19	16	15	10	32	4	21	2	11	5	21	5	13	7	19	17	17
SECOND NIGHT	pot-nights			145		130		150		135		140		135		140		110		135		140		135	
	No. caught			57	19	50	19	40	24	31	15	16	31	17	18	17	15	8	14	2	15	21	9	34	7
	% trap success			39	13	38	15	27	16	23	11	11	22	13	13	12	11	7	13	1	11	15	6	18	5
THIRD NIGHT	pot-nights			20		70				105		200				140		110		135		140		135	
	No. caught			9	2	20	14			30	5	29	52			19	12	10	8	8	7	28	11	46	4
	% trap success			45	10	29	20			29	5	15	26			14	9	9	7	6	5	20	8	34	3
ALL NIGHTS	pot-nights	470		310		330		300		375		480		270		420		330		405		420		405	
	No. caught	177	108	120	49	111	61	73	53	83	40	59	128	22	46	39	42	23	45	17	39	59	46	93	34
	% trap success	38	23	39	16	34	18	24	18	22	11	12	27	8	17	9	10	7	14	4	10	14	11	23	8

8. BIRDS

Julian Reid

8.1 Introduction and Aims

Unlike other aspects of the natural history, birds are a well documented component of the environment at Coongie and in the wider region (e.g. Badman 1988).

The species list compiled over the years is now comprehensive, and May (in LAB 1986) gives a lengthy list of birds that he has encountered on Innamincka Station in eight or more years birdwatching in the region, having conducted trips at all times of the year. Notably, May's list contains several species not previously acknowledged to occur in the region, including two rare waterbirds in Australia, the White-winged Tern and Pectoral Sandpiper.

Most recent ornithological research in the Far North East has included observations made at Coongie and other parts of the Upper Cooper. Although birdlife along the Upper Cooper is richer and more abundant than that of the middle and lower reaches, Badman (1988) is to be applauded for having published an exhaustive account of the birds of the Lower and Middle Cooper, regions which had been largely neglected by modern ornithologists. Badman's work shows that significant and very large concentrations of waterbirds do occur on the large lakes of the drier reaches of the Cooper, when the water is available, while the record (Parker 1980) and claims (in Badman 1988, and a report to Gary Drewien, pers. comm.) of the endangered Night Parrot also attest to the Lower Cooper's significance.

The Coongie Lakes wetlands have received greatest prominence in the conservation field, because of the waterbird populations they are known to support. Australia's unique and threatened Freckled Duck regularly inhabits the wetlands (Dr S.V. Briggs pers. comm. and LAB 1986), while the diversity of waterbirds recorded and occasionally the numbers of waterfowl have been a feature. Its listing as a wetlands region of international importance under the RAMSAR Convention highlights the area's significance. The actual Coongie lakes are the most "permanent" of the regional wetlands (besides the deeper waterholes, which are not strictly regarded as wetlands - see Mollenmans et al. 1984), and this boosts their importance. Nevertheless, other wetlands in the wider region are considered to be as important, but have been little documented or publicised by comparison (Reid in Mollenmans et al. 1984). The known examples are Tirrawarra Swamp, Embarka Swamp and the massive Goyder's Lagoon complex on the Diamantina River to the north-west of Coongie. These vegetated swamps provide different habitats to those found in the lakes, and being typically ephemeral features, are arguably more productive (e.g. see Chrome 1986) with respect to waterfowl breeding. It is this range of habitats, together with the range of hydrological regimes operating and the overall naturalness of the region, which undoubtedly make these wetlands more important waterbird reserves than the widely acclaimed, but quite altered, wetlands of the State's Murray and South East districts.

A primary aim, then was to document the species of waterbirds occurring in the Coongie Lakes system, their abundance over the survey period, habitat preferences, and any observed breeding events, so that this highly significant facet of the Coongie environment could be documented.

Similarly, detailed observations were to be made of waterbird numbers and activity on wetlands in the wider region as time allowed.

The Coongie Lakes District also supports many dryland birds having conservation significance in South Australia (Reid in Mollenmans et al. 1984), and therefore, another aim was to document the habitat preferences, seasonal abundance and breeding activity of these and other birds of the surrounding terrestrial habitats.

It was realized at the outset of the study, that observations made over a 10–11 month period in a highly variable desert environment have limitations, if drawn upon to attempt an overall understanding of the district's birdlife. Being highly mobile, arid zone birds can undergo dramatic population shifts (geographically) in response to seasonal conditions, and Schodde (1982) states that this capacity for nomadism is the most distinctive behavioural trait of desert birds. Still, the observations are presented, and they faithfully portray the birdlife at Coongie in 1987. When considered with previously accumulated knowledge, they can be extended to reach some generalized conclusions about longer term patterns. Nevertheless it will require further systematic, long-term studies, such as Badman's (1988), before a sound understanding of the region's birdlife, in terms of habitat preferences, seasonality and breeding patterns, can be assembled and presented. It is to be hoped that the invaluable records of May (summarized in LAB 1986) will be published in full, as analysis of his longer term observations would certainly advance progress towards this goal considerably.

In keeping with a broader aim of the project, it was necessary to assess the effects of activities such as mining, grazing, tourism/recreation and hunting on the region's birdlife. The associated impacts (potential and observed) are addressed later in this chapter.

8.2 Methods

Because the birds of the Coongie Lakes District had been reasonably well documented, especially when compared with other groups of organisms, and because of their relative conspicuousness, less time and resources were devoted to ornithological studies than the other groups studied. However, waterbirds were studied in some detail, while field notes of bird observations were made while actively engaged in other activities, and so a comparable level of data was gathered. It is likely, however, that species of land-birds may have avoided detection, due to the limited time invested in specifically searching for birds in the district's wide range of terrestrial habitats. For instance, two species observed by visiting ornithologists, who spent short periods in the district assisting with fieldwork, were not detected by the author.

8.2.1 Waterbirds

Waterbirds were counted systematically at two monthly intervals in the lake system (Coongie, Marroocoolcannie, Marroocutchanie, Toontoowaranie and Goyder), using a boat with outboard motor. Breeding was investigated when encountered; otherwise the boat travelled at a constant, moderate speed, stopping to estimate the size and species composition of large flocks or to make distant identifications with binoculars. The lake system was covered, in this way, over a two or three day period, while engaged in other aquatic activities as well (e.g. limnological sampling).

On one occasion (March 1987) a light plane was chartered to conduct an aerial count of waterfowl on all the lakes simultaneously. However, the practice was discontinued, because the aerial counts yielded fewer birds than a boat count conducted at about that time, while identification to species was a problem as well.

Duck counts from the boat were thought to yield reliable figures early in the year, but as the lakes filled and then spilled over into the densely vegetated lignum margins, counts from then on seriously underestimated total duck numbers. The few incursions by foot into the flooded lignum habitat revealed that it was favoured by most species of duck, and supported considerable numbers (on the more open waters within the habitat). Most of this habitat was inaccessible (by boat or foot).

Towards the end of the survey, as Lake Goyder filled (and then spilled into the adjoining Marradibbadibba), counts on the massive lake were precluded by time constraints. Boating was confined to the western portion of the lake only, and so the occasional traverse around its south-western, western and northern margins by vehicle was conducted to supplement the counts by boat.

Additionally, notes were kept of waterbirds encountered on casual waters in the district and on these and other wetlands in the wider region.

8.2.2 Terrestrial Birds

Birds were recorded at the thirty permanent sites, while conducting the systematic pitfalling/vegetation sampling programme, to yield information at six weekly intervals in the district's range of terrestrial habitats. Actual censusing was not performed, but relative abundance was estimated on the basis of audial and visual clues.

These lists were analysed qualitatively to yield information such as habitat preference and seasonal status, as well as to look for seasonal shifts in habitat preference. This analysis was aided by maintaining a record of bird observations, detailing habitat notes, while travelling between sites and in the course of other duties.

Because of the remarkable rainfall events experienced within the region from early May 1986 to March 1987, special effort was made to document breeding events of the bush-birds. The association between significant rainfall events and aseasonal breeding in desert birds has long been a subject of interest (reviewed by Schodde 1982).

Notes were kept of interesting bird behaviour, and in particular of dietary items of seed-eating birds within the region. Some of these observations are presented in the Findings.

8.3 Findings

Over the course of the survey (November 1986 to September 1987), some 169 species of birds were definitely recorded in the study region (the area depicted in Fig. 1.1). Of these, all but eight (i.e. 161 species) were recorded from the Coongie Lakes District, which not only reflects the great amount of time spent at Coongie compared with other districts, but also highlights the richness and diversity of the birdlife to be found there. The number of birds recorded compares favourably with the total seen by May (in LAB 1986) on Innamincka Station over an eight year period - 177 species, while Badman (1988) recorded 160 species from the length of the Cooper during his long-term survey. In addition, there were four species tentatively identified during this study, including a tantalizingly brief glimpse of two birds at night in February which were thought to be Night Parrots.

In all there have been 205 species of bird reliably recorded in that part of the North East, defined by the Diamantina River and Birdsville Track to the west and the southern margin of the Strzelecki Desert to the south (excluding the Lake Frome District), and as approximately depicted in Fig. 1.1 (data from Reid in Mollenmans et al. 1984, May in LAB 1986, Badman 1988 and this study). This region has a higher species diversity than any other truly arid region in Australia; for example Badman (1979) recorded 173 species from the "southern and western Lake Eyre Drainage" region (although a few species have been added to the list since - Badman 1988), while fewer than 170 species have been recorded in three large, generally waterless, sandy deserts reviewed by Gibson and Cole (1987). The principal factors are undoubtedly the regularity (virtually annual) of flow along the Cooper and Diamantina, and the nature of the associated riparian vegetation communities. Below the Coongie Lakes - Embarka Swamp and Goyders Lagoon "termini" respectively, flow along these rivers is irregular.

Many of the species recorded at Coongie are accorded conservation significance in the most recent treatment of this topic in relation to birds of South Australia (Parker and Reid 1985), and the most significant examples are treated below. All 24 species classified as rare, vulnerable or endangered in South Australia are indicated in Table 1.1, which lists the species recorded during the survey, and indicates their residency status over the period and whether they were found breeding. A further 15 species are classified as uncommon (SAOA 1985).

Table 1.1

The species of bird recorded at Coongie and in the wider region during the survey. Nomenclature follows S.A.O.A. (1985).

Key to Symbols:

A	-X	species not recorded at Coongie;
	-R	species recorded (virtually) all months at Coongie;
	-R*	species recorded all months, but thought not to be strictly resident (transient populations);
	-T	species not recorded all months at Coongie;
	-S	species recorded (virtually) only in "summer";
	-W	species recorded (virtually) only in "winter";
	-(W,S)	species either much more common or mainly recorded in winter and summer respectively.
B	-X	species not recorded in other districts;
	-L	species of limited occurrence in wider region;
	-W	species widespread in wider region;
	-K	Koonchera District;
	-I	Innamincka District;
	-C	Cobblers District;
	-M	Moomba District;
	-T	Tirrawarra District.
C	-B	breeding definitely recorded;
	-?B	strong evidence to suggest breeding;
D	Abundance Within District (Region)	
	-R	rare in (Coongie) district- very few or recorded rarely;
	-L	low numbers (or moderate numbers rarely);
	-M	moderate numbers;
	-C	common to very common (large numbers or widespread and encountered frequently.
E	Conservation Status Within S.A. (After Parker and Reid 1985, SAOA 1985)	
	-E	Endangered;
	-V	Vulnerable;
	-R	Rare;
	-U	Uncommon;
	-MC	Moderately Common;
	-C	Common.

Species	A	B	C	D	E
Emu *Dromaius novaehollandiae*	R	W	B	L	MC
Great Crested Grebe *Podiceps cristatus*	(W)	L		R	R
Hoary-headed Grebe *Poliocephalus poliocephalus*	R	L		M	MC
Australasian Grebe *Tachybaptus novaehollandiae*	W	X		R	MC
Australian Pelican *Pelecanus conspicallatus*	R	L		C	C
Darter *Anhinga melanogaster*	R	X		M	R
Great Cormorant *Phalacrocorax carbo*	R	L		L	MC
Pied Cormorant *Phalacrocorax varius*	R	L	B	M	C
Little Black Cormorant *Phalacrocorax sulcirostris*	R	L		L	C
Little Pied Cormorant *Phalacrocorax melanoleucos*	T(W)	L		L	C
Pacific Heron *Ardea pacifica*	R	L		M	MC
White-faced Heron *Ardea novaehollandiae*	R	L	B	M	C
Great Egret *Ardea alba*	R	L	?B	L	MC
Little Egret *Ardea garzetta*	S	X		L	V
Rufous Night Heron *Nycticorax caledonicus*	R	X	B	L	U
Glossy Ibis *Plegadis falcinellus*	T(S)	L		L	R
Sacred Ibis *Threskiornis aethiopicus*	R	L		L	C
Straw-necked Ibis *Threskiornis spinicollis*	R*	L		L	C
Royal Spoonbill *Platalea regia*	R(S)	L		L	MC
Yellow-billed Spoonbill *Platalea flavipes*	R	L	B	M	MC
Plumed Whistling-Duck *Dendrocygna eytoni*	T	L		R	R
Black Swan *Cygnus atratus*	R	L	B	C	C
Freckled Duck *Stictonetta naevosa*	R(W)	X		M	V
Australian Shelduck *Tadorna tadornoides*	R	L		L	C
Pacific Black Duck *Anas superciliosa*	R	L	B	M	C
Australasian Grey Teal *Anas gracilis*	R	W	B	C	C
Australasian Shoveler *Anas rhynchotis*	R(S)	L		M	M
Pink-eared Duck *Malacorhynchus membranaceus*	R	W	B	C	MC

Hardhead Aythya australis	R	L		M	U
Maned Duck Chenonetta jubata	R	W		C	C
Blue-billed Duck Oxyura australis	(W)	L		L	R
Musk Duck Biziura lobata	T	X		L	MC
Black-shouldered Kite Elanus notatus	W	L		R	MC
Letter-winged Kite Elanus scriptus	T	L	B	R	R
Black Kite Milvus migrans	R	W	B	C	C
Black-breasted Buzzard Hamirostra melanosternon	R	L		L	R
Whistling Kite Haliastur sphenurus	R	L	B	C	MC
Brown Goshawk Accipiter fasciatus	W	L		R	MC
Collared Sparrowhawk Accipiter cirrhocephalus	T(S)	L	B	L	MC
White-bellied Sea-Eagle Haliaeetus leucogaster	T	X		R	U
Wedge-tailed Eagle Aquila audax	R	W	B	M	C
Little Eagle Hieraaetus morphnoides	R	L	B	M	MC
Spotted Harrier Circus assimilis	T	W	B	L	MC
Marsh Harrier Circus aeruginosus	(W)	L		L	MC
Black Falcon Falco subniger	R	W	B	L	U
Australian Hobby Falco longipennis	R(S)	L	B	L	U
Grey Falcon Falco hypoleucos	T	L		R	V
Brown Falcon Falco berigora	R	W	B	M	C
Australian Kestrel Falco cenchroides	R	W		L	C
Stubble Quail Coturnix novaezelandiae	R*	L		L	C
Little Button-quail Turnix velox	T(S)	X		L	C
Australian Crake Porzana fluminea	X	K		L	C
Spotless Crake Porzana tabuensis	X	K		L	MC
Black-tailed Native-hen Gallinula ventralis	T(S)	L	?B	M	MC
Dusky Moorhen Gallinula tenebrosa	R	X	B	L	MC
Purple Swamphen Porphyrio porphyrio	R(W)	L		M	C
Eurasian Coot Fulica atra	R	L	B	C	C
Brolga					

Grus rubicundus	R	L	B	L	V
Australian Bustard					
Ardeotis australis	T	L		L	V
Bush Thick-knee					
Burhinus grallarius	(W)	X		R	E
Painted Snipe					
Rostratula benghalensis	X	M		R	V
Masked Lapwing					
Vanellus miles	R	W	B	M	C
Banded Lapwing					
Vanellus tricolor	T(S)	W	?B	M	MC
Red-kneed Dotterel					
Erythrogonys cinctus	R(S)	L		L	MC
Red-capped Plover					
Charadrius ruficapillus	T	L		L	C
Black-fronted Plover					
Charadrius melanops	R	L	B	M	C
Inland Dotterel					
Peltohyas australis	X	L		L	U
Black-winged Stilt					
Himantopus himantopus	R(W)	L		M	C
Banded Stilt					
Cladorhynchus leucocephalus	W	X		R	MC
Red-necked Avocet					
Recurvirostra novaehollandiae	T(S)	L	B	C	MC
Wood Sandpiper					
Tringa glareola	S	X		R	U
Common Sandpiper					
Tringa hypoleucos	S	L		R	U
Greenshank					
Tringa nebularia	S	L		L	MC
Marsh Sandpiper					
Tringa stagnatalis	S	X		L	U
Latham's Snipe					
Gallinago hardwickii	S	X		R	V
Black-tailed Godwit					
Limosa limosa	S	X		R	U
Sharp-tailed Sandpiper					
Calidris acuminata	S	L		M	C
Pectoral Sandpiper					
Calidris melanotos	S	X		R	R
Red-necked Stint					
Calidris ruficollis	S	L		L	C
Curlew Sandpiper					
Calidris ferruginea	S	X		L	C
Australian Pratincole					
Stiltia isabella	(S)	W		M	MC
Silver Gull					
Larus novaehollandiae	R	L		M	C
Gull-billed Tern					
Gelochelidon nilotica	R*	L	B	L	U
Whiskered Tern					
Chlidonias hybrida	R	L	B	M	MC
Caspian Tern					
Hydroprogne caspia	R	L	B	M	C
Peaceful Dove					
Geopelia placida	R	L	B	C	MC
Diamond Dove					
Geopelia cuneata	R	W	B	C	MC

Common Bronzewing					
Phaps chalcoptera	R	L		R	MC
Flock Bronzewing					
Phaps histrionica	R(S)	L	?B	M	R
Crested Pigeon					
Ocyphaps lophotes	R	W	B	C	C
Galah					
Cacatua roseicapilla	R	W	B	C	C
Little Corella					
Cacatua sanguinea	R	W	B	C	MC
Cockatiel					
Nymphicus hollandicus	T	L		L	MC
Budgerigah					
Melopsittacus undulatus	R*	W	B	C	C
Mallee Ringneck					
Barnardius barnardi	R	X		L	MC
Red-rumped Parrot					
Psephotus haematonotus	R	X	B	C	C
Bluebonnet					
Northiella haematogaster	R	W		M	MC
Bourke's Parrot					
Neophema bourkii	X	I		R	U
Blue-winged Parrot					
Neophema chrysostoma	W	L		L	V
Pallid Cuckoo					
Cuculus pallidus	W	L		R	MC
Fan-tailed Cuckoo					
Cuculus pyrrhophanus	W	X		R	MC
Black-eared Cuckoo					
Chrysococcyx osculans	T	X		R	U
Horsfield's Bronze-Cuckoo					
Chrysococcyx basalis	R*	L		L	C
Southern Boobook					
Ninox novaeseelandiae	T(W)	X		R	MC
Barking Owl					
Ninox connivens	R	X		M	V
Barn Owl					
Tyto alba	T(W)	X		L	MC
Tawny Frogmouth					
Podargus strigoides	R	X		L	MC
Australian Owlet-nightjar					
Aegotheles cristatus	R	L		M	MC
Spotted Nightjar					
Caprimulgus guttatus	T	X		R	MC
Fork-tailed Swift					
Apus pacificus	S	L		M	MC
Red-backed Kingfisher					
Halcyon pyrrhopygia	R	L	B	M	MC
Sacred Kingfisher					
Halcyon sancta	R*	X		L	MC
Rainbow Bee-eater					
Merops ornatus	S	L	B	M	C
Singing Bushlark					
Mirafra javanica	T(S)	L		L	U
White-backed Swallow					
Cheramoeca leucosternum	R	W	B	M	MC
Welcome Swallow					
Hirundo neoxena	(W)	L		R	C
Tree Martin					

Cecropis nigricans	R	L	B	C	C
Fairy Martin					
Cecropis ariel	R*	W	B	C	C
Richard's Pipit					
Anthus novaeseelandiae	R	W	B	M	C
Black-faced Cuckoo-shrike					
Coracina novaehollandiae	R*	L		L	C
Ground Cuckoo-shrike					
Coracina maxima	T(S)	L	B	L	U
White-winged Triller					
Lalage sueurii	T(S)	L		L	MC
Red-capped Robin					
Petroica goodenovii	(W)	L		L	MC
Jacky Winter					
Microeca leucophaea	W	X		R	MC
Rufous Whistler					
Pachycephalus rufiventris	W	X		R	MC
Grey Shrike-thrush					
Colluricincla harmonica	R	X	B	M	C
Restless Flycatcher					
Myiagra inquieta	R	L	?B	R	MC
Grey Fantail					
Rhipidura fuliginosa	W	X		R	C
Willie Wagtail					
Rhipidura leucophrys	R(W)	W		M	C
Chirruping Wedgebill					
Psophodes cristatus	R	L		C	C
Cinnamon Quail-thrush					
Cinclosoma cinnamomeum	R	W	B	M	MC
Chestnut-crowned Babbler					
Pomatostomus ruficeps	R	L	B	M	MC
Clamorous Reed Warbler					
Acrocephalus stentoreus	T	L		L	C
Little Grassbird					
Megalurus gramineus	T	L		L	MC
Rufous Songlark					
Cinclorhamphus mathewsi	R*	L	?B	M	MC
Brown songlark					
Cinclorhamphus cruralis	T	W	?B	M	C
Variegated Fairy-wren					
Malurus lamberti	R	W	B	C	C
White-winged Fairy-wren					
Malurus leucopterus	R	W	B	C	C
Eyrean Grasswren					
Amytornis goyderi	R	W	B	M	MC
Grey Grasswren					
Amytornis barbatus	X	K		L	R
Western Calamanthus					
Sericornis campestris	X	C		L	U
Weebill					
Smicrornis brevirostris	S	X		R	C
Chestnut-rumped Thornbill					
Acanthiza uropygialis	?R	X	?B	R	C
Southern Whiteface					
Aphelocephala leucopsis	R	L	B	M	MC
Banded Whiteface					
Aphelocephala nigricincta	R	L	B	L	R
Brown Treecreeper					
Climacteris picumnus	R	L	B	M	MC

Spiny-cheeked Honeyeater Acanthogenys rufogularis	R	X		L	C
Yellow-throated Miner Manorina flavigula	R	W	B	C	C
Singing Honeyeater Lichenostomus virescens	R	W		L	C
White-plumed Honeyeater Lichenostomus penicillatus	R	W	B	C	C
Golden-backed Honeyeater Melithreptus laetior	R	X	B	R	R
Pied Honeyeater Certhionyx variegatus	T	X		R	R
Crimson Chat Ephthianura tricolor	R*	W		M	MC
Orange Chat Ephthianura aurifrons	R	W	B	M	MC
Yellow Chat Ephthianura crocea	X	K	B	R	V
Gibberbird Ashbyia lovensis	T	W		L	U
Mistletoebird Dicaeum hirundinaceum	(W)	L		M	MC
Red-browed Pardalote Pardalotus rubricatus	R	W	B	M	MC
House Sparrow Passer domesticus	T	L		M	C
Zebra Finch Poephila guttata	R	W	B	C	C
Common Starling Sturnus vulgaris	T	X		R	C
Australian Magpie-lark Grallina cyanoleuca	R	W	B	C	C
White-breasted Woodswallow Artamus leucorhynchus	R	L		M	MC
Masked Woodswallow Artamus personatus	(S)	L		M	MC
White-browed Woodswallow Artamus superciliosus	T	L		M	MC
Black-faced Woodswallow Artamus cinereus	R	W	B	C	C
Australian Magpie Gymnorhina tibicen	R	W	B	M	C
Australian Raven Corvus coronoides	R	L	B	C	C
Little Crow Corvus bennetti	R	W	B	C	C

UNCONFIRMED RECORDS

Long-toed Stint
Calidris subminuta
Night Parrot
Pezoporus occidentalis
Hooded Robin
Melanodryas cucullata
Crested Bellbird
Oreoica gutturalis

The endangered Bush Thick-knee was heard often and seen twice in the winter period and always in floodplain habitats, generally adjacent to water. The species feeds preferentially in grasslands, and a pair was observed at the edge of Emu Flat (flooded Sporobolus mitchellii grassland). Generally nocturnal, the species roosts on the ground during the day in well wooded (often grassy) habitats, and an individual was seen in this habitat c. 10 km south of the main camp. The species was heard calling at night from riparian woodland along the North-West Branch. Despite all records being made in the winter period, Blakers et al. (1984) found no evidence for seasonality within the species' Australian range, while May (in LAB 1986) shows records on Innamincka Station for all seasons.

The vulnerable Freckled Duck is listed among the 10 rarest waterfowl in the world (Martindale 1986). Cowling (1979) recommended that it be entered in the I.U.C.N. Red Data Book as having "Indeterminate" status pending the publication of results from continuing studies of the species ecology and status. Freckled Duck were present throughout the year on the lakes, generally in small numbers e.g. groups of 20 to 50 were seen on all the lakes apart from Marroocoolcannie, and a similar number resided on Embarka Swamp once it was flooded. Approximately 100 duck were present on the Coongie Lakes at most times with numbers varying from lake to lake, as birds shifted between the lakes. However, in early June, a spectacular aggregation developed on the southern, shallow lagoons of Lake Toontoowaranie. In May, 125 were counted there, while at least 600 were present a few weeks later in several big rafts. Others were seen skulking in the flooded lignum margins of these bays and of the inlet of Browne Creek, and because of the extent of this habitat (a preferred habitat of the species - Martindale 1986), it is likely that several hundred more were present. With the smaller numbers present on the other lakes, 1000 is considered to be a realistic estimate of the species abundance in the Coongie Lakes system in early June. Heavy rains later in the month caused this aggregation to disperse away from the lakes along with the other ducks in the district (this withdrawal from the lakes was noted several times over the survey period following a heavy rain).

The species was most often seen in shallow water and lignum habitat, while at no stage were males observed in breeding dress (the base of the male's bill becomes red as the bird enters a reproductively active phase).

Good numbers of the rare Australasian Shoveler were seen throughout the survey period, with a maximum of 600 birds in late summer - most of these were on Lakes Goyder and Toontoowaranie in their drying phase. The species was occasionally recorded on waterholes and was seen at Embarka Swamp and Koonchera Waterhole.

The Brolga, vulnerable in South Australia, was present throughout the year in small numbers, mainly on the outer lakes. A maximum of c. 20 could be accounted for, which included progeny of the 1986 breeding season. Scattered birds were seen elsewhere along the Cooper, and nine were present in the Koonchera District in May.

Also vulnerable, the Painted Snipe (a rare Australian subspecies) was recorded for the first time in the North East this survey, at a large ephemeral swamp (Della Road Bore No 2) between Moomba and the Strzelecki Creek. A male was observed in April in wet clayey margins of a Chenopodium nitrariacium dominated part of the swamp.

Other rare waterbirds encountered were Great Crested Grebe, Darter, Little Egret, Glossy Ibis, Plumed Whistling-Duck, Blue-billed Duck, Pectoral Sandpiper and Latham's Snipe. In particular, the populations of the Darter and Glossy Ibis on the Cooper (and the Tree-Duck on the Diamantina) are significant in the state context.

Three of the 17 species of diurnal raptore recorded are of Australian conservation significance viz. Grey Falcon, Letter-winged Kite and Black-breasted Buzzard, while the breeding raptore community supported by the Strzelecki Creek and the Upper Cooper (in S.A.) is a feature of the region (Cox 1982). The Grey Falcon is Australia's second rarest diurnal raptore (e.g. Slater 1980), and its eggs are eagerly sought (illicitly) by egg-collectors. The Cooper, Strzelecki (and presumably Diamantina) systems are likely to be an Australian stronghold for the species. The species definitely breeds along the Upper Cooper (cf Badman 1988), although no further details are given, nor should breeding details be published for Australia's rarest birds of prey, unless adequate protection from nest poachers can be assured. Three individuals were seen over the survey period along the Strzelecki and Cooper Creeks, while the species was also seen on the Diamantina in June 1984 (unpub. data). Cox (1982) reported that three pairs of the rare Black-breasted Buzzard resided in the Coongie District in 1975. At least two pairs were present along the Kudriemitchie Channel over the survey period, and scattered sightings were made elsewhere in the district and along the Upper Cooper. The attractive eggs of this species are also highly prized by egg-collectors. This species and the rare Letter-winged Kite were found breeding along the Strzelecki Creeks during the survey period (Jim Puckridge and Max Waterman, pers. comm.). One Letter-winged Kite was observed at Coongie in February. The ecology of the kite is closely linked with the population dynamics of the native long-haired rat Rattus villosissimus. Despite wet conditions, the rat was not observed to plague anywhere in the region, and consequently the Letter-winged Kite was inconspicuous.

The vulnerable Bustard was recorded sporadically during the year. The species was most common in the grassy flats of the Upper Strzelecki floodplain following the heavy summer rains. Otherwise individuals were seen sparingly in the Cooper region and in the stony country north of Innamincka.

The Flock Bronzewing has declined alarmingly in the last 100 years (Slater 1980, Frith 1982) over its central Australian range. Moderate numbers are still reported occasionally in the channel country of north-east South Australia (Reid in Mollenmans et al. 1984), and it was heartening to find several hundred in the Coongie Lakes District over the summer period. Several groups of up to 80 were sighted, although most birds were seen individually or in small parties. The species favoured the low white dunes of the fringing dunefield, and all feeding observations (c. 10) were of Phyllanthus seeds, while many other observations were made of the pigeons in locally dense "swards" of the two Phyllanthus species. P. lacunarius is a character plant of the district's low white dunes. Another exciting observation was that of the male's breeding flight-display, given by several birds over Lake Apachirie in March and April. Although nests were not searched for or found, the behaviour of female Flock Pigeons in the ensuing two month period certainly indicated breeding in the dense ephemeral low shrubland/herbland of the dry lake-bed. The male's display is a fascinating spectacle, which although overlooked by Frith (1982) in his extensive review of the pigeons and doves of Australia, has been previously and comprehensively described by Williams (1970). Breeding is thought to have been completed by the end of May, and few birds were subsequently seen.

The Blue-winged Parrot, regarded as vulnerable in South Australia because of extensive clearance of its breeding forested habitat in the South East, winters in central and south-eastern Australia, with the channel country apparently being one of its main wintering grounds (see map in Blakers et al. 1984). Scattered birds were seen in the Coongie Lakes District, and around Innamincka and Koonchera, with the last observation in the middle of August of several birds in ephemeral forbland under a lignum overstorey on the Marroocutchanie floodplain.

A thriving and delightfully vocal population of the Barking Owl exists along the North-West Branch. Observations (or more correctly aural records) over the year suggested that pairs were evenly spaced along the Channel, roughly one kilometer apart, wherever the channel was lined with a good cover of red gums. The species distribution appears to be restricted by the presence of red gums, and no birds were observed or heard in the coolibah woodlands fringing the district's lakes. However, the species does forage away from the channel and birds were seen/heard up to a kilometer distant in coolibah-floodplain habitats. The few birds seen roosting during the day were all perched in parts of red gums that overhung the Cooper, and regrettably no pellet deposits could be found along the banks (it had been hoped that a seasonal analysis of the species diet could be undertaken). In the late autumn-winter period, Barking Owls were heard to give their high pitched, wavering "screaming woman" call (of Fleay 1967), while another call heard in January was a shrill, insect or frog like, twittering/chirruping. The Upper Cooper is certainly the stronghold for this vulnerable species in South Australia, and its riparian red gum woodland must be afforded adequate protection.

The Golden-backed Honeyeater had only been recorded once in South Australia, prior to Parker's 1980 record from Cuttipirie Corner Waterhole (Reid in Mollenmans et al. 1984, S.A. Parker pers. comm.). Badman (1988) lists a subsequent record from near Innamincka in September 1984, made by R.N. and T. Sim. Over the survey, three groups were observed, one regularly along the final eight kilometer stretch of the Kudriemitchie Channel. This group bred twice, in autumn and winter, and may have split during the year to form a second group, which was observed several times along Browne Creek in the latter half of the study only. These are the first breeding records (fledged young both times) for the species in the State. Group size was five or six, and a third, similar sized group was encountered in Tirrawarra Swamp in April. A group had been recorded in the same north-western corner of the Swamp previously (June 1984 - unpub. data).

In the dunefields of the Coongie Lakes District, the rare Banded Whiteface was encountered regularly, with two breeding events recorded (a recently vacated nest was located at 15W in May, and nest building in July/fledged young in August at several sites). Repeated observations made at several sites (e.g. 15W, 14E) is suggestive of sedentary behaviour within a large home range. The Eyrean Grasswren (formerly classified as Endangered in the I.U.C.N. Red Data Book) was also moderately common in the district's dunefields; the species was generally encountered in sandhill cane-grass habitats, but was also observed to cross interdune corridors and was seen in lignum twice (once in an extensive lignum patch approximately one kilometer from the nearest dune near Site 15E). The grasswrens were also considered to be sedentary over the year, with a more limited home range area than the Banded Whiteface. A nest with three eggs was located in a sandhill cane-grass tussock in late February at Site 14E, which is at odds with Schodde's (1982) assertion that the species breeds only in the spring. Juvenile birds were observed in early September, suggesting a typical late winter-early spring breeding event as well. Singing birds were heard frequently through the summer-autumn period, and then again in late winter and spring, and it is likely that the species bred over most of the survey period (except for the late autumn-mid winter period) in response to the prevailing wet conditions.

Further afield, the continued presence of the Grey Grasswren and Yellow Chat in the Koonchera District was confirmed. A pair of the latter had commenced nest building in the typha at Pandiburra Bore in February, while the grasswrens were seen in lignum around Koonchera Waterhole on both the February and May visits.

8.3.1 Waterbirds

At least 20 000 waterfowl (duck and swan) occupied the Coongie Lakes (virtually) all year. The number observed on the lakes dropped dramatically immediately following heavy rains in the region (e.g. only 3 000 in the July count, although the northern shoreline of Goyder and the southern extension of Marroocutchannie were not visited and may have yielded many more thousands), when the open lake surfaces became almost devoid of ducks. In excess of 35 000 waterfowl, estimated in August, was the maximum over the survey period, with Grey Teal and Pink-eared Duck constituting the great majority of this number.

These figures alone justify the claims that the Coongie Lakes system is a wetland of international importance. For a wetland to be considered for inclusion in the RAMSAR Convention, it needs to be demonstrated that at least 10 000 waterfowl regularly occur there. The occurrence of rare species, such as the congregation of 600 to 1 000 Freckled Duck on Lake Toontoowaranie, amplifies the system's importance.

There are few previous counts of waterfowl on the Coongie Lakes, with which to compare this year's data. Based on aerial and boat traverses made of the entire system in late September 1983 (NPWS unpub. data, L. Delroy pers. comm.) a total estimate of 15 000 was made, and the majority of the birds identified were Hardhead. However, an aerial reconnaissance of the Middle Cooper, conducted at the time, revealed thousands of duck (mainly Grey Teal) on recently flooded areas. This was a moderate sized flood at the end of a severe drought (Badman 1988), during which the Coongie Lakes apparently dried completely (in early 1983), and the preponderance of Hardhead on the lakes accords with Badman's observations that the species is the first colonizer (amongst the ducks) of reflooded ground. In August 1979, Coongie Lake was teeming with waterfowl, which included two Northern Shoveler (Close and Jaensch 1981) - the first record of the species in the State. No estimates were made at the time, but in retrospect, 20 000 is given as a conservative estimate. Field notes recorded at the time (R. Jaensch unpub. data) show Grey Teal and Pink-eared Ducks to have been most numerous in their "thousands". Smaller but still large numbers were present on Lake Toontoowaranie at the same time (pers. obs.). The number of waterfowl on Coongie Lake itself has generally not been as great in recent years (M. Steel pers. comm.), with increased tourism and hunting pressure having been blamed for this in the popular press.

Surprisingly no definite breeding records of ducks on the lakes were made over the survey period, whereas breeding was observed or reported in the district (or nearby) along the Kudriemitchie Channel (Grey Teal in January) and in ephemeral wetlands (temporary swamps and Tirrawarra and Embarka Swamps) following the February rains (Grey Teal, Black Duck and Pink-eared Duck). Most of the common ducks have bred at Coongie (e.g. Rix 1974, Reid in Mollenmans et al. 1984), and it is likely that breeding on a limited scale may have passed undetected over the year, while it is considered that a larger scale breeding event may have been imminent on Lake Goyder as the study was finishing, with the reflooding of vast sections of the lake and its margins occurring in late winter-early spring (an appropriate trigger for a customary spring breeding season e.g. Frith 1977 and see Chrome 1986). Of the many suitable coolibah hollows inspected around the lakes over the year, only two showed recent signs of nesting by duck (perhaps used in spring 1986). The far more extensive banks of temporarily inundated lignum were not searched for nests.

One possible species of duck to breed on the lakes was the Musk Duck - a male was observed displaying on Toontoowaranie in May. In contrast to the ducks, swans bred regularly (in small numbers) over the study period. Based on the size of cygnets seen ,together with direct observations of nests, at least five breeding events occurred between August 1986 and August 1987 inclusive (the end dates, November 1986, February 1987 and April-May 1987). A virtually continuous breeding event is perhaps an equally valid interpretation of the data. Breeding occurred on four lakes (not Marroocoolcannie), Browne Creek and Embarka Swamp. Swan numbers on the lakes varied from c. 1 000 at the start of the study to c. 2 000 by the end, with the increase probably attributable to both breeding success and immmigration from Embarka and other swamps as their waters receded in spring. A flock of swan was observed on Lake Talinnie, after it filled with rain in June, while another interesting observation made repeatedly after heavy rainfall in the district, was the regular departure of c. 20 swan soon after dusk each night, flying from Coongie Lake to undiscovered pastures due west of the base camp; the birds were heard to return just before dawn on many mornings (whenever consciousness pertained). This behaviour continued for about a month on two occasions following rain, and presumably terminated when the "fields" dried out.

Many swans, unable to fly while moulting, sought refuge on the lakes between February and July, and these large open water bodies may similarly act as refuges for other species of moulting waterfowl, when their reduced powers of flight render them more vulnerable to predation.

Most abundant of the ducks at all times of the study were the Pink-eared Duck and Grey Teal, and by August when the other species of duck had become comparitively less numerous, the two species constituted some 30 000 of the 35 000 waterfowl estimated to be in the lakes system.

Pacific Black Duck, Australasian Shoveler, Hardhead and Maned Duck each generally numbered less than a thousand individuals over the survey period, and maximum numbers recorded are presented below:

Pacific Black Duck - c. 300 in April/May, but perhaps as many as 500 were present at most times of the year, given the species dispersed pattern of distribution over the lakes;

Australasian Shoveler - c. 600 in January/February (mostly on Goyder and Toontoowaranie) after which numbers dropped to 2-300;

Hardhead - an aggregation of 1 000+ on Toontoowaranie in February probably represented the bulk of the district's population with few being seen on other lakes at this time; numbers subsequently dropped to 500+;

Maned Duck - 550 were counted on the drying margins of Goyder in February and 400+ in May, before this lake began to fill, when most birds left the district; perhaps a maximum of 700 in the district over the summer, but widespread through the region with 1 000+ on Embarka Swamp and many hundreds scattered on roadside borrow pits.

Other species of duck recorded in the Coongie Lakes system were the Plumed Tree-Duck (two on the North-West Branch in February), Musk and Blue-billed Duck which were both seen in small numbers only. The last species was present between February and early July, and it is assumed to be a winter migrant to the district (e.g. Frith 1977, although Badman 1988 has recorded the species on the Lower Cooper in November). Forty Blue-billed Ducks were seen in a loose flock on Lake Goyder in July, which was the largest number recorded, and they apparently departed soon after for the birds were not observed a week later or on subsequent visits. Small numbers of Great Crested Grebe were seen on most of the lakes and occasionally the main channel over the same period (autumn-winter), and the species shares its open water habitat preference with the Musk and Blue-billed Ducks.

Pelicans, which are known to breed fairly regularly on the islands of Lake Goyder (M. Steel pers. comm.), did not breed this year. At least 5 000 were present on the lakes over summer prior to the big February rains, but less than a thousand remained after this event. The lakes apparently were a refuge for the species, which spread out along the Cooper (and presumably Diamantina) once the rivers started flowing e.g. several hundred appeared at the Innamincka Causeway in February-March taking advantage of the bountiful food supply provided by migrating fish attempting to get upstream across the causeway. The pelicans moved between the lakes over the summer period, and the high altitude arrival from Toontoowaranie and subsequent spiralling descent onto Goyder of a thousand pelicans in February provided an inspiring spectacle. The largest flock seen over this period numbered c. 2 500, on Toontoowaranie in January, and in excess of 1 000 were seen on all five lakes. This summer flocking habit contrasted sharply with the individual territoriality displayed by birds along the North-West Branch over winter. Single birds occupied contiguous, four or five hundred meter stretches of the channel, and vigorously approached and displayed to neighbours that encroached on the territory, with much braying and lifting of the wings. The birds were quite curious of boats at this stage and would tentatively approach the row-boat. Unfortunately with no fish at hand, it could not be tested whether the birds would accept offered food or if the boat was regarded more as an intruder than potential food source. At the same time small flocks continued to feed and roost together on the lakes, and so it was interesting to compare these opposing strategies.

The numbers of Eurasian Coot increased from c. 1 000 in summer to 2600 by the end of the study. A large breeding event in winter (many juveniles first noted in June and July) and immigration from drying swamps further afield explain the increase. Two thousand were observed on Embarka Swamp in winter, and birds may have moved to Coongie in spring as the water level in the Swamp dropped. Coots were not observed to disperse away from the lakes following heavy rains.

Other large concentrations of waterbirds noticed in the district included 3 000 Red-necked Avocet in summer, and 500+ Black-winged Stilt and 600+ Hoary-headed Grebe in winter all on Lake Goyder, which also supported the largest migratory wader and tern populations. It is interesting to observe that the avocet concentration occurred when Lake Goyder was somewhat saline, while the stilts occurred in abundance once the lake had refilled and was quite fresh. The avocets departed with the February rains and were found breeding in temporary swamps in the Moomba region in March and April. The behaviour of the grebes in tight flocks, and their association with wheeling groups of Whiskered Tern indicated they were following schools of small fish.

Pied Cormorant numbers were fairly stable over the year at c. 1 300, with most birds congregating on the south-east bay of Coongie, Marroocoolcannie and especially Marroocutchannie. About one hundred birds gathered in early autumn in the north-western portion of Coongie Lake, and after a noisy courting period, some 12 – 20 pairs commenced nesting. By mid-winter all the birds had deserted the area, without any young having been raised, and it is possible that human disturbance (boating) contributed to the lack of success.

The other species of cormorants were much less abundant, and least common was the Little Pied, which was only recorded in the last four months of the survey. The Darter was distributed evenly along the main channels and around the main lakes, and c. 100 were estimated to be present throught the year. No nests were located, and surprisingly this species has yet to be found breeding along the Cooper in South Australia (Badman 1988).

Herons, ibis and spoonbills were well represented, with all but two (Plumed and Cattle Egret) of the species known from the region recorded. The Yellow-billed Spoonbill and White-faced and Pacific Herons were the most common and regularly encountered of this group. The spoonbill bred successfully along the North-West Branch and on Coongie Lake (20 nests in all) in autumn; the birds commenced nesting immediately following the big February rains and the initiation of steady flow into the system. One pair of White-faced Herons built and briefly occupied a nest along the Channel in February, but quickly deserted. Numbers of the Pacific and White-faced Herons varied through the year, and they were frequently encountered on small ephemeral pools following rain - nine Pacific Herons frequented one small swamp for a month in March. The Pacific Heron became less numerous in the winter-spring period

The Rufous Night Heron roosted by day in either one or two colonies, totalling 40 birds, along the North-West Branch between the base camp and Coongie Lake over the summer period. They dispersed in March, presumably to breed in the smaller channels (Browne, Ellar and Appanburra), where juveniles were seen in May-June.

Forty Royal Spoonbill were observed on Toontoowaranie in February and over the summer months, this species was equally as or more common than the Yellow-billed on the lakes, with the reverse situation applying to channel habitat. However, few were seen after summer. Glossy Ibis was also most common over summer with a maximum of 140 seen on Marroocutchannie in February, while none were seen for three months between May and August. Less than ten Sacred Ibis were present most of the year, while Straw-necked numbers fluctuated greatly, but were generally uncommon (or absent). In excess of 500 Straw-necked Ibis were encountered on a moderate sized swamp ("Della Road Bore No 2") between Moomba and Innamincka in April.

The Dusky Moorhen was confined to channel habitat, and mainly occurred on the North-West Branch, where birds were breeding between January and May. Small numbers of the Purple Swamphen were also present in this habitat over most of the survey, particularly on the margins of the estuaries of the Cooper, Browne and Ellar Creeks. However, in August and September, many hundreds were present in flooded low herbage around the extensive northern margins of Lake Goyder.

Three species of tern and the Silver Gull were present in moderate numbers for much of the year, although the Gull-billed Tern appeared to be absent at times, and was the least common of the species. The Whiskered Tern was the most common (up to 500) and virtually confined to lake habitat. The Caspian Tern (up to 400) was frequently observed over channels as well as lakes, while the Gull-billed Tern occupied lake and ephemeral pool habitats (all three species were seen on the extensive Embarka Swamp also). The three species of tern bred on Lake Goyder in April, presumably on the islands, and recently fledged juveniles of the three species were observed there in May. Interestingly, most of the Caspian Terns (c. 300) moved to Marroocoolcannie in early June, where the adults creched their progeny on a large sandy spit. During April adult Whiskered Terns were seen to take fish from Coongie and then fly north with fish in bill, until out of sight well beyond the margin of the lake. Silver Gull numbers peaked at c. 500 in the winter, but no evidence of breeding was noted.

Of the waders, sightings of the Pectoral Sandpiper (Goyder and Marroocutchannie) and Black-tailed Godwit (Goyder) were the most interesting. In addition the five small calidrid waders tentatively identified as Long-toed Stints on Lake Goyder in February would be the first record for the Cooper (Badman 1988). The 104 Marsh Sandpiper counted on Lake Goyder in February is an unusually large concentration for this species (e.g. Badman 1988). Most abundant of the migratory waders was the Sharp-tailed Sandpiper - 300+ in February and 500+ in September on Goyder. About 50 Greenshank were observed from the air in March on a temporarily filled large saline flat to the north of Lake Talinnie, while the 35 Banded Stilts seen on Talinnie in July constitutes the only record of this species for the study. A few Wood and Common Sandpipers were seen in channel habitat and the former species was also present on Emu Flat when it reflooded in September. A single (presumably Latham's) snipe was flushed by Dr A. Black from the northern margin of Goyder in September.

Aquatic habitats in the Coongie Lakes District

Different suites of waterbirds tend to occupy the major aquatic habitats that can be readily recognized within the district, although the composition of and numbers of species within these suites fluctuate with the changing conditions. A complication is caused by the temporal variability of habitat, such that, for instance, a large portion of Lake Goyder can be 1.5 m deep for some of the year and inhabited by open-water species, and shallow water/wet mud habitat in a drying phase with an entirely different range of waterbirds.

The deeper (1+ m) open waters of the lakes and waterholes were favoured by cormorants, pelican, coot, grebe species, Caspian Tern, swan, the stiff-tailed ducks, and the Dusky Moorhen (channels only) - most of these species were commonly seen feeding in shallower waters as well, as at the margins of the lakes and channels. The dabbling and filter-feeding ducks and the Hardhead generally avoided this habitat for foraging in, but large flocks congregated on the middle of the lakes (a safe environment) at times when roosting or loafing.

The richest waterfowl habitat was provided by the inundated lake margins where there was associated vegetation e.g. flooded lignum, thick (often submerged) beds of the sedge _Cyperus gymnocaulos_ or the amphibious grass _Pseudoraphis spinescens_, submerged _Myriophyllum_ herbland, _Sporobolus mitchellii_ dense grassland, and _Sclerolaena intricata_ dominated, varied low shrub/herblands. Ducks were most often seen feeding in these habitats, especially when first inundated, and up to 10 000 ducks were counted on each of Lake Goyder (S. intricata) and the Marroocutchannie southern extension (S. mitchellii) in August. The depth of water in these habitats varied from very shallow to about one metre. Many other waterbirds occupied this habitat, namely egrets, herons, spoonbills and ibis, in the shallower waters, and Masked Lapwings and Black-winged Stilts in shallower water again. Backwaters along the main channels provided similar habitat to that described above, and were particularly important for the nesting Yellow-billed Spoonbills in the autumn. Both in the drying phase and when reflooding, the areas around the inlets of the North-West Branch and Browne and Ellar Creeks were favoured habitats for waterbirds, with extensive flats of lignum and Sporobolus mitchellii being a feature of the mouths of Browne and Ellar Creeks.

Receding margins of lakes with damp mud/clay and bare or vegetated surfaces were popular with waders - dotterals, plovers, lapwings, sandpipers and stints - over summer.

The minor channels off the main system (e.g. the outlets of Apachirie, Walkooanie and Appanburra) were distinctive channel habitats because of the absence of fish in them, and supported small mubers of a wide range of waterbirds. Because the main Appanburra channel (between Lakes Toontoowaranie and Appanburra) was not sampled, the presence or absence of fish could not be ascertained, and it is unknown whether water (and therefore, presumably fish) remained from the last flow event to enter this channel, or whether it was simply rain-filled like the minor channels mentioned above.

After heavy rains in the district, innumerable shallow pans filled for varying periods on the floodplains and in the dunefields, and it is assumed that the departure of the bulk of the ducks from the lakes that coincided with these events resulted from their withdrawal to the larger of these ephemeral waters in the wider district. Small numbers of duck

(Grey Teal, Pink-eared, Maned Duck and Australian Shelduck) were seen on smaller pools and pans close to Coongie, along with a wide range of other waterbirds (Brolga, herons, Great Egret, the three ibis, two spoonbills, lapwing, Black-fronted Plover and Black-tailed Native-hen).

Finally, Lake Talinnie was the only saltlake with water visited during the survey. It filled with rain at least three times over the period and attracted birds on each occasion e.g. Black Swan, Australian Shelduck, Grey Teal, Red-necked Avocet, Black-winged Stilt, Banded Stilt, Red-capped Plover, Sharp-tailed Sandpiper, Silver Gull, Gull-billed Tern, and in March was observed to be teeming with small shrimps with a red column posteriorly (thought to be brine shrimps).

Thus the Coongie Lakes district is shown to have a variety of aquatic habitats, and this range of habitats, more than any other factor, accounts for the diversity and richness of the district's aquatic avifauna. Equally important as the spatial variability is the temporal variability of the habitats - on two scales. First, within a flow/flood event variation is expressed as the system fills, attains its greatest depth and coverage, and then recedes, while secondly, the variable magnitude of successive events results in different conditions during and between these events.

Also the manner in which the sequence of lake-fillings is staged adds another dimension to the temporal variation within flow events. As witnessed this year, the ducks and other birds move between the lakes to capitilize on particular situations suited to their dietary needs, foraging methods or reproductive condition, which change as the lakes fill and recede at different times and rates. The concomitant salinity changes, especially in the outer, "more terminal" and "less permanent" lakes presumably play a big part here as well.

There are three other points worth considering here. A larger flooding than occurred this year, and which sends Cooper water into the peripheral channels and lakes e.g. Apachirie, Appanburra and the Sturt Ponds would add another dimension to habitat variability and hence waterbird abundance and behaviour within the district. Successive dry years coupled with below average flows along the Cooper results in drying out of the lakes (occasionally totally). In such periods the waterholes and Lake Coongie (if still holding water) are extremely important refuges for the waterbirds which remain in the district, and management practices will need to reflect their importance and sensitivity at these times. Furthermore a subsequent reflooding of the lakes after a complete draw-down can be expected to result in a highly productive, waterfowl breeding event (Crome 1986). With temporal variation being an inherent and such a crucial factor in the Coongie Lakes environment, operating at several levels, this facet of the ecosystem and its consequences with respect to the district's fluctuating waterbird populations not only warrants further study, but will **need** to be understood if the district is to be managed responsibly and at the same time be subject to increased visitation. In the absence of more detailed information, the area should not be opened to tourists beyond the limits (pressure) prescribed later in this report.

Five species of waterbird, which have been recorded in recent years, were not detected in the Coongie Lakes District during the survey, namely Plumed Egret, Chestnut Teal, and the Australian, Baillon's and Spotless Crakes (nor were some vagrant species such as the Northern Shoveler, but they do not require discussion). In particular, the absence of the crakes was surprising, as much suitable habitat existed (in the form of shallowly inundated lignum) at different times of the year. The Australasian Crake was quite common im this habitat at Coongie in August 1979 (pers. obs.) and Badman (1988) regards this species as being common throughout the Lake Eyre region in boredrain habitat. The district is outside the customary ranges of the egret and the teal (and perhaps of the other two crakes as well), and these species probably only appear at irregular intervals.

Wetlands in the Wider Region

Three wetland complexes outside of the immediate Coongie district are highly significant and they all regularly contain water (virtually annually) as a result of river flow. Badman (1988) has identified the most important wetlands of the Middle and Lower Cooper, but they are filled less regularly than Tirrawarra and Embarka Swamps of the Cooper Creek and the Goyders Lagoon complex at the junction of the Diamantina and Warburton system.

Tirrawarra Swamp, located on the North-West Branch, receives water annually, but is thought to dry out most years as well. It is densely vegetated with lignum and river coobah, and because of this cover cannot support large numbers of waterfowl. However, Pacific Black Duck bred there during the survey, while in June 1984 may thousands of Black-tailed Native-hen were present - the number of advanced young observed indicated a massive breeding event (unpub. data). Tirrawarra Waterhole, the swamp's inlet is a magnificent waterhole, that is regrettably being degraded by the activities of tourists, SANTOS employees and professional rabbiters alike. The degree of significance of the Tirrawarra Waterhole-Swamp complex as waterbird habitat cannot be ascertained until it is further studied.

Embarka Swamp lies on the Main Branch of the Cooper. A large area of the swamp has been developed for gas (and oil) production. Tall embankments cause water to pond behind them to some degree, while large basins, from which earth was extracted to construct the embankments, have created an artificial open-water habitat within the swamp. These developments have undoubtedly altered the swamp's hydrology, but effects on the biota can only be speculated upon in the absence of any pre-development information. Possibly, larger numbers of waterfowl can congregate because of the open-water habitats, but the risks associated with this development are potentially catastrophic. An oil-fouled Silver Gull was observed on the swamp during the survey, and the hazards posed to wildlife by hydrocarbon pollution need no further elaboration here. Waterfowl numbers on the open water habitats of the swamp were estimated at between five and ten thousand over the survey period, and many more thousands were no doubt present in the invisible portions (i.e. the great majority) of the swamp. Most of the swamp is covered with lignum, although the swamp is as neither densely vegetated nor channellised as Tirrawarra Swamp. Ideal waterbird breeding habitat, Pink-eared Duck and Black Swan were observed breeding this year, while many more species were found breeding by L. Pedler in spring 1983 (Mollenmans et al. 1984). The same range of waterbirds known to occur at Coongie is thought to occur at Embarka (fewer of the migratory waders have been recorded, but virtually all other species have been), and further research is required to establish just how productive the swamp is. Small numbers of Chestnut Teal and Plumed Egret were present in June 1984 (unpub. data), while of more significance is the record of Grey Grasswren by I. May in 1982 (pers. comm.). Unfortunately the swamp (or at least its margins) are currently heavily grazed by cattle, and action is required to prevent further damage.

Similar habitats are known to lie between Innamincka and Tirrawarra and Embarka Swamps on both branches of the Cooper, but there is no information available with which to assess their extent or significance.

Goyders Lagoon (see Fig. 1.1) covers an area and is of a complexity, an order of magnitude greater than the two swamps discussed above. Standing astride Koonchera Dune, the observer is struck with the awesome majesty of the area - a vast flat swamp with no visible bounds to the west, in a gibber plain/orange sand-dune setting. Virtually all recorded information pertaining to the Lagoon's birdlife has been gathered in the Koonchera District; the other 95% remains an enigmatic mystery. The available data, however, attest to the area's productivity and richness of birdlife (e.g. Cox 1982). Two visits were made to Koonchera Waterhole, and in May (by which time the Diamantina had flooded through and receded somewhat) some 11 000 duck were counted, including 100 Plumed Tree-Duck. Obviously a detailed study of Goyders Lagoon will reveal many more riches and significant discoveries (between 1975 and 1982, the area yielded three new state records - Grass Owl and Grey Grasswren, Cox 1982; and Yellow Chat, Black *et al*. 1983).

8.3.2 Terrestrial Birds

Of the 161 species recorded at Coongie during the year, 103 are regarded as terrestrial birds, which represents a species-rich dryland avifauna for an arid zone district. This richness is largely dependent on the presence of the Cooper Creek within the district, and two factors are involved. Many desert birds require drinking water. Granivorous species especially, drink daily (Schodde 1982), at least in the warmer months, but many nectarivores and insectivores (e.g. honeyeaters) also need free water, and Schodde (1982) estimates that roughly half of the arid zone's dryland birds depend on drinking water, and the Kudriemitchie Channel is a bountiful and reliable source. Lining the channels and margins of the main lakes, the riparian woodland of *Eucalyptus microtheca*+/- *E. camaldulensis*, with its dense crown cover and structural diversity (commonly four, well-developed strata to the channel communities), supports a varied and prolific bird community. Numbers and diversity of the dryland birds decline rapidly with distance from water, and the more open, generally low habitats of the floodplains and dunefields are species-poor by comparison.

Reid (in Mollenmans *et al*. 1984) has drawn attention to the surprising absence of a group of birds from the Far North East of South Australia, citing Weebill and Yellow-rumped Thornbill as examples. Confirmed records of these species have since been published (Badman 1988), while two Weebills were seen in open coolibah-floodplain habitat between Innamincka and Scrubby Camp WH in December, this survey. In fact the only species which appear to have virtually continuous distributions around this region but not through it are the Inland Thornbill and Varied Sittella, neither of which have been recorded yet from the Cooper Creek - Diamantina region in South Australia. However, some twenty species, which have been recorded infrequently in the region, are undoubtedly irregular in their appearance within the region, and much less common overall than in adjacent parts of Australia - examples include Pink Cockatoo, Hooded Robin, Rufous Whistler, two species of thornbill, White-fronted Honeyeater, Striated Pardalote and Grey Butcherbird. Probable reasons are the absence of mallee and mulga communities within this region, and related to this, the prevailing openness of the Simpson, Sturts Stony and Strzelecki Deserts. The consequent paucity of "shrubby" habitats (characteristic of mallee and mulga lands) within the region accounts for the absence/limited occurrence of many of the species.

Several observations made through the year are highlighted in this section, before presenting a more systematic account of habitat preferences, seasonality, breeding events and limited dietary information. The observation of an adult Fan-tailed Cuckoo in May constitutes the first record of this species in the region. The bird was watched in riparian woodland near the Coongie Yards for about fifteen minutes. The species is known to be highly mobile, but its movements are little understood (Blakers et al. 1984), with a northerly movement after the spring breeding season indicated. As this bird was at least 500 km out of the species customary range (to the south and east), it is assumed to have been a migrating vagrant.

The presence of a pair of adult White-bellied Sea-Eagles, confirmed this species (previously disputed - Badman 1988) presence in the region. The pair was seen over most of January along the Channel and delta area of Coongie Lake.

The Golden-backed Honeyeater has remained somewhat of an enigma in South Australia until the last few years. The presence of three groups in the Tirrawarra Swamp - Coongie district was established, with two breeding events recorded (autumn and winter). The species can now safely be assumed to be resident (if rare) along the Upper Cooper in South Australia. The rare Pied Honeyeater was recorded twice (4 in February and 20 in September), and the birds' behaviour each time indicated that they were on passage. The similar and also highly nomadic Black Honeyeater was not recorded over the survey period, but was seen at Cuttipirie Corner WH in June 1984 (unpub. data). Both species have been recorded rarely in the region (Badman 1988).

The relative abundance of Banded Whiteface and Eyrean Grasswren, and the fact that both species bred in the Coongie Lakes District, are significant. The species occupy different habitats within the district's dunefields, and a comparative study of their ecology would prove fascinating - both species have stout finch-like bills and include a large proportion of seeds as well as insects in their diet (e.g. Schodde 1982). Cinnamon Quail-thrush were also moderately common in fringing dunefield and the sandier floodplain habitats, and a nest with eggs was found on the ground (built neatly into a small depression) in September. Birds were seen feeding fledged young in February, but no indication of breeding in the autumn-early winter period was noted. It is perhaps to be expected that numbers of these generally uncommon species will fall when the next drought grips the district, but these and other species obviously have the capacity to recover, as shown by their abundance in 1987, only four years after the devastating drought of 1983 (see Badman 1988).

The richness of the bird community inhabiting the riparian woodlands in the district is a significant feature of the district. Regrettably the habitat and therefore its biological values are being degraded by current and escalating tourist pressure and practices. Tourist behaviour will need to be modified and numbers regulated, if this alarming trend is to be reversed, and so adequately protect this thin but vitally important strand of vegetation. A highly significant component of this rich bird community is the breeding raptore population associated with the riparian woodland within the Coongie district and wider region. The woodland communities fringing the major river systems within the region constitute a stronghold for breeding populations of Black Falcon, Grey Falcon, Australian Hobby, Whistling Kite, Black-breasted Buzzard, Little Eagle and Letter-winged Kite (for five species, arguably the most important stronghold in South Australia).

Habitats

Several distictive avian habitats can be recognized in the district, while many others grade from one to another.

1. The river red gum dominated riparian woodland which lines the main channel of the North-West Branch supports the richest bird community. The structural diversity given to this habitat by the two tiered tree stratum (red gum and smaller coolibahs and bean tree), small tree layer (river coobah, broughton willow, plum-bush and Eremophila bignoniiflora), shrub and low shrub/forb strata, lends aesthetic appeal, as well as allowing the many bird species to co-exist. Species largely confined to this habitat are Barking Owl and Mallee Ringneck, while the Sacred Kingfisher and Restless Flycatcher are most frequently encountered here. Otherwise the species composition is similar to that of the coolibah woodlands, which are of wider occurrence in the district, and the dominant birds, common to both are listed below. The Barking Owl may be restricted to red gums because of its breeding requirements. The Mallee Ringneck is rare in the Coongie district, in contrast to its relative abundance further upstream (e.g. Scrubby Camp WH and Innamincka), and the cause of this rarity and of the species absence from coolibah-only habitats is unknown. Downstream, along the Main

Branch, the species was recorded at Munjoorooanie WH, where a few red gums are growing - the westernmost locality known for the ringneck and red gum on the Cooper.

2. Coolibah woodland habitats occur widely in the district's floodplain areas, but are best developed (tallest trees and closest cover) where they fringe the red gum habitats along the main channel, line the minor channels and main lakes, or occur as more extensive woodlands (sparingly) on some of the district's dry (or former) lake beds (such as the string from Lake Massacre north to Lake Apachirie, lying to the west of the North-West Branch). These habitats are not as structurally diverse as the red gum woodland, although they often have a moderately dense understorey of lignum (where subject to regular inundation), which can support a larger number of shrub inhabiting birds, such as wrens and Chirruping Wedgebill. Interestingly, the Brown Treecreeper preferentially forages on the trunk and limbs of coolibahs (e.g. Badman 1988), and were not seen to forage on red gums (presumably the species would find it difficult to grip the smooth bark). The species also spends much time foraging in litter on the ground, and occurs widely in the district, around the margins of all the main lakes (including Marradibbadibba), along some of the minor channels, and in coolibah woodland well to the west of the North-West Branch. The species was also observed at Cuttipirie Corner WH, beyond the limits of red gum along the Cooper (contra Badman 1988). It was uncommon along the banks of the Kudriemitchie Channel in red gum dominated habitats, and why the species distribution along the Cooper is basically confined to the limits of the red gum remains a mystery (Badman 1988).

Birds typically associated with the district's woodland habitats include most raptores, Bush Thick-knee, Crested pigeon, Peaceful Dove, the cockatoos and most parrots, Tawny Frogmouth, Australian Owlet-nightjar, kingfishers, martins, Black-faced Cuckoo-shrike, Grey Shrike-thrush, Restless Flycatcher, Rufous Songlark, Brown Treecreeper, Yellow-throated Miner, Spiny-cheeked Honeyeater, White-plumed

Honeyeater, Mistletoebird, Red-browed Pardalote, Australian Magpie-lark, White-breasted Woodswallow and Australian Raven. More open (and stunted) coolibah habitats support some of the above as well as being the preferred habitat of Diamond Dove, Bluebonnet, Chestnut-rumped Thornbill, Southern Whiteface, Ground Cuckoo-shrike, Jacky Winter and Black-faced Woodswallow. These open habitats generally occur a little distance away from the more permanent waters and on the periphery of the floodplain.

3. Shrublands of 1-2 m height (with or without an overstorey of coolibah) within the district's floodplains are dominated by lignum, with small patches of old man saltbush and Queensland bluebush locally prominent. The two species of wren and Chirruping Wedgebill occupy this habitat, in conjunction with a range of other birds, depending on the composition, presence or nature of the associated plants e.g. a coolibah overstorey supports doves, honeyeaters, and the Red-browed Pardalote, while in a lush grassy understorey following summer rains, quail, songlarks, the Singing Bushlark and Zebra Finch are encountered, and Richard's Pipit can be expected in parts with an open ground cover.

Within the dunefields, the same habitat occurs sparingly in a few interdunes with the same range of birds, and an open shrubland of Acacia ligulata (with or without other wattles, cassias and Eremophila longifolia) predominates on many dune slopes and some sandy interdune corridors. The associated birds include the wrens, Banded Whiteface, Singing Honeyeater, Red-capped Robin, and occasionally Southern Whiteface, Chirruping Wedgebill, Chestnut-crowned Babbler, Diamond Dove and Horsfield's Bronze-Cuckoo.

4. Many parts of the floodplain have low herbage as the dominant life-form, with few larger shrubs and trees. The plants tend to be ephemeral, and so the habitat changes with the seasons and prevailing conditions. Richard's Pipit is perhaps the only bird regularly encountered in such habitat, although the Cinnamon Quail-thrush is frequently seen in

areas with a sandy surface. Other species forage in these habitats, depending again on the composition and life cycle stage of the plants, and just a smattering of larger shrubs (usually lignum) or coolibahs allows White-winged Fairy-wrens, Southern Whiteface, Black-faced Woodswallow etc. to occupy the habitat. On the whole, however, this habitat is the poorest for birdlife in the district.

5. The dunes exhibit a range of vegetation types and many of the plants are annual and seasonal. The White-winged Fairy-wren is the character species of the dunes, accompanied by smaller numbers of Eyrean Grasswren where there are tussocks of cane-grass, and Variegated Fairy-wren where A. ligulata is prominent (along with the other species listed above in 3.), while the White-backed Swallow is the other regular and widespread inhabitant of the dunefields. Zebra Finches and Budgerigahs are common when appropriate plants are seeding following rain (as elsewhere in the district), while Brown Falcon, Cinnamon Quail-thrush and Little Crow were the next three most frequently encountered species in the dunefields during the survey.

Breeding

Forty-four species of dryland bird were found breeding in the district over the survey period, and another five were strongly suspected of breeding as indicated by their behaviour (e.g. Flock Pigeon as described earlier). Nests of some sedentary and quite abundant species such as the Chirruping Wedgebill were not located, although they (almost) undoubtedly bred during the year.

Breeding amongst a range of birds was readily apparent at the start of the study (November and December) and by January most nests had been vacated (martins, parrots, raptores, Zebra Finch, Little Crow). Stragglers into January included a pair of Little Eagles and Rufous Songlark (as judged by the latter's behaviour), while a pair of Red-backed Kingfishers began excavating a nesting tunnel in January. This sequence of events is consistent with a typical spring breeding event, dragging on into mid-summer as a result of the several heavy rains experienced in the latter half of 1986 (e.g. see Schodde 1982).

However, the big rains in mid February initiated (or extended) another breeding event. An interesting observation was made in early February of a pair of Peaceful Doves that started collecting twigs and building only hours after a light shower. The following species were found, or showed convincing signs of, breeding between late February and May - Zebra Finch, Little Crow, Little Eagle, Emu, Peaceful and Diamond Dove, Crested Pigeon, Flock Bronzewing, Rainbow Bee-eater, White-backed Swallow, Eyrean Grasswren, White-winged Fairy-wren, Orange Chat, Australian Magpie-lark, Rufous Songlark, White-plumed Honeyeater, Golden-backed Honeyeater, Yellow-throated Miner, Banded Whiteface, Brown Falcon, Budgerigar, Grey Shrike-thrush and Richard's Pipit. The behaviour of many other species in this period indicated they were breeding too (e.g. song bouts of Brown Songlark, Singing Bushlark, Stubble Quail and Little Button-quail). This significant autumn breeding event is at variance with Schodde's (1982) hypothesis that "autumn breeding itself becomes important only when drought that had depressed breeding in the spring is broken by summer rain". In this case good rains had resulted in a successfull and prolonged previous spring breeding season.

Schodde's next contention, that "There is a significant pause in breeding during winter in June and July", was not fully supported by the next series of observations made in the Coongie district. Little nesting activity was discerned in June (Wedge-tailed Eagle inspecting a nest, Chestnut-rumped Thornbill giving a distraction display with a grub in its bill, and Red-backed Kingfishers establishing territories, subsequently observed taking food to the nest in July), but was in full swing by July, continuing through to October (J. Puckridge pers. comm.), when observations concluded. The mid-winter to spring breeders included Wedge-tailed Eagle, Little Eagle, Whistling and Black Kite, Black Falcon, Collared Sparrowhawk, Spotted Harrier, Brown Falcon, Little Crow, Australian Raven, Australian Magpie, Black-faced Woodswallow, Brown Treecreeper, the cockatoos and most parrots, martins, honeyeaters, Variegated Fairy-wren, Eyrean Grasswren, Southern and Banded Whiteface, Chestnut-crowned Babbler, Zebra Finch, pigeons, Red-backed Kingfisher, Grey Shrike-thrush and Red-browed Pardalote. There does appear to have been a brief hiatus amidst this near continuous bustle of breeding in late autumn - early winter. Only light rains fell (in the immediate Coongie district - a maximum of 12 mm in early May) in the defined autumn season, but the next big fall of 57 mm over 12-21 June apparently triggered an immediate breeding response by a number of species, similar to the case in February. The date of the June rains may be significant, on and just after the shortest day-length of the year, as increasing day-length is the proximate stimulus initiating breeding in birds of temperate latitudes.

Seasonality

Few birds exhibited clearly defined seasonal migrations in and out of the district/region, while many species were patently nomadic within the region, and a few were thought to be in passage (e.g. Spotted Nightjar, Black-eared Cuckoo and Pied Honeyeater). Species, such as the White-browed and Masked Woodswallows, Rainbow Bee-eater and White-winged Triller, while clearly moving south when seen frequently in September (i.e. in passage) were present as summer visitors (bee-eater) and/or nomadic visitors (other three) based on earlier observations through the year.

Species considered to be largely nomadic within the region **this year** (it is stressed that the situation is likely to differ from year to year), i.e. species seen in varying abundances in most months of the study, were Cockatiel, Budgerigar, Horsfield's Bronze-Cuckoo, Sacred Kingfisher, Black-faced Cuckoo-shrike, Clamorous Reed Warbler, Little Grassbird, Rufous Songlark, Brown Songlark, Singing Bushlark, Little Button-quail, Stubble Quail, Bustard, Crimson Chat, Orange Chat, Masked and White-browed Woodswallows. Many of these species were less common in winter than at other times of the year, and is partly attributed to a general movement to northern Australia for some species (e.g. triller, kingfisher, cockatiel) and the generally drier conditions that prevailed over the last half of the study (larks, quail and bustard).

Predominantly winter visitors to the district were Blue-winged Parrot, Barn Owl, Pallid Cuckoo, Welcome Swallow, Brown Goshawk, Jacky Winter, Grey Fantail, Red-capped Robin and Mistletoebird, while the lone observation of Rufous Whistler in July may reflect a winter visitor or a bird on passage, returning south for the spring. In addition the abundance of Willie Wagtails and Fairy Martins greatly increased over winter, and the latter species was very scarce in late summer and early autumn, apparently being entirely absent for a month, while the records of Kestrel and Brown Falcon show a similar trend. Just as many species were more abundant over the (extended) summer period, namely Collared Sparrowhawk, Spotted Harrier, Ground Cuckoo-shrike, and most of the species listed in the previous paragraph, but only the Rainbow Bee-eater was known to vacate the region entirely over winter.

The Restless Flycatcher was observed in very small numbers throughout the survey period, and its status is thus concluded to be rare and largely sedentary (in April a wandering bird was located at the ephemeral swamp near Della Road Bore No 2 referred to earlier) within the region.

Foraging Observations

The economy of many of the diurnal birds of prey in the district is very firmly based on the rabbit, and this animal's great abundance is the main reason for the impressive and highly significant raptore populations in the wider region (D. Baker-Gabb pers. comm.). The rabbit's observed greater abundance in the proximity of the main channels and water-bodies also helps to explain the concentration of raptores along the major arteries (Strzelecki and Cooper Creeks), and so the concentration isn't simply a function of availability of suitable nesting sites. After the rabbit, bearded dragons were the most abundant prey item.

The two eucalypts, three common species of mistletoe, and Crotalaria cunninghamii (rattle pod) were the most important targets for nectarivorous species observed in the Coongie district. Yellow-throated Miners and the Golden-backed and White-plumed Honeyeaters probed the flowers of all these species. In addition, Crimson Chats and Mallee Ringnecks were regularly observed at the big, yellow flowers of the rattle pod (or parrot pea). The ringnecks destroyed the flowers, snapping them off at or puncturing their base to get to the nectar. Only one observation was made of birds probing Eremophila flowers, that of a White-plumed Honeyeater repeatedly at the flowers of E. bignoniiflora, despite a heavy flowering event for this species and E. longifolia (both have large flowers). The fruits of the second mistletoe to flower (Amyema preissii) were ripening as the Mistletoebirds arrived en masse in April, and they switched to Lysiana exocarpi in June (through to the end of August), when that species began to produce copious fruit, and as the amyema failed. Interestingly, the summer flowering Diplatia grandibractea (host specific to coolibah) was not seen to bear fleshy fruit, but the sequence of flowering of the three mistletoe species seemed surprisingly well timed (from the honeyeaters' perspective). The White-plumed, Singing and Spiny-cheeked Honeyeaters and Yellow-throated Miner also took the mistletoe fruits, with the White-plumed observed taking ruby saltbush berries as well.

Few detailed observations were made of the granivores' dietary preferences. Zebra Finches were partial to the seeds of Aristida spp, while the corellas and galahs were frequently seen during the autumn in open floodplain habitat, harvesting the seeds of chenopod summer annual species. In winter, the large seeds of the prevalent New Zealand spinach *Tetragonia tetragonioides* were favoured by the cockatoos. In the late summer and autumn, seeds of the prolific floodplain plant *Portulaca oleracea* were consumed by a wide range of the smaller granivores (including rodents as well as the cockatoos).

8.4 Management Considerations

Significance

The birdlife at Coongie is rich and colourful, and is a very important component of the district's environment. In particular, the waterbird community and the birds associated with riparian woodland have high conservation significance. A characteristic feature of many of the birds (aquatic and dryland species) is their nomadic behaviour, and so it is important that large areas of land are conserved to allow their natural patterns of movement and dispersal to continue. The species of particular conservation significance are indicated in Table 8.1 and they are discussed in previous sections (see also Parker 1980).

The Coongie Lakes wetlands are considered to provide important drought refuge habitat for the region's waterbirds, and management will need to reflect the sensitivity of the environment in times of drought.

Breeding waterbird populations are also significant, as is the large population of waterfowl supported on the lakes generally. The numbers of Freckled Duck which congregate at times are highly significant as well.

The significance of Tirrawarra and Embarka Swamps and Goyders Lagoon is emphasized.

Areas of woodland, occupying dry lake-beds to the west of the North-West Branch (from Lake Massacre to Lake Apachirie), support a significant bird community (which includes the endangered Bush Thick-knee) which is worthy of special protection.

The Australian Bustard was observed to be seasonally, locally plentiful along the Upper Strzelecki floodplain (and in the recent past along the major creeks emanating from the stony tablelands to the north of Innamincka HS), and so these habitats are also accorded significance.

No species of bird appears to be restricted to specific habitat types within the region's dunefields, although the possibility of the importance of areas of spinifex to the Night Parrot's economy should not be overlooked (see Badman 1988 for further details).

Impacts

The two most disturbing impacts documented over the year were:

1. disturbance of waterbirds (especially breeding birds) by boating activities, and
2. the rapid degradation of the riparian woodland habitats, caused by unregulated camping practices.

Evidence of (illegal) duck-hunting was noted several times over the year, while shooting, in general, was heard most days/nights in the busier tourist periods.

The impact of cattle grazing in districts surrounding the Coongie Paddock was noted, and degradation was particularly apparent along the Cooper Creek frontage (around Innamincka and Embarka Swamp), along parts of the Upper Strzelecki floodplain) and along creeks and around bores in the Merninie land system to the north of Innamincka HS. The decline of species such as the Bustard, Flock Pigeon and Night Parrot has been attributed (in part) to pastoral activities. Rabbit grazing is also undoubtedly continuing to degrade the landscape, again particularly in habitats close to water.

The exotic House Sparrow has become established at Moomba as a consequence of that town's appearance over the past two decades, and the species continues to colonize any newly created, inhabited facility within the region. The species presence in the region had been firmly established prior to the arrival of the hydrocarbon industry.

Gas and oil production in the vicinity of Embarka Swamp has undoubtedly caused ecological change. Large pits, a legacy of the building of the raised embankments which intrude into the Swamp, have created areas of deeper, open-water habitat, and this artificial habitat supports a large waterbird population. A population of the rare Grey Grasswren has not been seen since its discovery at Embarka a number of years ago, and a thorough search for the species is warranted.

<u>Recommendations</u>

1. that boating in the Coongie Lakes District and along the North-West Branch be prohibited, and the activity and impact of canoeing to be monitored.

2. strict regulation of camping and visitor activities within the Coongie Lakes District, so that the highly significant aquatic and riparian woodland habitats are afforded adequate protection.

3. that surveys of wetland habitats in the wider region be undertaken (Embarka Swamp, Goyders Lagoon, lakes to the north of Lake Goyder, swamps to the west of Innamincka, and the smaller wetlands to the east of Coongie fed by the creeks in the Oonabrinta district).

4. that a long-term study of waterbirds on the Coongie Lakes be initiated, and that the establishment of an R.A.O.U. Bird Observatory be investigated.

5. that the public be actively discouraged from visiting the outer lakes and the western side of the district in general, as it is in these areas that the largest concentrations of waterbirds and threatened terrestrial birds occur.

6. that a provision be made within the management plan for exclusion of people from the Coongie district in times of drought or during other periods of environmental stress, when the behaviour of waterbirds indicates that such action is warranted.

7. that grazing and mining developments not occur in the region's significant wetlands (including the creeks and swamps of the stony tableland).

8. that cattle continue to remain outside of the Coongie Paddock, so that species, which have been demonstrated to be adversely affected by grazing, have a large area set aside for their protection.

9. BIOLOGICAL SIGNIFICANCE

Julian Reid

The archaeological, biological, historical and natural landscape significance of the Coongie Lakes District has been reiterated many times over the last decade, and despite certain measures having been taken, such as its listing under the RAMSAR Convention, calls are still being made for "full national park status for this area of exceptional beauty" (Howard Whelan 1988, Aust. Geographic No. 9). Undoubtedly the area is deserving of complete protection, including that afforded by national park status and World Heritage Listing, as proposed by the Conservation Council of South Australia, for a wide variety of reasons. As well as this formal protection, the area requires a large input of resources (staff, signs, interpretive material, protection works) for effective management to be exerted. It is mainly the biological significance of the Coongie district and the wider region which will be addressed in this chapter, although the district's other natural or landscape values will be mentioned briefly. Issues raised here are summarised only, and details which have been presented in the earlier chapters, are not necessarily presented again here. For example, all the species of conservation significance occurring in the district and wider region are not listed.

It is concluded that the **most significant** feature of the Coongie Lakes environment is the main channel and lake system for a number of reasons:

- its naturalness, beauty and setting in the surrounding arid landscape;

- the absence of regulation of flow along a major river such as the Cooper Creek;

- the range (temporal and spatial) of aquatic habitats represented in the district, from major permanent channels to large ephemeral lakes, densely vegetated swamps and temporarily inundated marshy floodouts;

- the diverse and abundant fauna it supports, including endemic, rare and threatened species;

- the basically natural functioning of the aquatic ecosystem, little changed by the impacts of human activities.

When these factors are considered together (e.g. a major, unregulated, unpolluted, beautiful river and wetland sysytem in the arid core of Australia supporting highly significant if ephemeral faunal populatuons), the district's uniqueness and high conservation value can be readily appreciated - to no other part of Australia does such a combination of characteristics pertain. Furthermore the entire length of the North-West Branch is identified as having the utmost conservation significance and should be afforded every protection. Having naturally defined limits, the entire Branch can be managed cohesively as a unit within the overall Cooper Creek system, to ensure the adequate protection of its most significant features midway along (Tirrawarra Waterhole/Swamp complex) and near the end of its length (the Coongie lakes and their associated channels). Because of the potentially rapid transfer of "impacts" downstream, it is vitally important that the higher reaches of the North-West Branch be protected as stringently as its middle and terminal portions.

Some of the components of the Coongie Lakes District's environment, which are of importance or significance, are itemised or briefly discussed below, and are matters requiring consideration whenever issues of management and protection of the district's resources are raised.

The River Red Gum Fringe

The riparian red gum woodland which lines the main channels of the North-West Branch (e.g. Kudriemitchie, Tirrawarra and Scrubby Camp Waterholes) is probably the **single most important** physical component of the environment (its occurrence is due to the frequency of flow events along this branch), by providing:

- a major source of nutrients and organic carbon to the aquatic system;

- habitat (litter layer and arboreal substrates) for a distinctive community of reptiles, four species of which are confined to the habitat;

- habitat (structural diversity and size of timber) for a rich and highly significant bird community, including rare and endangered elements of the South Australian avifauna;

- structural complexity (through snags and overhanging or partly submerged fringing vegetation) to the aquatic environment.

When it is considered what a tiny fraction of the regional land surface, the red gum woodland comprises, its inherent susceptibility to damage can be appreciated.

Features of the aquatic environment

The waterholes and more permanent lakes provide drought refuge for the wide range of aquatic fauna (fish, frogs, waterbirds, the Cooper Creek tortoise, water rat and countless invertebrates) when dry regional conditions persist for a year or more. The greater the severity of the drought, the more important and sensitive these refuges become.

The waterholes in particular support the most diverse frog, fish and aquatic invertebrate and plant communities found in the region, and within the Coongie district, the especial significance of the last five kilometers of the main channel is noted (for breeding raptores and waterbirds as well as the animals groups above).

The backwaters are important habitat for the animal groups listed above, and become productive feeding grounds on rising water levels, while supporting populations of the nationally threatened grass *Echinochloa inundata*.

The unpredictability, productivity and temporal and spatial variability are features of the system.

Recently flooded margins and floodouts of the lakes are highly significant for the numbers of ducks they can support, and the outer lakes (Marroocutchanie, Toontoowaranie and Goyder) support the largest numbers seasonally.

The aquatic fauna is a curious and significant blend of tropical, eyrean and temperate (south-eastern) elements.

Tirrawarra Swamp is the only locality at which callop are known to breed in South Australia, and also supports threatened plants and birds.

Species of conservation significance include the callop (a biochemically distinctive population), Cooper Creek catfish, Cooper Creek tortoise (endemic to the lower Cooper), Gilbert's water dragon, undescribed species of Cyclorana (burrowing frog only known from Coongie in South Australia), the biogeographically important outlying population of water rat, Freckled Duck and a number of other rare or threatened waterbirds.

The frog community is the richest known in central Australia, and the waterbird community, although highly variable, is also very diverse and at times numerous.

Terrestrial Biota

There are many facets of the terrestrial environment, which increase the conservation worth of the Coongie district and wider region, and the following points are considered most significant:

- the richness and importance of the bird community tied to the red gum riparian woodlands has been highlighted above, and the populations of breeding raptores, Barking Owl, Golden-backed Honeyeater, Bush Thick-knee and endemic, distinctive populations of Red-rumped and Mallee Ringneck Parrots are especially significant.

- the Night Parrot's persistence in the Cooper Creek region.

- the number of rare and threatened birds and mammals known to occur.

- the diversity of plant communities, the species richness and the number of nationally rare or threatend plants known to occur.

In the State context, rare plants, inadequately conserved plant alliances, and important disjunct populations were recorded, with the discovery of a new species of Brachycome being a highlight of the study - this species may prove to be another endemic of the region.

The coolibah woodlands and other floodplain habitats associated with the district's generally dry lake beds support a rich bird community, similar in composition to that of the riparian woodland, and including the endangered Bush Thick-knee. In particular the system of dry lakes and peripheral floodplain on the western side of the district (i.e. form Lake Massacre near Tirrawarra Swamp to Lakes Talinnie and Appanburra in the north) have high conservation significance.

Dunefields in the Coongie Lakes District support a rich reptile community, and rare species of plant, bird and mammal, and they are an important component of the district's landscape and environment. Although dunefields are extensive in the wider region, it is argued that they should be afforded complete protection in the Coongie district, so that a representative and viably sized area of land around the lakes and Tirrawarra Swamp, encompassing the range of dryland habitats, is retained free from further pastoral and mining activities. Within the district, spinifex communities are identified as having special importance for dune-dwelling animals, and they support rare and localized reptile and mammal populations (e.g. ningaui, spinifex hopping-mouse, Centralian blue-tongue and Lerista aericeps).

The point made above is pertinent to the issues of "wilderness" and aesthetic values of natural landscapes with regard to the needs of visitors. There is no doubt that the establishment of mining facilities significantly degrades these qualities of the environment, even if they can be demonstrated to have little biological impact other than at the local scale. To the south of the Coongie district, in the area of the Tirrawarra and adjacent gas and oil fields, there are the continual signs of the mining industry's occupation - formed roads, power lines, well heads, traffic, people, noise, dust, myriad tracks, borrow pits and other signs of earthworks, pipelines and their marker posts, signs etc (i.e. many of the trappings of the modern age). It is vital that representative areas be kept free of these disturbances within the region, and the dunefields of the Coongie district are a logical choice, so that present and future generations of visitors can experience the unspoilt beauty and natural wonders of the district's remarkable range of landscapes and environments.

With approximately 25 000 individuals visiting the Innamincka region in 1987, and with the annual number of visitors likely to dramatically increase over the next few years, their needs (both in terms of the experience they will seek and want to have guaranteed, and the support facilities required) as well as their impacts, will have to be given careful consideration. Much planning, research and management (and therefore, above all, sufficient funds) will be required, if the visitor and the environment are not to suffer in the "stampede" for an outback experience along the Cooper and around the Coongie Lakes. Certainly, more than the 11 people currently offering services at Innamincka and the occasional or seasonal presence of two rangers, will be required.

Further Afield

Innamincka Station encompasses a quite remarkable range of wildlife habitats, which include the red sandplain and uncoordinated red dunefield of the Marqualpie Paddock, the stony tableland and rolling gibber to the north of the homestead (including some sizeable hills with interesting caves and overhangs), several dunefield types, Cooper Creek frontage and associated wetlands, Cooper Creek floodplain, Strzelecki Creek and floodplain, and the Christmas Creek, miniritchie creeks, ephemeral swamps and numerous saltlakes. All of these districts and environments require further investigation if the concept of multiple land-use is to be applied **successfully** to this Station (because conservation and adequate protection of the region's natural resources comprise one of the land-uses, and potentially conflicting land-uses will not be able to be practised sympathetically without further investigation of the biological value and conservation significance of these districts).

The sparse information available certainly indicates the importance of the Marqualpie and Oonabrinta districts, the upper Strzelecki floodplain and the Cooper Creek frontage generally. The occurrence of the nationally endangered plant Frankenia plicata in the north-east corner of Innamincka Station highlights this district's importance.

Beyond the boundaries of Innamincka Station, important areas include the highly significant Embarka Swamp and Goyders Lagoon, Cobblers Sandhills (a distinctive landform assemblage which is virtually unknown biologically), the ephemeral lakes to the north of Lake Goyder (fed by occasional run-off from the Cordillo Downs tablelands), and the gibber plains in the vicinity of Koonchera Dune and Pandiburra Bore.

10. IMPACTS

Julian Reid and Jake Gillen

Human activities within (and even some outside of) the Cooper Creek region have long been effecting change to the natural patterns and process of the environment. These changes are here termed impacts and they vary both in the degree of change and in the severity of the problems they cause, and they may be direct or indirect consequences of the human activity. For example, the spread of the rabbit into the region from south-eastern temperate Australia late in the nineteenth century has had disastrous consequences for the region's biota, but was not a deliberate step taken by people working in or visiting the region. Similarly, within the Coongie Lakes District, most exotic plants are found along the Cooper and in floodplain areas generally, and is indicative of their water-borne introduction. However, many of these problems are being accentuated or facilitated by current land-use practices. Weeds are proliferating in terms of new species entering the region and increased occurrence of previously established species, and the problem is partly attributable to mining activities and increased visitation, while the likelihood of greater rabbit persistence around borrow pits containing water has been referred to in Chapter 6.

Potential and currently existing impacts are considered in this chapter and divided into the broad categories of pastoralism, rabbits, mining and tourism, before addressing the more difficult issues (in terms of resolution of the problems) of protection of the entire Cooper Creek catchment, and finally, problems specifically evident in the Coongie Lakes District.

Pastoralism

This subject has been treated in detail by LAB (1986). In that report, the many problems for the natural environment caused by the long history of grazing on Innamincka Station were discussed. Chief amongst these has been the extensive degradation of the Cooper Creek frontage and around other watering points on the station. In particular, the appearance of the river frontage in the Innamincka district is deplorable, resulting from the combined pressure of heavy grazing and high levels of uncontrolled tourist activity, and contrasts quite dramatically with sections of the North-West Branch which have received less grazing and tourist activity in recent years. Sheet erosion, scalding and gullying are all evident and if allowed to proceed unchecked will cause certain sections of the Cooper to be reduced to the pitiful state of some of northern Australia's most highly degraded rivers, such as the Gregory and Ord, from which cattle have had to be permanently destocked and very expensive land rehabilitation programmes instituted. During the survey period, two other biologically significant areas were observed to be under heavy grazing pressure - Embarka Swamp and the north-eastern paddocks of Innamincka station.

Specific problems caused by pastoral occupation, which need to be addressed (e.g. prevented or researched and then appropriate management decided) include:

- grazing in highly significant areas (such as the Coongie Lakes District, other important wetlands, and portions of the Upper Strzelecki floodplain, Marqualpie and Oonabrinta districts) amounts to an unacceptable impact, through selective removal of plants, trampling and compaction of the soil, accelerating erosion, alteration of wildlife habitat, visual disturbance etc;

- overgrazing around watering points/areas and favoured feeding areas;

- nutrient enrichment of Cooper Creek (and smaller creeks in the stony country, and the Strzelecki Creek);

- grazing by feral horses (descendants of former stock horses);

- soil compaction, accelerated erosion, puddling of waterholes, trampling of fringing vegetation.

Rabbits

Rabbits are considered to have wrought the most deleterious changes on the Coongie Lakes landscape and biota, and continue to be a major problem. Their fecundity allows the population to increase rapidly in response to favourable conditions, and subsequently, as the country dries and feed becomes scarce, the population crashes but not before removing much of the vegetative cover. The highest rabbit densities appear to be supported in areas close to reliable water sources, such as the Cooper and lakes' frontage.

Particular issues involve:

- their capacity to selectively and severely over- graze (causing decreased plant diversity and plant cover, and in the long-term depletion of perennial species);

- surface disturbance of sandy environments (through burrowing and foraging activities);

- nutrient loading (especially noticeable around the lake margins).

Undoubtedly the composition and structure (e.g. density) of the myriad plant communities found in the Coongie district and wider region have changed dramatically as a result of the last hundred years grazing by exotic herbivores (sheep, cattle, horses, camels and rabbits principally), and this process will continue, resulting in the death of established, long-lived perennial species, which are unable to regenerate under the grazing regime.

A number of commercial rabbit shooters operate full-time in the region, and it was observed that their frequency of vehicle use along parts of the Cooper was causing pronounced scalding of floodplain and adjacent dune habitats (e.g. around Kudriemitchie Outstation and south of Tirrawarra Waterhole).

Mining

Generally the impacts associated with the exploration for and extraction of gas and oil are not as extensive as the effects of grazing, and some are quite localized, thus enabling the industry (and government) to minimize environmental damage by the appropriate siting of facilities and structures. However, at the regional and district scale, networks of seismic lines are certainly extensive, and in some landform types, permanent and erosive. It is accepted that within most dune systems seismic lines will naturally regenerate, provided they are not subsequently traversed - this problem occurs in oft-visited parts of the region, such as around Coongie. This ease of access is considered to be a major problem in highly significant environments. Currently, while few tourists are prepared to venture far from made tracks or seismic lines, many people are encouraged to explore the more remote areas by following seismic lines.

In contrast to the spasmodic occupation by seismic crews of all parts of the region, more stable populations arise with the establishment of gas and oil fields brought into production. The visual environment in these districts is greatly altered, and this impairment is considered to be unacceptable in the most significant natural landscapes of the region (such as the Coongie Lakes District). In this context, the appropriate siting of Moomba (in a fairly ordinary landscape) is acknowledged, while many of the installations in the Tirrawarra Satellite district were also appropriately sited. However, certain structures, such as production wells, have to be located directly above the retrievable deposit, and in these cases there is no such choice of site. Rather, the choice is to establish the well, or to leave that deposit in the ground (under prevailing technological and economic conditions - directional drilling, in the opinion of SANTOS engineers, cannot be contemplated at distances more than a few hundred meters from directly above the deposit). There are areas of significance within the Cooper Basin from which production should be excluded, such as the Coongie Lakes District, and wetlands in general, should be avoided.

One highly significant wetland, Embarka Swamp, is currently a major gas producing area, and the swamp's hydrology has been greatly affected as a result, with a number of raised embankments running out into the western half of the swamp to provide year-round access to the numerous wells. The implications of the altered hydrology for the swamp's biota have been only scantily considered or studied. Hydrological changes in the wider region (Strzelecki Creek, Tirrawarra Swamp and elsewhere along the Cooper) attributed to earth-moving operations by the mining industry have been suggested, with respect to even quite small movements of earth, such as windrows at the edge of seismic lines, and insufficient research has been carried out to support or allay these fears.

Certainly the potential for hydrological change exists, and given the desirability of the Cooper Creek remaining in as near pristine state as possible, especially the North-West Branch, any development with this potential should not occur along the Branch and its adjacent floodplain. Also the potential for extremely damaging hydrocarbon pollution exists wherever the paths of Cooper waters and oil cross (e.g. pipelines across the Cooper or production wells on the floodplain). It is considered that the risks, however slight, are unjustifiable along the length of the Cooper, if the potential for pollution can be demonstrated to exist.

Other impacts associated with the mining industry's presence in the region include:

- spread of weeds along major tracks;

- provision of artificial watering points;

- increased pressures placed on the environment because of the presence of a large, mobile workforce;

- provision of access by way of seismic lines to large parts of the region;

- general visual impairment of environments wherever activities are concentrated, and related effects of noise and increased dust levels.

<u>Tourism</u>

Because such a wide range of people, having diverse interests and therefore engaged in diverse activities, can be classed together as tourists or visitors, the range of associated impacts is also wide. Many problems are pressing, and their severity is rapidly increasing as the numbers of visitors escalate. Activities that impinge on the aquatic systems in the region and the associated riparian woodland fringe are deemed to be having the most severe impact and are in most urgent need of being addressed. In particular, the highly significant Coongie Lakes environment has experienced a visitor population explosion in the last two years, and in the absence of any regulation or control of activities, the area is condidered to be under severe stress, with the experience of the general visitor suffering as a consequence.

A range of impacts are itemised below:

- illegal use of nets for fishing in the Cooper;

- the probable over-harvesting of fish in the system;

- pollution of the river by lack of proper garbage removal, use of detergents and other chemicals;

- sanitation, water quality and nutrient loading problems;

- disturbance of wildlife and other visitors by use of boats, chainsaws, generators, guns and trailbikes;

- removal of fallen timber and cutting of standing (live and dead) timber for firewood, which if permitted to continue will cause increasingly severe degradation and impoverishment of the aquatic and associated red gum and coolibah woodland communities, as well as resulting in a highly visually impaired landscape (to which the Innamincka district bears ample witness);

- co-incident with the above, the removal of litter for starting fires and the trampling of the aquatic margins by many pairs of wheels and feet, is significantly contributing to the process of degradation;

- spread of weeds (via clothes, pets and vehicles) is increasing with increased numbers of tourists and the greater accessibility within the region;

- potential for further introductions of exotic fish (brought into the region as live bait) into the Cooper, which may have been the pathway by which the goldfish entered the system;

- track proliferation (especially in popular areas) and associated compaction of soils and/or erosion;

- illegal hunting of wildlife;

- the use of seismic lines by tourists (and other users) after the seismic programme has concluded prevents their regeneration;

- finally, although not of a biological nature, the damage caused to archaeological sites (driving through middens, theft of items, graffiti and other acts of often unwitting vandalism) has reached extremely serious proportions along the length of the Cooper Creek in the region.

Cooper Creek Catchment Protection

The Cooper Creek's headwaters are in central-eastern Queensland, and the great majority of water that flows through the lower reaches (within South Australia) originates in Queensland. Many agricultural and industrial land-uses (including damming proposals) have the potential to alter flow regimes, water quality and characteristics, and volume of water, and so destroy one of the most significant facets of the Cooper - its naturalness and lack of regulation. Studies of the Murray River and other regulated temperate rivers in Australia are beginning to reveal the type and extent of adverse effects hydrological regulation can have on aquatic fauna, although the research is hampered by the paucity of detailed information gathered prior to regulation.

Chemical spills, fertilizer, industrial or urban waste-water run-off, salinization, introduction of exotic fauna and plants, increased erosion and general pollution are all potentially damaging, upstream inputs with downstream impacts, and probably occur to a limited degree already in some cases.

Action is required at the national level, with the participation of Queensland and South Australian authorities, to discuss these issues and then investigate ways in which the appropriate protection can be conferred.

Coongie Lakes District

Currently there are no cattle grazed in the Coongie Lakes District, nor is there any oil or gas production. However the evidence of past pastoral occupation and hydrocarbon exploration within the district is readily apparent.

The activities of rabbits and visitors are having at present the most serious impact on the district's environment. The diverse activities of visitors and their associated impacts are the subject of the next chapter, and so will be only summarised here.

Visitor activity is concentrated on and around Coongie Lake itself and along the Kudriemitchie Channel, with a much reduced pressure exerted on the other lakes (presumably largely due to lack of knowledge of their existence or access routes). However, given the crowding experienced at Coongie over peak visitation periods in 1987, interest in finding less heavily visited parts of the lakes system was commonly expressed by visitors, and many people searched for or asked about negotiable routes to cross from the east to west side. Spread of tourist activity is considered to be highly undesirable, and urgent action is required to prevent it; otherwise the waterfowl populations and other significant natural features of the environment will certainly suffer.

The most disturbing features of tourist activity observed at Coongie over the year were:

- the rate of timber depletion;

- the disturbance of waterbirds (particularly breeding birds) by outboard-powered boats, which were the probable cause of desertion in some cases;

- the noise and therefore disturbance created by guns, boats, chainsaws, generators, and constant vehicle activity along the numerous and proliferating tracks;

- active hunting of wildlife and the reliably reported use of gill-nets along the Kudriemitchie Channel;

- the litter (rubbish and uncovered toilet paper) problem;

- denudation of the dunefield's vegetation in close proximity to Lake Coongie due to vehicular activity (for sport as well as access around the lake);

- the rapid degradation of popular camping sites (imparting a distinctive bare appearance to the sites);

- the lack of consideration shown to other users by a minority of visitors, in terms of antisocial behaviour (littering, excessive noise, use of firearms, and general disturbance of a peaceful environment).

Certainly the Coongie Lakes District is a rewarding environment, offering a range of experiences to the visitor, and the area should remain open to the public to appreciate and enjoy, as long as their activities neither impinge upon other people's experience nor detract from the natural qualities of the environment which make the district so important.

It is also important to recognize the sensitivity of the environment and allow for total closure of the district in times of drought (or other times of stress) when protection of the district's biological resources should have priority over visitor use.

11. VISITOR SURVEY

Jacqueline Gillen

11.1 Aims and Introduction

This study was undertaken to provide data concerning visitor pressure at Lake Coongie and Innamincka in far north-east South Australia during 1987.

The term 'visitor' has been used to describe both tourists and persons involved in environmental research at Innamincka and Lake Coongie. Both types of visitors have some common interests and activities in that their intention is to observe, experience and live in the natural environment for limited periods of time. Both groups are very mobile and are generally self-sufficient in terms of transport, fuel, shelter, food and safety. Unlike those people who earn an income within the Innamincka/Lake Coongie region, the visitors' interactions with the environment are non-exploitative: no aspect of the environment is deliberately reaped for commercial profit. Those people not considered in this report include the residents of Innamincka township, employees of SANTOS and Innamincka Pastoral Station, the regional rabbiters and any poachers or persons involved in the illicit commercial activities, unless they are participating as tourists or are actively involved in environmental research.

Visitor pressure has been gauged in terms of number of different people in the Innamincka/Lake Coongie region each day, what they do once they are there, some of the impacts their presence and activities have upon the environment and how they react toward the environment and its current management.

This research sought to provide both quantitative and qualitative data. The quantitative material relates information about both current visitors to the region and methods for estimating future tourist pressure. The description of current visitors includes the number, age and sex of individuals and groups in the region, their place of residence or responsible supervisory body, the duration of stay, their means of transport and movement patterns, and their domestic and recreational activities including cooking, washing, abluting, yachting, fishing etc. Further quantification has been made of the effects of these activities upon the environment eg. tree felling and denudation. Qualitative information was also collected from tourists only, to portray their interests in the environment at Lake Coongie and Innamincka and to express their views on the future management of this region. Due to the spatial limitations placed upon this report only the quantitative material has been summarised.

This material does include the number of individuals, groups and vehicles within the region during 1987 and their impact upon the environment.

It is hoped that the collection and analysis of this information will provide a clear indication of the very high visitor pressure experienced at both Innamincka and Lake Coongie. In particular it will both portray the immediate and long term issues requiring management related to this high visitation provide assistance and in facilitating the management of visitors to this area such that the tourists quality of experience is guaranteed thereby enhancing their appreciation of this unique and highly sensitive setting.

11.2 Methods

As stated in the Introduction two types of visitor presence and behaviour have been observed and evaluated. These types are:

1. the tourists visiting Innamincka and Lake Coongie over a seven day period commencing 8 July 1987. The choice of this holiday period was made to ensure that a maximum amount of tourist information could be obtained due to the coincidence of school vacations in Victoria, Queensland, South Australia and New South Wales.

It is considered that information recorded from the interviews conducted on two week days and two weekend days during the week commencing Wednesday 8 July 1987 and finishing on the evening of Tuesday 14 July 1987 is representative of visitor behaviour and attitudes at all times;

2. the environmental research teams conducting studies of the region from 1 December 1986 to 1 December 1987.

Four survey methods were used to collect and quantify the data. These are:

1. a count of most visitor numbers by groups, individuals and vehicle types during the tourist survey period in July 1987. This was achieved by head counts conducted at the Innamincka Trading Post and at Road Counter 1 and recorded on master lists (refer Appendices 11.1 and 11.2); for most of the year commencing 1 December 1986 number of visitors have been recorded by road counters located in the Coongie Lake region and by extrapolation from fuel sales at the Innamincka Trading Post;

2. a questionnaire administered to tourists at the Innamincka Trading Post and Lake Coongie on both the east and west banks of the North-West Branch of Cooper Creek (refer Appendices 11.3 and 11.4);

3. the establishment of photo-points to make visual records of the long term environmental effects of visitor use of this area;

4. the quantification of timber use, soil disturbance and faeces production per individual such that some aspects of the environmental impact of visitors residing in the Innamincka/Lake Coongie region can be extrapolated from the number counts.

For the purpose of this report, information pertaining to the number count of visitors in the region, number of questionnaires administered to tourists during the survey period and the number of groups and persons recorded at the road counter stationed at the entrance to Coongie Lake (eastern approach from Innamincka) will be summarised in the following section, 11.3 FINDINGS. Information related to the impact of tourists upon the environment such as a description of the photo points and the calculations of annual tourist pressure, timber use, soil disturbance and faeces production will be addressed in section 11.4 IMPACTS.

All information presented is brief, and only gives a summarised account of the findings and impacts. For further detailed analysis of the data, refer to Visitor Studies - Full Report (Gillen 1988).

11.3 Findings

11.3.1 Count of Visitor Numbers

(a) Number of Tourists Recorded during the July Survey

Tourists at Innamincka and both Coongie East and Coongie West have been well represented in this report. All tourists at Coongie West were interviewed. Of the total number of 348 groups sighted at the Innamincka Trading Post, 175 groups (or 50.3%) were interviewed, 132 groups (or 37.9%) visited the Innamincka Trading Post more than once during the survey period, and the remaining 41 groups (or 11.8%) either declined an interview or were missed by the interview team. The total number of different groups sighted at Innamincka therefore was 216 groups (i.e. 175 + 41 or 348 - 132 = 216) of which 175 groups were interviewed, namely 81%. This represents a very high response rate.

At Coongie East, of the total 39 groups sighted by the interview team during the entire survey period that the team was resident in the region from 8 to 14 July, 36 full interviews were administered, two groups (or 5.1%) were either missed or declined an interview, and one group said it had been interviewed before (2.6%). Therefore the 36 groups who completed an interview schedule represented 92.3% of the total. This number is 50% of the total number of groups (i.e. 72 groups, refer Table 11.1) sighted entering the Coongie East region at Road counter one over this period. Once again this percentage is considered an adequate representation of the tourist population and, given the length of time necessary to administer each questionnaire, is a very high response rate.

During the four survey days alone some 320 different people were arriving at Innamincka each day and staying in the region for up to one week, and some 80 new people were recorded as arriving at Coongie East each day. These visitation rates are extraordinarily high, and given the prehistoric, historic and biological sensitivity of this setting (refer Luebber's 1988, and this report) and the present lack of any sanitary facilities and tourist management (with respect to the provision of heating fuel, rubbish collection and disposal, showers and toilets, interpretation, campsite or road signage, policing of illegal theft, damage, fishing, hunting and poaching), they may cause irreparable damage before adequate management is effected.

(b) Number of Environmentalists Recorded

With respect to the number of groups involved in environmental research, who visited the region from 1 December 1986 to 1 December 1987, six different groups have been identified. These groups are:

1. Julian Reid and Jake Gillen's Biological Survey for the South Australian Department of Environment and Planning;

2. Roger Luebber's Archaeological Survey for Aboriginal Heritage, Department of Environment and Planning;

3. Gary Drewien's Land Systems Mapping for the South Australian Department of Environment and Planning;

4. Elizabeth William's Archaeological Survey for ANU, Canberra;

5. Marie-Anne St. Clare's Biological Research for Flinders University, South Australia;

6. CSIRO Rabbit Research, Canberra.

Information was unattainable for the latter study. However, the total number of different individuals and the total number of people-days* have been recorded for the five former groups and are presented in Table 11.2.

TABLE 11.2

GROUP	No. Diff. Individuals	%	Total No. People-Days	%
Julian Reid & Jake Gillen	67	78	1426	73
R. Luebber's; Abl Heritage, S.A.	6	6.3	107	6
G. Drewien, Dept. E. & Pl, S.A..	6	6.3	84	4
E. Williams, ANU, Canberra	6	6.3	133	7
M.A. St. Clare, Fl. Uni, S.A.	3	3.1	210	10
TOTAL	88	100	1960	100

* NOTE: For the purpose of this study visitor pressure has been measured in people-days, where, for each day spent in the region by each individual one person-day is recorded.

11.3.2 Innamincka: Interviews

Interviews were conducted concurrently at Innamincka and on both the eastern and western banks of the North-West Branch of Coopers Creek at its entrance to Lake Coongie (refer to Fig. 11.1).

The interview station at Innamincka was located outside the Innamincka Trading Post as it was considered that most, if not all tourists at Innamincka would visit this shop to buy stores or fuel, to post mail, or to collect local information from the proprietor, Mike Steel. A team of three interviewers worked at this station during the shop's operating hours from 8.00am to 5.30pm on July 8,9,11 and 12, 1987.

Over the four day interview period a total of 2,361 people were sighted in 348 groups travelling in 708 vehicles (i.e. 679 cars, 19 motor bikes, 6 planes and 4 buses) (refer Table 11.3). Of these sightings it was noted that some groups remained in the Innamincka region over a number of days, visiting the Trading Post more than once during their stay. Therefore, of the total 348 groups sighted, 175 groups were sighted at least once, and of the remaining 173 groups sighted, 37 groups were not interviewed either because they did not leave their vehicles or because the interviewers were too busy and adopted the recognised "next to pass" technique of selection; 4 groups declined an interview; and 132 groups were sighted more than once at the Innamincka Trading Post (refer Table 11.4).

Accurate information has been collected by means of administered questionnaires for the 175 groups who were sighted at least once. (refer Appendix 11.3). It is this material which provides the basis for discussions and recommendations for management of tourists at Innamincka in this report. There were 1,287 individuals in the 175 groups interviewed. They were travelling in 413 vehicles (i.e. 398 cars, 7 motor bikes, 2 buses and 6 planes). The average number of people per group was 7.4; the average number of vehicles per group was 2.4 (refer Table 11.5); the average number of people per vehicle was 3.1.

11.3.3 Coongie East: Interviews and Road Counts

An interview team of two persons drove along the eastern bank of the northern section of the North-West Branch of Cooper Creek near its entrance to Lake Coongie and along the southern shore of Lake Coongie (refer Fig. 11.1 showing "Coongie East") interviewing as many groups as practicable between the hours of 8.00am and 5.30pm on the four survey days of July 8,9 11 and 12, 1987. During this time a total of 31 groups were sighted, of which 28 groups were interviewed; two groups were missed because they were leaving the Coongie Lake region and did not stop to be interviewed; and one group had been interviewed previously. A further eight groups were "opportunistically" interviewed during the week commencing on 8 July and completing on 14 July on days other than survey days as they arrived at the "Base Camp", Road Counter Station 1, or met interviewers while they were checking Road Counters 2 and 3 (refer to Fig. 11.1) and offered their information. Therefore accurate information has been recorded for a total of 266 people in 36 groups travelling in 86 vehicles (i.e. 80 cars, 3 motor bike and 3 planes) (refer Table 11.6). The average number of people per group was 7.4; the average number of vehicles per group was 2.4 and the average number of people per vehicle was 3.1.

In addition to the detailed interviews administered at Coongie East (refer Appendix 11.4) a series or road counters were installed to monitor the entry and exit of all vehicles to the Lake Coongie region on the eastern side of North-West Branch of Cooper Creek (refer Fig. 11.1, "Road Counter 1") as well as the movement of tourists along roads and shot-lines near Coongie Lake and on the western side of the North-West Branch (Refer Fig. 11.1, Road Counters 2,3 and 4). Road Counter 1 was monitored by a team of two people from 8.00 am to 5.30pm for seven consecutive days from Wednesday 8 July to

Tuesday 14 July, inclusive. Over the seven day period a total of 438 different individuals were seen entering the Coongie East area in 72 groups travelling in 143 vehicles (i.e. 140 cars, 3 motor bikes - refer Table 11.7).

The average number of people per group was 6.1 people; the average number of vehicles per groups was 2.0 vehicles; and the average number of people per day to enter the area was 62.6 people (or 10.3 groups per day). This is a very high visitation rate as a minimum of 1,753 people would visit this district over each four week school vacation (by extrapolation).

11.3.4 Coongie West: Interviews

Finally, an interview team of two persons was responsible for monitoring tourist movement and for interviewing tourists camped on the western bank of the North-West Branch of Cooper Creek near its entrance to Lake Coongie (refer Fig. 11.1 showing "Coongie West") between the hours of 8.00am and 5.30pm on the four survey days of July 8,9, 11 and 12, 1987. During this time a total of seven groups were sighted and interviewed. One further group was interviewed "opportunistically" on the 10 July as they arrived at the "Base Camp" (refer Fig. 11.1) and offered their information. Accurate information has been recorded for 59 individuals in eight groups travelling in ten cars, one row boat and on seventeen camels (refer Table 11.8). These numbers are remarkably fewer than those recorded for both Coongie East and Innamincka. It appears that Coongie West is far less frequented by visitors even during a time of peak pressure, namely the school vacation.

11.4 Impacts

For the purpose of this report environmental impacts have been measured quantitatively in mass (kg) of timber loss for firewood per person per day; volume (m^3) of faeces production per person per day; area (m^2) of surface soil disturbance per person per day;

and qualitatively in terms of visible rubbish proliferation, ground surface clearance and scalding, road proliferation and timber felling.

11.4.1 Photographic Records and Photo-points

Aerial photographs have been taken on three occasions this year, initially in late June 1987, then in late July 1987, and in late October 1987. These photographs recorded campsites and roadways in the Coongie East and Coongie West regions. It is anticipated that they will provide a baseline for comparison with aerial photographs to be taken in the future (should funding be made available) such that any new roads or campsites may be identified and the increase of tourist mobility and exploration documented.

Eleven photo points were established in the Coongie East Region on 8 September 1987, and a further four photo points were established in the Coongie West Region three days later (refer Fig. 11.2 for photo point sites). Each site was carefully selected with the specific intention of recording the impacts of tourist activities namely, camp-site clearing and camping, driving and sight-seeing, timber collecting and rubbish dumping. It is anticipated that the initial photos taken of these points will provide a baseline for comparison with photographs which were taken in late October 1987 after the school holiday period such that the visual effect of this peak in tourist pressure could be recorded.

Should funding be made available it is recommended that further photographs be taken routinely six to twelve monthly intervals to provide accurate documentation of the nature and extent of the rapidly growing tourist pressure in these regions. These photographic records could provide a cost-effective means for recording and analysing tourist behaviour for the purposes of planned tourist management.

11.4.2 Timber Loss from the Region for Firewood

During the ten day field trip undertaken by five authors of this report and ten volunteers in December 1986, a study was undertaken of some aspects of the group's activities and their impact on the immediate environment.

All timber which was locally collected and used as firewood over seven of the ten days was weighed. By dividing the total weight of timber used i.e. 250kg), by the number of people in the group (ie. 250/15 people = 16.7) and the number of days over which these measurements were made (i.e. 16.7 / 7 days = 2.38), a figure of the number of kilograms of timber used per person per day was calculated. It must be noted that these figures provide an absolute minimum figure for timber used, as the group observed was composed of environmentally sensitive individuals, and the time of observation was mid-December when temperatures during both the day and night were high; the daily maximum often being in the high thirties. Fires were only used for cooking and did not function as either a heating agent or a social focus during the night. To achieve a more realistic figure for tourist timber use in winter (i.e. the time for peak tourist use is winter from April to October), the findings for use timber per person per day should be increased by a factor of 50% thereby bringing it to 3.57kg per person per day (i.e. 2.38 x 1.5 = 3.57). Even this figure may be overly conservative, because large groups (as with the December fieldtrip) would tend to use proportionately less timber per person, i.e. a similar sized fire would suffice for a group of 15 as an averaged sized group of seven or eight people.

Following consultation with Mr John Riggs of the Woods and Forests Department, South Australia, a conversion factor has been calculated to adjust kilogram weight of dry timber to numbers of living, native hardwood trees of the age and stature of the Eucalyptus camaldulensis and Eucalyptus microtheca found in the Cooper Creek region on Innamincka Station. It is estimated that such a tree would be on an average ten to fifteen metres (say twelve metres) in height and have a trunk of 450mm diameter when measured one metre above the ground. Such a tree would support 1340kg of 'wet' timber which, when 25% of its weight in water is removed, would supply a total of 1005kg of burnable firewood (i.e. 1340 x 0.75 = 1005). Therefore, given that one person burns 3.57 kg of timber per day, it would only take 282 people to burn the dried wood of a eucalypt in one day.

11.4.3 Faeces Production

During the 10 day December field trip undertaken by fifteen people in 1986, observations were made of the number of long drop loo pits which were used (i.e. 15 pits). The total volume of each pit (i.e. 0.3m x 0.3m x 1.5m = .135 m^3) was calculated and multiplied by the number of pits used to give a total volume of faeces (i.e. 0.135 x 15 = 2.025 m^3). To evaluate how much faeces one person produced in one day this total volume was divided by the number of people (i.e. 2.025/15 = 0.0135) and by the number of days (i.e. 0.135/10 = 0.0135). Therefore one person introduces 0.0135m^3 of faeces per day into the region of habitation (strictly speaking, this figure refers to the volume of faeces and disturbed soil produced per day per person).

11.4.4 Surface Soil Disturbance

Following completion of the tourist survey in July it was recorded that 100% of the groups interviewed used "a spade and loo paper" when defecating. Consequently, it was considered necessary to roughly calculate the area of surface soil which would be disturbed by each person per day. In this way it was hoped that some quantification of soil erosion, top soil loss and extent of fouling could be made.

Given that one person produces 0.0135m^3 of excrement per day and that the average size of pit dug for this activity would be 0.006m^3 (i.e. 0.0.15m deep x 0.2 x 0.2 = 0.006m^3) then the number of pits per person per day would be 2.25 (i.e.

0.0135/0.006 = 2.25). Further, given that each person would defecate no closer than 1m to the next site of soiling, then the absolute minimum area of soil disturbed per person per day will be $2.25m^2$.

11.4.5 Future Low-Cost Monitoring of Tourist Numbers and Impacts

Four means, by which future tourist numbers can be approximated, their impacts on the environment estimated and the rate of environmental response to these impacts calculated, have been integrated into the methodology for this study. Each of these monitoring techniques provide a cost effective means for continued recording, approximations and analysis of tourist pressure at the Innamincka Township and Coongie East regions, as they require a minimum of maintenance, staffing and funding. These techniques are:

1. the conversion of fuel sales at the Innamincka Trading Post to provide an approximation for the number of tourists residing in the Innamincka region;

2. the calibration of road traffic counter numbers at Seven Mile Cattle Yards and Coongie East, to provide information on the number of tourists and vehicles entering, leaving and residing the Coongie East district;

3. the calculation of a "Spin Off" factor relating the number of tourists residing in the Innamincka region to the number of tourists arriving at and residing in the Coongie East districts;

4. the use of aerial photographs and the establishment of permanent photo points to record visually the impacts of tourist pressure and environmental responses to that pressure over time in both the Coongie East and Coongie West Regions (refer previous section 11.4.1).

1. Conversion of Fuel Sales at Innamincka Trading Post to approximate Tourist Pressure in the Innamincka Township Region

For the duration of the four tourist survey days at Innamincka the interview team was stationed from 8.00am to 5.30pm each day to coincide with the operating hours of the shop. It was assumed that most, if not all, tourists at Innamincka would buy fuel at the Trading Post. This place is the only outlet for fuel in Innamincka, the nearest alternative outlet being Moomba some 140km away. However, Moomba is a "closed mining community" and as such does not sell fuel to tourists unless they are in dire circumstances or by prior arrangement. Therefore, the closest public refuelling station is at Lyndhurst some 460km south-west of Innamincka.

All vehicles sighted at the Trading Post were recorded on daily Master Schedules. Vehicles were identified by their registration number so that multiple visitations by any vehicle were recorded on a daily basis and the number of different vehicles residing in the region each day could be summarised. Similarly, daily figures for the number of new vehicles could be checked (refer Table 11.9). Fuel sales on each of the four survey days were also recorded. On the last two survey days (namely, 11 and 12 July) all vehicles which bought fuel at the Trading Post were also recorded.

For the purpose of this report, tourist pressure is based upon the number of different vehicles sighted at an interview station each day. Therefore, if a vehicle is sighted on two or more consecutive days that vehicle is recorded as being in the region on each of those occasions. However, if the same vehicle is seen more than once on one day, it is recorded only on its first sighting for that day and any further sightings of that vehicle on that day are disregarded with respect to the calculation of tourist pressure per day.

By checking the vehicle registrations recorded on the Master Schedules the total number of different vehicles to visit the Trading Post each day could be evaluated, as could the number of new vehicles to the region each day.

By dividing the number of vehicles recorded as buying fuel into the total volume of fuel sold on each day (i.e. the 11 and 12 July) the average number of litres sold to each vehicle could be calculated. Similarly, factors for the number of litres sold per different vehicle sighted, the number of litres sold per new vehicle in the Region, and the number of litres sold per vehicle sighting in the region can be calculated (refer Table 11.10).

Further, using the figure calculated for the average number of people per vehicle at the Innamincka Trading Post (refer Table 11.9) and the fuel sale figures one may calculate the numbers of people travelling in different vehicles; the number of people in new vehicles; and the total number of people sighted at the Trading Post each day.

2. Calibration of Road Traffic Counter Recordings at Seven Mile Cattle Yards, Coongie East District.

For seven consecutive days during the survey period a road traffic counter at Seven Mile Cattle Yard was monitored and daily recordings were compared with data collected by two persons observing vehicles entering and leaving the Coongie East region. For each unit increment registered on the traffic counter one vehicle (or 2 axles) was recorded. The data collected by both the counter and the team of observers have been integrated to provide a means of evaluating four factors such that future road count records will provide meaningful approximations of visitor patterns. These factors are:

1) the average number of axles per vehicle travelling to and from Coongie East, namely 2.2 and 2.3 axles per vehicle respective. The number of axles is greater than 2.0 as some vehicles had a trailer or caravan in tow (refer Table 11.11 for statistics);

2) the proportion of vehicles travelling to and from the Coongie East district of the total vehicles recorded by the counter, namely one in two and one in three respectively (although these proportions will vary from one sampling period to the next);

3) the average number of people per vehicle travelling to and from the Coongie East districtegion, namely 3.2 and 2.8 respectively. Therefore the average number of people per vehicles is 3.0;

4) the approximate number of vehicles or people residing at Coongie East on a daily basis. The tourist pressure at Coongie East is measured by the number of vehicles or people residing within the region each day namely, 40.7 vehicles or 122 people (refer Table 11.12) given that nominally 70% of those arriving stay at least one night and 45% of those arriving stay two nights only (Figures taken from Master Schedules).

3. Calculation of "Spin Off" of Tourists at Coongie East as a Percentage (and Ratio) of the Total Number of Different Tourists Sighted at the Innamincka Trading Post.

This calculation was made by dividing the number of vehicles (or the number of people in those vehicles) at Coongie East per day (refer Table 11.11) by the total number of different vehicles (or the number of people in those vehicles) sighted at the Innamincka Trading Post, and subsequently to convert this fraction to a percentage by multiplying it by 100.

The ratio of vehicles (or tourists) at Coongie East per day to the number of different vehicles (or tourists) sighted at Innamincka Trading Post daily is calculated by dividing the number of vehicles (or people) at Coongie East per day into the total number of different vehicles (or tourists) sighted at Innamincka Trading Post on a daily basis (refer Table 11.9). The calculations are as follows:

1) "Spin-Off' Percentage Factor =

$$\frac{\text{No. vehicles at Coongie East per day}}{\text{No. different vehicles sighted at Innamincka per day}} \times 100$$

2) "Spin-Off" Ratio Factor =

$$\frac{\text{No. different vehicles sighted at Innamincka per day}}{\text{No. vehicles at Coongie East per day}}$$

In the future when the Innamincka Trading Post and road counter at Seven Mile Cattle Yard are unstaffed it is anticipated that the fuel sales at the Trading Post will then be used to estimate both the total number of different vehicles (and tourists) in the Innamincka Township region and the total number of vehicles (and tourists) in the Coongie East district. This is to be achieved by using the weekly fuel sales at the Trading Post and dividing them by 23.3 to determine how many different vehicles in the region. By multiplying the solution by the percentage "spin off" at Coongie East an estimate of vehicle pressure may be calculated. Further, should the road traffic counter remain at Seven Mile Cattle Yards the approximation can be cross-checked against the road count and any variation between the two figures for tourist pressure will indicate any variation in the rate of vehicle visitation to Coongie East. The calculations are as follows:

1) Approx. No. of vehicles arriving in Innamincka Region on a weekly basis

$$= \frac{\text{Total weekly fuel sales, Innamincka}}{\text{23.3 (i.e. No. litres fuel sold per different vehicle in Innamincka Region)}}$$

2) Approx. No of vehicles arriving at Coongie East weekly = $\frac{\text{Total weekly fuel sales, Innamincka}}{\text{23.3 x "Spin off" Ratio}}$

11.5 <u>Significance</u>

It is evident that the current visitor pressure is rapidly escalating due to increased media attention drawn to the region by Dick Smith's Australian Geographic article, newspaper and television coverage related to environmental research near Lake Coongie and to the government's proposal to make Innamincka Station a Regional Reserve under the National Parks and Wildlife Act. In the year 1986, total petrol sales at Innamincka were 264,000 litres, which represents 15,891 different tourists and a visitor pressure of 35, 124 people-days. By comparison in the ten months from 1 January 1987 to 31 October 1987, 406,329 litres of petrol were sold at Innamincka, representing 24,460 different tourists and a visitor pressure of 54,061 people-days. It can therefore be approximated that the total number of tourists to Innamincka doubled during 1987.

Current tourist numbers are having a marked detrimental effect on the quality of this environment and hence on the quality of experience received by all tourists to the Innamincka/Lake Coongie region. The sheer magnitude of their numbers have meant that rubbish and faeces production have become major issues of community health. The evident lack of sufficient sanitary facilities and tourist management must be addressed immediately if the environment is to sustain its inherent, natural assets and qualities, and to continue to be attractive to the increasing number of tourists.

Similarly, the rapid loss of local mature trees lining the water courses is a matter of urgency. In 1987 alone it has been estimated that the equivalent of 230 mature specimens (of <u>Eucalyptus microtheca</u> or <u>Eucalyptus camaldulensis)</u> have been felled by visitors to the region and used as firewood. Even the tree planting project carried out by Marden High School and SANTOS since 1985 cannot keep pace with this loss, as they are only planting 100 trees per year.

Further, the biomass production by Eucalyptus camaldulensis apparently reaches 3.2 tonnes/hectare/year in areas having 200mm annual rainfall (Buckley 1985). This being so, in order for a wood-lot to be established which could meet current demands, (namely, 230 trees per year or 308.2 tonnes of green timber - refer section 11.4.2, one tree = 1340kg 'wet timber') an area of 96.3 hectares per year will need to be available for cropping. However, as Buckley stated, the central Australian eucalypts E. camaldulensis and E. microtheaca are relatively sparse, and are generally restricted to ephemeral water courses where ground water is available. The extent of watercourse shoreline necessary for such an undertaking at Innamincka/Coongie Lakes is impractical, and the economic costs of installing and irrigating some 250 to 400 hectares (i.e. 3 to 5 years supply) of woodlot would be significant. It is therefore critical that the current use of local trees for firewood be addressed immediately.

Fortunately, the visitors are at present self-selected and are interested in the unique wetlands environment, as well as the numerous recreational activities this setting has to offer from camping and bushwalking, to boating, fishing, sailing and exploring. These people represent a broad cross-section of the Australian community. They choose to travel extreme distances on anything from a motor bike or camel to a conventional vehicle, four wheel drive or by plane to experience 'first hand' the raw beauty of an environment free of predators and to experience the companionship associated with shared adventures in this unique South Australian, outback setting. The historic associations of the area are also a remarkable draw-card for many. Most appear to be well intentioned, enthusiastic and in search of knowledge. Given the particular nature of this visitor population, it is essential and urgent that clear, educative interpretation be provided at Innamincka and all heritage sites and camp sites both along Cooper Creek and near Lake Coongie. The in situ requirement is important.

11.6 Recommendations

The intention of the following recommendations is to promote sound heritage and economic management in an expedient way such that tourist experience and appreciation of this unique environment will be enhanced.

11.6.1 Immediate Problems and Recommendations

1. **Crowding** Due to: i. the recent national and state publicity of the ii. the consequent rapid increase in tourists.	1. REGULATE the number, size and location of campsites by PERMIT AND FEES. region;
2. **Denudation** of all campsite areas due to: i. timber collection for campfires; ii. site clearance for tents and camping; iii. movement of vehicles around trees for shade.	11. BAN ALL CAMPFIRES and regulate pressure by PERMITS and/or FEES. permits and/or fees

3.	**Rubbish Proliferation** in all campsite areas due to: i. the rapid increase in tourists to the area; ii. the lack of rubbish collection programme.	111. Inform tourists of their responsibility for rubbish disposal at the Innamincka tip by interpretive material to be located at Innamincka and all campsites and heritage sites.
4.	**Sanitation and Pollution** due to: i. the rapid increase in tourists to the area; ii. the lack of any public ablution facilities in the area.	IV. Construct public ablution facilities at Innamincka. V. Provide 'Pit-Drop' Loos V. (or equivalent) at all approved campsites.
5.	**Erosion** due to: i. denudation (refer above); ii. current practice of "spade" for loo; iii. road proliferaon, especially across dunes at Coogie Lakes; iv. cutting of claypans by 4WD vehicles during wet weather.	VI. Protect dune crests where approved road/crossings are located VII. Close roads during rains until surfaces are dry.

6. **Road Proliferation** due to:	
i. insufficient sign posting to indicate places of cultural, historic or biological significance;	VII. Provide clear signs on all roads indicating both access and no through roads.
ii. insufficient sign posting to indicate access to campsites;	IX. Provide accurate maps of the area and remove inaccurate maps from circulation.
iii. inadequate and inaccurate maps to the above.	
7. **Noise Disturbance** to breeding bird and wildlife, and to campers in the region due to:	X. Ban all use of i generators ii motor boats iii motor bikes iv chainsaws v guns at Coongie and limit use of generators and motor boats to Innamincka, ONLY.
i. Use of generators, motor bikes, chainsaws and guns.	

11.6.2 Controversial Issues and Recommendations

1. **Zoning and Regulation** of access to tourists

It is recommended that the Coongie Lakes and Innamincka region be zoned for exclosure of tourists from parts of the region, and that their access to the remaining areas be regulated through the payment of fees for a permit.

For this report the zoning and regulation of tourist access has been based on the following requirements of SA National Parks and Wildlife Service as the responsible Government body to protect and ensure the:

i biological and cultural integrity of the region;
ii safety of people within the Reserve boundaries;
iii security against abuse, theft or vandalism of pastoral, mining and National Parks stock, material, property and equipment etc;
iv practical, effective and economic management of the Reserve

To this end the following recommendations for zoning and regulation of access are given (also refer to Fig. 11.3):

i Exclusion of all tourists from the western side of the North-West Branch of the Cooper Creek and all lake and swamp banks other than the south-west bank of Coongie Lake so as to limit the region requiring management and surveillance;

ii Exclusion of tourists from camping adjacent to:
a. recognised sight-seeing locations;
b. sites of biological, cultural or historical significance e.g. Cullyamurra Engravings, the Dig Tree, the mouth of the North-West Branch of Coopers Creek at Coongie Lake;

iii <u>Seasonal Closure of the roadway to Coongie Lake and the North-West Branch of Cooper Creek</u> from the first weekend in October to the last weekend in March every year, commencing October 1987, so as to:

a. protect the quality of the environment during a time of extreme climatic stress;

b. ensure human safety during times of extreme heat.

iv <u>Regulated Closure of the roadway to Coongie Lake and the North-West Branch of Cooper Creek during times of rain and drought</u> so as to:

a. protect the quality of roadways;

b. protect the environment against the cutting of claypans, the leaching of top soil and the erosion of sand-dunes;

c. ensure human safety.

v <u>Limit the location and size of Campsites</u> along the North-West Branch of Cooper Creek, the southern shore of Coongie Lake and the southern bank of Cooper Creek to areas which are:

a. easily accessible and requiring limited new roadworks;

b. already recognised as camping areas e.g. Kudriemitchie and Scrubby Camp.

vi <u>Regulate the activities of campers in biologically sensitive areas</u> e.g. by banning generators, fires, motor boats and bikes, chainsaws and guns.

vii <u>Regulating the location of roadside camps</u> along the Cordillo Downs Road and Strzelecki Track.

2. **Fees and Permits**

It is recommended that the fee for Permits be adjusted according to the number of guaranteed experiences associated with the campsite/sightseeing location and use, given that all of the tourists pay a minimum fee for base-line expectations of:

i a clean, well-maintained and managed environment, free from unsanitary conditions, litter and pollution;

ii good signs, road surfaces and interpretive material including information shelters and local maps.

Increases in charges should be based upon the following:

i the extent, quality and availability of extra interpretive material i.e. site specific material distributed at places of biological, cultural and historic sites;

ii the degree of scenic beauty requiring extra management to be maintained e.g. Scrubby Camp vs Cooper Creek frontage vs Coongie Lake frontage;

iii access to wilderness experience. The further the place is from settlement and the more "natural" the setting, the greater the management and maintenance costs incurred;

iv degree of guaranteed visual, spatial and auditory privacy.

Refer to Fig. 11.3 for suggested zoning.

3. **Development**

It is strongly recommended that permits and fees be adjusted so that the most highly sought attractions of the region be regarded as the most valuable. The users who pay for the privilege of a remote isolated, wilderness experience must receive value for their money: namely, a highly regarded, wildlife and bird sanctuary of international significance.

Under NO conditions should large scale commercial, enterpreneurial developments like that proposed for Wilpena Pound be considered in the Coongie Lakes District as:

i Coongie Lake and the associated wetlands are a unique, fragile environment of international significance having been listed on the Ramsar Treaty in July 1987 as being a semi-permanent freshwater system in a desert environment;

ii The prime attractions of the region to tourists are:

Scenery and Wilderness: 59% response

Isolation, Peace and Quiet: 51% response

namely their experience of remoteness from concentrated human occupation and activity. Therefore, to provide development considered to be of "international standard" would mean that the specific tourist attraction of this region would be destroyed.

4. **Rangers**

It is recommended at least one Ranger be stationed permanently at Innamincka Township as the tourist pressure in this region is beyond managable limits given the township supplies:

1 airstrip

1 general store

1 hotel/motel

NO Ablution facilities

NO regular public rubbish collection and

has a permanent population of nine people, while the annual visiting population is projected to be in excess of 30,000 different people during 1987.

Further it is recommended a second Ranger be stationed at Kudriemitchie Outstation on a seasonal basis.

The Rangers' roles should include:

i collection of fees;

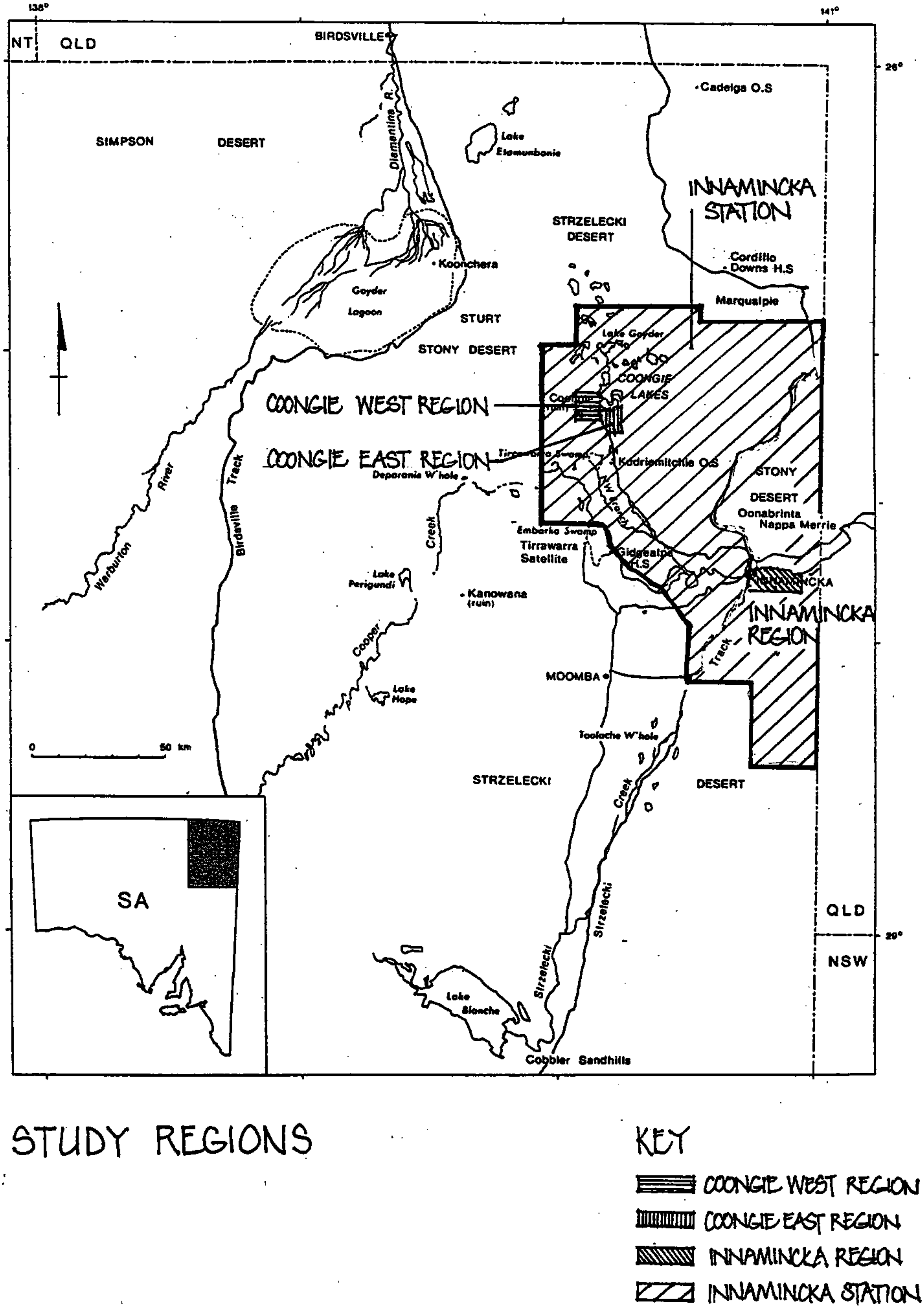
ii policing of bans on campfires, generators, motor boats, motor bikes, chainsaws, guns and nets;

iii maintenance of rubbish collection, ablution facilities, roadworks, signs and interpretation material.

5. **MORATORIUM** It is strongly recommended that all tourist use and access to the North-West Branch of Cooper Creek and Coongie Lake be prohibited until a thorough plan of management for the area is designed and can be professionally implemented. Such was the plan of action adopted by the Qld NPWS for Lawn Hill Gorge NP, which similarly had pre-existing visitor use causing environmental degradation, and which is now a showcase as a splendidly managed national park featuring items of oustanding natural, biological and archaeological significance (J. Reid pers. comm.).

Figure 11.1a

The Far North-East, showing study regions referred to.



COONGIE LAKES DISTRICT

SOUTH AUSTRALIA

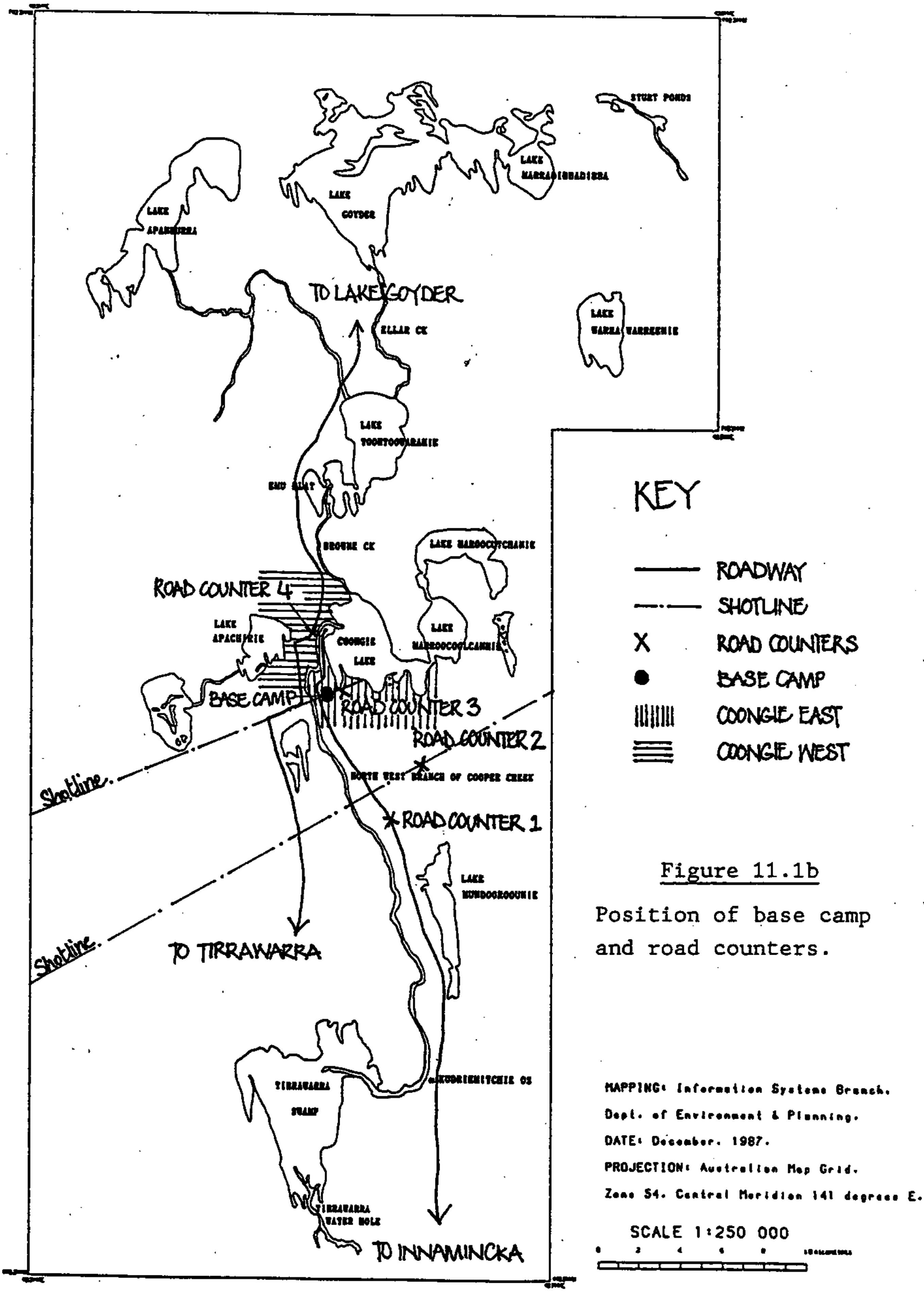


Figure 11.1b

Position of base camp and road counters.

ROAD COUNTERS, BASE CAMP, 'COONGIE EAST', 'COONGIE WEST'

COONGIE LAKES DISTRICT

SOUTH AUSTRALIA

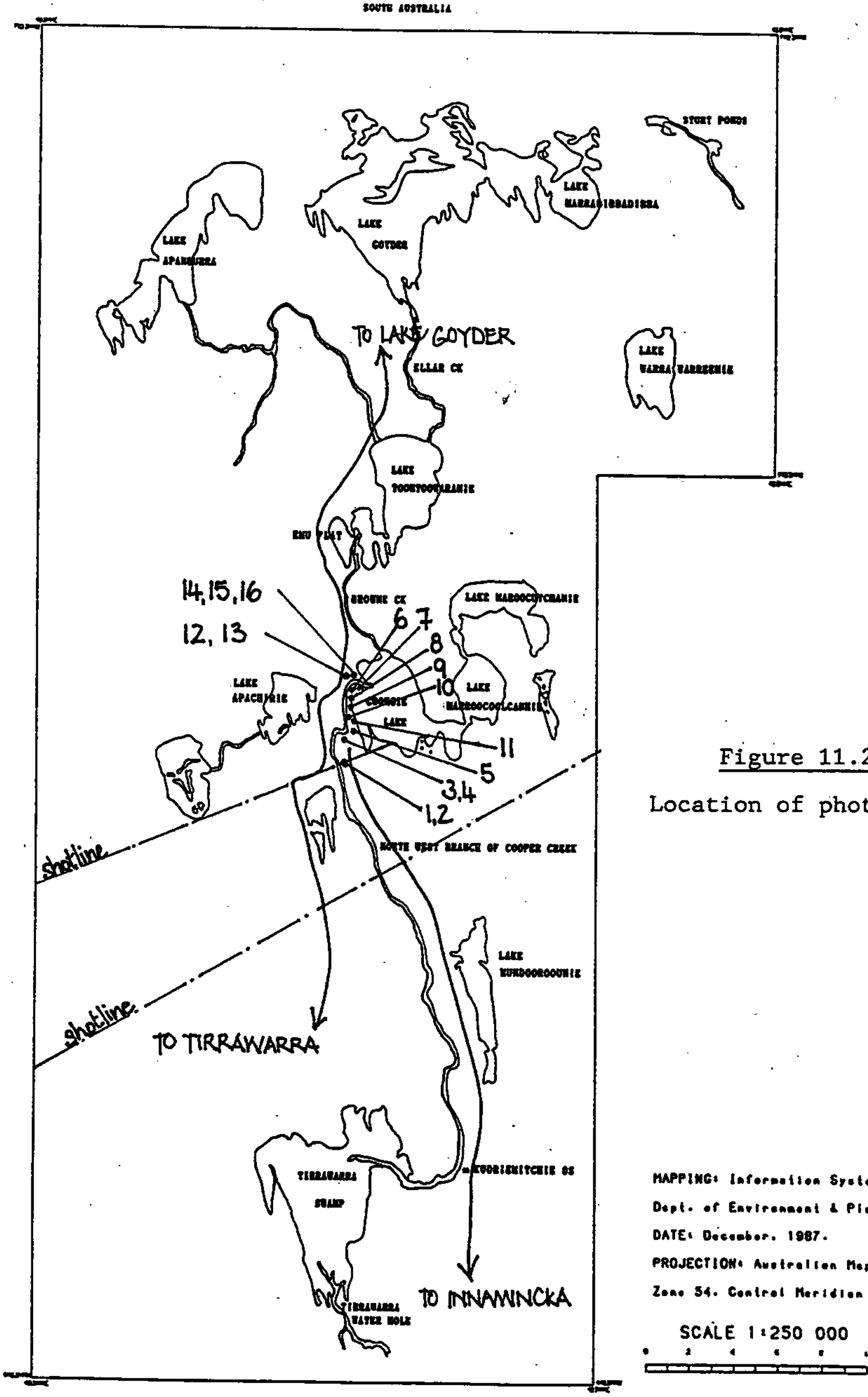


Figure 11.2

Location of photopoints.

MAPPING: Information Systems Branch.

Dept. of Environment & Planning.

DATE: December, 1987.

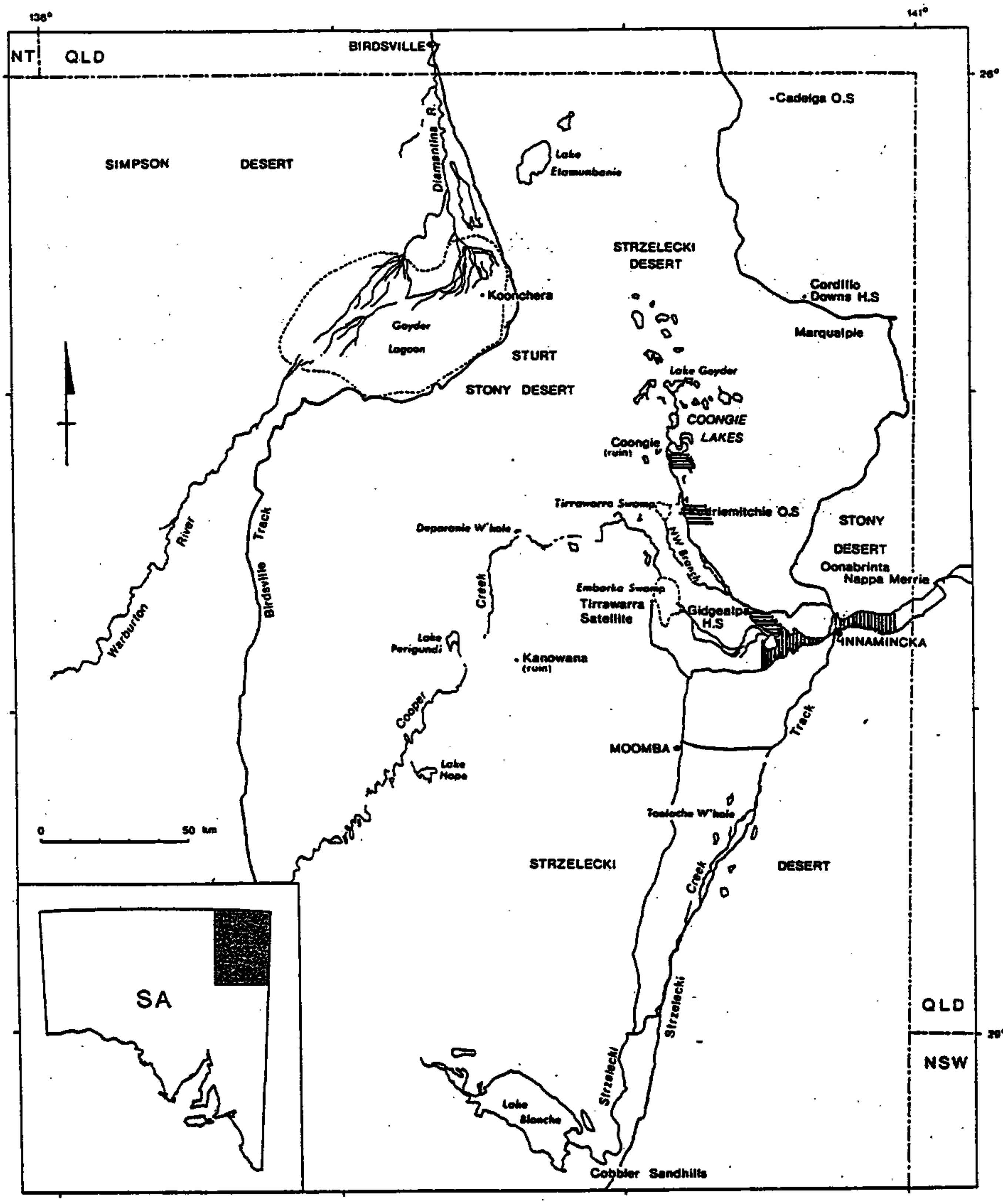
PROJECTION: Australian Map Grid.

Zone 54. Central Meridian 141 degrees E.

PHOTO POINTS

Figure 11.3

Map of study area showing recommended zoning of camp-sites.



RECOMMENDED ZONING

KEY

≡ N° & size of camp regulated

IIIII N° & size of camp unregulated

☐ Camping prohibited

TABLE 11.1

Total Number of People, Groups and Vehicles sighted at Road Counter 1 during survey period, July 1987.

Date	Total No of people				Total No of groups		Total No of Vehicles					
	to lake Coongie		from L Coongie		to lake Coongie	from L Coongie	to lake Coongie			from L Coongie		
	known	unknown	known	unknown			1	2	3	1	2	3
July 8	95	0	21	0	15	6	31	2	1	9	0	2
July 9	60	0	72	1	7	12	17	0	1	24	2	0
July 10	10	5	20	1	5	5	9	0	0	8	0	0
July 11	70	1	29	0	14	6	22	1	11	11	0	3
July 12	96	0	45	0	14	10	30	0	6	13	1	4
July 13	65	0	46	1	9	13	19	0	5	16	0	10
July 14	42	0	66	0	8	15	12	0	1	23	0	5
	438	6	299	3	72	67	140	3	25	104	3	24

Key

1 = car (conventional or 4WD)
2 = motor bike
3 = other (trailer, canoe, boat etc)

TABLE 11.3

Total number of people, groups and vehicles sighted at Innaminka Trading Post each day of interviewing.

DATE	Total No of People	Total No of Groups	Total No of Vehicles Cars	M/bikes	Planes	Buses
July 8	806	105	197	12	1	2
July 9	683	95	207	7	2	2
July 11	462	82	149	0	0	0
July 12	410	66	126	0	3	0
	2361	348	679	19	6	4

TABLE 11.4

Number of people and groups which were missed, declined an interview or sighted more than once at the Innaminka Trading Post during the 4 day survey period.

Date	No People			No Groups		
	Missed	Dec-lined	Repeat Sighting	Missed	Dec-lined	Repeat sighting
JULY						
8	25	4	104	16	1	16
9	20	5	405	11	1	43
11	9	0	221	6	0	36
12	11	5	265	4	2	37
	65	14	995	37	4	132

TABLE 11.5

Number of People, Groups and Vehicles interviewed at Innaminka Trading Post each day, over the 4 day survey period.

Date	No People Interviewed	No Groups Interviewed	No of Vehicles			
			Cars	M/bikes	Planes	Buses
July 8	673	72	200	7	1	2
July 9	253	40	85	0	2	0
July 11	232	40	76	0	0	0
July 12	129	23	36	0	3	0
	1287	175	397	7	6	2

TABLE 11.6

Number of People, Groups and Vehicles Interviewed at Coongie East over the survey period.

Date	No People Interviewed	No Groups Interviewed	No of Vehicles Motor Bikes	Planes	Conventional Cars	4WD
July 8	76	9	-	1*	3	19
July 9	40	7	2	-	1	12
July 10	18	3	-	-	2	4
July 11	25	5	-	-	-	8
July 12	57	7	1	-	1	15
July 13	14	3	-	1+	-	2
July 14	36	2	-	-	-	11
	266	36	3	2	7	71

* NOTE
This plane landed at Innamincka and its passengers were driven to Coongie East by friends who met them at the Innamincka Trading Post on their arrival.

\+ NOTE
This plane landed on a disused airstrip on Lake Apacherie on the western side of the North-West Branch of Coopers Creek near Coongie East and its occupants travelled to Coongie East by an inflatable boat they brought in the plane.

TABLE 11·7

Number of People, Groups and Vehicles which were Missed, Declined an Interview or were sited more than once at Coongie East during the survey period.

Date	No People			No of Groups			No of Vehicles								
	Missed	Declined	Repeat sighting	Missed	Declined	Repeat sighting	Missed			Declined			Repeat sightings		
							1	2	3	1	2	3	1	2	3
July 8	unknown	0	0	1	0	0	3	0	0	0	0	0	0	0	0
July 9	0	3	2	0	1	1	0	0	0	1	2	0	1	0	0
July 11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
July 12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		3	2	1	1	1	3	0	0	1	2	0	1	0	0

Key
1 = Cars
2 = motor bikes
3 = planes

TABLE 11.8

Total Number of people, groups and vehicles to be interviewed at Coongie West during the survey period July 1987.

Date	Total No. People	Total No. Groups	Total No. of Vehicles				
			4WD	Conventional Cars	Boat	Planes	Camels
8 July	2	1	-	-	1	-	0
9 July	13	3	4	-	-	1*	0
10 July	25	1	6	-	-	-	0
11 July	17	2	-	-	-	-	13
12 July	2	1	-	1	-	-	0
	59	8	10	1	1	1	13

*** NOTE**
The occupants of this plane arrived at Moomba and hired a 4WD vehicle to travel to Coongie West.

TABLE 11.9

Total Number of People and Vehicles sighted at Innamincka Trading Post during the Four Day Survey Period, July 1987.

Date	Total No of people sighted including repeat sightings	Total No of vehicles sighted including repeat sightings	Av. No of people in each vehicle	Total No of different vehicles sighted excluding repeat sightings	Total No of new vehicles sighted excluding repeat sightings	Total No of vehicles buying fuel	Total Fuel Sales (L)
8 July	806	212	3.8	186	210*	-	4153
9 July	683	218	3.1	177	88	-	4386
11 July	462	149	3.1	128	76	54	3175
12 July	410	126	3.3	116	39	36	2455
TOTAL	2361	708	N/A	607	413	90	14169
AVERAGE	590	177	3.3+	152	68	45	3542

*** NOTE**

As this was the first day of the survey a majority of the recorded vehicles were sighted for the first time. By comparison the 9, 11 and 12 July figures show a marked decrease in the number of new vehicles registered on the Master Schedules and they appeared more representative of the 'normal' tourist pattern of population influx.

+ NOTE:

This figure is slightly exaggerated as more people were interviewed on the first day, therefore the figure 3.1 has been used.

TABLE 11.10

Fuel Sales Per Vehicle at Innamincka taken from Recordings made over Survey Period, July 1987.

Date	Fuel Sales (L) per vehicle sighted incl. repeat sightings (ie Total fuel sale / Total No veh sightings)	Fuel Sales (L) per different vehicle sighted excl. repeat sightings (ie Total fuel sale / No different veh)	Fuel Sales (L) per new vehicle sighted excl. repeat sightings (ie Total fuel sale / No New veh)	Fuel Sales (L) per vehicle buying fuel (ie Total fuel sale / Total veh buying)
8	19.6	22.3	N /A	-
9	20.1	24.8	49.8	-
11	21.3	24.8	41.8	58.8
12	19.5	21.2	62.9	68.2
TOTAL	80.1	93.1	154.5	127.0
AVER	20.125	23.3	51.5	63.5

TABLE 11.11

Information on the number people, vehicles and axles recorded at road counter 1, during the survey week, July 1987.

Date	Number of people				Number of Vehicle		Av No People/Veh		No Axles		Av Axles/Veh		Total counts on Road Counter I
	to L Coongie		from L Coongie		to L Coongie	from L Coongie	to L Coongie	from L Co	to L Coongie	from L Coongie	to L Coongie	from L Coongie	
	known	un-known	known	un-known									
8 July	95	-	21	-	33	9	2.9	2.3	76	21	2.3	2.3	48.5
9 July	60	-	72	1	17	26	3.5	2.9	37	55	2.2	2.1	46
10 July	10	5	20	1	9	8	2.5	2.9	19	20	2.1	2.5	19.5
11 July	70	1	29	-	23	11	3.2	2.6	53	25	2.3	2.3	39
12 July	96	-	45	-	30	14	3.2	3.2	65	30	2.2	2.1	475
13 July	65	-	46	1	19	16	3.4	3.1	41	43	2.2	2.7	42
14 July	42	-	66	-	12	23	3.5	2.9	25	48	2.1	2.1	36.5
	438	6*	299	3*	143	97	3.2*	2.8	316	242	2.2	2.3	279

*NOTE The average number of people per vehicle has been calculated for vehicles with a known number of passengers, only

TABLE 11.12

Number of Vehicles stopping over in the Coongie East Region each night during the survey week, July 1987.

	Number of vehicles stopping over in the Coongie East Region each night							
Date of Arrival	8 July	9 July	10 July	11 July	12 July	13 July	14 July	
8 July	33	23	15	-	-	-	-	
9 July	-	17	12	8	-	-	-	
10 July	-	-	9	6	4	-	-	
11 July	-	-	-	23	16	10	-	
12 July	-	-	-	-	30	21	14	
13 July	-	-	-	-	-	19	13	
14 July	-	-	-	-	-	-	12	
								Total
Total	33	40	36	37	50	50	39	285
							Average No vehicles per night	40.7

VISITOR SURVEY INNAMINKA/COONGIE LAKE REGION

UNIVERSITY OF ADELAIDE, 1987

App. 11.1

MASTER SCHEDULE - INNAMINKA TRADING POST

DATE:

INTERVIEWERS:.......................
....
....
....

TIME COMMENCED:

TIME COMPLETED:

ID No	Vehicle Registration	Time of Interview	No of People in Vehicle	Interviews				Comments (Please note vehicles travelling together)
				Interviewed	Declined	Missed	Interviewed Before	

VISITOR SURVEY INNAMINKA/COONGIE LAKE REGION

UNIVERSITY OF ADELAIDE, 1987

App. 11.1

MASTER SCEDULE - PETROL SALES and MOTEL USE and RAINFALL

Innaminka Trading Post

Recorder's initials	Date	Time	Bowser 1	Bowser 2	Deisel	Other	No of Motel Occupants	Comments	Rain-fall

VISITOR SURVEY INNAMINKA/COONGIE LAKE REGION

UNIVERSITY OF ADELAIDE, 1987

OBSERVATION SCHEDULE - CAMPSITES

1-2
3-4
5-8
9-12
13-16
17
22

LOCATION: Innaminka / Coongie Lake (Please indicate on attached map)

OBSERVATION ID:

INTERVIEW X-REF:

DATE:

VEHICLE ID:

TIME:

OBSERVERS:

1. GROUP STATUS

Type of Group	Tick	Description
Private		
Guided		
Club		
School		
Other		Please state:

23-28

2. GROUP COMPOSITION and BEHAVIOUR

	Child 0 to 16yrs		Yg Adult 17 to 25 yrs		Adult 26 to 55yrs		Oldies 56 yrs +		
	M	F	M	F	M	F	M	F	
Number of Individuals									
Activities: Walking/Sightseeing									
Sports Games									
Swimming									
Fishing									
Motor Boating									
Sailing/Canoeing									
Shooting									
Wood Collecting									
Wood Cutting									How?
Vandalism									What?
Other									What?

Please record any comments:...
....
....
....
....

VISITOR SURVEY INNAMINKA/COONGIE LAKE REGION
UNIVERSITY OF ADELAIDE, 1987

App. 11.2

OBSERVATION SCHEDULE - COONGIE ROAD COUNTER

ID No	Vehicle Registration	Time Observed	Direction of Travel		No of People in Vehicle	Type of Vehicle				Accessories			Tot. No. Axles	State of Residence	Length of stay at Coongie (dys)
			to Coongie	from Coongie		Conv	4WD	Mini Bus/ Bus	Other	Trailer	Caravan	Other			

VISITOR SURVEY INNAMINKA/COONGIE LAKE REGION

UNIVERSITY OF ADELAIDE, 1987

MASTER SCHEDULE - ROAD COUNTERS
Coongie Lake Region

Recorder's Initials	Date	Time am & pm	Readings			
			Counter 1	Counter 2	Counter 3	Counter 4

App. 11.2

VISITOR SURVEY INNAMINKA/COONGIE LAKE REGION

UNIVERSITY OF ADELAIDE, 1987

MASTER SCHEDULE - INTERVIEWS
Coongie Lake Region

ID No	Vehicle Registration	Location	Time of Interview	No of People in Group	Interviewed	Interviews			Comments (Please note vehicles travelling together)
						Declined	Missed	Interviewed Before	

VISITOR SURVEY INNAMINKA/COONGIE LAKE REGION
UNIVERSITY OF ADELAIDE, 1987

INTERVIEW SCHEDULE - INNAMINKA TRADING POST

DATE:
TIME:

INTERVIEW ID:
VEHICLE ID:
INTERVIEWER:

1-2
3-4
5-8
9-12
13-18

1. GROUP COMPOSITION: People

Age	No of People M	No of People F
0-5 yrs		
6-17 yrs		
18-25 yrs		
26-55 yrs		
56 & over		

19-22
23-26
27-30
31-34
35-38

Vehicles

Vehicles	Con	4WD	Mini-bus	Bus	Motor Bike	Ute/ Truck	Semi-Tr'r	Other
No of Vehicles								

* Other, please state:.....................

39-56

2. PLACE of RESIDENCE

	SA	Vic	NSW	Qld	NT	ACT	WA	Tas	O/S
No of People									

*O/S, please state:.........................

57-60
61-64
65-68
69-72
73-76

3. GROUP STATUS

Type of Group	Tick	Description
Private		
Guided		
Club		
School		
Other		Please state:

77-80
81-82

4. PREVIOUS INTERVIEW

Have you been interviewed before on this trip ? YES / NO

If YES, When ?.......................

Where ?......................

(If YES at INNAMINKA ., DISCONTINUE interview.
If NO, or at ROAD COUNTER, or at COONGIE LAKES, CONTINUE interview.)

83
84-85
86-87

5. PREVIOUS VISITS — Have you visited the Innaminka region before ? YES / NO

If YES, When, and how long for ? 88

	WHEN		HOW LONG
	Month	Year	Length of Visit
First Visit			
Second Visit			
Third Visit			
More than 3*			

* Please state how many.......... 89-108

6. DURATION of THIS VISIT — How long do you intend to stay in the Innaminka region on this trip ? 109-115

DURATION	TICK
Overnight	
Less than 1 wk	
A fortnight	
A month	
Over a month	
Other*	

* Please state:.............

7. ACCESS TO REGION — (Please write responses to these questions BELOW and MARK ON MAP attached.)

(a) What route did you use to get to the Innaminka region ?
....
....
Why ?...
....

(b) What places have you visited in this region on this trip ?
....
....

(c) What places do you intend to visit in this region ?
....
.... 116-163

(d) Where have you stayed in this region on this trip ?
....
....
For how long ?..
....

(e) Where do you intend to stay ?............................
....
For how long ?..
....

(f) Have you seen any evidence of Aboriginal occupation in the region ? YES / NO
If YES, where ?...
....

(g) What route do you intend to take home ?..................
....
Why ?...
....

8. Any further comments ?.......................................
....

VISITOR SURVEY INNAMINKA/COONGIE LAKE REGION

UNIVERSITY OF ADELAIDE, 1987

INTERVIEW SCHEDULE - COONGIE LAKE

1-2
3-4
5-8
9-12
13
18

CAMPSITE LOCATION: INTERVIEW ID:
DATE: VEHICLE ID:
TIME: INTERVIEWER:

1. GROUP COMPOSITION: People

Age	No of People M	F
0-5 yrs		
6-17 yrs		
18-25 yrs		
26-55 yrs		
56 & over		

19-22
23-26
27-30
31-34
35-38

Vehicles	Con	4WD	Mini-Bus	Bus	Motor Bike	Ute/ Truck	Semi-Tr'r	Other
No of Vehicles								

* Other, please state:......................

39
56

2. PLACE of RESIDENCE

	SA	Vic	NSW	Qld	NT	ACT	WA	Tas	O/S
No of People									

*O/S, please state:.........................

57-60
61-64
65-68
69-72
73-76

3. GROUP STATUS

Type of Group	Tick	Description
Private		
Guided		
Club		
School		
Other		Please state:

77-80
81-82

4. PREVIOUS INTERVIEW

Have you been interviewed before on this trip ? YES / NO 83

If YES, When ?........................ 84-85

Where ?........................ 86-87

(If YES at COONGIE LAKE, DISCONTINUE interview.
If NO, or at ROAD COUNTER, or at INNAMINKA TRADING POST, CONTINUE interview.)

5. PREVIOUS VISITS

Have you visited the Coongie Lake region before ? YES / NO

If YES, when, and how long for ?

	WHEN		HOW LONG
	Month	Year	Length of Visit
First Visit			
Second Visit			
Third Visit			
More than 3*			

* Please state how many..........

88

89-108

6. DURATION of THIS VISIT

How long do you intend to stay in the Coongie Lake region on this trip ?

DURATION	TICK
Overnight	
Less than 1 wk	
A fortnight	
A month	
Over a month	
Other*	

* Please state:............

109-115

7. ACCESS TO REGION

(Please write responses to these questions BELOW and MARK ON MAP attached.)

(a) What route did you use to get to the Coongie Lake region ?
....
....
Why ?...
....

(b) What places have you visited in this region on this trip ?
....
....

(c) What places do you intend to visit in this region ?
....
....

(d) Where have you stayed in this region on this trip ?
....
....
For how long ?..
....

(e) Where do you intend to stay ?............................
....
For how long ?..
....

(f) Have you seen any evidence of Aboriginal occupation in the region ? YES / NO
If YES, where ?...
....

(g) What route do you intend to take home ?..................
....
Why ?...
....

116-163

8. PURPOSE of VISIT

What was the purpose of your visit here on this trip ?

	TICK	DESCRIPTION
Recreation		
Work		Employer ?
Study		Supervising body ?
Other		Please state:

164
173

9. INTEREST in COONGIE LAKES

What is it about Coongie Lakes which interests you ?

	TICK	DESCRIPTION
Recreation		
Boating		
Fishing		
Art/Photography etc		
European History		
Aboriginal History		
Biology		Please identify:
Other		Please state:

174
191

10. CHOICE of CAMPSITE

Why did you choose this place for your campsite ?

	TICK	COMMENTS
Proximity to others		
Privacy		
Been here before		
Access		Please state:
Other		Please state:

192
203

11. ACCESS to CAMPSITE

Did you have any unnecessary trouble getting to this site ?
YES / NO

	TICK	COMMENTS
Bad roads		
Bad signage		
Vehicle trouble		
Other		

204
214

12. FACILITIES and SERVICES

What have you brought with you on this trip to make your stay here as enjoyable as possible ?

	TICK	COMMENTS
Generator		
Motor Boat		
Motor Bikes		
Canoe		
Caravan		
Chainsaw		
Porta-loo		
Other		

215
228

13. EMERGENCY

What provisions have you made incase of an emergency ?

	TICK	DESCRIPTION
Transceiver Radio		
Spare Tyres		
Spare Water		
Spare Fuel		
First Aid		
Towing Gear		
Other		

229
[illegible]

14. FIREWOOD Do you have any trouble with firewood ? YES / NO
If YES, please state what trouble:......................... 245
....
.... 249

15. LOOS What do you do for a loo ?

	TICK	DESCRIPTION
Spade and loo paper		
Dig a communal pit		
Porta/Chemical loo		
The Bush will do		
Other		

Please record any other comments.......................... 250
.... 261
....

16. RUBBISH What do you do with your rubbish ?

	TICK	DESCRIPTION
Take it away		
Burn it		
Bury it		
Nothing		
Other		

Please record any other comments.......................... 262
.... 273
....

17. WASHING Do you have any trouble with washing ? YES / NO
If YES, please state whay trouble:........................ 274
.... 278
....

18. WATER What do you do for water ?

	TICK	COMMENTS
Bring it in		
Collect from Lake		
Collect from Channel		
Other		

Please record any other comments.......................... 279
.... 288
....

19. ENJOYMENT What is the most enjoyable aspect of your camping experience here ? 289
292

Please record all comments.................................
....
....
....
....

20. Any further comments ?..................................... 293
.... 296
....
....
....

12. RECOMMENDATIONS

Julian Reid and Jake Gillen

Innamincka Station encompasses a wide range of highly significant wildlife habitats and this range is considered to be fairly representative of habitats in the Far North East as a whole. Undoubtedly the Coongie Lakes and the entire length of the North-West Branch constitute the biological "jewels" of the region, and they require immediate protection and sympathetic management. For reasons elaborated upon in earlier chapters, it is essential that the whole Cooper Creek system be afforded appropriate protection - if such protection were not to be secured, conservation efforts along the North-West Branch in the longer-term may prove to be in vain.

The following series of recommendations addresses five main topics in relation to the conservation and management of the natural resources of the Coongie Lakes District and wider region, namely Rabbits, Stock Grazing, Mining, Tourism and Protection of the entire Cooper Creek System. In addition, detailed suggestions on the management of people within the Coongie district are presented.

The rabbit problem is currently unmanagable. Within the Coongie Lakes District in particular, the impact of rabbits is considered to be as severe as any impact identified in earlier chapters. It is recommended that further funding be made available to investigate all potential forms of control.

Cattle are not presently grazing the Coongie Paddock, and it is strongly recommended that stock continue to be excluded from the entire paddock. The Coongie Paddock's perimeter fence is incomplete, nor is the paddock adequately subdivided to enable appropriate stock control. An extensive (and therefore costly) fencing programme would need to be implemented before stock could be reintroduced. Under the circumstances, this course of action is considered unwarranted, given the conservation significance of the area and the biologically degrading effects of cattle grazing (particularly in and adjacent to wetlands). Reserves in the arid zone need to be large for effective biological conservation. A large area, for example, allows nomadic birds to undergo population shifts within reserved land, and threatened species such as Australian Bustard, Flock Pigeon and Night Parrot, whose decline has been attributed (at least in part) to the effects of pastoralism, belong in this category.

Furthermore, other districts within the Innamincka Lease have been identified as having high conservation value, namely the entire Cooper Creek frontage, the Upper Strzelecki floodplain, Marqualpie Paddock and the Merninie land system. Cattle grazing in these districts was observed to be having an adverse impact on their natural qualities (particularly around watering points or along creek frontages), and appropriate action to redress this situation is recommended.

The hydrocarbon-bearing Cooper Basin covers a vast area of north-eastern South Australia and south-western Queensland. Gas and oil are currently extracted at numerous localities within the Basin. Notwithstanding the fundamental importance of this industry, it is argued that relatively small areas having especial natural significance, within such a vast area, should be set aside as conservation reserves, free from mining activities. The Coongie Lakes District (as defined in Fig. 12.2) is identified as such an area, and accordingly the recommendation is made that further exploration should not be undertaken within the boundaries depicted.

As well, the potentially catastrophic effects of oil pollution within the Cooper Creek system should always be given due consideration, and so it is recommended that oil-producing wells and oil-bearing pipelines should not be sited in, along or across the Cooper Creek and associated wetlands, within the Cooper Basin region generally. A general recommendation is made that all seismic lines should be graded over (and made "impassable") once they are finished with; furthermore seismic lines should stop short of tracks, along which the public will be permitted to traverse.

With the level of tourism likely to continue to escalate, many pressing problems and issues need to be addressed, namely depletion of timber resources causing habitat loss, garbage disposal, sanitation and health, water quality problems, rapid degradation of river and lake frontages (also causing habitat loss), disturbance to and destruction of wildlife, illegal netting and possible over-harvesting of fish, off-road vehicle use, track proliferation, vandalism of significant natural and cultural sites, insufficient information and signage.

With such a large number of people seeking the range of experiences offered within the region, it is considered appropriate for revenue to be raised from the visiting population, and that the money should be invested in the management and regulation of the public's activities within the region to both ensure adequate protection of the most significant natural values and provide a guaranteed experience for the visitor.

A general recommendation is made that visitor access, numbers and activities should be strictly regulated in the Coongie Lakes District, and that **continual ranger presence** will be required at Coongie, at least over the seven month tourist season. Passive forms of recreation only should be encouraged in the Coongie district, while outlets for more active pursuits (e.g. boating, four wheel driving) should be confined to the less sensitive parts of the Innamincka district. NPWS staff should be present wherever highly significant environments or sites are visited or camped in or near, within the wider region.

The importance of securing protection for the entire Cooper Creek catchment is emphasized, and it is recommended that discussion and negotiations with the relevant Queensland and federal authorities be instigated as a priority. For instance the Cooper Creek frontage in the adjacent Nappa Merrie district in Queensland is being degraded in a similar manner, because of high levels of unregulated tourist activity. It is urged that the Queensland National Parks and Wildlife Service be kept informed of developments in the Innamincka region, while ideally that Service's involvement (and that of ANPWS) in the management of the greater region should be sought. The more fundamental issues, however, concern the **maintenance** of **water quality** in and **natural flow regimes** along the Cooper Creek.

Finally, it is stressed that where an area of the size under discussion eperiences heavy visitor pressure and is subject to multiple land-use (as is proposed), it is crucial that a thorough understanding of the biological patterns and processes be gained. Without this information, sound management of the region's biological resources cannot be implemented. Accordingly, in addition to further management-oriented research being undertaken, it is strongly recommended that a data-base, which is amenable to GIS manipulation, be established.

RECOMMENDATION 1. No development along the entire length of the North-West Branch from where the Cooper Creek diverges to the terminal lakes to the east and west of Lake Goyder, including strict regulation of camping and visitor use.

IMPLICATIONS

1. No seismic line activity across the North-West Branch and adjacent floodplain.

2. No gas or oil production from immediately along the Branch and adjoining floodplain.

3. No pipelines, powerlines, roadways or other easements across the North-West Branch.

4. No town or major tourist development along the Branch.

5. Action to prevent possible damaging developments within the Queensland catchment areas (e.g. agricultural developments, irrigation etc.).

RATIONALE

The Cooper Creek in South Australia is a unique example of an unpolluted, unregulated major river. Compared with the highly regulated rivers of southern and eastern Australia, the Cooper Creek serves as an extremely important example of a naturally functioning system. Recent listing of the Coongie Lakes District under the Ramsar Convention is evidence of the international recognition of its significance.

Research findings have shown its fish populations exhibit a range of responses to flooding and drying, or flowing and static events. Those natural patterns have been drastically altered in regulated rivers, often to the severe detriment of native fish species.

The natural integrity of the system would be threatened indirectly or directly by the above developments. Obvious damage could arise from altered hydrology, altered erosional/depositional patterns, possible hydrocarbon or other pollution, or altered nutrient patterns causing problems which could be magnified through the district's fragile ecosystem.

RECOMMENDATION 2. Continued exclusion of stock from Coongie paddock, inclusion of Marqualpie paddock as a conservation zone, and exclusion of stock from the length of the North-West Branch (see Fig. 12.2).

IMPLICATIONS

1. Fencing western boundary of Coongie Paddock.

2. Fencing of waterholes along the southern half of the North-West Branch to exclude stock. Allowing for provision of water reticulation to stock watering points away from the channel.

3. Eradication of feral horses, cattle and camels from the exclusion area.

RATIONALE

This district incorporates the most important and sensitive features known to exist on Innamincka Station. Apart from a few wild cattle, and several small groups of wild horses, the Coongie Paddock has been free of stock for approximately five years as a consequence of the bovine tuberculosis disease control programme. To bring this paddock back into operation would require extensive fencing to enable continued disease control. Exclusion of stock would spare this expense. The obvious recovery of the Coongie paddock, aided by the two calendar years of above average rainfall, should not be arrested.

"Because of the high conservation values of the Coongie Lakes complex, the dominent use of this area should be the preservation and maintainance of the wetland habitats for wildlife use. While the area has not been grazed for over three years, future livestock use should be allowed only if it does not conflict or interfere with the primary objective of conservation management" (LAB 1986).

We recommend that the reintroduction of cattle into the Tirrawarra Waterhole/Swamp to Lake Goyder system should not occur.

Although rabbit numbers are at times appallingly large, as at present, the condition of the land within this district is vastly superior to that of the Cooper frontage further upstream on Innamincka Station where restocking has occurred in recent years. The difference in range condition is immediately visually apparent if, for example, the Innamincka frontage is compared with the Kudriemitchie Channel frontage. Additionally the contrast across the Innamincka and Pandie Pandie boundary fence is startling with Pandie Pandie Station having heavily restocked its southern paddock in recent years.

The inclusion of the north-east corner of Innamincka Station, principally Marqualpie Paddock, is important. This area includes a red sandplain and unco-ordinated/irregular red sand dunefield, referred to in Mollenmans et al. (1984 pp 38-41). Although this district has been poorly studied it is considered to be biologically unique in South Australia and worthy of conservation park status with stock grazing excluded.

The creation of such an area free of stock grazing would be of the utmost conservation significance. The area would then incorporate a wide range of dune, sandplain, floodplain and water course landscapes, representative of the bulk of the biological diversity to be found in the Cooper Creek Environmental Association 8.4.4.

<u>RECOMMENDATION</u> 3. Exclusion of public vehicles from the western side of the Coongie Lakes District.

<u>IMPLICATIONS</u>

1. Closure of the several tracks that lead from the Birdsville Track to Coongie Lakes/Tirrawarra District.

2. Closure of the Tirrawarra to Coongie Lakes track to general public.

3. Closure of the seismic line tracks on the eastern side of the immediate Coongie district and of the track around the lakes (i.e. from the east side of Lake Coongie to Lake Goyder and hence to the west side).

4. Co-operation of SANTOS in achieving most of the above actions (i.e. by imposing restricted access, locked gates etc.).

5. Allowing only SANTOS and authorised vehicles on official business to use the mining roads and tracks on the west side.

6. Closure of mining tracks that cross the North-West Branch to all vehicles and prevention of use of the Kudriemitchie Crossing.

7. Restricting visitor access to the east side only and allowing only one point of entry via Innamincka and Kudriemitchie.

RATIONALE

Currently road access to many points along the North-West Branch from the west exists. In particular the ready access to Tirrawarra Waterhole, Tirrawarra Swamp, Kudriemitchie Waterhole, Lakes Coongie, Toontoowaranie and Goyder and the generally dry lakes - Apachirie, Talinnie, Apanburra, Marradibbadibba - is damaging. Public focus is already being drawn to the more isolated areas on the western side to "escape" the existing overcrowding on the eastern side.

To restrict vehicle access to the east side would ease the problems of management of the District by both S.A. NPWS and SANTOS.

This would also help prevent the replication of problems being currently experienced on the east side (e.g. denudation of timber, and vegetation and damage to archaeological sites).

RECOMMENDATION 4. Ease visitor pressure on the Coongie district by encouraging Innamincka to be the focus of human activity in the area.

RATIONALE

The Innamincka district is already degraded through a long history of heavy stock grazing, and more recently, tourism. Controls are required to prevent further general degradation, to allow recovery of certain areas and to protect significant sites.

Innamincka is the logical focus for tourist activity with its historical sites, aboriginal engravings, Callyamurra Waterhole, fuel supplies and stores. The town is located on a major tourist route with visitors travelling via Tibooburra, Lyndhurst and Northern Flinders Ranges, Birdsville via Cordillo Downs and south-west Queensland via Arrabury or Nappa Merrie.

Ranger presence is required at Innamincka as are tourist information and interpretive material.

RECOMMENDATION 5. Closure of Coongie District to allow a management plan of the area to be formulated and established before allowing visitor access.

RATIONALE

Due to the rapid escalation of visitation to the area, it is becoming rapidly degraded. If the area is to be managed effectively, visitation needs to be strictly controlled. This will become increasingly difficult if present patterns of behaviour and activity become established and entrenched.

RECOMMENDATION 6. Strict control of visitor access and activities within the Coongie District.

IMPLICATIONS

1. Establishment of a ranger station at Kudriemitchie Out-station. Possible provision of camping ground near this station to cater for new arrivals to the district. Only NPWS staff to control and maintain camping grounds/sites, and to conduct and lead tours (e.g. to view wildlife or interpret archaeological sites) - not to be done by private operators.

2. Camping within the district by permit only and in designated campsites for vehicular traffic, and upon receipt of an appropriate permit fee ($15-20/night).

3. Vehicles not to be allowed on the western side of the channel; that camping outside of designated sites by hikers, canoeists etc. only be permitted after consultation with the ranger.

4. Fires not be permitted anywhere within the district.

5. Generators, chainsaws, motor powered boats, motorcycles, guns etc. not be permitted within the district.

6. Aircraft not be allowed to land except in the case of emergency, and aircraft movements controlled in district.

7. Rubbish to be carried out of the district by campers. Rubbish disposal provision to be supplied within Innamincka township area.

8. Camping for visitors with vehicles to be restricted to several discrete areas along the southern shore of Coongie lake and the Kudriemitchie Channel, five km from the channel's entrance to the lake. Numbers of campers and campsites must reflect the sensitivity of the area (see Fig. 12.1).

9. A series of self-guided walking trails be established along the Cooper and around the southern shore of Coongie Lake and through the dunefields between the channel and the southern margin of the lake.

10. Closure of all other tracks and seismic lines in the district to public vehicles (after assessing which if any are to be utilized for access to camping sites).

11. No fishing permitted along North-West Branch (the indications point to declining fish stocks).

RATIONALE

The recommendations above are based on the attitudes of visitors interviewed over the year and on the findings of the biological studies reported in earlier chapters.

The noise of outboard motors, trailbikes, chainsaws, generators, aircraft etc. currently detract from a wilderness experience and contribute to a significant erosion of the district's biological and aesthetic values. The most severe of the impacts upon wildlife resulting from these activities include the disturbance of breeding waterbirds and disturbance generally under drought or other extreme conditions.

It is considered worthwhile to provide a camping experience to the public in the vein outlined above so that a camping unit has sole access to a limited stretch of lake shoreline or channel frontage, and without the noise or visual impact of generators, outboard motors, bikes or ablution blocks to detract from their experience of the environment. A camping fee of $15-20 per vehicle per night is recommended (e.g. $15 for a vehicle with one or two people and an additional $2 for each extra person per vehicle.

The Cooper Creek channel is considered to be a richer, biologically more important and generally more sensitive environment than Coongie Lake itself. In particular, the last five km of the channel (and especially the delta area), which includes an extensive backwater system is seen to be especially significant (e.g. for breeding waterbirds and raptors, and fish populations). Therefore it is recommended that camping not be allowed along this section of the channel, nor along the immediately adjacent (western) shore of Coongie. Rather a series of self-guided walking trails should be established in these areas for use by campers and day-visitors alike

The northern margin of Coongie Lake is considered to be the most important for waterfowl (breeding and non-breeding concentrations). The two most south-easterly bays and the area of the channel which connects Coongie with Marroocoolcannie are also significant, and so it is recommended that camping be restricted to the south-western shoreline. Waterfowl numbers, while not great on this south-western portion of Coongie Lake, were reasonably plentiful there this past year, and so it is considered to be a suitable area for dispersed camping.

Coongie Lake can be considered as the sacrifice zone within the system of lakes, and that provided the other four semi-permanent lakes are afforded stringent protection, it is to be hoped that little environmental damage will occur overall. Certainly Lakes Goyder, Toontoowaranie and Marroocutchanie are/have been important breeding sites for waterbirds, and along with the northern margin of Coongie can support significant numbers of non-breeding waterfowl. It should be incorporated into the plan of management that at certain times, it may be necessary to exclude people entirely from the district e.g. in times of severe regional drought and at other times when very large numbers of waterfowl are using Lake Coongie as a refuge. As well the activities of campers upon the lake (e.g. canoeists, sail-boarders) will need to be monitored for impact upon breeding waterbirds.

The Coongie Lakes currently attract a considerable volume of day visitors. Their numbers and impact will need to be monitored and restrictions applied if necessary. A parking facility will need to be established with access to walking trails.

A ranger station should be established near Kudriemitchie Outstation, which should be the sole access-point into Coongie (for the general public), so that traffic into the district can be monitored as necessary. The condition of the track from Innamincka to Coongie should not be improved dramatically, and day-visitors should be charged for admission into the Coongie district (e.g. to cover the costs of maintenance of this track).

<u>Other recommendations include:</u>

- the exclusion of camping from the Tirrawarra Waterhole and Swamp complex, which is conidered to be a biological powerhouse.

- the careful monitoring, and if necessary, regulation of camping further upstream along the North-West Branch.

- that World Heritage Listing for the Tirrawarra Waterhole to Lake Goyder district be explored and initiated,with the concomitant exclusion of mining and grazing (see Fig. 12.2).

Further Research

- that a more thorough biological survey of Innamincka Station be undertaken in the near future to ensure that areas of high conservation significance are identified and managed appropriately. Particular attention should be paid to the stony tableland, Strzelecki floodplain, north-eastern dunefield and sandplain, and Cooper Creek Main Branch environments. Furthermore all wetlands along the length of the Cooper require thorough investigation.

- a detailed hydrological study to be undertaken of the Cooper Creek, to include the investigation of altered hydrological patterns as a result of human activities, as well as to gain a more thorough understanding (including a predictive component) of the regional hydrology. The installation of flow-guaging stations is required.

- that the current biological sampling programme be extended to cover a three year period as a minimum.

- based on the results of the three year sampling programme, that an appropriate monitoring programme be formulated and implemented to aid management of the district's biological resources e.g. monitor particular species or habitats which may reveal indications of stress within the environment.

- primary biological surveys to be undertaken of significant environments/districts within the greater region e.g. Embarka Swamp (this swamp should be the subject of a long-term hydrological and biological investigation so that the effects of SANTOS operations can be assessed), Goyders Lagoon, Cobblers Desert, northern gibber plains, southern Simpson Desert, and the string of lakes to the north of Lake Goyder (after an appropriate rainfall event).

ANTICIPATED PROBLEMS OR UNRESOLVED ISSUES

1. Human sanitation in camping zones

The proper disposal of human faecal waste requires further consideration should camping be regulated in the dispersed pattern recommended earlier. Concrete-lined pit toilets could be installed (near the tops of but screened by high dunes), but it would be anticipated that at least ten would be required to ensure that far flung campers make use of them.

2. Money required to effect these recommendations

The cost of fencing, compensation for the pastoral lessee, deployment of rangers at Kudriemitchie and Innamincka would be considerable. Yet unless visitors to the Coongie district are carefully regulated and their activities controlled, and unless stock are permanently excluded from the district, environmental degradation will continue - to the detriment of the district's biota and the human experience of the environment.

If the State cannot finance these measures, federal assistance should be sought, even if this entails transfer of some of the control over management of the reserve to ANPWS. Certainly the Coongie Lakes District is of high national (and international) conservation significance.

The establishment of an R.A.O.U. Bird Observatory in the Coongie district (e.g. at Kudriemitchie) could also be considered as a cost-effective way of exerting some management control over the district, should it prove impossible for a ranger to be based there permanently. Observatory functions could serve the dual purpose of monitoring (of waterbird numbers, river and lake levels, meteorological and hydrological events etc.) so essential for effective management of a popularly visited but sensitive environment.

As well as raising revenue directly from the region's visitors (as recommended above), further income should be derived from the gas and oil producing and supply operations - a minor increase in gas charges would generate sufficient funds to cover most of the management programmes required to identify, conserve and enhance the region's outstanding natural features.

3. <u>Closure of Tracks to Public Vehicles</u>

It is assumed, that if the entire Innamincka Pastoral Lease were to become NPWS administered land, vehicular access could be denied to the public as is the case with existing reserves. However, access to Coongie (for at least part of the way) via Pandie Pandie, Clifton Hills and Gidgealpa Stations needs to be prevented as well, and so legislative changes may be required to effect this control.

The general public should only be allowed to travel on specified and clearly marked tracks. Such controls would aid NPWS management of the reserve, as well as allowing greater ease of management (and protection of facilities/stock) for the current lessees (Kidman Pastoral Co. and SANTOS).

Concomitantly, harsh penalties should be imposed for transgressors of NPWS regulations in the proposed reserve.

4. <u>Lawn Hill Gorge NP, Qld as a Model for Park Management</u>

The management of Lawn Hill Gorge NP, which is naturally and culturally, an extremely rich as well as a highly sensitive environment, is considered to be a fine model, upon which to base many aspects of management of the Coongie Lakes area. Situated in the Gulf Country, the actual gorge is a narrow strand teeming with aquatic and terrestrial (in the fringing gallery forest) life and with many other outstanding natural qualities, placed incongruously in a semi-arid setting of spinifex and low scrub. The parallels with Coongie are obvious, and park planners, involved with Coongie, are advised to study the plan of action/management adopted for Lawn Hill Gorge.

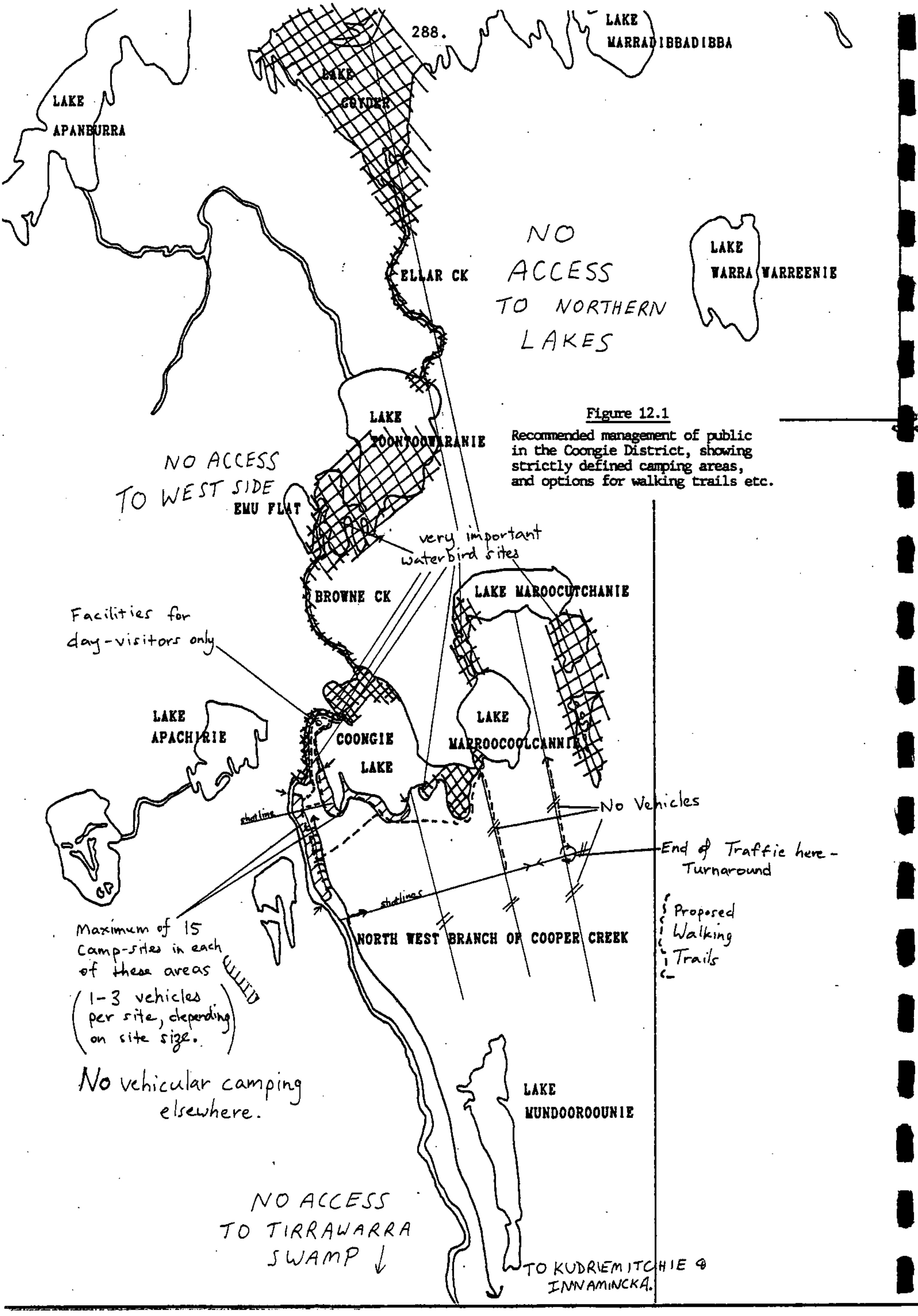


Figure 12.1

Recommended management of public in the Coongie District, showing strictly defined camping areas, and options for walking trails etc.

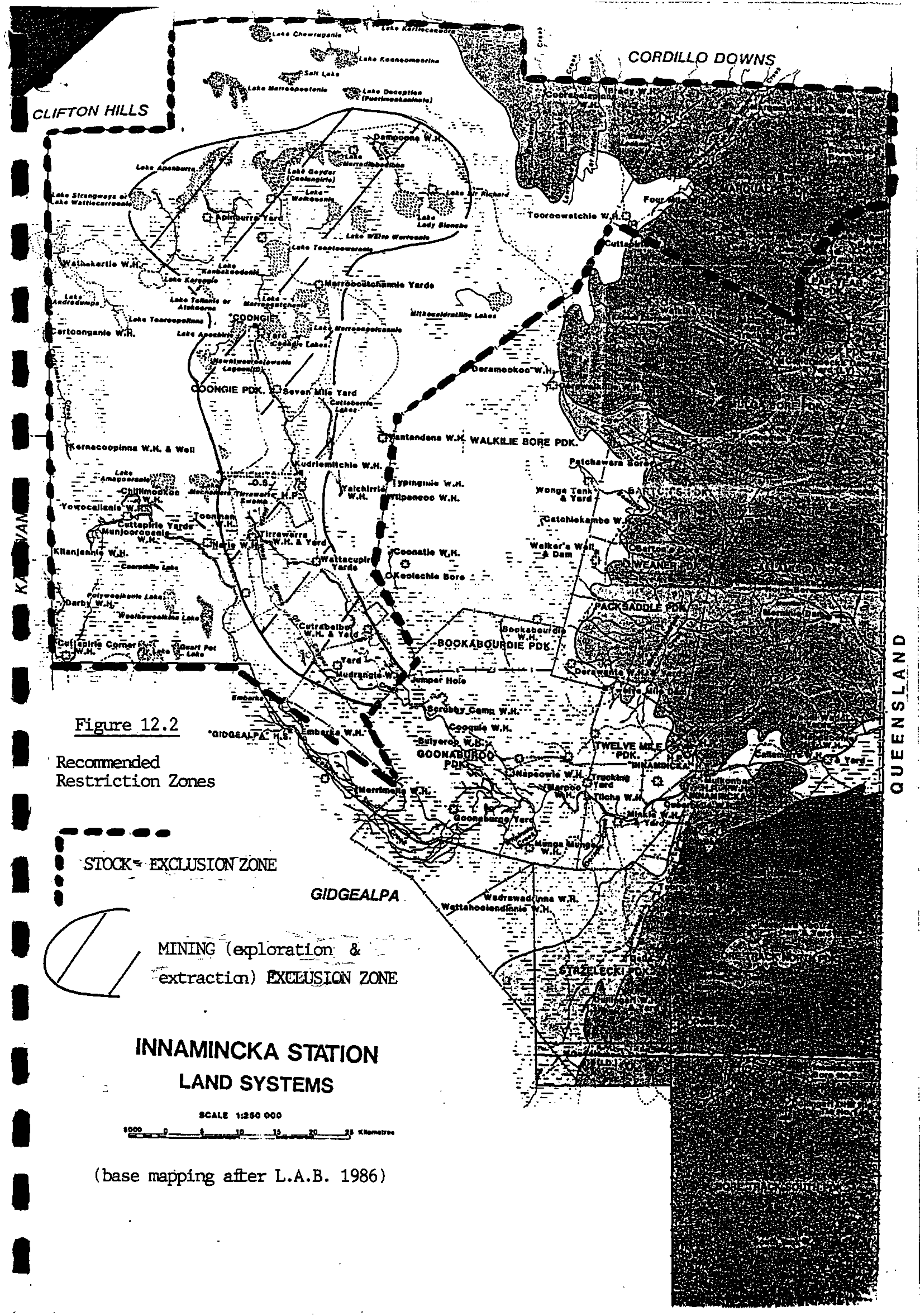


Figure 12.2 Recommended Restriction Zones

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Literature Review of Selected Topics

by Penny Paton, October 1987

Under the constraints of limited available time, brief reviews of the literature pertaining to selected topics have been made. The topics covered herein relate to the Problems of management of a biologically significant wetland environment in an arid zone - in this particular case, the Coongie Lakes District in the Far North East of South Australia.

One topic, which was to have been reviewed, had to be aborted due to the lack of available published material; the issue in question concerns the effect of litter loss from underneath a riparian woodland canopy upon the litter fauna, both invertebrate and vertebrate fauna. A significant loss of litter occurs under moderate to heavy camping pressure, with obviously detrimental but little documented impact on animals requiring that cover. Another topic requiring further investigation is the calculation of rates of production of firewood in an arid zone riparian woodland community.

This literature review will be appended to the final report of the Coongie Lakes Study (Reid and Gillen in prep.). This study is being conducted by a research team for the South Australian Department of Environment and Planning. The study was made possible through a generous donation by Dick Smith of Australian Geographic and mediated by The National Parks Foundation of South Australia

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I Terrestrial

Experience at Whyalla and Leigh Creek South indicates that various problems are created by the introduction of a large and highly mobile population into a formerly isolated arid region. These problems relate specifically to off-road vehicle usage, shooters, recreational miners, spread of weeds, interference to Aboriginal sites (D.E.P. 1983) and, in the Coongie area, uncontrolled access through seismic lines and denudation of timber for camp fires.

OFF-ROAD VEHICLES (ORV)

ORVs cause erosion, damage vegetation, are detrimental to fauna and can damage pastoral improvements. Webb & Wilshire (1983) have summarized the effects of ORV use on arid and semiarid vegetation thus:

1) ORV use will reduce perennial plant cover and above-ground biomass and the degree of loss is dependent on the intensity of use.
2) A reduction in perennial plant density often occurs in ORV use areas, especially in areas of "moderate" to "heavy" use. The terms "moderate" and "heavy" are relative and may vary from site to site.
3) In areas of ORV use (primarily open or competitive areas), the smaller shrubs are often the first to be damaged or eliminated.
4) Annual species are affected in similar ways to the perennials. However, slight disturbance may cause no measureable differences with regard to either annual or perennial plants or show some positive response by increasing cover or density.
5) Some perennial plants can recover from ORV impacts if the plant crown has not been completely killed, and if sufficient time is given between impacts some species will resprout. The best estimates on resprouting perennial plant recovery appear to be around 10 to 20 years, but soil recovery may be much longer, requiring centuries or even millenia.

A study of the effects of ORVs on the biota of the Algodones Dunes in California (Luckenbach & Bury 1983) found that areas heavily used by ORVs had virtually no native plants.

Studies in the California Desert on the effects of ORV use on native mammals are probably broadly applicable to Australian arid areas. These studies indicate that ORV activities represent disruptive and often destructive influences on native wildlife (Webb & Wilshire 1983). They show that the noise of dune buggies and motorcycles: 1) definitely caused hearing losses in animals, with little or no recovery; 2) interfered with their ability to detect predators; and 3) caused behaviour in an unnatural manner that put the animal in a situation that could result in death. Sand dune inhabitants are particularly vulnerable to ORV sounds because of the unique acoustical characteristics of sand dunes and because of the animals' sensitive hearing.

A study of the effects of ORVs on the biota of the Algodones Dunes in California showed a marked decline in arthropods, lizards and mammals in ORV-used areas compared with nearby controls (Luckenbach & Bury 1983). All sand-adapted species were greatly reduced in habitats where ORVs operated. The biota was negatively affected even by relatively low levels of ORV activity. Areas heavily used by ORVs had virtually no wildlife.

The management implications of these findings are:

1) to restrict vehicles to defined tracks;
2) to ban off-road driving; and
3) to locate tracks away from the habitat of any threatened or endangered plants and animals.

ILLEGAL SHOOTING

Illegal shooting of protected animals already occurs in the Coongie Lakes area. Its incidence would be lessened by increased numbers of visitors and regular patrols by N.P.W.S. rangers.

UNCONTROLLED ACCESS THROUGH SEISMIC LINES

It is generally agreed that seismic tracks are unlikely to significantly impair the long-term conservation function of an area, provided the tracks are left unused following the seismic survey. The impacts of seismic lines generally are transient and short-term, but there are some exceptions. Damage to playa lake surfaces is likely to persist because removal of marks and imprints depends on infrequent filling of the lakes with water (N.P.W.S. 1983). Accelerated erosion which is probably irreversible (Graetz & Pech 1982) has occurred in landscapes associated with playa lakes as a consequence of track-making through erosion-prone soils over slopes. Clayed access and supply roads differ markedly from seismic tracks. The clay capping is impermeable to water and regereration of plants is slow (N.P.W.S. 1983).

Although most of the direct impacts of petroleum exploration are transient, the potential exists for permanent impact. Continued use of the track network by visitors will retard their regeneration and over the long-term may result in increased erosion not evident under the present light levels of use. The problem therefore lies in preventing subsequent use of tracks in order to allow regeneration to take place. One method of inhibiting public use of seismic lines is to disguise their junction with main roads by flattening windrows. Also a rational policy of main roads needs to be developed and sign-posted to keep tourists on main roads (Alexander 1981).

TREES IN ARID AREAS AND EFFECTS OF THEIR DENUDATION

Trees in arid areas provide shade, shelter from winds and aesthetic appeal and prevent water and wind erosion. By reducing wind activity, they protect the land surface and maintain the hydrological status of the land type (Hall *et al*. 1972).

Trees in any habitat are obviously important to the animals that directly use them for food and/or shelter. However, they are equally important for the various microhabitats that they provide for many terrestrial species (Biggins in van der Sommen *et al*. 1983). The presence of trees influences the type of understorey and ground vegetation and the leaf litter produced by trees is important for some animals, e.g. as a source of invertebrate prey for some reptiles, birds and mammals. Damage to the ground vegetation and leaf litter layer represents reduced food and shelter, as well as increased exposure and vulnerability to predators, for these animals.

The removal of dead timber, kindling and leaves for fires and the cutting of live wood when these resources are exhausted is a widespread management problem in camping areas around Australia. It is particularly detrimental in the Coongie Lakes area 1) because the stands of timber are very limited, i.e. to the banks of the Cooper, the edges of the lakes and to areas inundated occasionally by floodwaters; and 2) because of the aridity of the area. Regrowth of trees in areas of low rainfall is much slower than in areas of higher rainfall. For example, Table 1 shows the S.A. Department of Agriculture estimates for the likely production rates from woodlots planted for firewood harvesting.

Table 1 S.A. Department of Agriculture estimates for likely production rates from woodlots

Annual rainfall (mm)	Annual production (tonnes dry wood/ha)
300	1
500	2
700	3
900	4

Obviously trees in arid areas grow more slowly than those in wetter areas. The rainfall in the Coongie Lakes area is about 200mm/year. Moreover, in areas of high camping intensity, tree seedling regrowth is likely to be negligible.

There are several options available in dealing with the firewood problem.

1) a total ban on fires. This would be unpopular with campers and difficult to police without adequate staff.

2) the provision of firewood from other areas, combined with a ban on collecting wood *in situ*. This would be inoperable for two reasons. The cost of bringing in firewood would be prohibitively expensive, due to the isolation of the Coongie Lakes area. Secondly, unless camping areas were clearly defined and very limited in area, this would be impossible to police.

II Aquatic

Liddle & Scorgie's (1980) review paper on the effects of recreation on freshwater plants and animals is so comprehensive and relevant that I have presented a photocopy of most of the paper and merely added a few notes on the relevant pages.

(add to page 189)

Turbidity (after Hilton & Phillips 1982)

The concern with increased turbidity of water is that this may reduce the light penetration to submerged macrophytes and thus reduce their growth. Yousef et al. (1974) demonstrated that in shallow lakes, boat activity could increase the turbidity of the water column. These increases depended on water depth, motor power and the nature of the sediment deposit.

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Pollution from Outboard Motors (after Hilmer & Bate 1983)

The effect of outboard motor fuel oil on the photosynthesis, chlorophyll a concentration and extracellular pH of the culture medium of five phytoplankton species in an estuary was investigated. Chlorophyll a concentrations were not significantly affected, whereas the photosynthetic rates of two species were severely depressed. The fuel oil also caused an inhibition of the increase in extracellular pH of three species. The results indicated that fuel oil tended to have a marked inhibitory effect on the photosynthesis of phytoplankton communities as a whole, while individual species may be unaffected. This type of oil pollution would probably be found in lagoons and quiet siderms, whereas, in fast-flowing streams, current action would probably dissipate the fuel oil.

Liddle & Scorgie's (1980) excellent review does not address the problem of the effects of water-based recreation on other humans. The most obvious effect of power boats on other users is the noise they generate. Sailing and canoeing, on the other hand, have low levels of disturbance to other users (N.P.W.S. of NSW, undated).

OIL SPILLS AND OIL POLLUTION

The possibility of an oil spill into the Cooper Creek/Coongie Lakes system should not be overlooked. However, predicting the likely impacts on fauna and flora is difficult for a number of reasons. One of the most important is the lack of research on oil spills in semi-permanent wetlands in arid regions. Other relevant factors are:

1) the amount of oil released into the habitat;
2) the type of oil released into the habitat;
3) the physiography of the spill area;
4) the season of the spill;
5) the weather conditions at the time of the spill;
6) the biota of the affected area;
7) the previous exposure of the area to oil; and
8) the treatment methods (after Burk 1977).

This paper synthesizes available data on the effects of oil spills on soils, plants and animals. With caution, these data could be extrapolated to the Coongie Lakes area with some degree of accuracy.

The degree of damage to soils caused by an oil spill depends on the level of contamination. Where contamination is relatively low, the oil could be degraded by microbial activities (especially if the oil is paraffinic, like Nigerian oil). However, where the pollution is more serious, soils become less fertile because nutrients essential to plant growth become scarce, while those that are toxic to plants become more available (Ikporukpo 1985). This effect on soil micro-organisms may persist for several years, unless the soil is rehabilitated.

Kinako (1981) investigated the effect of an experimental oil spill on the number of plant species and productivity of a tropical grass-herb community in Nigeria. The spillage had a devastating effect on the simple ecosystem, with at least 50% of the species becoming extinct immediately. Perennial species generally were less affected. Productivity was reduced by as much as 74%. The intensity of the effects tended to be inversely related to the structural complexity of the community.

Research on a freshwater marsh in Massachusetts yielded some similar results (Burk 1977). There, the composition of the vegetation in the marsh was studied for 4 years following an accidental oil spillage (3800 litres of fuel oil). Total plant cover, total number of species, mean number of species per quadrat progressively reduced in high and mid-marsh zones for 2 years. Eighteen of the species found before the spill were not found the following season. Perennial species were generally less affected than annuals immediately following the oil spill. Marked changes in relative abundance of the dominant species of high and mid-marsh zones occurred from year to year. The vegetation of the high and mid-marsh zones had substantially recovered by the third and fourth years. The low marsh vegetation was apparently unaffected immediately following the oil spill, but in succeeding years the species diversity declined and luxuriant growth of three species occurred.

It is well documented that overall microbial communities (particularly bacteria) often increase in response to an oil spill, even though some microbial populations may decrease. Apparently, certain groups of microorganisms are capable not only of withstanding the toxic effects of oil, but actually have their growth stimulated by the source of highly reduced carbon provided by petroleum hydrocarbons (Werner, Adams & Lamarra 1984).

A study in the United States looked at the consequences of oil pollution on the decomposition of macrophytic plant litter in the littoral zones of freshwater lakes (Werner, Adams & Lamarra 1984). The authors theorized that in the event of an oil spill on a lake, the littoral zone would probably be the most affected. They investigated the decomposition of _Typha latifolia_ and _Potamogeton foliosus_ litter and addressed two aspects: the rate of decomposition and the use of dissolved oxygen by the decomposer organisms. The crude oils reduced the rate and extent of litter decomposition of the plant litter in the two lakes studied. However, the metabolic activity of the oil-exposed decomposer community was greater than, or equal to, that of unoiled controls. Up to 4.8 times as much oxygen was required to oxidize oiled plant matter compared with unoiled plant litter.

Baker & Morita (1983) demonstrated the effects of spilt crude oil on a range of microbial activities in stream mud. Rates of CO_2 production, nitrogen fixation and methanogenesis, V_{max} for glucose and phosphate levels were all determined in the presence and absence of crude oil. Four weeks after the addition of oil the V_{max} and phosphate levels were significantly reduced and remained so, but methane and CO_2 production rates were significantly increased. Nitrogen fixation was not affected by 0.1%(v/v) oil, but was reduced after eight weeks by 1.0% oil.

Another method of assessing the effect of crude oil on living organisms is to compare the toxicities of different crude oils on one organism. Rogerson, Berger & Grosso (1982) examined the toxicity of 10 crude oils on the survival of a freshwater planktonic rotifer Asplancha sieboldi. Rotifers exhibited a wide range of sensitivities to the oils tested, and generally, the lighter more volatile crude oils were the most toxic, a well established fact in the field of petroleum biotoxicology.

A review paper by Miller, Stout & Alexander (1986) suggests that in temperate latitudes, where invertebrates often produce several generations per year, the effects of oil pollution can be somewhat reduced. For example, after a catastrophic decline in the number of invertebrates, recovery was rapid in the six months following a 28,000 litre spill on a North Carolina stream. Experimental oil spills conducted on small streams in the United States found that there was a loss of total density of invertebrates, a reduction in species richness, increased growth of filamentous algae in non-turbid rivers and the proliferation of some chironomids, particularly those from the subfamily Orthocladineae. The toxic fraction of crude oil to zooplankton and to algae, probably in the aromatic hydrocarbons, is normally lost quickly by volatilization in the first 24 hours.

The effects of oil spills on higher animals is not as well documented. In Nigeria, where spills appear common, affected fish either become less productive or die; dead fish floating on the surface or washed up on beaches are a common feature of severe pollution (Ikporukpo 1985). Birds are likely to be affected in two ways. Firstly, their prey items will probably be reduced and secondly, their feathers will be physically contaminated by the oil.

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