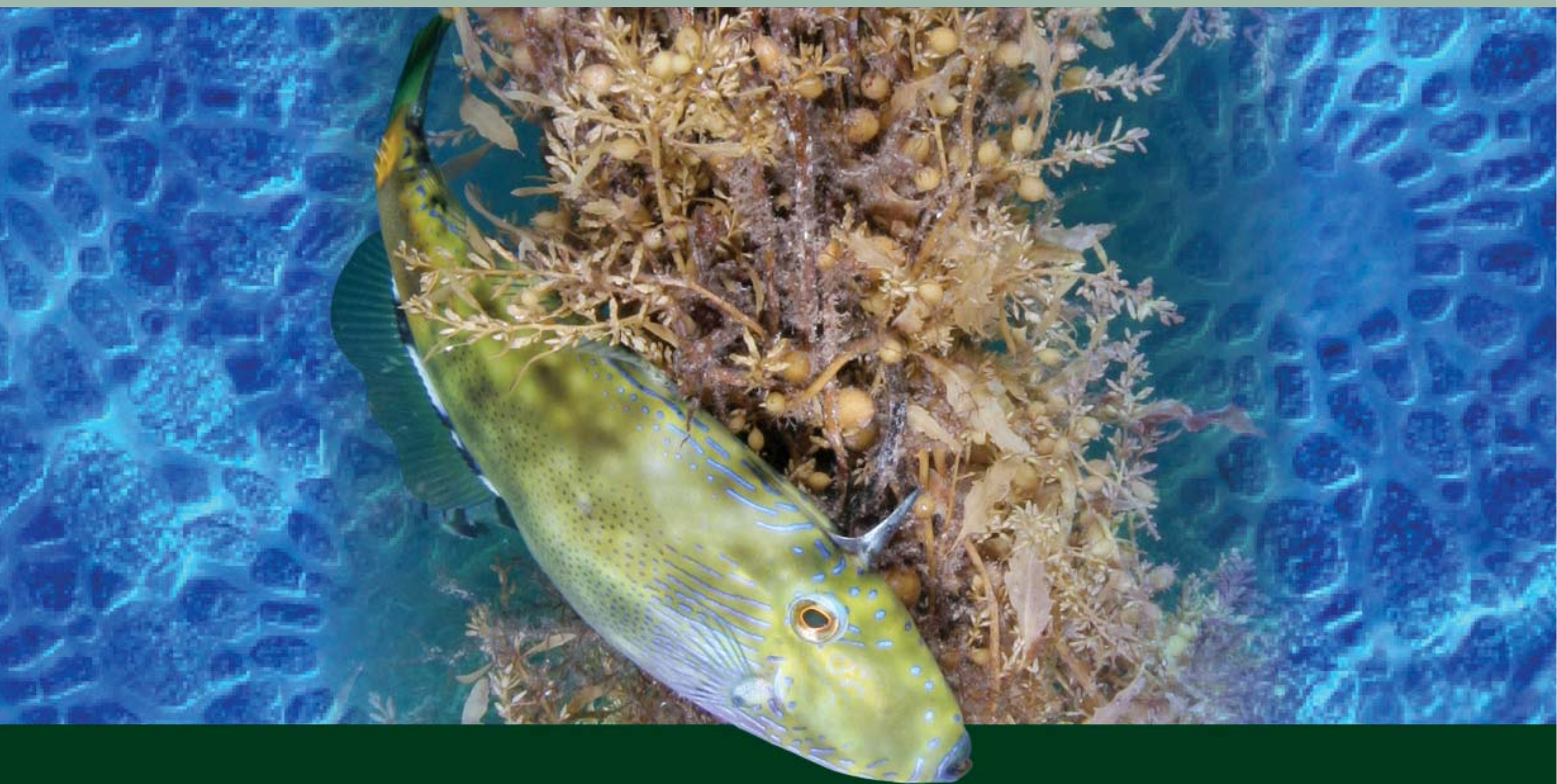
Monitoring marine fishes of conservation concern on Adelaide's coastal reefs: combined results of 2009/2010 and 2010/2011 surveys for the southern blue devil and harlequin fish

Report to the Adelaide and Mount Lofty Ranges Natural Resources Management Board

Technical Report 2011/07



Department of
Environment and
Natural Resources

Government
of South Australia

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Photographs: Left – Southern blue devil, *Paraplesiops meleagris*, at Seacliff Reef; Right – Harlequin fish, *Othos dentex*, at Aldinga Reef. Photo credits: Simon Bryars

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Table of contents

Summary

The southern blue devil (*Paraplesiops meleagris*) and harlequin fish (*Othos dentex*) are coastal reef fishes endemic to southern Australia. Both species are of conservation concern in the Adelaide and Mount Lofty Ranges Natural Resources Management (AMLR NRM) region due to threats from fishing, poor water quality, and habitat degradation. However, there are no historical baselines or current estimates of population sizes for either species. Nonetheless, obtaining reliable population data on these two species is crucial for assessing their conservation status and for conducting ongoing monitoring programs. Furthermore, while the site fidelity and movements of individuals has not been studied, such data would be useful for natural resource planning and management. A species-specific approach of studying the blue devil and harlequin fish has additional potential benefits for the AMLR NRM region: the two species may act as indicator species for the health of local reefs, and they can act as flagship species to focus public attention on generic threats to local reef ecosystems and to highlight the need for improved protection of the habitats that they rely upon.

Both the southern blue devil and harlequin fish have characteristic iridescent blue marks covering their bodies that offer potential for photographic identification (photo-ID) of individual fish. Using these markings it may be possible to develop a non-destructive/non-invasive photo-ID capture-mark-recapture technique to study population demographics and monitor site fidelity. Thus the specific aims of the present study were to:

1. Assess the potential of natural markings for photo-ID of individual blue devils and harlequin fish.
2. Utilise photo-ID and capture-mark-recapture techniques to make population estimates and investigate site fidelity of blue devils and harlequin fish at a number of different sites.

Analysis of photos from a range of sources (including community divers) confirmed that the markings on adult blue devils and adult harlequin fish are unique to individual fish and that they are temporally stable across several years. Using the photo-ID technique, a number of scuba diver surveys were conducted at five reefs off Adelaide between December 2009 and April 2011: Aldinga Reef (n = 6), Seacliff Reef (n = 8), Northern Outer (n = 2), Macs Ground (n = 2), and Milkies (n = 2).

Survey data on harlequin fish were limited, with just three individuals photo-catalogued at Aldinga Reef. No harlequin fish were sighted at Seacliff Reef, Northern Outer, Macs Ground, or Milkies. While the abundance of harlequin fish at Aldinga Reef was too low to enable a population estimate, the natural marking technique was still useful for providing data on site fidelity. For example, from my surveys and historical photographs at Aldinga Reef, one individual harlequin fish has been sighted on six separate occasions over a 3-year period, indicating that it either resides permanently there or frequently re-visits the site. Another fish was re-sighted on three different days on exactly the same rock ledge.

Population estimates were able to be generated for blue devils at Seacliff Reef, Northern Outer, Macs Ground, and Milkies. Using three different capture-mark-recapture calculation techniques, population size estimates of blue devils along a 300 m section of Seacliff Reef were 32 (Lincoln-Petersen method), 39 (Schnabel method) and 40 (pseudo-removal method). Based upon cumulative photo-cataloguing, the minimum total population size is 41 fish. It is apparent that traditional fish survey techniques would have greatly underestimated the population size of blue devils at

this location; on average ~50% of the total population was sighted on any given survey. Blue devils at Seacliff Reef also showed a high degree of site fidelity and their home ranges were estimated to be relatively small (33 linear metres of reef).

Population estimates of blue devils based upon two surveys ~1 month apart were generated for Northern Outer (9 fish), Macs Ground (7), and Milkies (10). Most of the fish were re-sighted on the second survey within a few metres of the first survey location. Numerous blue devils were also sighted at Aldinga Reef, where 48 individuals were photo-marked and catalogued but a population estimate using capture-mark-recapture was unable to be generated.

The project has demonstrated that:

1. Natural markings on blue devils and harlequin fish differ between individual fish and are temporally stable across several years.
2. Blue devils are site-attached with a relatively small home range.
3. Photo-ID of natural markings provides a valid technique for deriving population estimates of blue devils.
4. Numbers of blue devils are likely to be considerably higher than perceived numbers that are based on limited survey effort or traditional diver surveys.

The photo-ID capture-mark-recapture technique is now at a stage where it can enable long-term ongoing community monitoring of blue devils and harlequin fish in the more accessible and popular dive sites around South Australia. Indeed, ongoing submission of photos to the author is being undertaken by several individuals and is about to be commenced by several dive clubs. Ultimately it is hoped that community monitoring can be continued and expanded to additional reefs around South Australia, including reefs within marine parks.

In addition to providing new information on the blue devil and harlequin fish, the project has also been highly successful in promoting the two fishes as flagship species for improved natural resource management of Adelaide’s reefs through mainstream media coverage and public extension activities.

Introduction

In early 2000, a Marine Species of Conservation Concern Working Group began developing a list of marine species of conservation significance in South Australia (SA). Marine species of conservation concern includes those species where there are concerns regarding status and threats, but for which insufficient information is available to indicate a need to list the species under protective legislation. Following on from this earlier work, the Adelaide and Mount Lofty Ranges Natural Resources Management (AMLR NRM) Board commissioned a report by Baker (2007) on marine and estuarine fishes of conservation concern in the AMLR NRM region. The Baker (2007) report provided a detailed discussion of a number of potentially threatened bony and cartilaginous fishes, including the southern blue devil and harlequin fish.

The southern blue devil (*Paraplesiops meleagris*) and harlequin fish (*Othos dentex*) are coastal reef fishes endemic to southern Australia (Gomon et al. 2008). They are restricted to shelf waters of <45 m depth and prefer rocky reefs with drop-offs, caves, and ledges (Edgar 2008, Gomon et al. 2008). Maximum total lengths are 36 and 76 cm for the blue devil and harlequin fish, respectively (Hutchins and Swainston 2002). While both species are considered to be site-attached (Baker 2010), no information is available on site fidelity, home range size, or movements. Both species are relatively rare compared to other medium-sized reef fishes in most parts of SA (S Bryars, unpublished data), and are also considered to be iconic reef fishes in SA.

While very little is known about the basic biology of the blue devil and harlequin fish, recent work by Saunders et al. (2010) found them to be surprisingly long-lived and therefore intrinsically vulnerable to fishing pressure. Both species are incidentally captured on hook and line by commercial (Fowler et al. 2009), recreational (pers. obs.), and charter boat fishers (Saunders et al. 2010). The harlequin fish is also targeted by recreational spearfishers, and is taken as bycatch in commercial and recreational lobster pots (Baker 2010). However, there is little protection for blue devils and harlequin fish within SA, with no limits on the recreational take of either species. Coastal habitat degradation may also be a threat in some regions (Baker 2010), including the AMLR NRM region (Baker 2007) where historical and ongoing degradation of reef and seagrass systems has been well documented (Bryars et al. 2008, Connell et al. 2008). Indeed the disappearance of the harlequin fish from Port Phillip Bay in Victoria has been linked to poor water quality (Gomon 2001). Consequently the blue devil and harlequin fish are of conservation concern in SA (Baker 2007, 2010) and are two species currently being utilised to inform the zoning process within South Australia's new system of 19 multiple-use marine parks.

The conservation concerns for the blue devil and harlequin fish are largely based upon a combination of their intrinsic vulnerability to fishing (Saunders et al. 2010), perceived threats from fishing and habitat degradation, and on anecdotal reports of localised declines. However, there are no historical baselines or current estimates of population sizes in the AMLR NRM region or other parts of SA. Nonetheless, obtaining reliable population data on these two species are crucial for assessing their conservation status and for conducting ongoing monitoring programs. Furthermore, while the site fidelity and movements of individuals has not been studied, such data would be useful for natural resource planning and management.

Non-destructive estimates of abundance and size structure of reef fishes are usually conducted using scuba diver surveys (e.g. Edgar et al. 2004, Shepherd et al. 2009) or remote underwater video camera drops (e.g. Kleczkowski et al. 2008). Similarly, the site fidelity and movement of benthic reef fishes are usually studied by scuba divers tracking tagged fish (e.g., Barrett 1995, Samoilys 1997, Lowry and Suthers 1998) or increasingly via acoustic telemetry (e.g., Lowe et al. 2003, Tolimieri et al. 2009). However, in some instances the use of natural markings that enables identification of individual fish can have certain advantages over these more traditional techniques. A natural method of 'tagging' individual site-attached fish that is temporally stable would: (1) combat double-counting that can occur using divers or video, (2) obviate the need to capture fish for tagging which can cause mortalities and other complications, (3) counter tag loss (external 'dart-type' tags may be lost, and physical 'brandings' fade over time), (4) enable much longer term monitoring (acoustic tags have a finite life), and (5) enable accurate estimates of absolute population size.

While the technique of using natural markings to identify individuals in the marine environment is well known for whales (e.g. southern right whale, Pirzl et al. 2009) and sharks (e.g. whale shark, Meekan et al. 2006; white shark, Domeier and Nasby-Lucas 2007), it is less known for bony fishes (e.g. blennies, Connell and Jones 1991; seadragons, Connolly et al. 2002, Martin-Smith 2011; labrids, Shepherd and Clarkson 2001, Shepherd 2005). Both the southern blue devil and harlequin fish have characteristic iridescent blue marks covering their bodies (Edgar 2008, see cover photographs) that offer potential for identification of individual fish. Indeed, observations of many photographs by the author and observations by community divers have indicated that the natural markings (i.e., the arrangement and shape of the iridescent marks) of larger fish might be useful in identifying individual fish. Furthermore, if these two species are indeed site-attached and have small home ranges, then it should be possible to estimate population sizes and track site fidelity on individual reefs using a natural mark and photographic recapture technique.

The present study proposes and assesses a capture-mark-recapture technique utilising natural markings and photographic identification (photo-ID) of individual blue devils and harlequin fish that will enable long-term data collection on population demographics and site fidelity. The current report builds upon results of the AMLR NRM Board-funded work of Bryars (2010). The study focussed on the nearshore reefs along the Adelaide metropolitan coastline from Outer Harbour to Aldinga. The study had four components: (1) historical photographic analyses, (2) multiple scuba surveys at Aldinga Reef, (3) multiple scuba surveys at Seacliff Reef, and (4) two consecutive scuba surveys at each of three other reefs off metropolitan Adelaide (Northern Outer, Macs Ground, and Milkies).

The specific aims of the study were to:

1. Assess the potential of natural markings for photo-ID of individual blue devils and harlequin fish.
2. Utilise photo-ID and capture-mark-recapture techniques to make population estimates and investigate site fidelity of blue devils and harlequin fish at a number of different sites.

A species-specific approach of studying the blue devil and harlequin fish has additional potential benefits for the AMLR NRM region: the two species may act as indicator species for the health of local reefs, and they can act as flagship species to focus public attention on generic threats to local reef ecosystems and to highlight the need for improved protection of the habitats that they rely upon. The current study also builds upon previous surveys of rare fish in the AMLR NRM region (Baker et al. 2008, 2009a; Bryars 2010) that were funded by the AMLR NRM Board.

Methods

Photo-ID technique

After inspecting numerous photographs of different blue devils and harlequin fish that had been taken by community and scientific divers, I identified that the lateral view of the head (and especially the gill cover or operculum region) was a likely area for photo-ID of larger individuals. In blue devils it is apparent that the blue spots on small fish (<~10 cm total length, TL) are quite different to adult fish and change with growth (Kuiter 1996, Gomon et al. 2008). However, in larger devils (>15–20 cm TL) there is often a distinctive shape(s) and arrangement of spots on the lower part of the operculum (Fig. 1) that showed great promise for photo-ID purposes. In harlequin fish I could not obtain suitable photographs of smaller fish (<20 cm TL), but the operculum/cheek area of larger individuals (>~20 cm TL) also showed potential for photo-ID (Fig. 2). It was evident that the left and right sides of individual fish of both species had different markings (Fig. 3). Due to the apparent ontogenetic change in markings, I focused on using the natural markings of larger fish only (although attempts were still made to photograph all sizes of fish in field surveys – see later). Photographic-matching (photo-matching) of individual fish was done by visual comparison of digital photographs on a PC screen.

Historical photographic analyses

To test the idea that the natural markings of larger fish were temporally stable (and therefore might be useful in capture-mark-recapture studies), I required a time-series of photographs of the same individual(s) for each species. Rather than commence a new study and monitor individuals over time, I was able to use historical photographs dating back many years that had been taken by community divers along the Adelaide metropolitan coastline. I was also able to compare photographs taken during my surveys (see later) with the historical photographs, and to also compare photographs taken across several months in my surveys. A photograph was deemed to be useful if it had a relatively clear lateral view of the left hand side (LHS) or right hand side (RHS) of the head, a date, and a location (local reef names were sufficient and GPS marks were not necessary). Suitable photographs from different dates were then compared for photo-matches. Photographs that were out of focus or incorrectly exposed were still useful in cases where the iridescent spots were discernible.

Field surveys

A number of field surveys were conducted using scuba divers during daylight hours only (see later). While there are some anecdotal reports of blue devils being more active at night, they are regularly sighted by divers during the day-time, thus making them amenable to day-time surveys. Likewise, harlequin fish appear to be diurnal ambush predators and are also suitable for day-time diver surveys (e.g. Edgar et al. 2006, Bryars unpublished data). Further evidence that harlequin fish are diurnal comes from the Baited Remote Underwater Video System (BRUVS) work of Kendrick et al. (2005) in which harlequin fish were only ever recorded during the day-time.

All diver surveys were conducted during periods of calm weather conditions when underwater visibility allowed visual detection and photography of individual blue devils and harlequin fish.

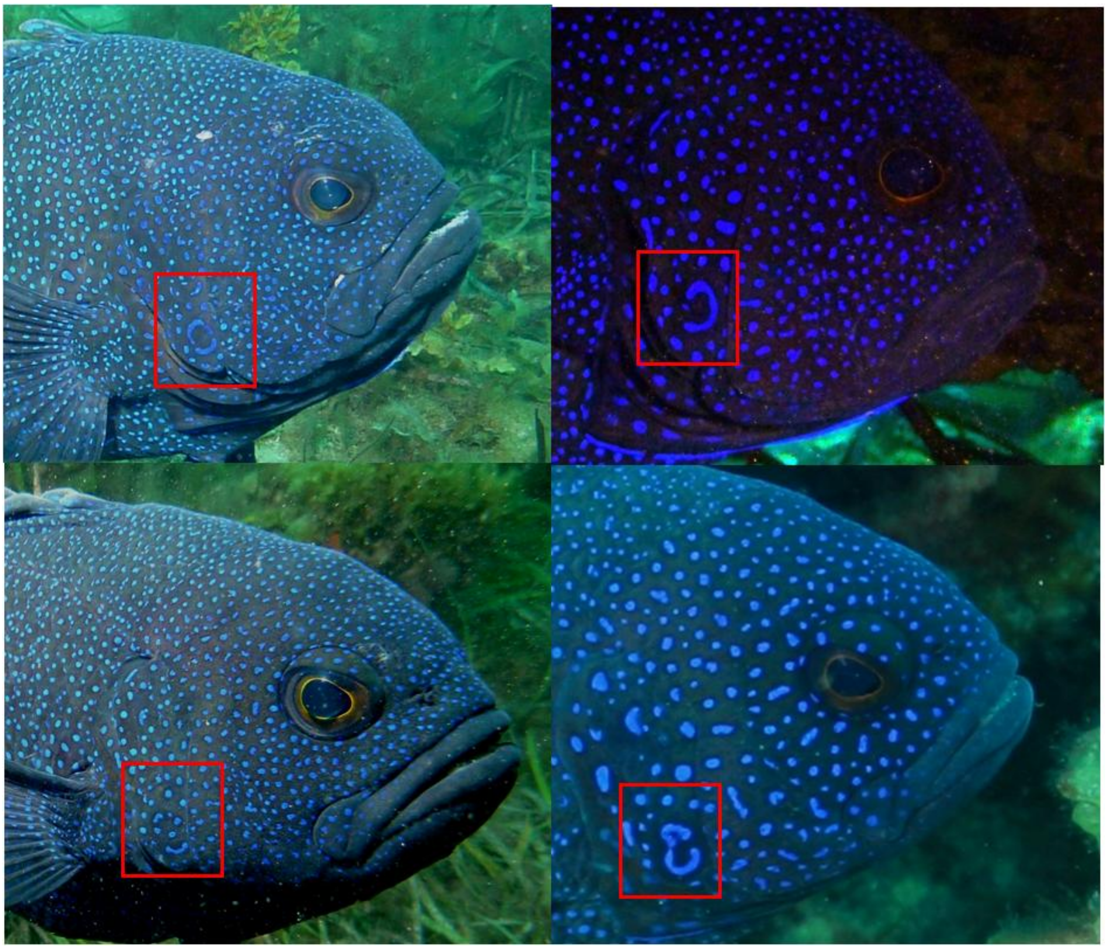

Figure 1. Photographs of four different blue devils showing variations in the markings on the operculum. The inset boxes indicate the focus area for comparisons. Photographs: Simon Bryars

Figure 2. Photographs of three different harlequin fish showing variations in the markings on the operculum and cheek area. Photographs: Simon Bryars (top and middle), Carl Charter (bottom)

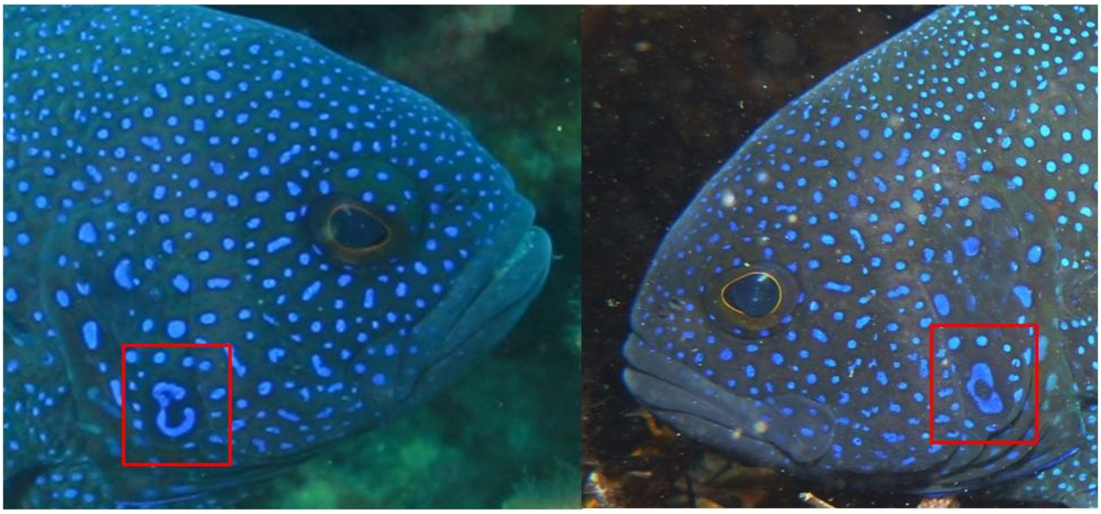

Figure 3. Photographs of the right and left sides of the same blue devil showing differences in markings on the operculum. The inset boxes indicate the focus area for comparisons. Photographs: Simon Bryars

Aldinga Reef surveys

Aldinga Reef is located ~40 km SW of the Adelaide CBD on the eastern side of Gulf St Vincent (Fig. 4). It is an expansive area of limestone reef that extends ~1200 m from the intertidal region off Snapper Point out to subtidal depths of ~18–20 m at 'The Drop-Off' (Figs. 4, 5). Much of the reef lies within a no-fishing/no-take Aquatic Reserve that has been in place since 1971. The reef system is topographically complex with caves, overhangs, and vertical walls (Fig. 5). At the seaward edge of the reef it drops into a sandy bottom habitat. Tidal currents are strong at the seaward edge of the reef system where invertebrate communities flourish. Due to the complexity of the reef, systematic diver surveys are difficult.

Six scuba diver surveys were conducted at Aldinga Reef (Table 1). The surveys were not systematic in nature but rather involved pairs of divers swimming separately along the reef searching for harlequin fish until their bottom time limits had been reached. When a harlequin fish was located, its position on the reef was noted and attempts were made to photograph the LHS and RHS of the head. If any blue devils were sighted they were also noted and photographed. The total searching time (for both divers combined) on Surveys 1–6 was 360, 140, 310, 300, 260, and 170 minutes, respectively. The Aldinga Reef surveys were conducted to (1) provide further photographic records to assess the temporal stability of markings in harlequin fish, and (2) assess the suitability of the site for estimating the population size of harlequin fish and blue devils.

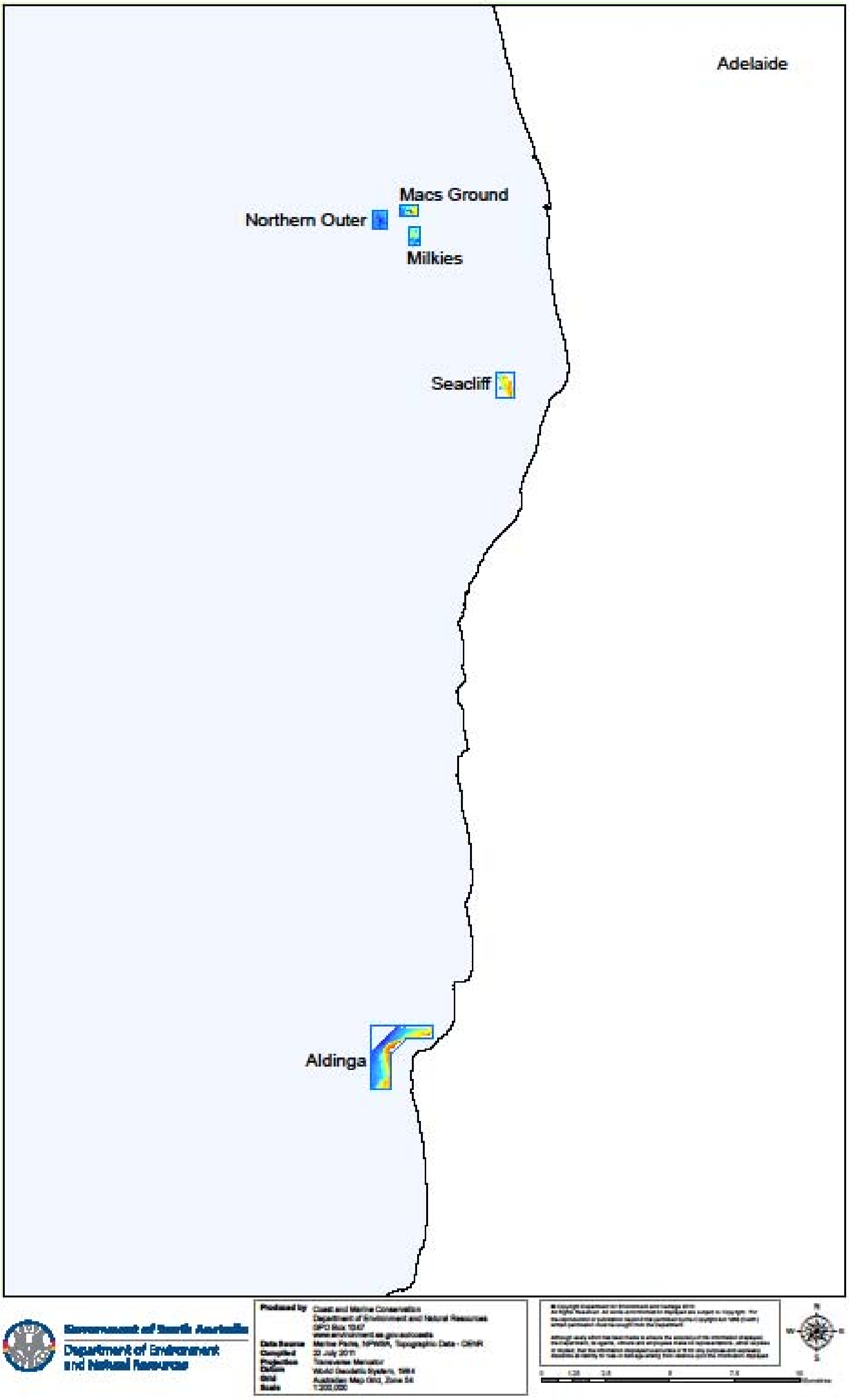

Figure 4. Locations of the five reefs off the coast of Adelaide in eastern Gulf St Vincent that were surveyed for blue devils and harlequin fish. The multi-coloured strips indicate benthic areas that were mapped using acoustic swath technology (see Figures 5–9).

Table 1. Sites and dates of surveys conducted for the southern blue devil and harlequin fish.

Site	Survey number							
	1	2	3	4	5	6	7	8
Aldinga Reef	22/12/09	16/2/10	21/5/10	24/2/11	25/2/11	4/3/11		
Seacliff Reef	9/2/10	24/3/10	12/5/10	13/5/10	6/12/10	14/1/11	10/2/11	7/4/11
Northern Outer	14/1/11	10/2/11						
Macs Ground	13/1/11	10/2/11						
Milkies	13/1/11	11/2/11						

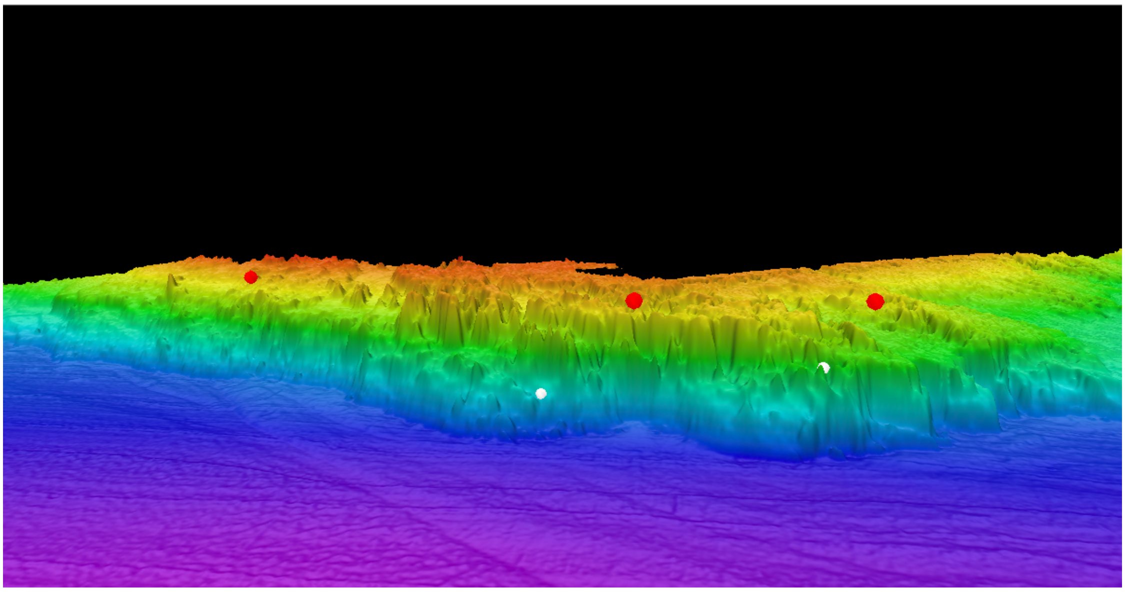

Figure 5. 3-D image of depth contours at Aldinga Reef 'Drop-Off' south of Adelaide. The colours grading from orange (shallowest, ~3 m) to purple (deepest, ~20 m) indicate depth as mapped by acoustic swath technology. The image is oriented as if looking from seaward (west) to landward (east). Diver surveys were conducted along the steepest sections of the reef (indicated by green and light blue colours) between the red dot to the left (north) and the red dot to the right (south). The middle red dot is where surveys were often commenced. The two white dots indicate roughly where two new harlequin fish were photo-marked.

Seacliff Reef surveys

Seacliff Reef is a subtidal reef located in ~12–15 m depth. The reef lies ~2 km offshore and ~15 km SW of the Adelaide CBD on the eastern side of Gulf St Vincent (Fig. 6). Seacliff Reef actually comprises a number of discrete sections of limestone that run in a N-S direction and that are separated by soft bottom habitat. The reef is a remnant of the coastline from ~10,000 years BP. The section of Seacliff Reef that I studied is at least 500 m long and comprises a series of ledges and caves with a relief of ~1–2 m above the adjacent sand to the east (Fig. 6). To the west, the reef merges back into sandy and seagrass habitat. The reef edge that has habitat suitable for blue devils (i.e. caves and crevices) varies in width from 1 m to ~20 m. The near-linear nature of the reef edge enables systematic searches along its length by a pair of adjacent divers.

Two preliminary trips to Seacliff Reef (29/01/2010, 02/02/2010) were conducted to position a series of 16 numbered star droppers (or markers) set at 20 m apart (= 300 m total length) in the sand immediately east of the reef edge (Fig. 6). The northern end of the array was ~50 m from the northern extent of this section of reef, while the southern extent of the reef was partly explored by divers but extended at least 200 m beyond the southernmost marker (Fig. 6). Systematic surveys of the entire 300 m marker array were then conducted on eight occasions between February 2010 and April 2011 (Table 1) using pairs of scuba divers to search for and attempt to photographically mark (photo-mark) all blue devils. Searches were also made for harlequin fish but none were sighted. While search effort was consistent across surveys, the actual time taken to complete each survey varied between 90–140 minutes depending on the underwater conditions (tides, water visibility) and the number of fish encountered (and thus the added time taken to photograph each fish).

When a fish was located, an attempt was made to photograph both sides of the head and particularly the gill cover region. A photographic catalogue (photo-catalogue) of the LHS and RHS of each successfully photo-marked individual was then created. The position of each fish along the reef was noted by assigning it to the nearest numbered marker. An estimate of total length of each fish was made to the following size class intervals: 0–5, 5–10, 10–15, 15–20, 20–25, 25–30, and 30–35 cm. Size estimates were periodically confirmed with the use of a hard rule placed next to a fish.

Population estimates were made using three methods: Lincoln-Petersen, pseudo-removal, and Schnabel (Greenwood and Robinson 2006). All three methods assume that the population is closed, which appears appropriate for this situation (see *Discussion* section). The Lincoln-Petersen method is one of the most basic population estimators requiring capture-mark-recapture data from just two surveys. The pseudo-removal and Schnabel methods utilise data from multiple surveys and are based on the premise that successive sampling surveys will result in progressively lower numbers of newly photo-marked fish. As a further test of the usefulness of conducting only two surveys to gain a useful estimate of population size, the Lincoln-Petersen method was calculated using two different data sets; one comparing Surveys 1 and 2, Surveys 1 and 3, Surveys 1 and 4, Surveys 1 and 5, Surveys 1 and 6, and Surveys 1 and 7 to see if estimates were consistent across the entire sampling period (14 mo), and another comparing subsequent pairs of surveys to see if estimates were consistent for surveys conducted across shorter timeframes of <2 mo (except for Surveys 4 and 5 which were conducted almost 7 mo apart).

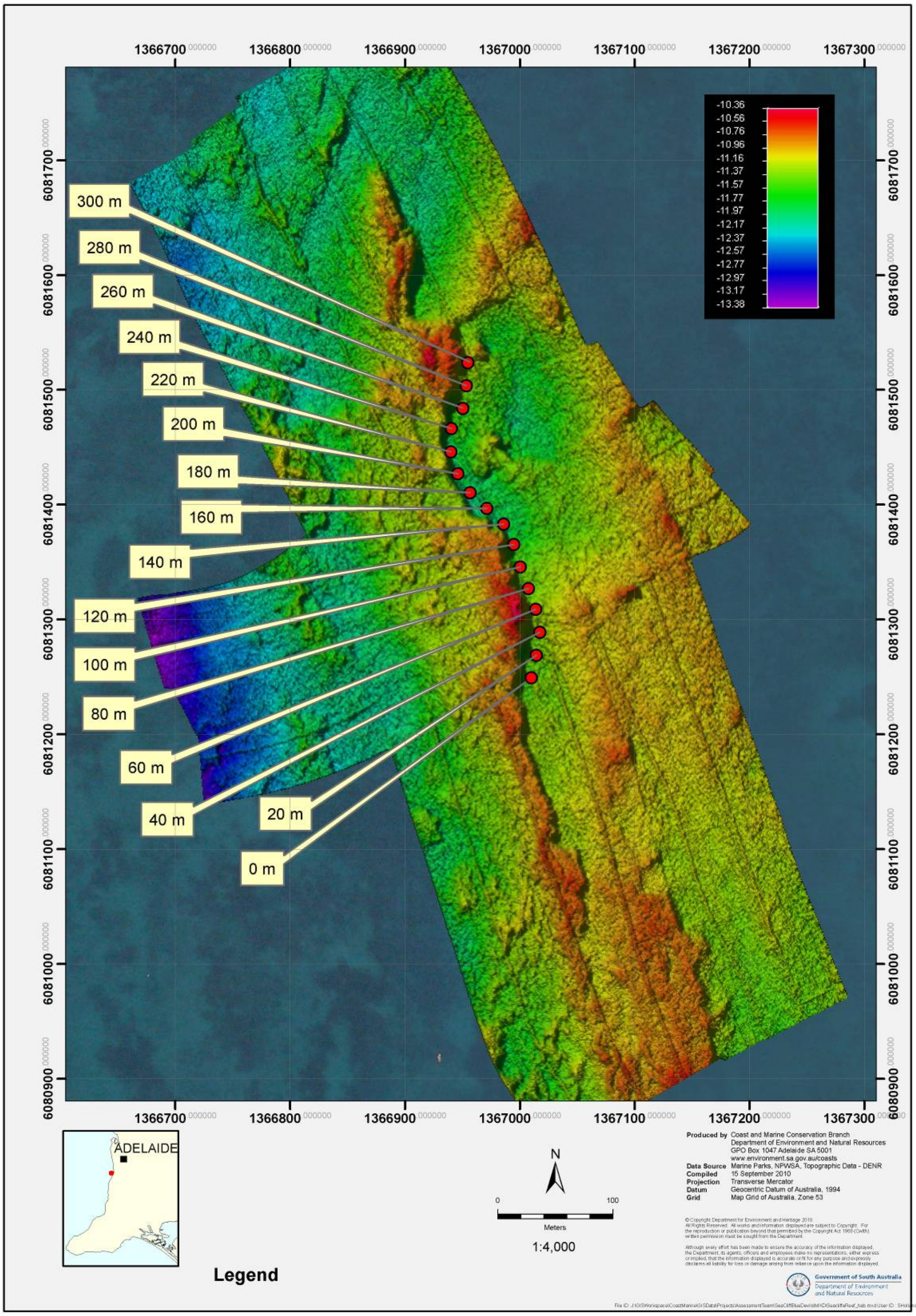

Figure 6. Location of 21 markers positioned every 20 m along a section of Seacliff Reef off Adelaide. The colours grading from red (shallowest) to purple (deepest) indicate depths (m) as mapped by acoustic swath technology. The reef edge inhabited by the blue devils has been highlighted by a black shadow to the east of the reef.

Northern Outer, Macs Ground, and Milkies surveys

Like Seacliff Reef to the south, Northern Outer, Macs Ground, and Milkies are all subtidal limestone reefs that are remnants of the coastline from ~10,000 years BP. Each of the three reefs lies ~5 km offshore and ~13 km SW of the Adelaide CBD on the eastern side of Gulf St Vincent (Fig. 4).

Northern Outer reef is located in ~20 m depth and runs in a N–S direction (Fig. 7). The section of Northern Outer that I surveyed is ~90 m long and comprises mainly a single almost unbroken ledge with a relief of ~1–2 m above the adjacent sand to the east. At the northern end of the surveyed section, the reef stops abruptly where it runs into sand, while immediately to the south-east of the surveyed section is a rubble bottom. To the west of the ledge is flat bottom reef covered in algae and invertebrates that eventually merges into sandy bottom.

Macs Ground reef is located in ~18 m depth and runs in an E–W direction (Fig. 8). The section of Macs Ground that I surveyed is ~120 m long and comprises mainly a single almost unbroken ledge with a relief of ~1 m above the adjacent sand and seagrass to the north. At the western end of the surveyed section, the high profile reef stops abruptly where it runs into sand and scattered rubble, while immediately to the east of the surveyed section is a rubble bottom. To the south the reef merges into sandy and seagrass habitat.

Milkies reef is located in ~18 m depth and runs in a N–S direction (Fig. 9). The section of Milkies that I surveyed is ~100 m long and comprises mainly a single almost unbroken ledge with a relief of ~1–2 m above the adjacent sand and seagrass to the east. At the northern end of the surveyed section, the reef stops abruptly where it runs into sand, while immediately to the south of the surveyed section is a rubble bottom. To the west, the reef merges back into sandy and seagrass habitat.

At all three sites, the reef edge that has habitat suitable for blue devils (i.e. caves and crevices) varies in width from 1 m to ~5 m. The near-linear ledge-like nature of the three reefs enables systematic searches along their entire length by divers.

Single droppers were placed at one end of each reef and a tape measure was laid out while a pair of divers surveyed for fish. The tape was used to document the position of each individual fish along the reef. Times taken to survey each section of reef were: Northern Outer ~20 mins, and Macs Ground and Milkies ~35 mins each. Each reef was surveyed twice, 27–29 days apart (Table 1). A population estimate was calculated for each reef using the Lincoln-Petersen method.

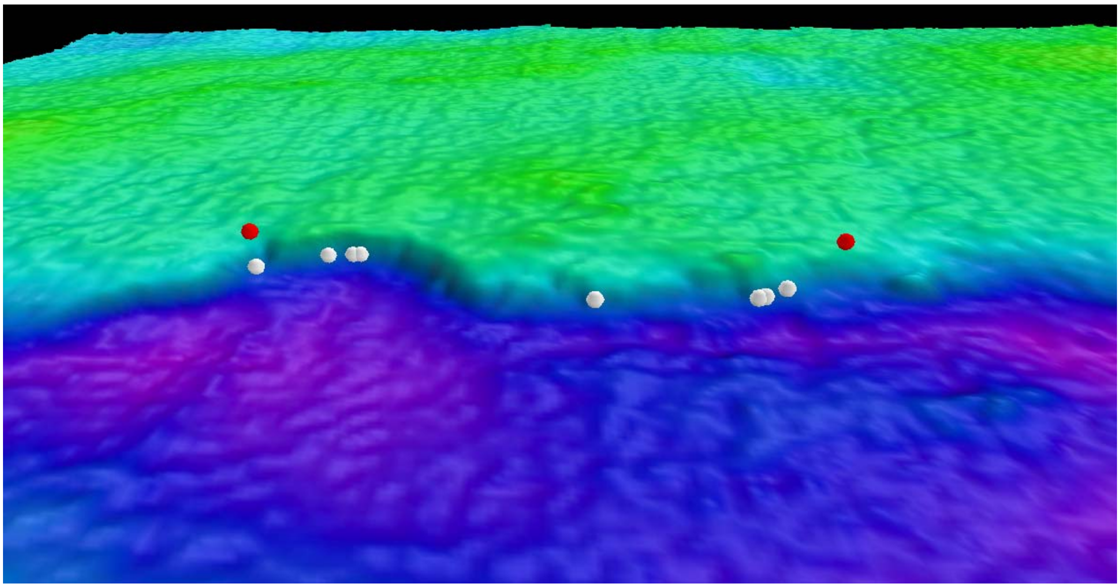

Figure 7. 3-D image of depth contours at Northern Outer reef west of Adelaide. The colours grading from green (shallowest, ~18 m) to purple (deepest, ~20 m) indicate depths as mapped by acoustic swath technology. The image is oriented as if looking to the west. Diver surveys were conducted along the section of reef between the red dot to the left (south) and the red dot to the right (north). The white dots indicate where each individual blue devil was first photo-marked (n = 8).

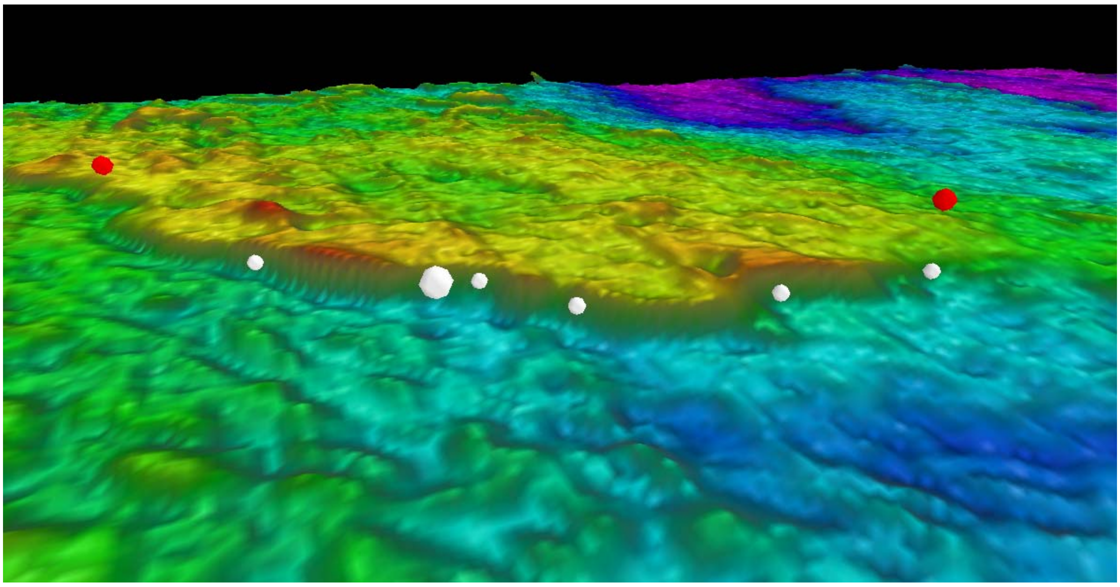

Figure 8. 3-D image of depth contours at Macs Ground reef west of Adelaide. The colours grading from red/orange (~16 m) to light blue (~18 m) indicate depths along the reef edge as mapped by acoustic swath technology. The image is oriented as if looking to the south. Diver surveys were conducted along the section of reef between the red dot to the left (east) and the red dot to the right (west). The white dots indicate where each individual blue devil was first photo-marked with the larger dot indicating that two fish were located at the same location (n = 7).

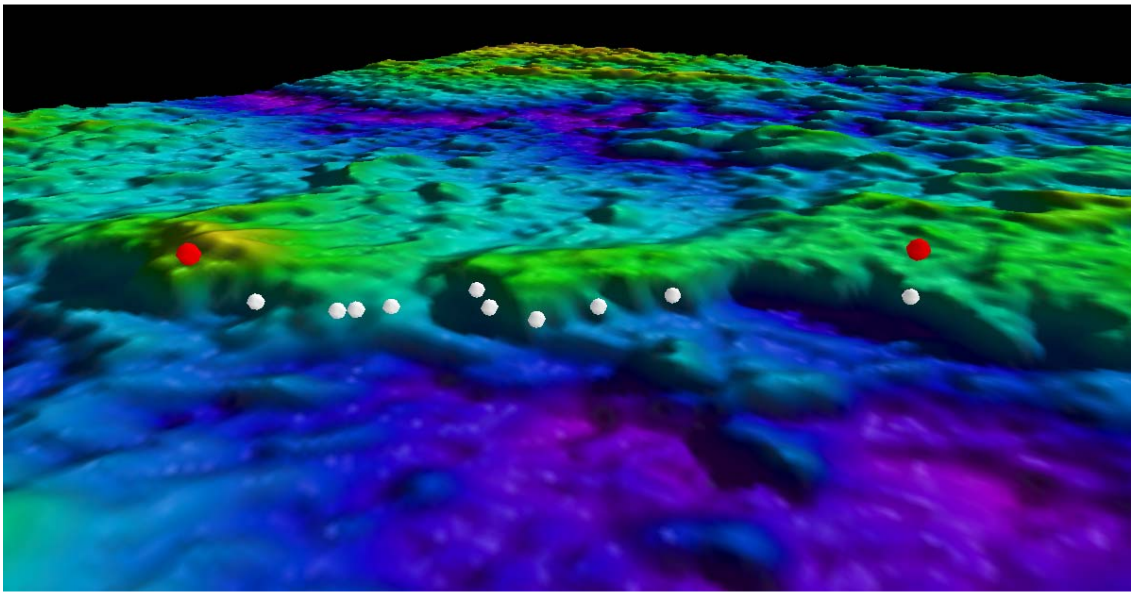

Figure 9. 3-D image of depth contours at Milkies reef west of Adelaide. The colours grading from light green (~16 m) to light blue (~18 m) indicate depths along the reef edge as mapped by acoustic swath technology. The image is oriented as if looking to the west. Diver surveys were conducted along the section of reef between the red dot to the left (south) and the red dot to the right (north). The white dots indicate where each individual blue devil was first photo-marked (n = 10).

Results

Historical photographic analyses

Two community divers in particular, Antony King and Paul Macdonald, were able to provide historical photographs of blue devils at a number of reefs off Adelaide dating back to 2005. From these photographs, several individual blue devils were photo-matched at the same reef across different years (e.g. Figs. 10–12). The longest period between photo-matches was 5 years (May 2005 to May 2010). Many individual devils were also photo-matched between different surveys across many months during the Seacliff Reef surveys (e.g. Fig. 13, see *Seacliff Reef surveys* below). There was some evidence that the markings in blue devils can change subtly across time-scales of years (e.g. Fig. 14). Nonetheless, the photo-matches confirmed that the natural markings on the operculum area were sufficiently stable in larger blue devils to enable their use in capture-mark-recapture population surveys. Despite extensive searches for historical photographs and six surveys at Aldinga Reef (see *Aldinga Reef surveys* below), only four individual harlequin fish were able to be photo-matched over time (two are shown in Figs. 15, 16). One of these fish was photographed at Aldinga Reef on six occasions: November 2007, October 2008, January 2009, December 2009, February 2010, and October 2010. Another fish was photographed on exactly the same ledge at Aldinga Reef on three occasions: May 2010, and twice in February 2011. A further two fish were photo-matched across 1 and 7 months, respectively, during a separate study on Kangaroo Island (Bryars, unpublished data).

From historical and more recent photos (see results of field surveys later), >100 different blue devils and >50 different harlequin fish have now been photo-catalogued across SA. Apart from photo-matches of the same individuals, all of the other fish can be readily separated using photo-ID. In some cases there may be superficial similarities between two individuals, but due to the high number of markings spread across each fish, it is always possible to find some distinguishing feature(s) of the markings to separate them.

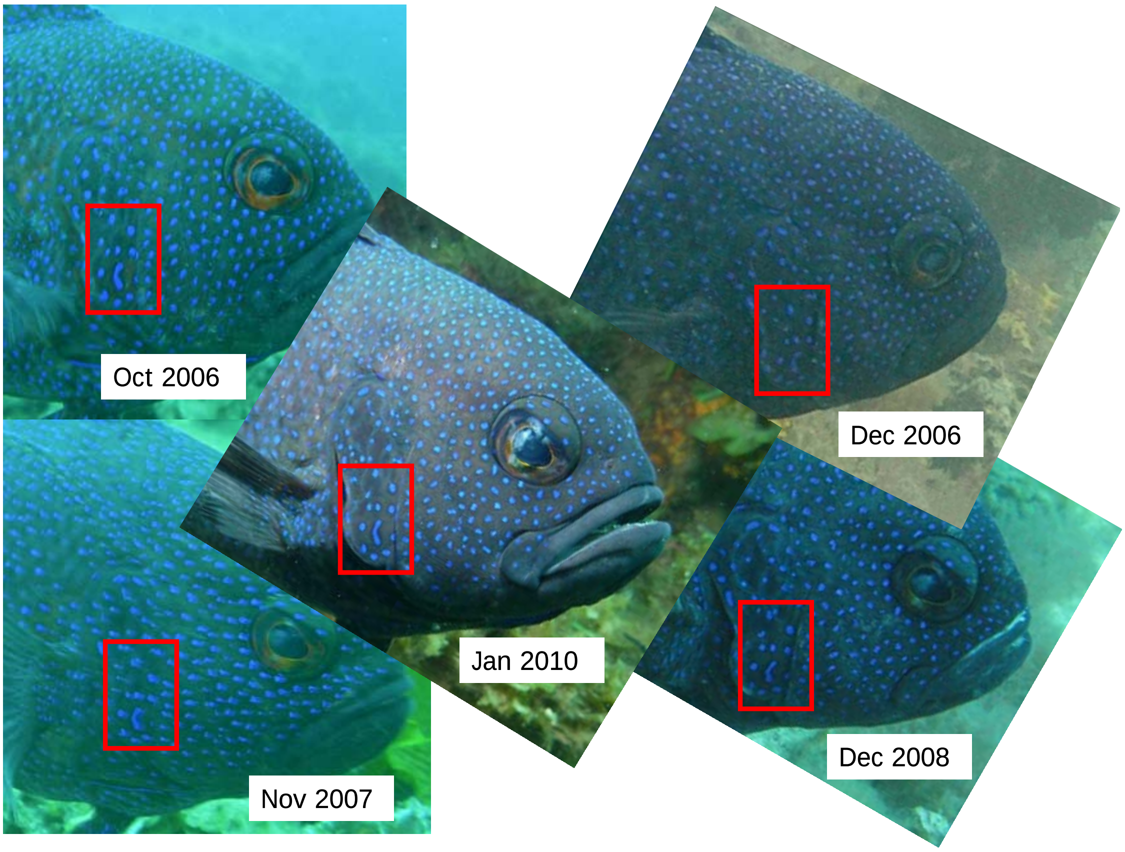

Figure 10. Time series photographs of the same blue devil at Seacliff Reef from 2006 to 2010. The inset boxes indicate the focus area for comparisons. Photographs: All by Antony King, except January 2010 by Simon Bryars.

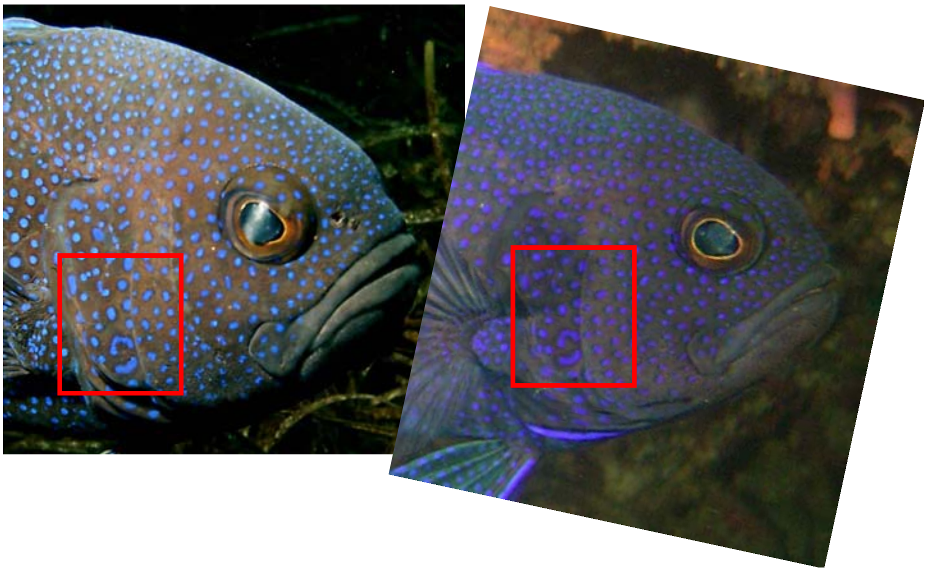

Figure 11. The same blue devil photographed at Macs Reef in February 2005 (left) and March 2006 (right). The inset boxes indicate the focus area for comparisons. Photographs: Paul Macdonald

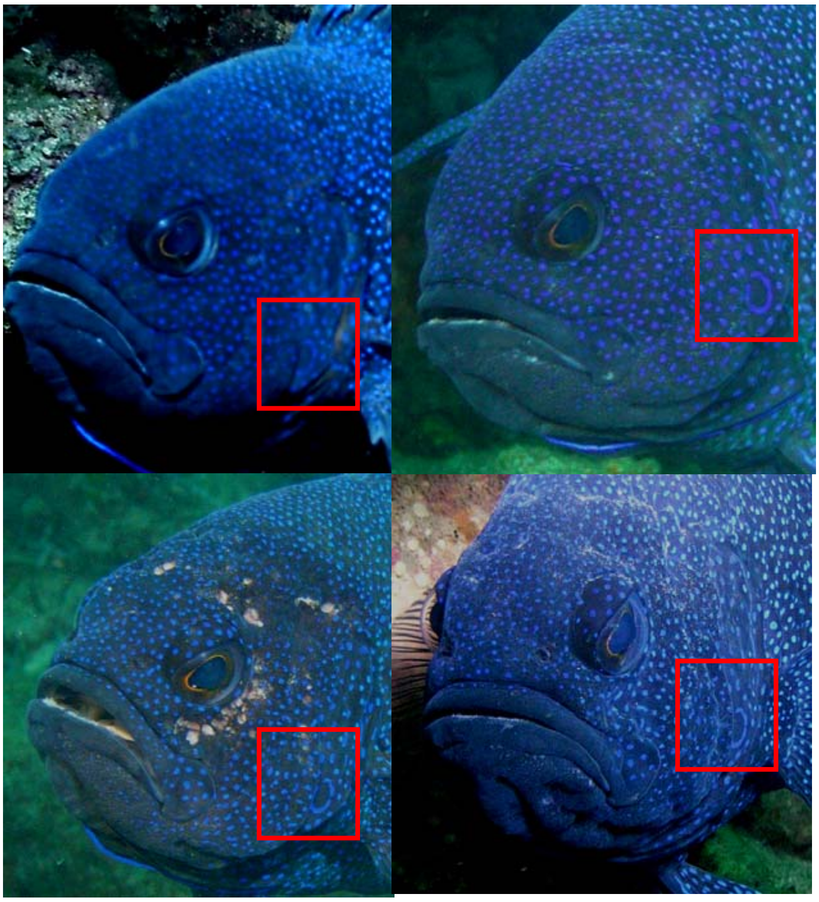

Figure 12. The same blue devil photographed at Seacliff Reef in May 2005, May 2006, April 2007, and June 2008 (from left to right, top to bottom). The inset boxes indicate the focus area for comparisons. Photographs: Paul Macdonald

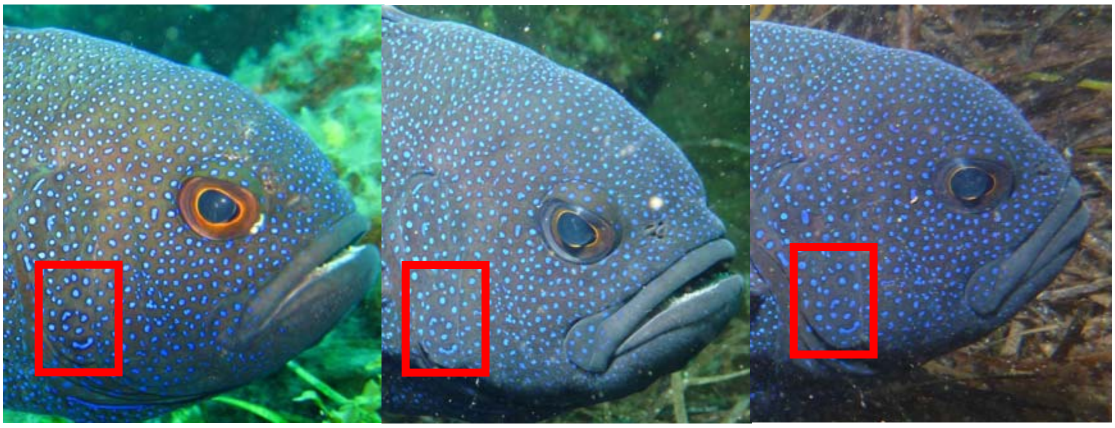

Figure 13. The same individual blue devil photographed at Seacliff Reef on Surveys 1–3 (left to right) during 2010 showing no change in markings on the operculum. The inset boxes indicate the focus area for comparisons. Photographs: Simon Bryars.

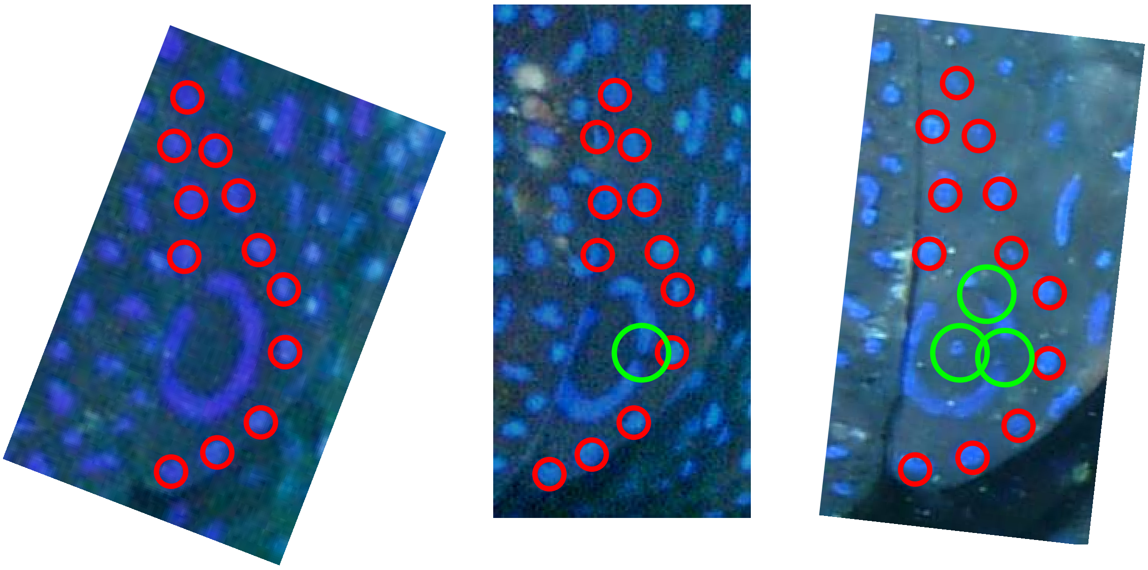

Figure 14. Close-up of the operculum of a blue devil photographed at Seacliff Reef in May 2006, April 2007 and January 2010 (from left to right), showing markings that were stable (red circles) and markings that changed (green circles).

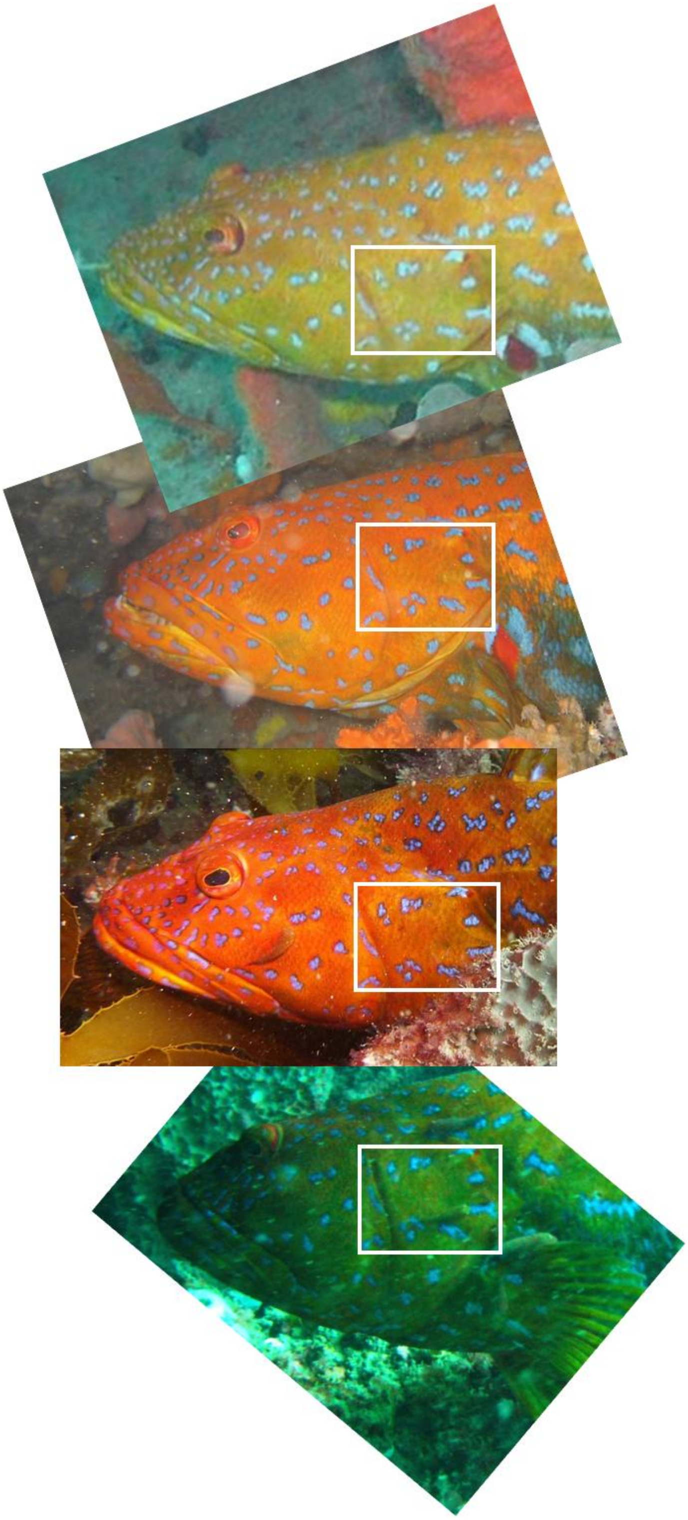

Figure 15. The same harlequin fish photographed at Aldinga Reef in October 2008, January 2009, December 2009 and October 2010 (from top to bottom). The inset boxes indicate the focus area for comparisons. Photographs (from top to bottom): Paul Bierman, Gary Doubleday, David Pearce, and Sam Owen.

Figure 16. The same harlequin fish photographed at Aldinga Reef in May 2010 (left) and February 2011 (right). The inset boxes indicate the focus area for comparisons. Note the western cleaner clingfish in the right-hand image. Photographs: Simon Bryars

Aldinga Reef surveys

From a total of 1540 minutes searching time, just six harlequin fish were sighted (two on Survey 2, one each on Surveys 3–6). Five of the sightings were made in the vicinity of the drop-off (~12–18 m depth), with the other sighting of a new fish in ~10 m depth to the east of the drop-off. Five of the six fish were reliably photo-marked and photo-catalogued. The harlequin fish from Survey 2 was photo-matched with the historical photo-catalogue and found to be the same individual as one previously sighted and photographed on the reef by community divers on five other occasions (see *Historical photographic analyses*). The new harlequin fish from Survey 3 was photo-matched with the fish from Surveys 4 and 5; on each occasion this fish was sighted on exactly the same rock ledge.

A total of six different harlequin fish have been photo-catalogued from community-supplied photographs and Surveys 1–6. Two of these fish were estimated by me to be ~50 cm TL, while one was ~40 cm TL. Numerous blue devils were also sighted across Surveys 1–6 and 48 of these were reliably photo-marked and catalogued. All of the blue devils were >15 cm TL. Due to the complexity of the reef and an inability to reliably resurvey the same section of reef on two separate occasions, it was not possible to generate a population estimate using the photo-ID capture-mark-recapture technique. Nonetheless, it is apparent that at least 48 blue devils are located along the reef.

Seacliff Reef surveys

A total of 41 blue devils were photo-marked across the eight surveys (Fig. 17). The number of new fish being photo-marked on each successive survey rapidly declined after Survey 2 (Table 1), and the total number of fish appeared to be reaching an asymptote (Fig. 17). The proportion of photo-recaptures from fish photo-marked on Survey 1 was relatively constant across successive Surveys 2–8 (Range = 0.45–0.72, Mean = 0.57; Table 2), indicating that the population was closed. The proportion of fish sighted on any given survey (assuming the total population is 41) ranged from 0.32 to 0.63, with a mean value of 0.49 (Table 2). There were very few fish on any given survey that were seen but not successfully photo-marked or photo-identified (Range = 0–5; Table 2).

Lincoln-Petersen calculations using pair-wise comparisons against Survey 1 gave a wide range of population estimates from 25 to 39 fish (Table 3, mean of 32 ± 3, 95%CI), which were all lower values than the minimum number of fish known to be in the study array (i.e., N = 41). The Lincoln-Petersen estimate from the first two surveys was 34 ± 6 (mean ± 95%CI, Table 3) fish which meant that the upper 95% CI of 40 fish was just below 41. However, other comparisons of subsequent pairs of surveys gave a wide range of estimates from 21 to 42 fish (Table 4). The only comparison that gave a higher value than 41 was that from Surveys 2 and 3 (N = 42, Table 4).

The pseudo-removal method gave a population estimate of 40 fish (Fig. 18), while the Schnabel method gave a population estimate of 39 fish (95% CLs 36–44); both of which were very close to the minimum number of fish known to be in the survey area (N = 41).

The majority of photo-marked fish were in the size classes of 20–25 and 25–30 cm (Fig. 19). No fish of <15 cm or >35 cm were either photo-marked (Fig. 19) or sighted during any of the dives. Almost all photo-marked fish were either recaptured next to the same dropper or one of the adjacent droppers from where they were initially photo-marked (three exceptions to this rule were fish that were captured and later re-captured once at a distance of two droppers away, i.e. 40 m). One individual was recaptured at the same dropper on all seven subsequent surveys. By using those fish that were recaptured at least three times, an estimate of home range length (linear distance along the reef) was made by multiplying the number of different droppers at which a fish was observed by a linear distance of 20 m per dropper. Home range length of reef was thus estimated at 33 ± 3 m (mean ± SE, n = 26). The spatial distribution of sightings along the reef was non-uniform with the southern half of the study array appearing to be home to a greater number of fish (Fig. 20), although it should be noted that some of these fish were sometimes photo-identified slightly to the south (~10 m) of the first dropper. On average there was 1.4 fish per 10 linear metres of reef (using N = 41 fish).

Table 2. Summary of photo-mark and photo-recapture data for blue devils at Seacliff Reef across Surveys 1–8 during 2010–2011. * assumes that total population = 41 and that fish sighted but not photo-marked/identified were different individuals to those photo-marked/identified on a given survey.

Parameter	**Survey number**								
	1	2	3	4	5	6	7	8	Mean
No. fish photo-identified	18	25	17	21	22	13	18	15	-
No. new fish photo-marked	18	12	4	2	1	1	1	2	-
No. fish already photo-marked from survey 1	-	13	9	12	10	7	13	10	-
Proportion of photo-recaptures from survey 1 out of the total no. fish photo-identified	-	0.52	0.53	0.57	0.45	0.54	0.72	0.67	0.57
Proportion of total population photo-identified	0.44	0.61	0.41	0.51	0.54	0.32	0.44	0.37	0.45
No. fish sighted	20	25	20	26	22	13	18	16	-
Proportion of total population sighted*	0.49	0.61	0.49	0.63	0.54	0.32	0.44	0.39	0.49

On four occasions divers observed what appeared to be a blue devil egg mass attached to the ceiling of a cave, and in each case there was a single fish that appeared to be tending to the eggs and displaying an aggressive posture towards the diver (see later). Two of these fish were observed in the study array on 8/2/10, one fish was seen to the north of the study array on 9/2/10, and the final fish was seen in the study array on 10/2/11.

Table 3. Estimates of population size (N) of blue devils at Seacliff Reef using the Lincoln-Petersen method when comparing Survey 1 with subsequent Surveys 2–8. M = number of fish photo-marked on initial survey, C = number of fish captured on next survey, R = number of fish captured on next survey that were re-captured from the initial survey (i.e. already photo-marked).

Parameter	Pair-wise comparison of surveys						
	1 vs. 2	1 vs. 3	1 vs. 4	1 vs. 5	1 vs. 6	1 vs. 7	1 vs. 8
M	18	18	18	18	18	18	18
C	25	17	21	22	13	18	15
R	13	9	12	10	7	13	10
N	34.3	33.2	31.2	38.7	32.3	24.8	26.6
Variance	10.1	22.4	9.5	28.9	30.5	3.1	8.4
95% CI	6.2	9.3	6.1	10.5	10.8	3.4	5.7

Table 4. Estimates of population size (N) of blue devils at Seacliff Reef using the Lincoln-Petersen method when comparing subsequent pairs of surveys. M = number of fish photo-marked on initial survey, C = number of fish captured on next survey, R = number of fish captured on next survey that were re-captured from the initial survey (i.e. already photo-marked). Survey 1 vs. 2 is shown in Table 3 and Survey 4 vs. 5 was not calculated.

Parameter	Pair-wise comparison of surveys				
	2 vs. 3	3 vs. 4	5 vs. 6	6 vs. 7	7 vs. 8
M	25	17	22	13	18
C	17	21	13	18	15
R	10	13	7	9	13
N	41.5	27.3	39.3	25.6	20.7
Variance	33.8	4.3	50.3	8.7	1.0
95% CI	11.4	4.1	13.9	5.8	2.0

Table 5. Estimates of population size (N) of blue devils at Northern Outer, Macs Ground, and Milkies reefs using the Lincoln-Petersen method with two separate surveys. M = number of fish photo-marked on initial survey, C = number of fish captured on next survey, R = number of fish captured on next survey that were re-captured from the initial survey (i.e. already photo-marked).

Parameter	Reef		
	Northern Outer	**Macs Ground**	**Milkies**
M	5	7	9
C	5	3	7
R	2	3	6
Cumulative no. fish	8	7	10
N	11.0	7.0	10.4
95% CI	5.9	0.0	1.5
No. fish / 10 m	1.2	0.6	1.0

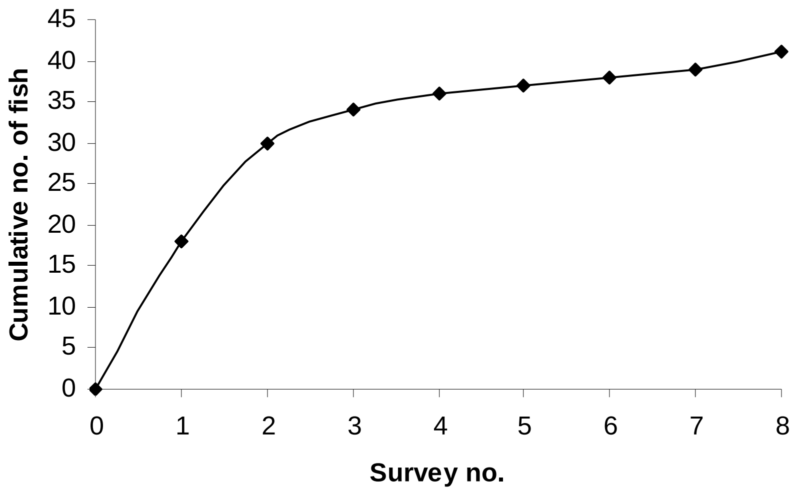

Figure 17. Cumulative and total number of blue devils photo-marked at Seacliff Reef on Surveys 1–8 during 2010–2011.

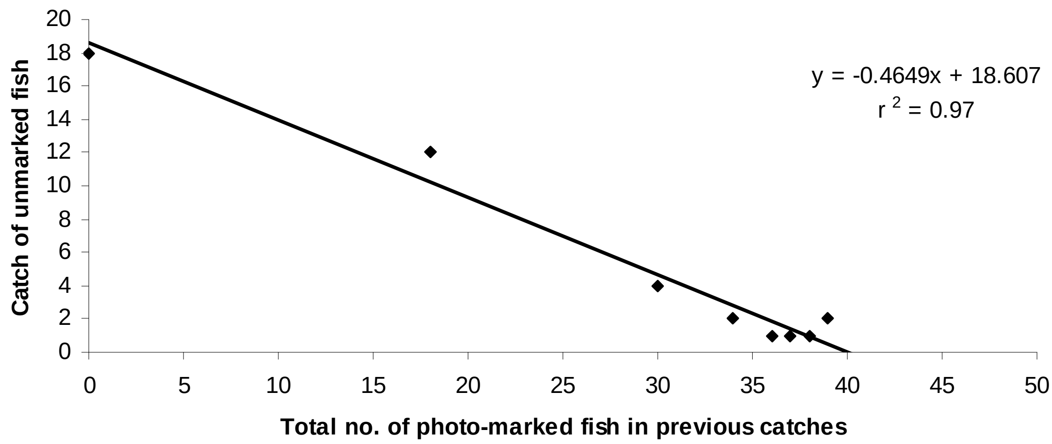

Figure 18. Estimate of total population size at Seacliff Reef using the pseudo-removal method. The intersection of the fitted regression line with the x-axis gives a total population estimate of N = 40 fish.

Northern Outer, Macs Ground, and Milkies surveys

Population estimates for the three deeper reefs were all <12 fish per site, with Northern Outer at 11, Macs Ground at 7, and Milkies at 10 (Table 5). No new fish were photo-identified on Survey 2 at Macs Ground (Table 3). All fish at the three reefs were between 15 and 35 cm TL (Fig. 21). All of the photo-recaptured fish were sighted within 20 m of the original location of photo-capture. On average, there were between 0.6–1.2 fish per 10 linear m of reef at the three deeper sites (Table 3), with fish spread out along the reefs (Figs. 7–9). No movement of fish was observed between these reefs or Seacliff Reef (i.e. no photo-matches of fish across reefs during the entire study).

On two occasions (once at Northern Outer and once at Milkies) during Survey 1 (13–14/1/11) divers observed what appeared to be a blue devil egg mass attached to the ceiling of a cave. In each case there was a single fish that was displaying aggressive behaviour or an apparently defensive posture towards the diver (e.g. Fig. 22). On Survey 2 (27 days after Survey 1) an attempt was made to find the egg mass seen at the Northern Outer site but it was no longer there.

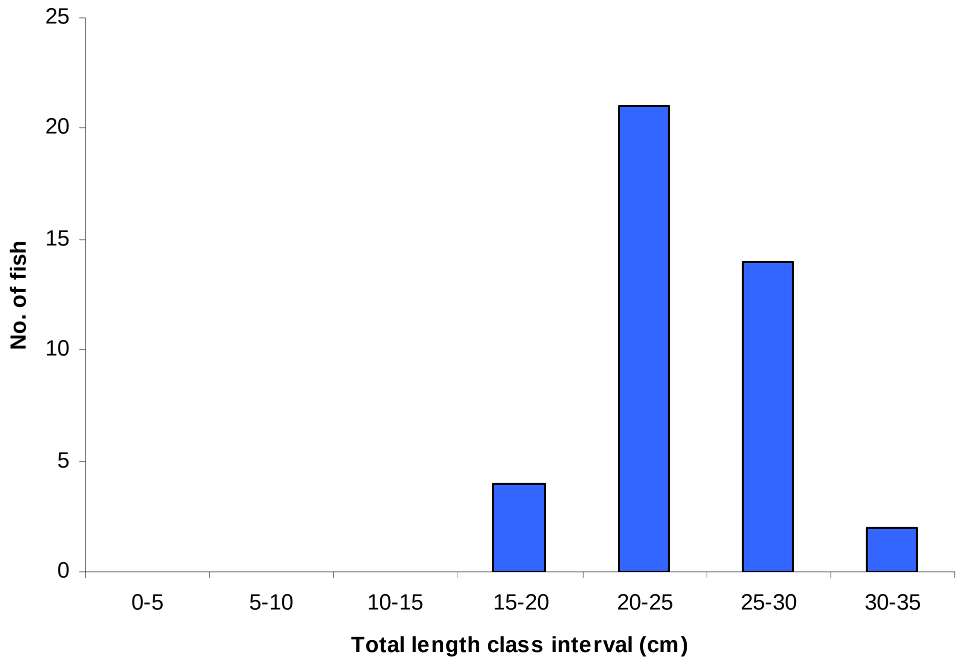

Figure 19. Size distribution of photo-marked blue devils at Seacliff Reef from Surveys 1–8 during 2010–2011.

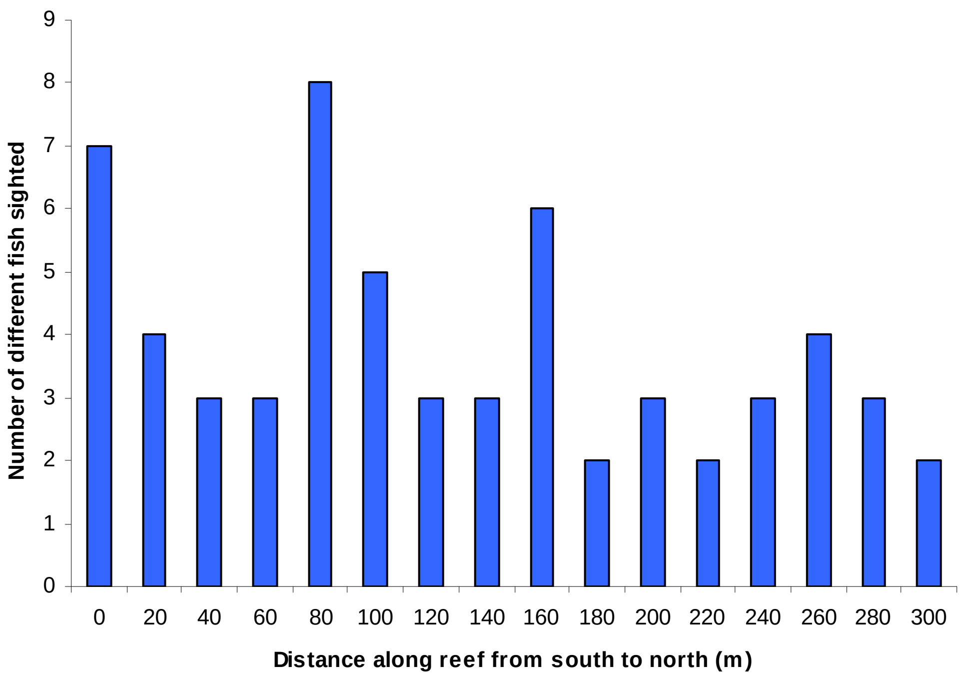

Figure 20. Spatial distribution of individual fish sightings along the length of Seacliff Reef from Surveys 1–8 during 2010–2011.

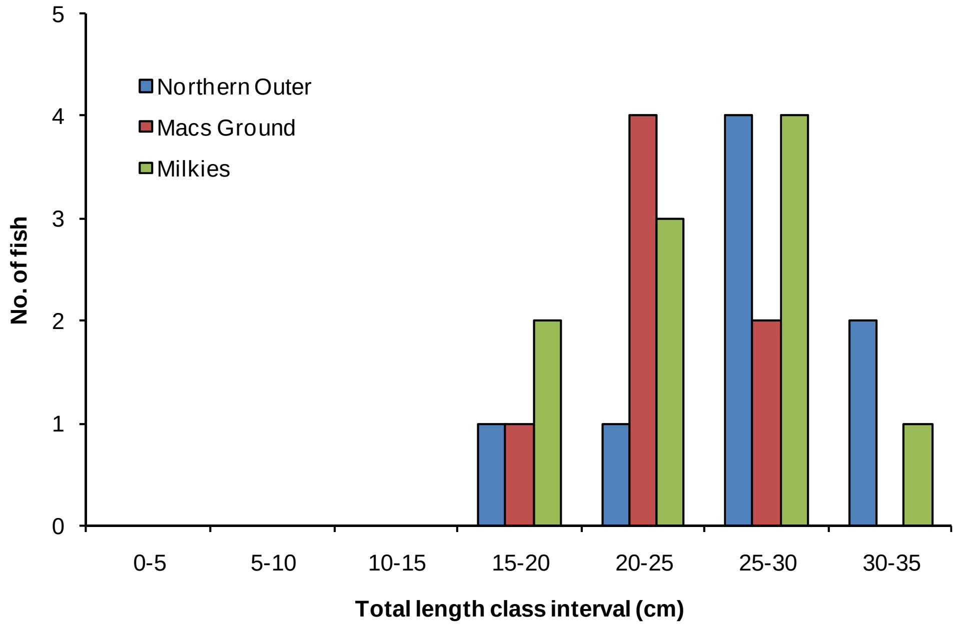

Figure 21. Size distribution of photo-marked blue devils at Northern Outer, Macs Ground, and Milkies Reefs from Surveys 1 and 2 during 2011.

Figure 22. An individual blue devil that appears to be guarding an egg mass attached to the ceiling of a cave at Milkies Reef on 13/01/2011. Note the flared gill cover and open mouth. Photograph: James Brook.

Discussion / Conclusions

Photo-ID

Photo-ID of individual fish was shown to be possible in larger specimens of both the blue devil and harlequin fish. The natural markings on the operculum/cheek of these species are sufficiently distinct and variable to allow identification by the human eye from photographs (and even in the field for some individuals, pers. obs.). Thus the blue devil and harlequin fish are amenable to capture-mark-recapture studies utilising photo-ID. The photo-ID technique proved to be possible even with poor quality photographs (e.g. out of focus, back scatter in water column, poor exposure), as long as the iridescent spots were discernible. Obtaining suitable photographs for photo-ID of blue devils and harlequin fish (and especially photographing both sides of the head) can at times be difficult and sometimes impossible if the fish flees or hides in a small cave. Nonetheless, on each of the eight Seacliff Reef surveys there were relatively few blue devils that were sighted yet unsuccessfully photo-marked/identified (Range = 0–5; Table 2). The use of historical photographs was highly useful as it provided an immediate outcome rather than tagging and monitoring fish for many years, and it also negated the need to tag individual fish (and thus risk injuring them).

Almost all of the blue devils photo-marked at Seacliff Reef were >20 cm TL, while the two harlequin fish with multiple photo-matches from Aldinga Reef were ~50 cm TL. As the growth curves of these two species indicate that growth slows markedly at >20 cm TL in devils and >40 cm TL in harlequins (see Saunders et al. 2010), it is likely that temporal changes in the pattern and shape of the iridescent markings may also slow down for these larger fish, i.e. the markings in larger fish are likely to be stable over many years. Indeed the markings of several blue devils changed little over many years. While there was some change in markings across years for one of the largest blue devils at Seacliff Reef, I was still able to photo-match this fish. It is possible that this fish was showing the effects of very old age or physical damage; historical photographs and personal observations during 2010 indicated that this fish was territorially aggressive and often had damage on its head. Indeed, this fish was not sighted again after Survey 4 and may have died, been chased out of the area by other fish, or been captured by fishers. While only four harlequin fish could be photo-matched across time in the current study, it is apparent that the markings in this species are also temporally stable.

Population estimates and demography of blue devils at Seacliff Reef, Northern Outer, Macs Ground, and Milkies

Photo-ID was successfully used in a capture-mark-recapture exercise for estimating the population size of blue devils at Seacliff Reef, Northern Outer, Macs Ground, and Milkies. The estimates of population size assumed that the populations at the four sites were closed, i.e. there were no births, deaths, immigration, or emigration. Due to the apparently high site fidelity of individuals it is unlikely that significant numbers of blue devils moved into or out of the any of the four reef sites during the study period (especially the deeper sites which surveyed twice just 2 mo apart). In addition, due to the size range of fish encountered, and their known slow growth rate and high longevity, it is highly unlikely that any new juveniles entered the reefs or that significant numbers of older fish died of natural causes during the study period (apart from the fish mentioned earlier). However, due to the high recreational fishing activity at the Seacliff Reef site (pers. obs.) it is possible that some mortality occurred from fishing, and the cumulative number of new marked fish at that reef suggests that a few new fish may have entered the array over the 14-mo study period (Figs. 17, 18) Nonetheless, supporting the notion that the Seacliff Reef population was closed are the relatively stable values for the proportion of marked fish on subsequent surveys after the first survey (Table 2). If the population was open then the proportion of marked animals on successive occasions would decline (Greenwood and Robinson 2006). Furthermore, additional surveys and photo-ID cataloguing of eight individual fish to the north and south of the Seacliff Reef study array indicated that none of these fish moved into the array over the study period.

Capture-mark-recapture techniques often assume that all animals in a population have the same probability of recapture (Greenwood and Robinson 2006). In the present study it was evident during the Seacliff Reef surveys that the smaller devils were sometimes shyer than larger fish, and there were also several larger fish that usually approached divers and were therefore photo-identified on most of the surveys. The survey technique that I used involved searching for fish that were both out in the open and hidden in caves/crevices, which would have reduced the bias towards photo-marking/identifying only larger or bolder fish that were out in the open. Survey effort was also kept relatively constant between each survey, which is important in census methods (Greenwood and Robinson 2006). However, it appears that the probability of capturing each individual was not the same and that this affected the population estimates using the Lincoln-Petersen method which were below the minimum population size (see discussion below). The sample sizes were also sufficiently low such that chance events of sighting or missing a few marked fish would have affected the Lincoln-Petersen estimates.

While I had hoped to determine the absolute population size through repeated sampling at Seacliff Reef, this did not occur as two new fish were found on the final survey. Assuming that the new fish on the later surveys were not immigrants, it is apparent that the minimum population size was 41 fish. The estimates of population size using the Lincoln-Petersen method gave values of 25–39 fish which were clearly underestimates, while the pseudo-removal and Schnabel methods gave better estimates of 40 and 39 fish, respectively. While the population estimates using the Lincoln-Petersen method were underestimates, the mean estimate (N = 32) and the first estimate from Surveys 1 and 2 (N = 34) each accounted for around 80% of the total population, which was markedly higher than any estimates that would have been counted using a single standard fish count. For example, on average ~50% of the total population of blue devils was unaccounted for on any given survey at Seacliff Reef (Table 2, this assumed that the total population was 41). Thus it is apparent that a traditional survey technique of counting fish along a transect line would on average have underestimated the total population size by around half.

While underestimation is inherent in fish count surveys (Edgar et al. 2004), for comparative usefulness, it is important that the proportion sighted out of the total population number is relatively constant between surveys. For species such as the western blue groper which have differing periods of emergence during the day for some size classes (Shepherd 2005), the time of day would thus influence counts. While we currently have no data on how emergence may vary over a 24-hour period in the blue devil, it was apparent that the proportion of the total population sighted did vary between the eight surveys (32–63%). Such variability needs to be accounted for in comparisons of relative abundance between sites using a standard fish count technique. Anecdotal observations by the author suggest that tidal flow and ambient light may be significant factors in the emergence (and thus chance of being sighted) of blue devils. One final point to note is that Seacliff Reef is a popular recreational dive location, and it is possible that some of the fish have become accustomed to divers. Thus the proportion of the total population that is emergent during surveys at Seacliff Reef may be different at this site compared to sites where diving is less common.

The population estimates at Northern Outer, Macs Ground and Milkies were all relatively low (range of 7 to 11). It is likely that the calculation (and thus accuracy) of these population estimates would have been influenced by the very small initial capture-mark sample sizes. Nevertheless, it is apparent that there are relatively few blue devils at these deeper reefs.

The lack of blue devils of >35 cm TL at any of the reefs was to be expected as the maximum size of the species is just 36 cm (Hutchins and Swainston 2002). However, the complete lack of fish <15 cm was unexpected and remains unexplained at this stage. Anecdotal observations suggest that blue devils attach eggs to rock surfaces inside caves and that the parents guard the eggs (Gomon et al. 2008, Bryars this report) and possibly even the young (Baker 2010). Given such a life history strategy (and the slow growth rate of blue devils) then I would have expected to observe some juveniles at the five reefs. Possible explanations for the lack of juveniles include, (1) the survey technique failed to locate them, (2) juveniles utilise different habitat or reefs to the adults, (3) larval fish are transported away from their natal reefs, (4) there has been repeated recruitment failure, (5) breeding and recruitment are naturally infrequent, (6) there is high juvenile mortality, and/or (7) juveniles are forced out of the area due to the effects of density-dependence. The first explanation seems unlikely given the intensive searching effort that was conducted along the five reefs. The second explanation is also unlikely as observations by other divers indicate that juveniles can occupy the same types of habitat as the adults, and juveniles are sometimes seen in the same caves as adults (Baker et al. 2009b, pers. obs., D Pearce pers. comm.). All of the remaining explanations appear plausible but are untested. Nonetheless, given the longevity, low population sizes, and territorial nature of the species it is unlikely that recruitment occurs (or needs to occur) on an annual basis. In addition, observations of juvenile fish appearing at new artificial reefs (e.g. ex-HMAS Hobart off Fleurieu Peninsula) suggest that larval dispersal does occur and may provide a means of colonising new areas; something which is unlikely to be achieved by larger fish once they become site-attached.

Which technique to use for estimating population size of blue devils?

Results from the various surveys of blue devils at the four reefs off Adelaide raise the question as to which technique is most appropriate to use for estimating population size of blue devils? In this context, there are several points to note: (1) if only a single traditional fish count survey is possible then the population size will be significantly underestimated, (2) if the ability exists to do two subsequent surveys then the photo-ID capture-mark-recapture technique allows a better population estimate to be generated, but it will still likely be a slight underestimate, and (3) if the ability exists to do >2 surveys using the photo-ID capture-mark-recapture technique then an even more accurate population estimate will be determined, but determining the absolute population size may still prove to be elusive. If using two or more surveys with photo-ID, then the accuracy of the population estimate will undoubtedly be improved if the initial number of fish captured and marked is maximised. However, this is not always possible on small reefs with small population sizes, and even on larger reefs there will be a trade-off between increasing the area of reef searched and the quality of the search effort (unless search time is not a logistically-limiting factor – which it normally is in ecological studies). Conversely, small discrete reefs with apparently small population size (such as Milkies) have the advantage that a photo-catalogue that is added to with multiple surveys (or opportunistic community records – see later) could eventually determine the absolute population size and structure.

Harlequin fish populations

Data on harlequin fish were very limited. While harlequin fish have been sighted previously by community divers at Seacliff Reef and other Adelaide metropolitan reefs further to the north (Bryars, unpublished data), none were sighted at Seacliff Reef, Northern Outer, Macs Ground or Milkies during the present surveys. At Aldinga Reef, only three different harlequin fish were sighted from ~800 minutes of diver searching effort. Comparison with data from reef fish surveys in some parts of SA (e.g. NE Kangaroo Island, Edgar et al. 2006, Bryars pers obs.; St Francis Isles, Shepherd and Brook 2003) indicates that the density of harlequin fish on Adelaide's metropolitan reefs is relatively low. Whatever the population size of harlequins actually is at these reefs, the low rate of encounters prevented the use of systematic surveys to derive population estimates for these locations. The technique still requires further testing at a location with higher numbers of harlequin fish (e.g. Kangaroo Island).

Site fidelity of blue devils and harlequin fish

Blue devils showed strong site fidelity and estimates of home range length were accordingly very small. It was evident that some of the fish were also territorial as I sometimes observed conflicts between individuals where a fish was chased out of an area, and some of the larger fish 'attacked' divers in their area. It appeared that some of the larger fish had a dominant role, and it is possible that there was some social group structure as I sometimes observed two devils in the same cave, but most often observed single fish in caves or out in the open. More formal observation and testing of their social behaviour are warranted.

While population estimates were not possible for harlequin fish, the use of the photo-ID technique is useful for deriving data on site fidelity in this species. For example, one individual harlequin fish has now been resighted on five occasions over a 2-year period at Aldinga Reef, indicating that either it resides permanently there or it frequently re-visits the site. The coral trout, *Plectropomus leopardus*, which is a similarly-sized and shaped member of the Serranidae family (but which is found in the tropics) appears to range over several kilometres of reefs as a mobile, opportunistic predator, but also maintains home sites for access to shelter and cleaning stations (Samoilys 1997). It is possible that the harlequin fish has a similar habit in temperate southern Australian waters and occupies a similar ecological role to *P. leopardus*. Appropriate studies (such as acoustic tracking) on the harlequin fish are required to test this theory[1].

Other natural history observations

Whilst undertaking the photo-ID aspect of the project, some other observations on the behaviour and life history of the harlequin fish and blue devil were also made; possible blue devil egg masses, likely aggressive/defensive postures in blue devils, and cleaner fish on harlequins and blue devils.

Members of the Plesiopidae family (which includes *P. meleagris*) apparently all possess demersal eggs held together by adhesive threads (Mooi 1990). Southern blue devils are purported to attach their egg masses to rock surfaces, usually inside narrow vertical crevices where a pair of adults guards them (Gomon et al. 2008). All of the apparent egg masses that were observed during the present study were attached to the ceiling of a cave with a single fish apparently defending it. This scenario is similar to what has been reported for the eastern blue devil in which an egg mass is attached to the ceiling of a cave where a male defends it (NSW DPI 2006). In five of the six cases the fish remained stationed with the egg mass touching its dorsal fin (or just above it) and the gill covers noticeably flared (e.g. Fig. 22). In the other case, the fish moved repeatedly away from the egg mass and towards the diver

[1] Subsequent acoustic tracking research by the author has demonstrated that harlequin fish are site-attached with relatively small home ranges.

in an aggressive manner. All of the apparent egg masses in the present study were observed during January and February; eastern blue devils are known to spawn during the warmer months. Nonetheless, despite the strong indications that blue devil egg masses were seen in the present study, egg samples and larval rearing are required to confirm their identity as blue devil eggs[2].

An apparently aggressive/defensive posture was observed on several occasions whereby the lower sections of the gill covers were flared downwards (Fig. 23), and sometimes the mouth was opened (Fig. 22). As most of the blue devils (> 95%) that were observed and photographed throughout the study were not displaying these traits, this behaviour must be viewed as atypical. On one occasion during May at Aldinga Reef two fish that were clearly 'paired' made aggressive approaches towards a diver, displaying flared gill covers and fully extended fins (Fig. 24). It is unclear why these fish were behaving this way but they may have been courting or defending an unseen egg mass or juvenile fish. Other fish that appeared to be paired were also occasionally seen inside caves during the study, but the vast majority of fish (> 95%) were observed as single fish.

At least eight of the photo-records of harlequin fish from different times at Aldinga Reef showed one or more western cleaner clingfish (*Cochleoceps bicolor*) on the head and body of the host. Western cleaner clingfish can remove small parasites from fishes and are known to set up cleaning stations amongst prominent sponges (Shepherd et al. 2005, Edgar 2008, Gomon et al. 2008). The harlequin fish that was sighted three times on exactly the same rock ledge at Aldinga Reef could have been occupying a fish cleaning station as each time it was being tended by several clingfish (see Fig. 16) and this location had several large sponges. Western cleaner clingfish were very occasionally seen on blue devils.

Potential advantages of photo-ID capture-mark-recapture over other techniques
The development of a robust photo-ID capture-mark-recapture technique for the blue devil and harlequin fish has several potential advantages over other fish survey techniques. Firstly, traditional population censusing techniques are unlikely to provide statistically rigorous data for blue devils and harlequin fish. For example, in diver fish surveys conducted in South Australia, scores are usually zero or a maximum of just 1 or 2 individuals per transect line (generally of 5 or 10 m width x 50 m length; e.g. Shepherd and Brook 2003, Edgar et al. 2006, Brock and Kinloch 2007, Baker et al. 2009b, Shepherd et al. 2009). Even in Western Australia where harlequin fish are reportedly more common than in SA (Baker et al. 2009b), Hutchins (2001) scored maximum abundances of just 2–5 harlequin fish during 45–60 minute scuba swims. Such low counts for blue devils and harlequin fish could be due to a number of factors including (1) their numbers are truly low, (2) fish are being missed because they are hidden in caves, or (3) in the case of harlequin fish, individuals are being missed because they are well camouflaged even when out in the open. Another potential problem with traditional diver surveys is that harlequin fish are often inquisitive (Kuiter 1996, Gomon et al. 2008, Edgar 2008, Bryars pers. obs.) and may follow divers during underwater operations (Edgar 2008); thus leading to the possibility of double-counting.

[2] Subsequent research by the author during January-March 2012 has confirmed that the egg masses are in fact those of the southern blue devil.

Figure 23. An apparently aggressive/defensive posture of a blue devil with the lower part of the gill cover extended downwards. Photograph: Simon Bryars.

Figure 24. An apparently aggressive display from a pair of blue devils with the fish in the foreground showing flared gill covers and fully extended fins. Photograph: David Pearce.

While the use of BRUVS is becoming increasingly used for benthic fish surveys and is very successful for some species, it is unlikely to be of great value for blue devils and harlequin fish. Blue devils are unlikely to be attracted by baits any great distance away from their shelter using BRUVS, and while harlequin fish have been detected using BRUVS, in the case of Kleczkowski et al. (2008) the numbers were too low for statistical comparisons, and the relative abundance recorded by Kendrick et al. (2005) was too low to contribute substantially to multivariate analyses of fish assemblages (even though the study was conducted in a region of Western Australia which is renowned for harlequin fish).

In contrast to the fish survey techniques described above, the photo-ID capture-mark-recapture techniques developed here offer the following potential advantages: (1) population size can be estimated, (2) population estimates will be sufficiently large and reliable to be statistically useful, and (3) double-counting is negated. Knowing the population size is critical from a conservation perspective as it is possible that the numbers of blue devils and harlequin fish are much greater than is generally perceived by divers, fishers, and the conservation sector. Conversely, numbers may actually be low and there may well be real cause for conservation concern for these two species.

Conservation concerns

Without comparative survey numbers in similar reefs away from Adelaide (which do not experience heavy fishing pressure or land-based pollutants) it is not possible to state whether the densities of blue devils at the four metropolitan reefs are what would be expected on an unfished reef, i.e. they may already have undergone population declines due to fishing and/or habitat degradation. However, given that fishing pressure is high at these sites and that blue devils will take a baited hook, it is somewhat surprising that any devils remain there at all. Possible reasons for this are that any captured fish are released alive and/or that the devils have learned to not take a baited hook. Recreational line fishers do not deliberately target blue devils and usually release them upon capture (pers. obs.). However, blue devils do suffer from barotrauma when caught on line (pers. obs.) and their post-release survival may be low. It is possible that the relatively shallow depth of Seacliff Reef is aiding post-release survival at that location, but for the deeper metropolitan reefs barotrauma is likely to be of greater concern.

The very small population sizes and bias towards larger, older blue devils at the three deeper reefs off Adelaide makes these sites intrinsically vulnerable to localised extinctions from activities such as fishing and aquarium collection. Blue devils currently have no protection in SA, yet their longevity and site-attachment means that if blue devils are removed from a site, it will take many years (and possibly decades) for larger older fish to repopulate the area. Given that there is a complete lack of small juveniles (<15 cm TL) at all of the reefs, repopulation would most likely rely on recolonisation via larval settlement from fish spawned on other reefs.

The Northern Outer, Macs Ground and Milkies reefs are all important sites for Adelaide’s recreational diving community and the ability to view blue devils in relatively shallow water (<20 m) that is in close proximity to Adelaide is one of the drawcards for these sites. Possible options for improving the protection for blue devils at these sites include: (1) total protection of blue devils off Adelaide’s metropolitan coast, (2) improved education about protecting blue devils (e.g. Baker 2011), and (3) introduction of no-take zones over these reefs. The first option would stop aquarium collection, but would not stop inadvertent capture by line fishers. However, if protected, any captured fish would need to be returned to the water immediately whereupon the success of protection would be dependent on the rate of post-release survival; the second option of education would assist here. The third option appears untenable as none of the reefs occur within existing marine parks or aquatic reserves, and the reefs are also popular recreational fishing grounds – indeed all of the reefs were discovered and named by local fishers. Significantly though, the high site fidelity and small home ranges of blue devils do make them very amenable to complete protection within no-take sanctuary zones in other areas across SA's new system of 19 marine parks.

Ongoing monitoring of blue devils and harlequin fish with community input
With ongoing submission of photos by community divers and the maintenance of a photo-catalogue the following benefits may be realised:

- Population size and structure of blue devils at Adelaide's reefs can be monitored for long-term (years) changes.
- Absolute population size and structure of blue devils at the smaller discrete reefs (Northern Outer, Macs Ground, Milkies) may eventually be determined.
- Recruitment events of juvenile blue devils (which may occur only every few years) can be monitored.
- Long-term site fidelity data of harlequin fish and a cumulative population count at Aldinga Reef can be collected.
- Community ownership of local reefs can be fostered.

Ultimately it is hoped that this project can be continued and expanded to other reefs off Adelaide and around South Australia, including reefs within marine parks. Once fully developed, it is envisioned that the photo-ID capture-mark-recapture technique will enable long-term ongoing community monitoring of blue devils and harlequin fish in the more accessible and popular dive sites around South Australia. It is highly likely that some individual fish have been living on the same reefs for many years and possibly even decades – given that the blue devil lives to at least 59 years and the harlequin fish to at least 42 years (Saunders et al. 2010).

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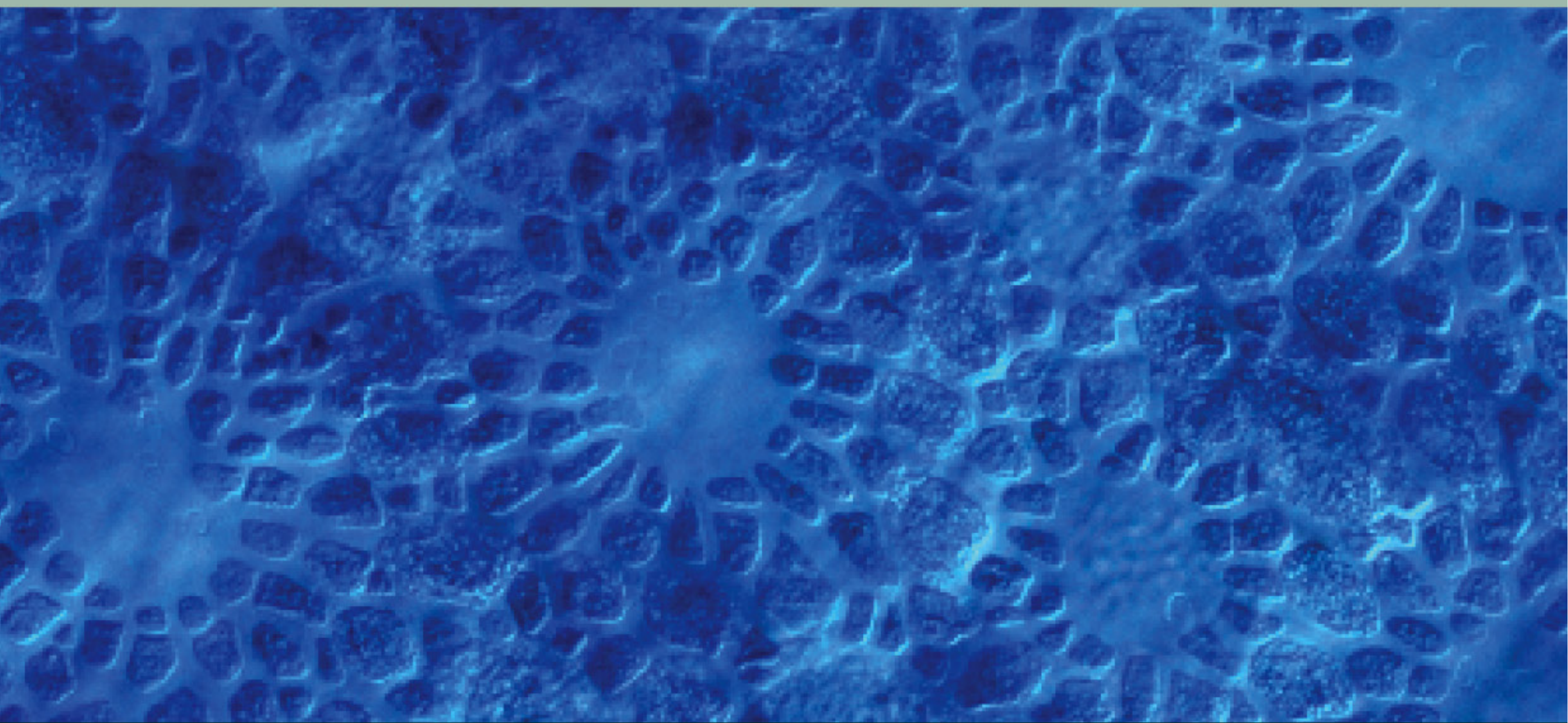

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