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Coorong, Lower Lakes and Murray Mouth (CLLMM) Wetland Condition Assessments, 2014

Report to the Department of Environment, Water and Natural Resources, South Australia.

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EXECUTIVE SUMMARY

The Coorong and Lower Lakes region, at the terminus of the Murray River in South Australia, is one of Australia's iconic wetland systems and has been formally recognised as internationally important under the Ramsar Convention since 1985. The wetlands support a diverse array of ecological, cultural, social and economic values to the surrounding region and its community.

This project involved the collection, collation and provision of field data from wetland habitat condition assessments undertaken at 191 wetland sites across the CLLMM region during April and May 2014, repeating earlier assessments undertaken in 2010 and 2003.

The results of the study indicated that:

- Water regime returned to pre-drought conditions for the majority of sites assessed, with the number of wetlands visited that were observed as being dry changing from 1.3% in 2003, to 75% in 2010 and back to 9.8% in 2014;
- 60% of sites visited in 2010 showed an improvement in habitat condition in 2014;
- Longer term habitat condition (between 2003 and 2014) saw the majority (76%) of sites either maintain or improve their condition ranking, with the remaining 24% showing a decline in condition;
- Changes in habitat community/vegetation association occurred at some sites, although results were mixed for most Ramsar wetland types;
- Closed depression, cove and lagoon landforms responded particularly well to increased water flows/levels; and
- Permanent Ramsar wetland types responded most favourably to post-drought flows.

Combined evidence from this and previous assessments show that habitat community and habitat condition changes are closely tied to changes in the hydrology (water regime) of the broader CLLMM wetland system, largely defined by River Murray flows and the influence of the barrages. In many cases, condition and vegetation community characteristics were found to return to their former states, even after a prolonged and extreme drought between 2006 and 2010. In contrast however, a smaller number of wetlands did not return to their former condition, while others maintained a consistent health and structure throughout the drought period.

Predicting the drivers of wetland condition and floristic change (that are not water regime based) is an important future consideration for the CLLMM region. The reported observations in this study help to provide a better understanding of the sensitivity, resilience and stability of various wetlands to extreme hydrological and environmental change. Their original condition, vegetation associations, position in the landscape, connectivity to larger water bodies and exposure to external threats such as weed invasion and livestock grazing, as well as human intervention in the form of artificial watering, appear to be important contributing factors in setting their trajectory or inertia (i.e. ability to withstand change) when major catastrophic events like the 2006-2010 drought arise.

The results of this study provide an excellent insight into the dynamics and natural recovery potential of a wetland system that was under severe and prolonged stress, and provides a number of positive insights that will inform the future management of the CLLMM site.

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1 INTRODUCTION

1.1 Background

The Coorong and Lower Lakes region, at the terminus of the Murray River in South Australia, is a focal region for the Department of Environment, Water and Natural Resources (DEWNR). Management across the site is coordinated and primarily delivered by DEWNR's Coorong, Lower Lakes and Murray Mouth (CLLMM) Program, consistent with the South Australian Government's "Long-Term Plan for the Coorong, Lower Lakes and Murray Mouth", released in June 2010 (DEH 2010). The goal of the Long-Term Plan is for the region to be a healthy, productive and resilient wetland system that maintains its international importance. An integral component of the CLLMM Program is the monitoring of the condition of wetlands throughout the region and the responses to adaptive management actions proposed in the Long-Term Plan.

In 1985, the Coorong and Lakes Alexandrina and Albert Wetlands were formally recognised under the Ramsar Convention, as internationally significant wetlands, supporting a diverse range of habitats and species. The area is also of high cultural significance for the local Ngarrindjeri Nation, forming an essential part of their living culture. A Ramsar Management Plan for the wetlands system was produced in 2000 to guide government agencies and the regional community in the management of this area (Seaman 2003). One of the key strategies of the plan was the development of a detailed mapping program and database for the Ramsar site. Between July 2002 and June 2003, field based wetland assessments were carried out as part of the Coorong and Lower Lakes Mapping Program (Seaman 2003). The data compiled through the assessment of 761 representative wetland sites provided the basis for subsequent monitoring of the condition of wetland habitats and any changes in wetland characteristics such as habitat types (i.e. dominant vegetation associations), hydrological regime, fauna utilisation, threatening processes and management actions taken. A full account of the wetland assessment characteristics are documented by Seaman (2003).

From the period 2006 to 2010, the region experienced a severe drought and consequently many of the CLLMM wetlands experienced unprecedented desiccation due to the lack of flows from the Murray River above Wellington and the receding of the shorelines of Lakes Alexandrina and Albert, the Goolwa Channel, the Finniss River, Currency Creek and other associated water bodies.

In 2010, Thiessen (2010) revisited a subset of 162 of the 761 original wetland sites to assess the effects of the drought on habitat condition and vegetation community associations as well as which wetland types were most prone to such extreme and extended drought conditions. Thiessen (2010) aimed to broadly identify:

- Changes in water regime
- Changes in habitat condition
- Changes in habitat community/vegetation association
- Response of different landforms types to increased water flows/levels
- Impact on range of Ramsar Wetland types

The condensed version of Seaman's original Habitat Classification Survey Template (Seaman 2003) is shown in Appendix A in the form of a Habitat Condition Datasheet, designed for rapid field-based assessment of wetland sites. The Habitat Condition Datasheet has provision for recording observations and data on:

- Wetland site location;
- Photopoint (yes/no, direction);
- Wetland Association (Landform, Type, micro relief, historical and current water regime and current water depth);
- Vegetation Association (a selection of broad vegetation types, cover, microhabitat, aquatic vegetation types and Aquatic score);
- Disturbances (range of listed disturbances and whether grazing was identified on site);
- Fauna (surface fauna, opportunistic observations, reliability);
- Recreation (list of common recreational activities or structure or other);
- Mapping (and whether a community change was observed);
- Revegetation (evidence and age of revegetation areas and opportunity to carry out revegetation);
- Restoration Potential;
- Zone Condition (qualitative assessment of core, toe of bank, bank and buffer zones into poor, average or good condition); and,
- Habitat Condition (qualitative assessment of overall wetland site on a scale from pristine, excellent, very good, good, degraded or completely degraded).

Descriptions and definitions for these assessment components are detailed in Seaman (2003).

Thiessen (2010) reported that habitat condition declined within the majority of wetlands sampled (54%), water regimes changed across the entire Lower Lakes system, and that vegetation associations were altered, favouring the proliferation of weed communities. Open water habitats and reed bed associations were found to be the most drought-sensitive wetland types, whilst *Duma florulenta* (lignum) and *Melaleuca halmaturorum* (saltwater paperbark) dominated wetlands were least affected by drought. Thiessen also noted that wetlands associated with the landforms of coves and lagoons were most affected by the drought.

Thiessen concluded that the decline in wetland condition was a result of low water levels that disconnected the fringing wetland habitats and that management intervention, such as artificial watering, livestock removal and revegetation, preserved the ecological character of wetlands within areas of the Goolwa Channel and the Narrung Wetlands. Thiessen outlined several recommendations with a primary focus on the future use of these drought management interventions, and giving priority to those habitats found to be most sensitive to drought induced change.

A range of future research directions (which are partly addressed in this report) were also proposed, and included follow up Habitat Condition Assessments of the Lower Lakes to periodically monitor changes in wetland condition under variable water regimes.

Further details on the history of the Coorong and Lakes Alexandrina and Albert Ramsar Wetlands, and background to the wetland habitat assessment program, are provided by Seaman (2003), Thiessen (2010) and other references cited in this report.

1.2 Project Scope

In April 2014, NGT Consulting was engaged by DEWNR to carry out a third series of wetland habitat condition assessments. As well as revisiting the 162 sites assessed by Thiessen (2010), NGT Consulting proposed the inclusion of extra assessments at a small number of additional sites likely to be of interest to the CLLMM program. This task provided an opportunity for review of a smaller number of sites (e.g. threatened species sites) that had not been assessed according to the standard methods outlined in this report since 2002-03, and would provide extra data of relevance and interest to project managers. Hence these additional assessments, including a site selection process, also formed part of the agreed project deliverables.

This report details the 2014 wetland habitat monitoring event with a focus on a comparative analysis against the previous two field assessment events of 2002-03 and 2010. Of particular interest to DEWNR is how the selected wetlands have changed since the return of water to the CLLMM system following the long period of drought between 2006 and 2010.

1.3 Project Objectives

The specific objectives of the project included:

1. Revisit sites visited by both Thiessen (2010) and Seaman (2003) and conduct wetland condition assessments
2. Prioritise, select and undertake wetland condition assessments at an additional (smaller) number of sites not visited since 2003, for inclusion in the study
3. Assess the response of selected wetlands to flows following severe drought (2006-2010) to capture information on:
    a. Changes in water regime
    b. Changes in habitat condition
    c. Changes in habitat community/vegetation association
    d. Response of different landforms types to increased water flows/levels
    e. Impact on range of Ramsar Wetland types
4. Provide data to support the development of the site Ecological Character Description (ECD)
5. Update the Ramsar habitat database to reflect current condition

2 METHODS

2.1 Study region and site selection

The study focused on the CLLMM region, including wetlands associated with Lake Alexandrina, Lake Albert, Finniss River, Currency Creek, Goolwa Channel, Hindmarsh Island, Mundoo Island and Coorong National Park (Figure 1). In total 191 sites were assessed during the present study. This included 152 sites of the 162 previously assessed in 2010, with the remaining 10 sites not assessed due to access restrictions:

- Permission was denied by one landholder to access sites due to their concerns of spreading Caltrop *Tribulus terrestris* (a Declared weed in SA) within and/or outside the property (6 sites); and,
- Physical and visual barriers to accessing or viewing sites, including dense and/or tall vegetation (e.g. Phragmites or Typha marshes) that was impenetrable on foot or obscured view of distant sites (4 sites).

An additional 39 sites previously assessed by Seaman (2003) were included in this assessment to specifically explore changes in the condition of sites deemed in either (a) completely degraded or (b) pristine condition during 2003 assessments, as well as (c) sites that support nationally threatened fauna (under the *EBPC Act 1999*). For the final category, interrogation and (where applicable) cross-referencing of the Biological Databases of South Australia (BDBSA) and relevant recent studies (Bice et al. 2013; Mason and Hillyard 2011; Wedderburn and Barnes 2013), identified sites where southern bell frog *Litoria raniformis* (nationally Vulnerable), Murray hardyhead *Craterocephalus fluviatilis* (nationally Endangered) and Yarra pygmy perch *Nannoperca obscura* (nationally Vulnerable) have been recorded – resulting in the further selection of 11 sites (of the 39 extra sites chosen) for this assessment.

Table 1. Number of Ramsar Wetland Types assessed in 2003, 2010 and 2014

Ramsar Wetland Types	**Number of Sites Assessed**			**Broad Ramsar Category**
	2003	**2010**	**2014**	
Irrigated land (3)	23	7	7	Human-made Wetlands
Seasonally flooded agricultural land (4)	28	5	11	Human-made Wetlands
Canals and drainage channels, ditches (9)	0	0	1	Human-made Wetlands
Sand, shingle or pebble shores (E)	20	1	4	Marine/Coastal Wetland
Intertidal marshes (H)	12	1	1	Marine/Coastal Wetland
Intertidal forested wetlands (I)	2	1	1	Marine/Coastal Wetland
Permanent rivers/streams/creeks (M)	18	12	12	Inland Wetlands
Seasonal/intermittent/irregular rivers/streams/creeks (N)	0	0	1	Inland Wetlands
Permanent freshwater lakes (O)	22	14	13	Inland Wetlands
Seasonal/intermittent freshwater lakes (P)	0	0	1	Inland Wetlands
Seasonal/intermittent saline/brackish/alkaline lakes and flats (R)	6	1	2	Inland Wetlands
Seasonal/intermittent saline/brackish/alkaline marshes/pools (Ss)	263	34	45	Inland Wetlands
Permanent freshwater marshes/pools (Tp)	258	59	65	Inland Wetlands
Seasonal/intermittent freshwater marshes/pools (Ts)	71	17	17	Inland Wetlands
Shrub-dominated wetlands (W)	24	5	7	Inland Wetlands
Freshwater, tree-dominated wetlands (Xf)	14	5	3	Inland Wetlands
TOTAL	**761**	**162**	**191**	

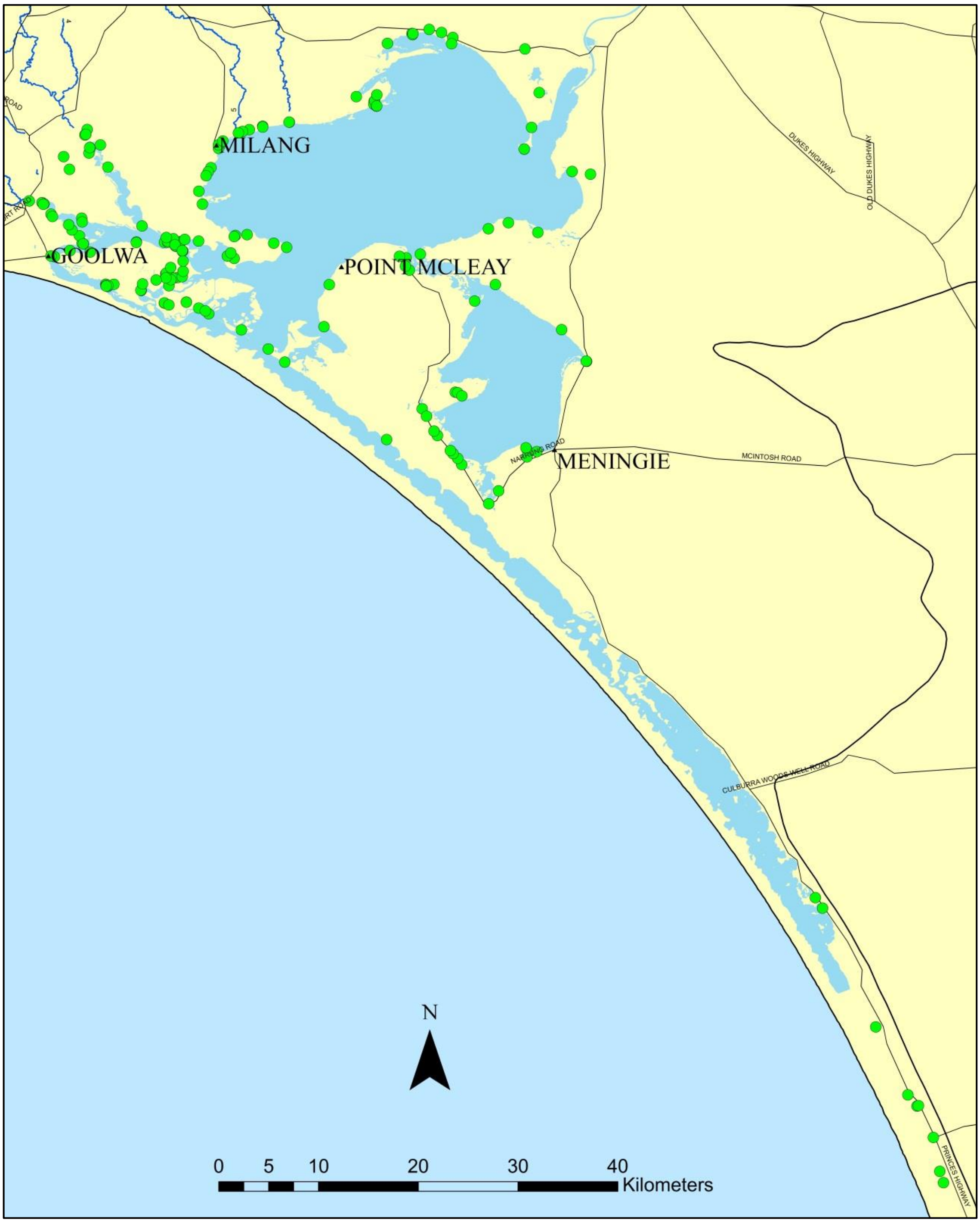


Figure 1. Map of the Coorong, Lower Lakes and Murray Mouth (CLLMM) region showing the location of 2014 wetland assessment sites (green dots)

2.2 Data Collection

Between 15 April to 15 May 2014, a total of 191 wetland sites (152 sites repeated from the 2010 assessment and 39 additional sites from 2003 mapping), representative of mapped wetland polygons were visually assessed following a methodology developed by Seaman (2003) and repeated by Thiessen (2010). To minimise the possibility of assessor variability impacting the scoring of habitat condition, as could reasonably be expected with individual interpretations of visual observations over the three assessment periods (i.e. between 2003, 2010 and 2014), the assessment team underwent peer to peer training with James Thiessen (2010 assessor) during their first day in the field. A copy of the standard Habitat Condition Datasheet is shown in Appendix A.

Data was collected using two methods. In-situ assessments were carried out where sites were accessible by the assessment team. Alternatively, sites were assessed remotely assisted by a Kowa spotting scope or Minolta Weathermatic 7 x 42 binoculars, as required. Sites were assessed either in-situ or remotely, mostly on the basis of re-establishing previous assessment/photo locations, but also on the basis of field-based safety considerations (i.e. the reasonable physical limitations of field staff negotiating impenetrable vegetation or deep water). Sites were often assessed from roadsides or other adjacent land where clear views of the wetland were obtained (particularly where wetlands occurred on private property).

A series of one or more photographs depicting each wetland site were taken as close as practicable to the geographic coordinates recorded for those taken in 2010. Images were recorded with a 5 megapixel digital camera built into a Garmin Montana GPS receiver. All images were automatically geotagged and saved to the internal memory of the device. The direction of each image was recorded using the Garmin's internal compass function and the bearing recorded to the nearest 22.5° (e.g. west; northwest; east north east; or south southwest). Where 2010 photopoint sites could not be reached or did not provide clear or accurate representation of the wetland within the visual proximity of the coordinates an alternative location for a photopoint was chosen. In some cases more than one photopoint was created to provide a more comprehensive visual depiction of the site.

2.3 Data Analysis

The following qualitative habitat measures were used to draw comparisons of wetlands characteristics previously reported in 2003 and 2010:

a) Water regime
b) Habitat Condition
c) Habitat Community Change
d) Ramsar Wetland Types , and
e) Presence of nationally threatened species

These habitat measures are described by Thiessen (2010) after Seaman (2003). See Appendix B for descriptions.

Additional information as per the Habitat Condition Datasheet (See Appendix A) was also collected to populate the CLLMM wetland database. The full data set was entered into a Microsoft Excel Spreadsheet and saved to a digital storage media (Appendix C) for subsequent entry into the DEWNR CLLMM Wetland Database.

3 RESULTS

3.1 Changes in Water Regime

Based on the repeat assessment of 152 wetland sites from 2010 visited again in 2014, a substantial shift in water regime was observed; clearly trending back towards site hydrology observed during the original assessment in 2003. The severity of the drought is plainly illustrated by the fact that the vast majority of wetlands were dry in 2010 (114 of 152 sites), but in 2014 this no longer remains the case.

Table 2 compares the composition of wetlands of permanent, semi-permanent, seasonal and dry water regimes for 2003, 2010 and 2014 for the sampled 152 wetlands. Water regimes for wetlands determined in 2010 and 2014 were derived from water depth estimated in the field at the time of each wetland assessment.

Table 2. Number of wetlands characterised by wetland regime in 2003, 2010 and 2014

WATER REGIME	2003	2010	2014
PERMANENT	78	37	72#
SEMI-PERMANENT	19	1	17
SEASONAL	53	0	48
DRY	2	114	15^
TOTAL	**152**	**152**	**152**

Includes 7 wetlands categorised as tidal
^ Includes 1 wetland categorised as intermittently flooded

Approximately two thirds of the 2014 sample set exhibited signs of hydrological change following the three years since the 2010 assessments (Figure 2). With the return of flows, 62% of wetlands sampled in 2014 returned to their 2003 water regimes, whilst 15% did not. Twenty three percent of wetlands did not experience any observable change in water regime (i.e. remained unchanged) between assessment periods 2003, 2010 and 2014 (Figure 3).

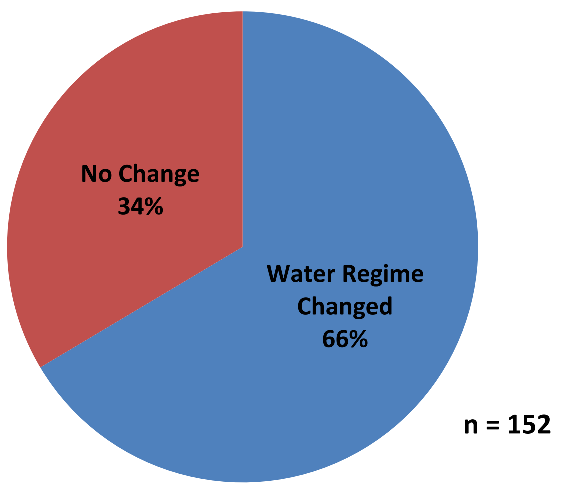


Figure 2. Percentage changes in water regime from 2010 to 2014

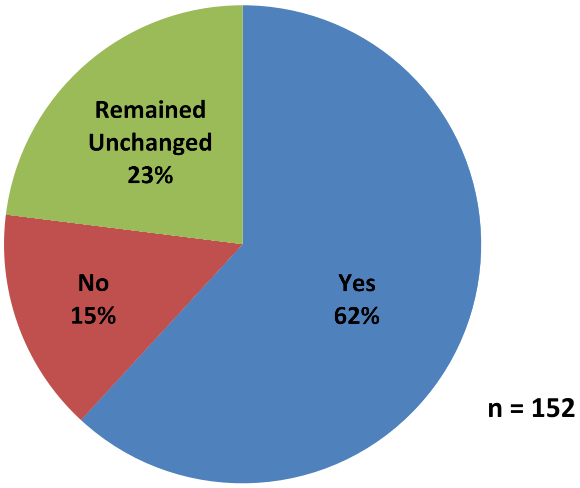


Figure 3. Percentage of wetlands that returned to 2003 water regime in 2014

3.2 Changes in Habitat Condition

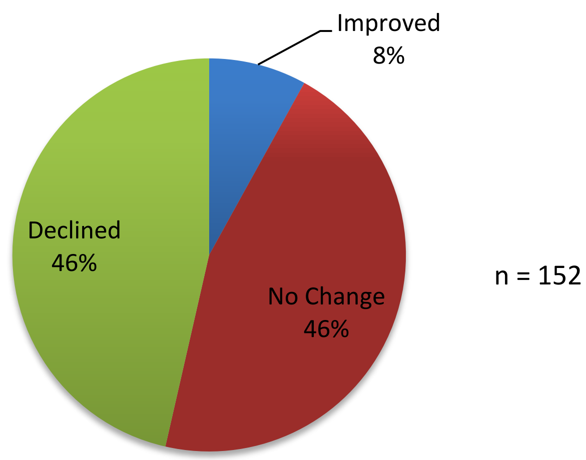
Recent changes (2010 to 2014) of the 152 sites assessed in this survey, showed that 92 (60%) were found to have improved in habitat condition, 7 (5%) had declined in condition, and 53 (35%) showed no observable signs of change in their condition from 2010. Table 3 details the direction of change for each habitat condition ranking from 2010 to 2014, detailing the number of sites that improved, remained stable or declined.

These results contrast with the changes of the same sites grouped by habitat condition from 2003 to 2010, which found that 9 (6%) of the sites improved, 79 (52%) of the sites declined, and 64 (42%) of the sites showed no observable signs of change in their condition. Figure 4 clearly contrasts the direction in the change in habitat condition between each survey event from 2003 to 2014.

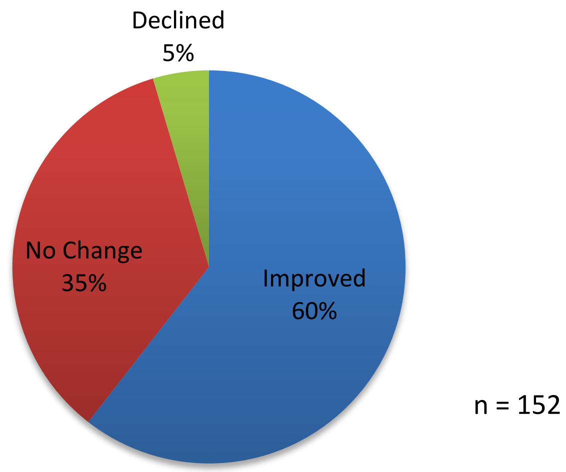
Table 3. Direction of change in habitat condition of 152 wetland sites assessed from 2010 to 2014 by order of their 2010 condition ranking

Habitat Condition Rank 2010#	No. Sites in 2010 Ranked	Distribution of Change in Habitat Condition from 2010 to 2014		
		Improved	No Change	Declined
Pristine	-	-	-	-
Excellent	7	-	7	-
Very Good	16	2	10	4
Good	50	27	20	3
Degraded	77	62	15	-
Completely Degraded	2	1	1	-
Total Number (%)	**152**	**92 (60)**	**53 (35)**	**7 (5)**

Ranking after Seaman (2003)



a) Habitat Condition Change 2003-2010



b) Habitat Condition Change 2010-2014

Figure 4. Habitat condition change of the same sample of 152 wetlands assessed from 2003 to 2010 and 2010 to 2014

Table 4 details the degree of improvement or decline of wetland condition from 2010 to 2014. It highlights that wetland sites ranked as degraded in 2010 improved by as much as four rank levels (e.g. from degraded to pristine) with the majority of improvements being between 1 and 2 ranking levels. One degraded site (an estuarine site below the barrages) underwent a remarkable, rapid transition to pristine condition. Degraded wetlands from 2010 exhibited no further decline in 2014, although 15 of the 77 degraded wetlands did not improve with the return of flows to the region. Wetlands ranked good in 2010 were the second most abundant group to improve in condition.

Table 4. Recent (2010 to 2014) Changes in Habitat Condition Rankings

Habitat Condition Rank 2010[#]	No. Sites in 2010 Ranked	Habitat Condition Rankings for 2014					
		Pristine	Excellent	Very Good	Good	Degraded	Completely Degraded
Pristine	-	-	-	-	-	-	-
Excellent	7	-	7	-	-	-	-
Very Good	16	-	2	10	3	1	-
Good	50	-	7	20	20	2	1
Degraded	77	1	7	15	39	15	-
Completely Degraded	2	-	-	-	-	1	1
Total	**152**	**1**	**23**	**45**	**62**	**19**	**2**

Devised by Seaman (2003)

Longer-term comparison (of the 191 sites assessed in both 2003 and 2014) revealed that 48% (92 sites) had not changed condition, 28% (54 sites) had improved and 24% (45 sites) had declined (Figure 5). Comparison by condition rank indicates that the majority of pristine (73%) and excellent (62%) sites retained their value whereas obvious improvement was most apparent in degraded (68%) and completed degraded (67%) sites (Table 5). Interestingly, in one of the most significant changes recorded, a site considered degraded in 2003 received an excellent rank in 2014. Declines were revealed in sites considered very good (44%) and excellent (38%) in 2003.

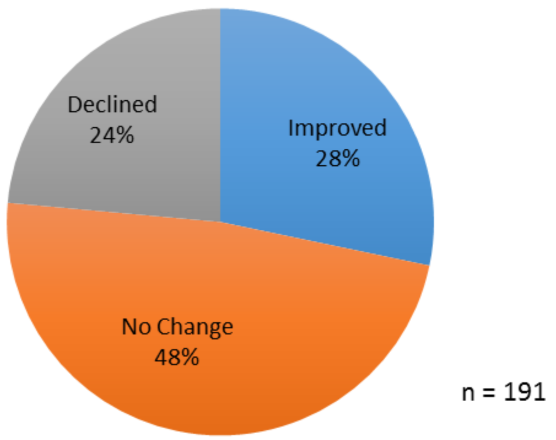


Figure 5. Longer term (2003 to 2014) change in habitat condition

Table 5. Longer term (2003 to 2014) Change in Habitat Condition Rankings

Habitat Condition Rank 2003[#]	No. Sites in 2003 Ranked	Habitat Condition Rankings for 2014					
		Pristine	Excellent	Very Good	Good	Degraded	Completely Degraded
Pristine	11	8	1	1	1	-	-
Excellent	34	-	21	7	6	-	-
Very Good	52	1	5	23	17	6	-
Good	43	-		14	24	4	1
Degraded	31	-	1	4	16	9	1
Completely Degraded	20	-	-	-	4	9	7
Total	**191**	**9**	**28**	**49**	**68**	**26**	**9**

Devised by Seaman (2003)

Plate 1 illustrates a wetland site on the Goolwa Channel estuary downstream of the Goolwa Barrage where a net improvement in habitat condition from 2003 to 2014 has occurred. This figure represents the change within a saltmarsh creek from very good (prior to drought), to degraded (at height of prolonged drought), to pristine (3 years post drought) condition.

Plate 1. Example of a net improvement in Wetland Habitat Condition at Site HIND0031 from 2003 to 2014.

2003 – Very Good

2010 – Degraded

2014 – Pristine

3.3 Response by Ramsar Wetland Type

Of the 13 Ramsar wetland types, Permanent freshwater lakes (O) responded most favourably to post-drought flows, with 92% of representative wetland sites showing an improvement in habitat condition. These were followed by Permanent freshwater marshes/pools (Tp) (71% improved), Seasonal/intermittent freshwater marshes/pools (Ts) (69% improved). Seasonal/intermittent saline/brackish/alkaline marshes/pools (Ss) responded least positively with 15% of its representative wetlands experiencing a decline habitat condition. Results for Ramsar types with a low number of representative sites (i.e. 5 sites and under) do not have a sufficient sample size to be considered reliable and, as such, these sites have been excluded from the analysis in Table 6. Table 6 details the responses of Ramsar wetland types to reintroduced flows to the CLLMM region as a function of habitat condition change.

Table 6. Response of Ramsar wetland types to return to flows (noting that those with small sample sizes of 5 or less sites have been excluded from the Table)

Ramsar Wetland Types	No. Sites Assessed	Habitat Condition Change		
		% Improved	% No Change	% Declined
Irrigated land (3)	7	57	43	0
Permanent rivers/streams/creeks (M)	12	50	50	0
Permanent freshwater lakes (O)	12	92	8	0
Seasonal/intermittent saline/brackish/alkaline marshes/pools (Ss)	33	42	42	15
Permanent freshwater marshes/pools (Tp)	55	71	27	2
Seasonal/intermittent freshwater marshes/pools (Ts)	16	69	31	0

3.4 Response of Landform Type

Of the 13 Landform types, Lagoon landform type responded most positively to post-drought flows with 100% (n=6) of representative wetland sites showing an improvement in habitat condition. Cove (88% improved, n=17) and Closed Depression (88% improved, n=8) types also responded well. Floodplain and Vegetated Bed Sediment Landforms responded least positively with 13% and 3% of their representative sites experiencing a decline in habitat condition. Results for Landform types with a low number of representative sites (i.e. 5 sites and under), do not have a sufficient sample size to be considered reliable and, as such, these sites have been excluded from the analysis in Table 7.

Table 7. Habitat condition responses of landform types since return of flows to CLLMM region (noting that those with small sample sizes of 5 sites or less have been excluded from the Table)

Landform	No. Sites Assessed	Habitat Condition Change		
		% Improved	% No Change	% Declined
Channel	21	62	38	0
Closed Depression	8	88	13	0
Cove	17	88	12	0
Floodplain	39	38	49	13
Lagoon	6	100	0	0
Open Depression	7	43	57	0
Vegetated Bed Sediment	35	54	43	3

3.5 Changes in Habitat Community – Vegetation Associations

Of the 152 sites assessed, a change in habitat or vegetation associations was observed in 37% (n=50) of sites (Figure 6). In many cases community change coincided with a return of water to previously exposed, dry and weed infested lake beds, coves, and lagoons (and associated fringing dead fringing reed beds). Additional to a change from terrestrial to aquatic conditions, the re-emergence of reed beds and aquatic herbs was observed in most cases. In several cases the emergence of *Typha domingensis* as a dominant species where previously *Phragmites australis* dominated reed beds have been reported, indicates a potentially significant difference in the response of these two species to post-drought rehydration.

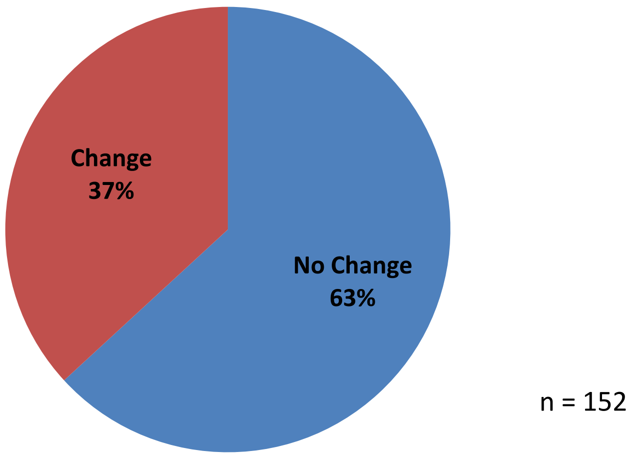


Figure 6. Habitat Community – Vegetation Association Change between 2010 and 2014

Plate 2 illustrates the post drought return of water to a small cove on Dunns Lagoon at Clayton Bay with associated change in habitat type over the 10 year period.

3.5.1 Habitat Change as a function of Ramsar Wetland Type

The response of Ramsar Wetland Types to habitat changes after the return of post-drought flows is highly variable. Figure 7 illustrates the number and percentage of wetlands, grouped by Ramsar Wetland Types that experienced community change from 2010 to 2014.

Eight Ramsar Types experienced some degree of change whilst no change in community occurred in five Ramsar Types. Four of the Ramsar types that experienced no change included tree and shrub dominated wetlands (Types I, W and Xf), that supported *Duma florulenta* or *Melaleuca halmaturorum,* suggesting a broad tolerance between normally wet and abnormally long dry periods. For an illustrated example, please see Plate 3.

For four of the Ramsar types, only one site represented each of these types in 2014, whilst four other wetland types had a sample size of less than 10. Such a numerically poor representation of each type is unlikely to be sufficient to confidently compare with other Ramsar types or draw conclusions with any high degree of certainty.

Plate 2. Example of change in habitat community – vegetation association at Site DUNN0010 from 2003 to 2014

2003 – Shallow open water cover with *Typha domingensis* reed beds (rear left)

2010 – Loss of open water habitat replaced with introduced grasses and scattered sedges

2014 – Return of open water habitat and re-established reed beds of *T. domingensis* and *Scheonoplectus validus*.

Plate 3. Melaleuca halmaturorum woodland, Site DUNN0017 as a representative site of the Ramsar Wetland Type, Freshwater, tree-dominated wetland (Xf); exhibiting minimal observable change from 2003 to 2014, as illustrating its persistence and tolerance to drought conditions in 2010 and return to soil saturation and likely seasonal inundation. This site maintained its Excellent Habitat Condition Ranking throughout the 11 year period. Note that the willow (Salix sp.) in the 2003 image has not shown signs of regeneration in 2014.

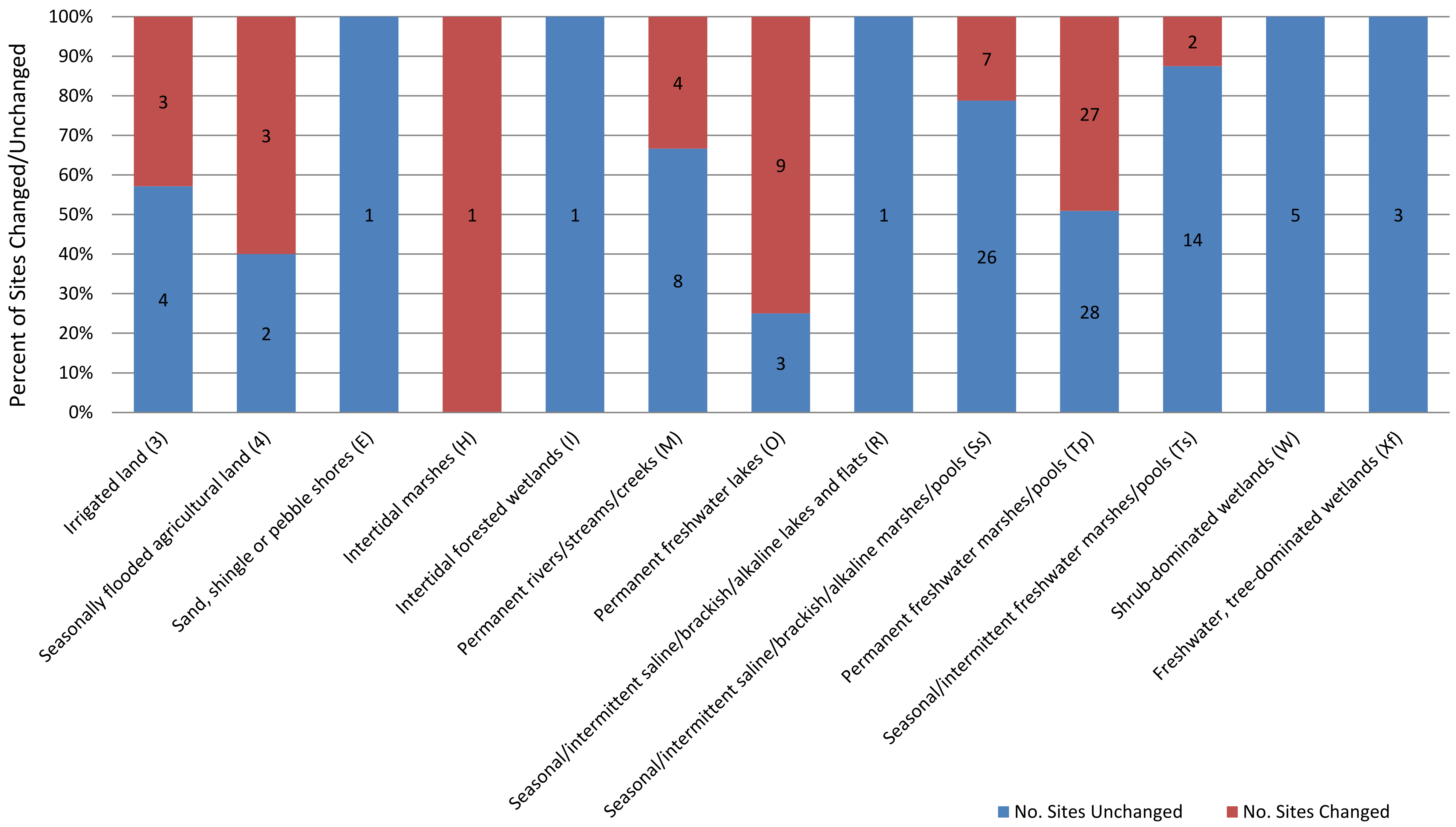
2003

2010

2014

Figure 7. Habitat Community - Vegetation Association Change by Ramsar Wetland Type from 2010 to 2014

n = 152



3.5.2 Habitat Change as a function of Landform

The response of Landforms to habitat change after the return of post-drought flows is presented in Table 8. Lagoons and Coves represented the landform groups that supported wetlands with the greatest percentage of habitat change; 100% and 94% respectively, of the 13 landform groups identified. Wetlands from the Floodplain, Open Depression and Vegetated Bed Sediment Landforms contributed least to habitat change from 2010 to 2014 with 13%, 14% and 26% habitat change respectively from a combined total of 74 wetlands that were assessed.

The Lagoon and Cove sites generally changed from dry, sediment beds in 2010 (mostly colonised by introduced grasses, often with scattered woody weeds and native samphire species) as a result of prolonged drought conditions to mostly open water areas, sometimes supporting aquatic herbaceous beds with fringing reed beds mostly dominated by *Typha domingensis*, *Phragmites australis*, *Schoenoplectus validus* or a combination of any of the three species in shallower areas by 2014. For a representative example, please see Plate 4.

The Floodplain and Open Depression sites in most cases remained as *Tecticornia sp.* dominated low samphire shrubland often in association with introduced grasses and adjacent areas of *P. australis* tall marsh on lower elevations.

Table 8. Habitat Changes responses of Landforms since return of flows to CLLMM region (noting that those with small sample sizes of 5 or less sites have been excluded from the Table)

Landform	No. Sites Assessed	Change in Habitat Community (%)
Channel	21	48
Closed Depression	8	50
Cove	17	94
Floodplain	39	13
Lagoon	6	100
Open Depression	7	14
Vegetated Bed Sediment	35	26

3.6 Changes at sites where nationally listed threatened species are recorded

Specific assessment of sites where nationally listed species have been recorded between 2003 and 2014 indicated all sites had either remained in similar condition (73%) or improved (27%) with no sites declining in condition (Figure 8). The improvement in condition was mostly realised in sites that were deemed degraded in 2003 with habitat condition improvements to either good or excellent occurring.

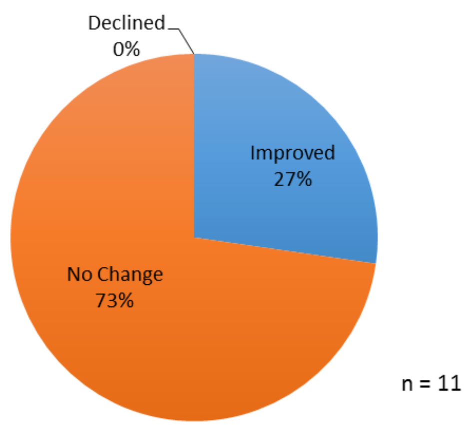


Figure 8. Changes in condition of sites where nationally listed species have been recorded

Plate 4. Representative of a Cove Landform, Site LALB0028, with a historical 'permanent' water regime, exhibits typical reversible change in habitat/vegetation type from open water with fringing reed beds in 2003 to introduced grasses with low, open samphire shrubland, before returning to its pre-drought habitat state in 2014.

2003 – Habitat condition rated as Excellent

2010 – Habitat condition rated as degraded

2014 – Habitat Condition rated as Very Good

4 SURVEY LIMITATIONS

4.1 Timing of survey

Wetlands are dynamic ecosystems driven primarily by the availability of water, with seasonal variations in the amount and timing of water having a major influence on the physical and biological characteristics of these systems. This series of wetland habitat assessments was carried out over a 5 week period during the latter part of autumn 2014. This period coincided within a seasonal transition stage in an annual hydrological cycle for wetlands in a southern mediterranean climate where wetlands generally experience rehydration and often a rise in water levels in response to increased inputs from stream flows, local rainfall and rising water tables associated with the onset of winter. Therefore results from a single snapshot of a wetland's condition at this time of year may vary depending on the volume and timing of this available water and other factors at the time of assessment. Multiple assessments reflecting each seasonal change throughout the wetting and drying cycle would provide a better way to monitor changes in wetland type, vegetation association, habitat condition and hydrological state. If this is not possible, then repeating future assessments at a similar time in the annual hydrological cycle is recommended.

4.2 Access to Wetland Sites

Ten wetland sites previously assessed in 2003 and 2010 were unable to be accessed due to:

- Permission being denied by one landholder to access sites due to their concerns of spreading Caltrop *Tribulus terrestris* (a Declared weed in SA) within and/or outside the property (6 sites), after initially agreeing to DEWNR's request several days prior to the field visit;
- Physical and visual barriers to accessing or viewing sites, including dense and/or tall vegetation (e.g. extensive Phragmites or Typha marshes) that was impenetrable on foot or obscuring view of distant sites (4 sites).

A communication strategy with additional lead-time is recommended to manage site access on private property during future assessments. This would include initial contact with landholders in advance of the field based component to highlight the upcoming field surveys and discuss any potential issues, then follow up contact closer to the survey to provide information on the timing of site visits. This strategy may assist the process of private land access negotiation.

Further, as a large proportion of sites on private property were assessed from "over the fence", opportunities to assess important wetland features may have been missed (e.g. the presence and amount of small or submerged vegetation obscured by dominant vegetation) that could affect, for instance, the score for habitat zones and ultimately the overall habitat score.

4.3 Assessment method

The rapid wetland method employed during this study and the 2010 study follows, in part, the descriptive assessment methodology designed by Seaman (2003) which employs a qualitative ranking of wetland habitat condition. Whilst the one day peer to peer training session assists in reducing assessment variability between assessors, it is perhaps unrealistic to suggest that entirely accurate calibration of the qualitative method can be maintained over a five week assessment period without the provision of other reference aids such as site photographs from previous assessment events in 2003 and 2010. Whilst 2003 and 2010 assessment data were provided prior to the fieldwork, the use of this previous site information as a comparative reference for the current assessment may also have an unwanted side-effect of biasing the current assessor whilst judging and scoring the various components of each site. This potential side-effect was a constant consideration for the 2014 assessors and every effort was made to assess each site on its current merits whilst understanding that the aim of comparative assessment requires the use of, and reference to, the previous information at hand.

Photographs depicting each wetland site were taken as close as practicable to the geographic coordinates recorded for those taken in 2010. As photographs from 2003 and 2010 were not provided until after the 2014 field assessments were completed there was some difficulty in ensuring that a suitably comparable photograph was taken. To overcome this, a series of photographs were taken where it was unclear which direction and field of view was recorded in previous images, so that images could be compared when previous images would become available. As occurred in the current study, it is recommended that bearings and geographic locations be recorded for each photograph taken to improve the accuracy and repeatability of recording visual characteristics of wetlands.

4.4 Sample size of representative wetland types, water regimes and other characteristics

The sample sizes for several of the wetland types, habitat conditions, water regimes ultimately determined/selected in 2010 were often very small, limiting the opportunity to make satisfactorily robust comparisons between the choice of assessment items available, across the three assessment events. The inclusion of additional sites from 2003 (as proposed by NGT Consulting) bolstered the sample size for underrepresented completely degraded sites (+17 sites) and pristine sites (+11 sites), improving the robustness of the comparative analysis of wetland condition and the subsequent degree of change in habitat condition between 2003 and 2014 (ie. the resilience and capacity of wetlands to respond to hydration after a major drought event).

4.5 Mapping

Based on the observation of 2013 aerial imagery overlaid by the wetland polygons provided by DEWNR, it is evident that the scale and detail of wetland mapping presents some significant inconsistencies. Some polygons are tiny and specific, while others are so large they often contain multiple wetland vegetation types (or other features/disturbances that impact upon condition rating – see example of the Goolwa Channel in Plate 5) as clearly defined by the aerial imagery. Many of the large sites assessed during this study contained multiple vegetation associations, meaning on-site decisions were often required for these wetlands on how far the assessment should range (to be representative of the wetland from the assessment point), to enable a fair comparison to previous assessments.

It is recommended that mapping of wetland polygons in the CLLMM region be updated to:

a) refine spatial differences in vegetation associations (or other clearly defining features of a wetland area such as open water);
b) record spatial changes in the extent of wetland areas and;
c) map any previously unmapped wetlands.

Plate 5. These images of six locations along the Goolwa Channel shoreline at Goolwa in 2014 illustrate the variation in habitat condition, habitat type/vegetation association, over a large area and the importance of recognising that a condition assessment at one location is not necessarily representative of the entire wetland polygon. Whilst this wetland polygon was assessed as Completely Degraded in 2003 it was given an average habitat rating of Degraded in 2014 based on the combined condition assessment from several locations along its length. The fact that generally healthy and extensive native reed beds occur along its length suggests that some areas are at least in Good condition as determined by the assessment criteria. The presence of a variety of waterbirds during the current study indicates that these areas provide suitable habitat resources to support these species.

5 DISCUSSION

5.1 Post-drought water regime

The principal objective of the 2014 study was to assess how wetlands within the CLLMM region responded to the return of River Murray flows following the millennium drought. Assessment in 2010, at the end of the drought, concluded that almost half of the 162 assessed wetlands where considered to be in degraded or completely degraded condition (Thiessen 2010). The present assessment highlighted that the return of “normal” water flows to the CLLMM region, led to a major and rapid change in the water regime of assessed sites; namely, two thirds of wetlands assessed responded well to increased flows and there was a large reduction in the number of wetlands that were found to be dry when compared to 2010 (from 114 of 152 in 2010, to 15 of 152 in 2014). Importantly, nearly two thirds of the wetlands returned to their 2003 pre-drought water regime indicating an overall major reversal in the hydrological status of CLLMM wetlands following the end of the 2006 to 2010 drought.

This high degree of response of wetlands to increased flows suggests the importance of the high level of connectivity of wetland ecosystems within the CLLMM region (as mentioned by Thiessen, 2010) and the major water bodies of Lakes Alexandrina and Albert, the Goolwa and other channels and tributaries. This is a function of both the landform itself, but also of the way in which the barrages in particular now play a major role in setting a benchmark upstream water level across the broader CLLMM area. In this way, the impact of the barrages on water regime cannot be understated. By setting a more static water level, the barrages have increased wetland permanence. More permanent wetland types are clearly more likely to experience dramatic changes in the face of extreme drought conditions, like those experienced from 2006-2010, than more seasonal wetland habitats.

Areas downstream of the barrages continue to display more variable hydrological regime over the 3 assessment periods, with limited oceanic connectivity during the period of several years of mouth dredging (during the earlier assessments), now replaced by a return to a more apparent tidal influence since the mouth has remained naturally opened due to sufficient River Murray flows over the barrages (refer to illustrated example in Plate 1).

Events over the past 10 years illustrate that extreme events such as extended drought challenge the concept of categorising wetlands into wetland regime (i.e. permanently flooded, seasonally flooded, etc). Hence care should be taken when extrapolating a solitary observation of water depth to arrive at a water regime determination. A snap-shot observation on a wetland may be influenced by seasonal variations or short-term climatic aberrations (e.g. drought, 1 in 100 year flood, higher than average annual rainfall), and should be recorded with an awareness of this context. Therefore, an observed change in a water regime should be clearly supported by other observational data such as observed vegetation type and habitat condition.

5.2 Post-drought habitat condition

Re-assessment of the habitat condition of sites assessed in 2010 (for 152 sites, as 10 sites were not accessed in 2014) revealed broad improvement in habitat conditions consistent with the restoration of pre-drought water regimes. In 2010, Thiessen (2010) reported that 54% of wetland sites declined in condition, whilst 41% remained stable and 5% improved in condition He also observed ‘that the majority of condition decline occurred in reed beds or open water habitats'. In contrast, the current study identified an almost equal reversal in habitat condition with 60% of wetlands improving in habitat condition, 35% remained stable and 5% declined in condition from 2010. Reed beds and open water areas contributed substantially to the number of wetland habitat types that responded positively to the return of flows from 2010 to the present. Whilst sensitive to drought conditions, it appears that reed beds and open water habitats respond rapidly and effectively to re-flooding after 5 years of desiccation. An assessment of longer-term changes to habitat condition showed that 45% of the 152 wetlands assessed for all three assessment periods either returned to their original 2003 condition or maintained a constant condition throughout the drought to the present survey, whilst 27% of wetlands made a net improvement. This sample set was poorly represented by wetlands assessed in 2003 that were either degraded or pristine in particular, potentially biasing the results. In response, this study identified and evaluated an additional 39 wetlands (17 completely degraded, 11 pristine and 11 allocated to four other categories) as part of the field study, which showed that there was only a minor shift in the spread of the net habitat condition change between 2003 and 2014.

Whilst re-flooding was an over-riding influence that contributed substantially to the improvement in habitat condition, other factors were also noted by the assessors when determining overall condition of wetlands. These included the presence or absence of revegetation sites (including their health, diversity and growth development) and human derived activities, in particular livestock grazing, which had the capacity to degrade vegetation, underlying substrate and water quality with their presence.

A qualitative assessment that ranks habitat condition, and is based on the broad definitions and interpretation of descriptive terms such as good, very good, degraded, by different (or even the same) assessors may not be sufficiently robust to distinguish individual changes in habitat condition over time or separate differences between similar or different types of wetlands. Also what one assessor values as an important characteristic in determining a wetland's condition may not be so important to another assessor and hence the determining characteristics may be weighted differently, potentially influencing condition ranking. Whilst the use of peer to peer training may partially reduce natural variability between assessors, much relies on common interpretations and understandings of important characteristics that determine wetland condition by multiple assessors. Robust testing of assessor variability may be a useful way to minimise variation in scoring of wetland habitat condition in the future. A potentially better approach is to adopt a numerical scoring system which compares each wetland with a benchmark undisturbed wetland community of the same type, such as the Victorian Index of Wetland Condition (ISC).

5.3 Reviewing habitat community change

Observations from this study support the 2010 findings that the availability of water not only affects change in the type of habitat community and vegetation association but also the hydraulic connectivity of individual wetland areas within the broader CLLMM system.

The return in 2014 of obligate wetland plants that were previously absent when many open water areas such as coves and lagoons became dry highlights that some wetland vegetation associations were able to return to their pre-drought state with sufficient return of water. Others transitioned to an entirely new state (with a different condition score), seemingly encouraged by shifts in composition that the drought encouraged, as indicated in Plate 6. For an earlier illustrated example, see Plate 1.

Plate 6. Representative of a Closed Depression Landform, Site LALB0075, with an historical 'seasonal' water regime, exhibits a transition from inundated shallow saline basin (fringed by samphire and Gahnia filum) in 2003 to a dry basin with colonising samphire in 2010. Further expansion of the samphire across the muddy sediments in 2014 illustrates that some sites may not return to their pre-drought habitat type under certain environmental variables that may favour a shift in habitat type.

2003 – Shallow water over mud sediment.
Habitat condition rated as Degraded

2010 – Early colonisation of samphire species over mudflat.
Habitat condition rated as Degraded

2014 – Increasing cover of samphire across the bed of the wetland.
Habitat Condition rated as Good

5.4 Reviewing Ramsar wetland type and landform

This study also supports the previous findings that some Landforms (in particular Lagoons and Coves) are more dramatically affected by changes in water availability than other Landforms, with respect to habitat community change and habitat condition. Ramsar Wetland Types are more variably affected, with habitat condition and habitat and vegetation association change of Permanent Freshwater Lakes mostly affected by large shifts from wet to dry and vice-versa. In contrast, changes in habitat community for Floodplain and Open Depression Landforms and Shrub-dominated and Freshwater, Tree-dominated Ramsar Wetland Types were less likely to occur in response to the effects of drought and return of 'normal' water levels to the broader wetland system.

The common theme appears to be the natural ecological tolerance of any particular vegetation community and its constituent plant species to such hydrological shifts. Limits of tolerance appear to be governed by their evolutionary development of physiological, morphological adaptations and reproductive strategies to survive under a given set of variable conditions (e.g. hydrological cycles, water quality, substrate type, etc).

5.5 Threatened species sites

It is worth noting that more detailed and quantitative habitat (and species) assessment processes are undertaken at threatened species sites in support of their specific values, and can be referenced elsewhere through the CLLMM program. However inclusion of the sites in this project effectively enabled these sites to have their values rapidly benchmarked against habitats found across the wider CLLMM site.

Hence, the results for wetland sites supporting nationally threatened species through this project were encouraging in that no sites were shown to have declined in condition since 2003, while 27% had actually shown an improvement in condition. While the small sample size of sites (11) and rapid assessment techniques make detailed analyses of this category of sites difficult, it is useful to be able to understand the general trajectory of health and dynamics of these sites, when compared to the wider regional dataset. For that reason alone it is suggested that these sites continue to be included in future wetland health assessments of the CLLMM region.

6 RECOMMENDATIONS

Based on the findings of the project, key future recommendations proposed for consideration include:

1. Ensuring that more detailed vegetation monitoring already undertaken at a smaller number of CLLMM wetland sites (Frahn *et al* 2013) is complementary with the outcomes of this project, and (if possible) in future both projects (should they be repeated) are able to work in conjunction to:
   - better describe and understand the mechanisms behind some of the substantial ecological shifts (including dramatic habitat recovery/changes) that were observed at some sites, but not others, in the 2014 survey;
   - inform predictions of the expected trajectories of future change of wetland habitats across the CLLMM region; and
   - permit the establishment of a small number of permanent photopoints for more regular (and accurately repeatable) monitoring of visual habitat change.
2. Repeating the habitat assessment process in 3-4 years, given the significant shifts in character and condition observed since 2010.
3. Look for potential enhancements to the general method that would make some forms of basic, more quantitative future assessment and analysis possible; in doing so, reducing the possibility of observer variability and increasing the scientific value that can be derived from what is a rare opportunity to undertake a comprehensive review of habitat condition at such a significant scale.

7 CONCLUSION

Combined evidence from wetland habitat condition assessments in 2003, 2010 and the current study show that habitat community and habitat condition changes are closely tied to changes in the hydrology (water regime) of the broader CLLMM wetland system, being largely defined by River Murray flows and the influence of the barrages. In many cases, condition and vegetation community characteristics were found to return to their former (2003) states, even after a prolonged and extreme drought between 2006 and 2010. In contrast however, a smaller number of wetlands did not return to their former condition, while others maintained a consistent health and structure throughout the drought period.

Better predicting the drivers of wetland condition and floristic change (that are not water regime based) is an important future consideration for the CLLMM region. The reported observations help to provide a better understanding of the sensitivity, resilience and stability of various wetlands to extreme hydrological and environmental change. Their original condition, vegetation associations, position in the landscape, connectivity to larger water bodies and exposure to external threats such as weed invasion and livestock grazing, as well as human intervention in the form of artificial watering, appear to be important contributing factors in setting their trajectory or inertia (i.e. ability to withstand change) when major catastrophic events like the 2006-2010 drought arise.

The results of this study provide an excellent insight into the dynamics and natural recovery potential of a wetland system that was under severe and prolonged stress, and provides a number of positive messages to inform the future management of the CLLMM site.

8 REFERENCES

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9 APPENDICES

Appendix A. Habitat Condition Datasheet

HABITAT CONDITION DATASHEET

OFFICE USE ONLY
Entered:..............
Corrected:...........

Object ID:.............................
DATE: ..../........./..........
OBSERVERS: ....

Government of South Australia
Department for Environment and Heritage

SITE INFORMATION

Location (GPS reference)

Datum ☐ AGD84 ☐ GDA94 (WGS84 OTHER:_______ Location derivation ___________

Plot : zone: _ _ _ easting: _ _ _ _ _ _ _ northing _ _ _ _ _ _ _ _ Accuracy: ______

Locality description ____

Tenure: .... Reserve or Property Name: ....

Site photos

Photo Numbers:

North		South	
East		West	
Other:			

Site photos taken? YES NO

Wetland Association:

Landform: channel closed depression floodplain vegetated island vegetated bed sediment
other ______________

Wetland System: Estuarine Riverine Lacustrine Palustrine Marine

Micro relief: structural relief undulating surface hummock mounds depressions slopes banks

Historical water regime: intermittently flooded permanently flooded semi-permanently flooded seasonally flooded

Current water regime: ______________________________ Water depth:

Water Depth: damp film < 3cm 3-10cm 10cm-0.5m open water dry bed

Vegetation Association:

Woodland Samphire Sedgeland Grassland Shrubland Freshwater wetland Forest

COMMENTS: ____

____

Cover: none < 5% 5 - 25% 25-50% 50-75% >75%

Microhabitat: ______________________________

Code	Description	Code	Description	U	undulations
AM	algae mat	M	molluscs	OW	open water
BH	bank hollows	Mo	mounds	P	perches
B	burrows	MF	mudflat	Po	pooling
D	detritus	N	nesting area	Ra	rocky areas
FS	freshwater soak	R	roosting	Sn	snags
H	hollows	Sa	sandy areas	SD	structural diversity
L	lignum	S	Sheltered area	SA	surface aquatics

Aquatic veg: algal floating vascular floating leaved
moss aquatic moss
lichen rooted floating leaved none

Aquatic score: low mod high

Disturbance: ______________________________

____

Code	Description	Code	Description	Code	Description
AR	access road	E	erosion	J	jetty
WE	water extraction	EX	excavated	MA	mown aquatics
BL	boat launch	FL	fencelines	W	weeds
C	camping	FS	fire scars	PF	pest fauna
Cl	clearance	G	grazing	R	rubbish
CB	cleared buffer	IG	intro grasses	SI	salt intrusion
DB	degraded bank	IP	intro plants	SE	sand extraction
Dbu	degraded buffer	IT	intro trees	WT	walk tracks

Grazing: yes no

Fauna:

Surface Fauna: molluscs crabs worms ants other insects ____________________

Opportunistic: ____________________

____

Reliability: 0-5m 0-50m 51-100m 101-250m 251-500m 501-1km 1-10km

Recreation:

bird watching boating area fishing shacks other ____________________

General Description: ____________________

Mapping:

Habitat mapped: YES NO

Habitat community change YES NO

COMMENTS: ____________________

Overstorey: presence absence

Revegetation:

Revegetation works: YES NO

Age of Reveg: 0-1years 1-3years 3-5years 5+years

COMMENTS: ____________________

Restoration potential:

Erosion present: YES NO ____________________

Weed Cover %: 0-25% 26-50% 51-75% 76-100% ____________________

Connectivity potential YES NO Current fencing: YES NO

Zonal Areas for Reveg buffer bank toe of bank core

Zone Condition: 1=poor 2=average 3=good

Buffer:	1	2	3	____________________
Bank:	1	2	3	____________________
Toe of bank:	1	2	3	____________________
Core:	1	2	3	____________________

Habitat Condition:

Pristine Excellent Very Good Good Degraded Completely Degraded

COMMENTS: ____________________

____

Basic Version 1.3 23/04/2010 J.Thiessen, CLLMM, DEH, 91-97 Grenfell St, Adelaide

Appendix B. Habitat Measures used by Thiessen in 2010 after Seaman (2003)

Habitat Measures used by Thiessen 2010 after Seaman (2003).

All information and references in this appendix see Thiessen (2010).

a) Water regime: the four Ramsar categories of permanent, semi-permanent, seasonal and dry were used to define water regime. During site visits in 2010 water levels were determined to measure the change in water regimes.

b) Habitat Condition – Seaman's (2003) six categories of habitat condition that were used to describe sites include: completely degraded, degraded, good, very good, excellent and pristine. Habitat Condition is a subjective assessment based on field observations. During assessment certain ecological values were considered, including hydraulic and habitat connectivity (and the interplay between); cover and abundance of native and introduced species; integrity of vegetation associations and the structure and health and vigour of the vegetation. Full descriptions of these categories are provided by Seaman (2003) and are included in full in Appendix A.

c) Habitat Community Change: Habitat is defined as "the place in which an organism lives, comprising physical structure, such as reef, sediments or water column properties, as well as biological structures, such as the dominant plant types" (p.161) (DEH 2010). Using this definition, a change in habitat can be determined by a change in the vegetation association which is the description of dominant and/or co-dominant overstorey and understorey species within the habitat (based on the survey of Seaman, 2003). The measure of a community change was assessed by comparing the vegetation associations mapped in ArcGIS by Seaman (2003) to the assessed vegetation association observed in 2010.

d) Ramsar wetland types: sites were assessed in relation to the 13 Ramsar wetland classifications, as previously described in Table 1

Appendix C. CLLMM Raw Data spreadsheet, scanned datasheets and site photographs in digital format (See attached disk).