

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



Simon Bryars

September 2010

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



**Government of South Australia**  
Department of Environment  
and Natural Resources

This publication may be cited as:

Bryars, S. (2010) Monitoring marine fishes of conservation concern on Adelaide's coastal reefs: results of 2009/2010 surveys for the southern blue devil and harlequin fish. Report to the Adelaide and Mount Lofty Ranges Natural Resources Management Board. Department of Environment and Natural Resources. 29 pp.

Department of Environment and Natural Resources  
1 Richmond Rd  
Keswick SA 5035

Cover photographs: Top – Southern blue devil, *Paraplesiops meleagris*. Bottom – Harlequin fish, *Othos dentex*. Photo credits: Simon Bryars

**For further information please contact:**

Department of Environment and Natural Resources  
Phone Information Line (08) 8204 1910, or  
see SA White Pages for your local  
Department of Environment and Natural Resources office.

Online information available at: <http://www.environment.sa.gov.au>

**Restrictive Licence**

© State of South Australia through the Department of Environment and Natural Resources. Apart from fair dealings and other uses permitted by the Copyright Act 1968 (Cth), no part of this publication may be reproduced, published, communicated, transmitted, modified or commercialised without the prior written approval of the Department of Environment and Natural Resources.

Written requests for permission should be addressed to:  
Design and Production Manager  
Department of Environment and Natural Resources  
GPO Box 1047  
Adelaide SA 5001

**Disclaimer**

While reasonable efforts have been made to ensure the contents of this publication are factually correct, the Department of Environment and Natural Resources makes no representations and accepts no responsibility for the accuracy, completeness or fitness for any particular purpose of the contents, and shall not be liable for any loss or damage that may be occasioned directly or indirectly through the use of or reliance on the contents of this publication.

Reference to any company, product or service in this publication should not be taken as a Departmental endorsement of the company, product or service.



**Government  
of South Australia**

Department of Environment  
and Natural Resources

## **Acknowledgements**

Thanks to the Adelaide and Mount Lofty Ranges Natural Resources Management (AMLR NRM) Board for financial support and to Tony Flaherty from the AMLR NRM Marine Group for encouraging the initial project proposal.

In-kind support was provided by the Nature Conservation and Coast & Marine Conservation Branches of the Department of Environment and Natural Resources (DENR). For field support, thanks go to Henry Rutherford, David Miller, James Brook, Ali Bloomfield, Adrian Brown, Alison Eaton, David Pearce, Shane Holland, and Dimitri Colella (all from DENR). Maps were generated by Shane Holland (DENR) and Swathe Services. Thanks to Angela Faulkner and Stephen Cox from the DENR media unit. Thank you to Peter Copley and Bryan McDonald (both DENR) for general support of the project. Thanks to Scoresby Shepherd (SARDI), Tony Flaherty (AMLR NRM), and Peter Copley (DENR) for reviewing a draft version of the report and providing useful feedback.

Special thanks to all of the divers and dive groups who kindly supplied photographs: Antony King, Paul Macdonald, James Brook, Hank van der Wijngaart, Gary Doubleday, John Bassett, Andrew Burnell, David Pearce, Carl Charter, John Bassett, James Brook, Gary Perkins, David Cowan, Danny Brock, Paul Bierman, Emily Moskwa, David Muirhead, Crystal Beckman, Ali Bloomfield, Adrian Brown, David Warren, Flinders University Underwater Club, Adelaide University SCUBA Club, and Adelaide SCUBA at Glenelg.

## 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 mark-recapture technique to study population demographics and monitor site fidelity. Thus the specific aims of the present study were to:

1. Assess the effectiveness of natural markings for photo-ID of individual blue devils and harlequin fish.
2. Utilise photo-ID to make a population estimate and investigate site fidelity of harlequin fish at a single site.
3. Utilise photo-ID to make a population estimate and investigate site fidelity of blue devils at a single site.

Analysis of historical photographs supplied by community divers showed that the markings on adult blue devils and adult harlequin fish were unique to individual fish and that they were temporally stable across several years. Using the photo-ID technique, a number of scuba diver surveys were conducted at Seacliff (n = 4) and Aldinga Reefs (n = 3) off Adelaide during the summer/autumn of 2009/2010.

Survey data on harlequin fish were limited, with just three fish sighted at Aldinga Reef. 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 the 2009/2010 surveys and historical photographs at Aldinga Reef, one individual harlequin fish has been sighted on five separate occasions over a 2-year period, indicating that it either resides permanently there or frequently re-visits the site. Numerous blue devils were also sighted at Aldinga Reef and 32 individuals were photo-marked.

A population estimate was able to be generated for blue devils at Seacliff Reef. Using three different mark-recapture calculation techniques, population size estimates of blue devils at Seacliff Reef ranged from 31 to 39 individuals along a 300 m length of the reef. It was apparent that traditional fish survey techniques would have greatly underestimated the population size of blue devils at this location. Blue devils at Seacliff Reef also showed high site fidelity and their home ranges were estimated to be relatively small (~30 linear metres of reef). No harlequin fish were sighted at Seacliff Reef.

The 2009/2010 surveys for blue devils and harlequin fish have provided some useful preliminary observations and data. However, to meet the original aims of this project, the following work is required:

- Collection of further photographs of harlequin fish (both new and historic) is required to confirm the temporal stability of markings for use in population surveys.
- Additional surveys for blue devils at Seacliff Reef during 2010/2011 to: (1) verify the absolute population size, (2) monitor for population change across years, and (3) better define home ranges and possible relocations along the reef.
- A population survey for harlequin fish (similar to that conducted for blue devils at Seacliff Reef) at a site where they are relatively abundant (e.g. Dudley Peninsula on Kangaroo Island).

In addition to providing new information on the blue devil and harlequin fish, the project has 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. Ultimately it is hoped that the project can be expanded to additional reefs off Adelaide and around South Australia, including reefs within marine parks. Once fully developed, it is envisioned that the photo-ID 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.

## 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 targeted for protection within the sanctuary zones of South Australia's new system of 19 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. 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; leafy seadragons, Connolly et al. 2002; 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 natural mark-'recapture' technique using 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 study focussed on the nearshore reefs along the Adelaide metropolitan coastline from Outer Harbour to Aldinga. The study had three components: (1) historical photographic analyses, (2) scuba surveys at Aldinga Reef, and (3) scuba surveys at Seacliff Reef.

The specific aims of the study were to:

1. Assess the effectiveness of natural markings for photo-ID of individual blue devils and harlequin fish.
2. Utilise photo-ID to make a population estimate and investigate site fidelity of harlequin fish at a single site.
3. Utilise photo-ID to make a population estimate and investigate site fidelity of blue devils at a single site.

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) 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 (Kuitert 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*

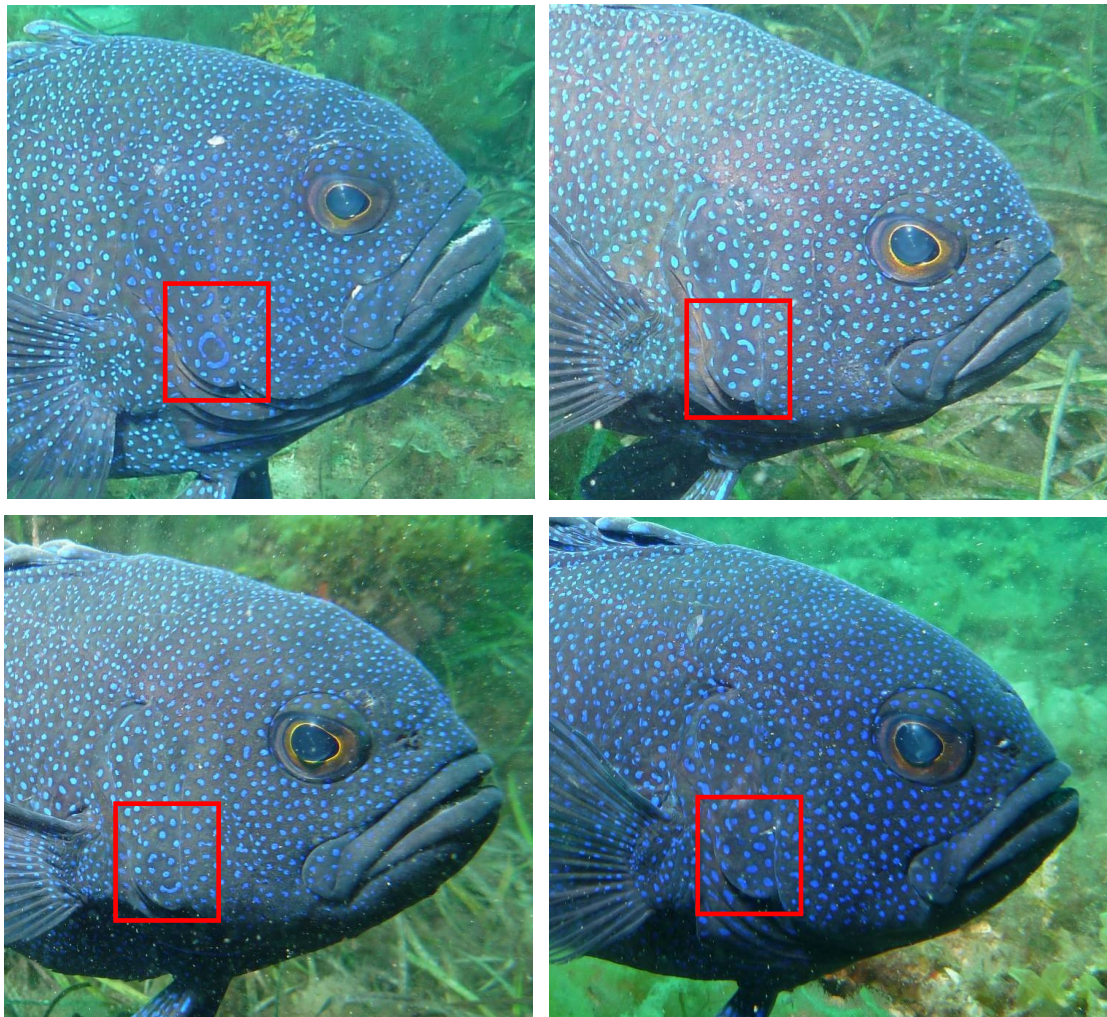
To test the idea that the natural markings of larger fish were temporally stable (and therefore might be useful in mark-recapture studies), I required a time-series of photographs of the same individual(s) for each species. Rather than commence a new study and monitor individuals over time, I was able 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 visible.

### *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). 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.



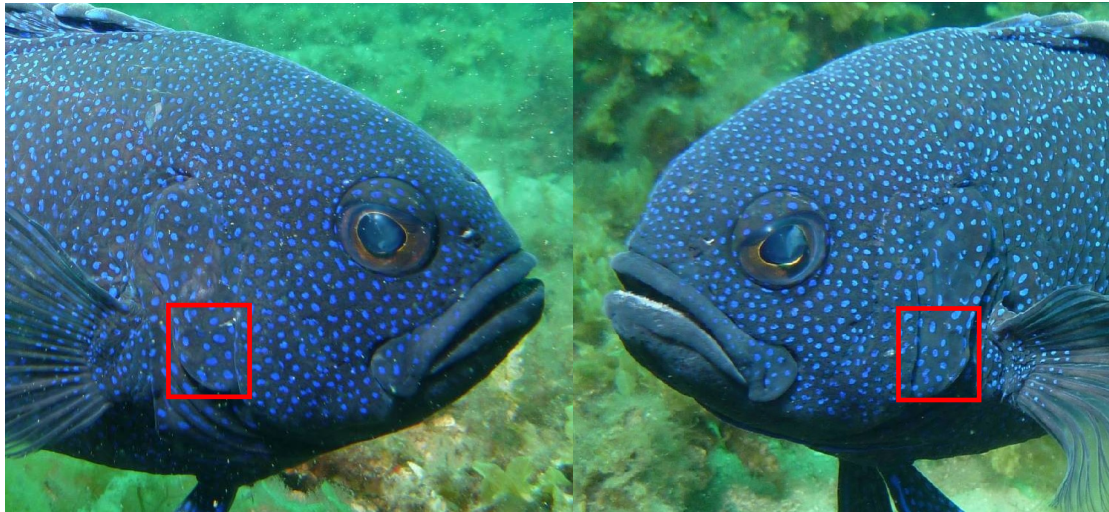


**Figure 1.** Photographs of four different blue devils showing variations in the markings on the operculum. The inset boxes indicate the focus area for comparisons. Photographs: Simon Bryars





**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)



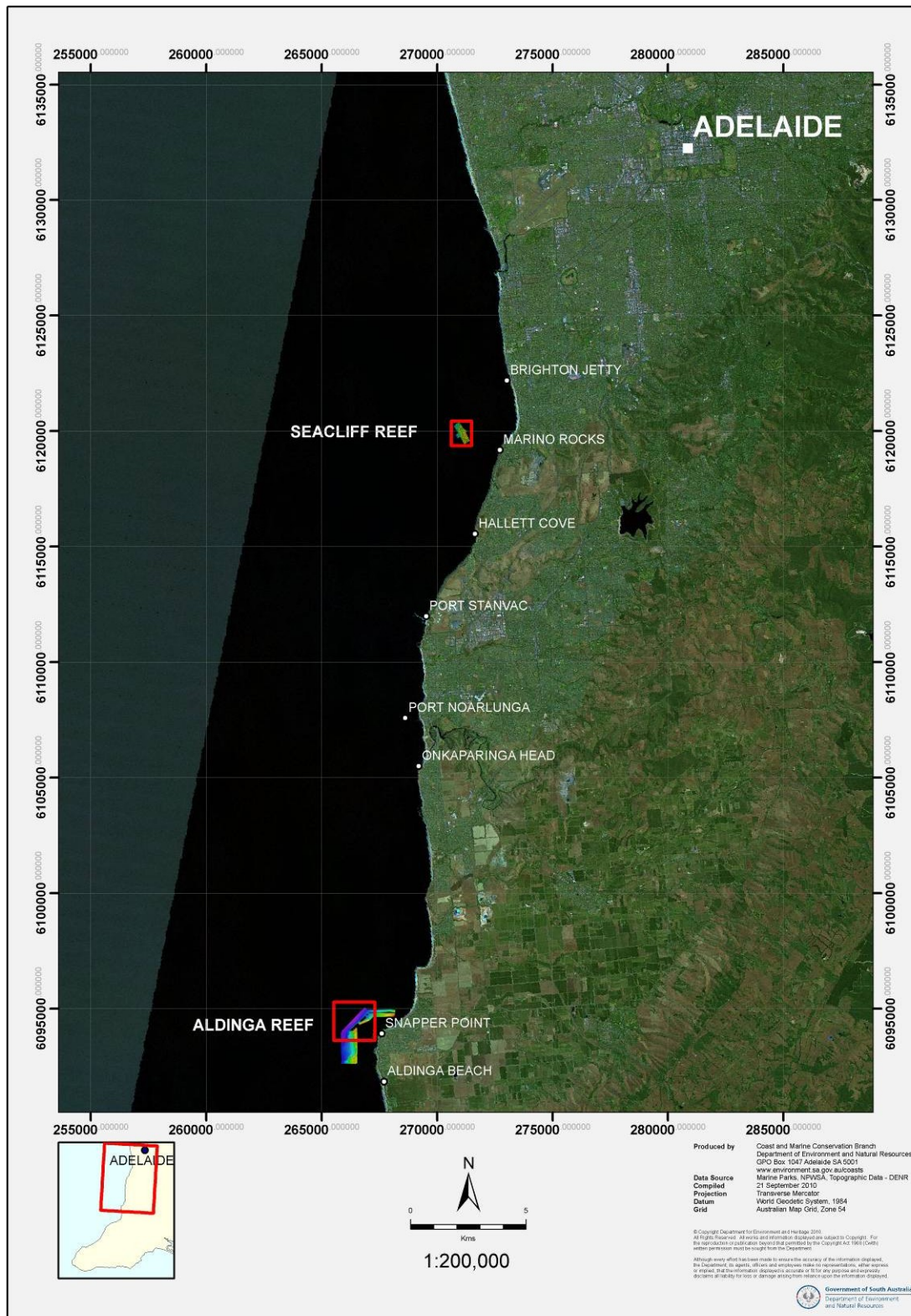
**Figure 3.** Photographs of the right and left sides of the same blue devil showing differences in markings on the operculum. The inset boxes indicate the focus area for comparisons. Photographs: Simon Bryars

#### *Aldinga Reef surveys*

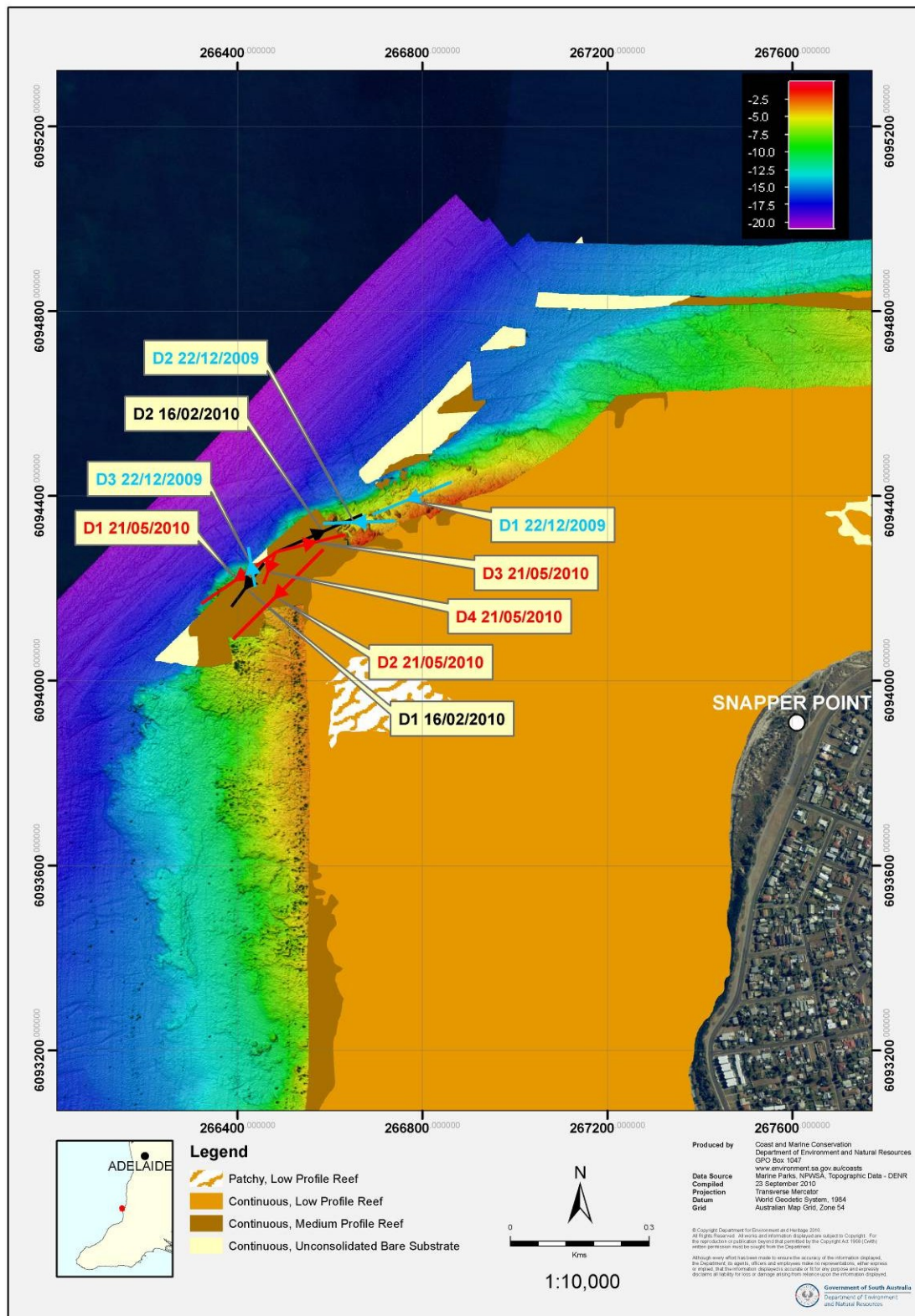
Aldinga Reef is located ~40 km SW of the Adelaide CBD on the eastern side of Gulf St Vincent (Fig. 4). It is an expansive area of limestone reef that extends ~1200 m from the intertidal region off Snapper Point out to subtidal depths of ~18–20 m at 'The Drop-Off' (Fig. 4). Much of the reef lies within 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.

Three scuba diver surveys were conducted at Aldinga Reef (Survey 1 = 22/12/2009, Survey 2 = 16/02/2010, and Survey 3 = 21/05/2010). 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 1-3 was 360, 140, and 310 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 Seacliff and Aldinga Reefs off the coast of Adelaide in eastern Gulf St Vincent. The multi-coloured strips indicate benthic areas that were mapped using acoustic swath technology (see Figures 5 and 6).



**Figure 5.** Location of diver transects on different dives (D1-4) across Surveys 1 (22/12/2009), 2 (16/02/2010) and 3 (21/05/2010) at Aldinga Reef 'Drop-Off' south of Adelaide. The colours grading from red (shallowest) to purple (deepest) indicate depths (m) as mapped by acoustic swath technology (note that swath mapping around The Drop-Off area is missing due to technical problems). The low and medium profile reef types shown underlying the swath mapping were created during a previous project for the AMLR NRM Board (DEH, 2008).

### *Seacliff Reef surveys*

Seacliff Reef is a subtidal reef located in ~12–15 m depth. The reef lies ~1 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 unexplored 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 four occasions (09/02/2010, 24/03/2010, 12/05/2010, and 13/05/2010) 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. The search effort between surveys was consistent at between 120–140 minutes for the two divers to complete the 300 m search (i.e., total search time = 240–280 min.).

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 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 three data sets: Survey 1 and 2, Survey 1 and 3, and Survey 1 and 4.



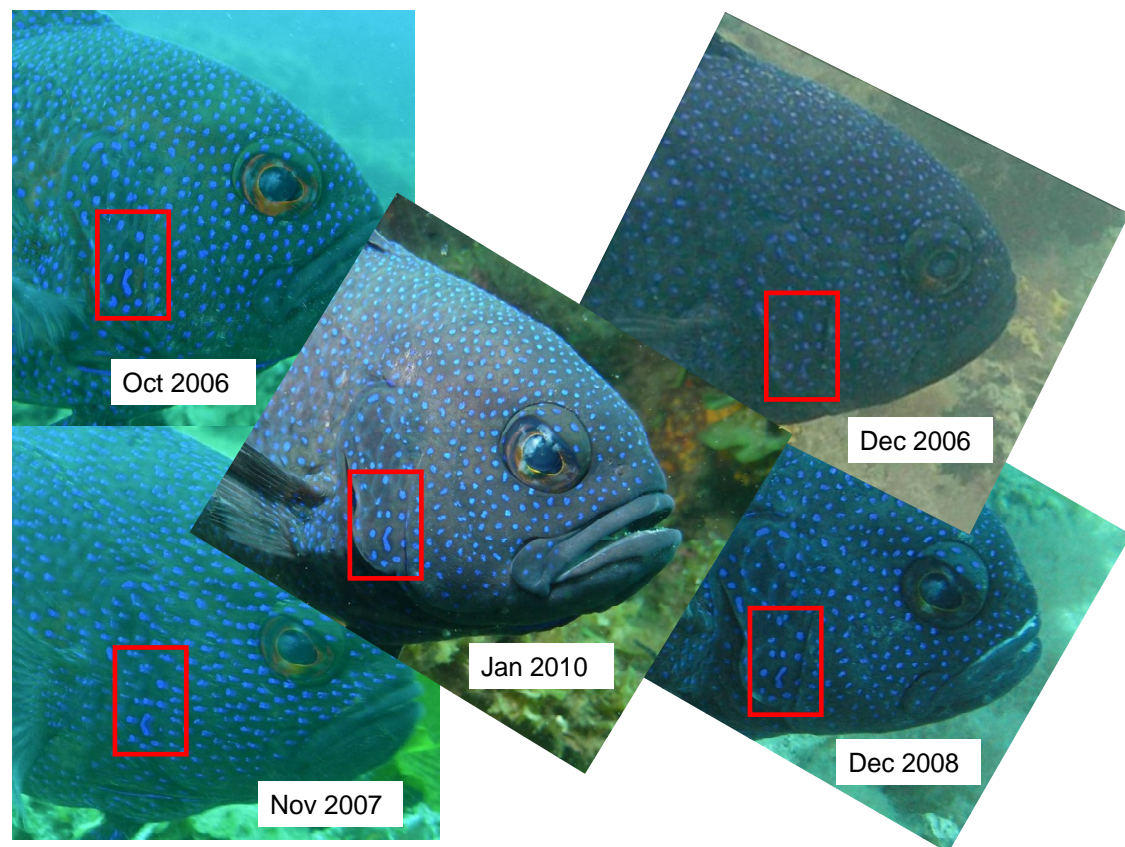


## Results

### *Historical photographic analyses*

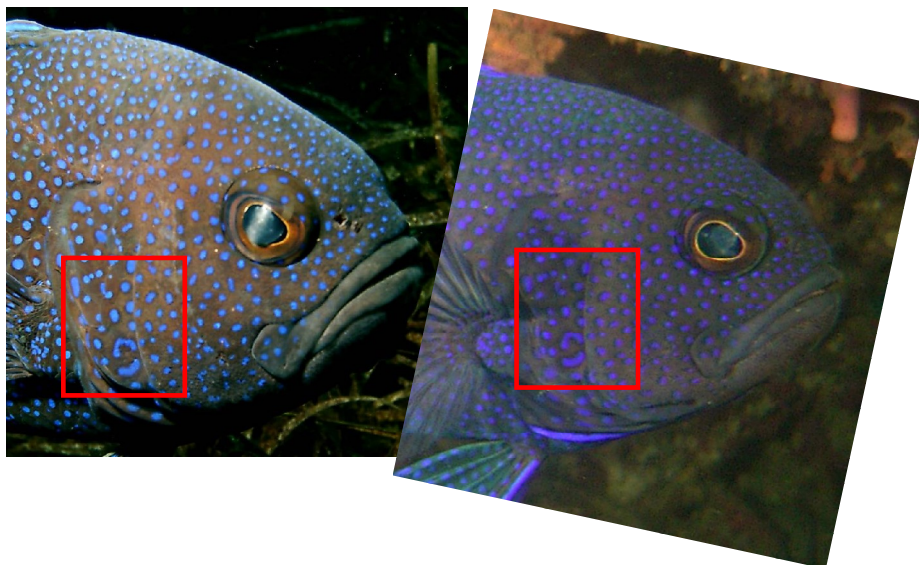
Two community divers in particular, Antony King and Paul Macdonald, were able to provide historical photographs of blue devils at a number of reefs off Adelaide dating back to 2005. From these photographs, several individual blue devils were photo-matched at the same reef across different years (e.g. Figs. 7–9). Many individual devils were also photo-matched between different surveys across several months during the Seacliff Reef surveys (e.g. Fig. 10, see *Seacliff Reef surveys* below). There was some evidence that the markings in blue devils can change across time-scales of years (e.g. Fig. 11). 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 mark-recapture population surveys. Despite an extensive search for photographs of harlequin fish, only one individual was able to be photo-matched over time (Figs. 12, 13). This single harlequin fish was photographed at Aldinga Reef on November 2007, October 2008, January 2009, and December 2009.

From historical and more recent photos (see field surveys below), >100 different blue devils and >30 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.

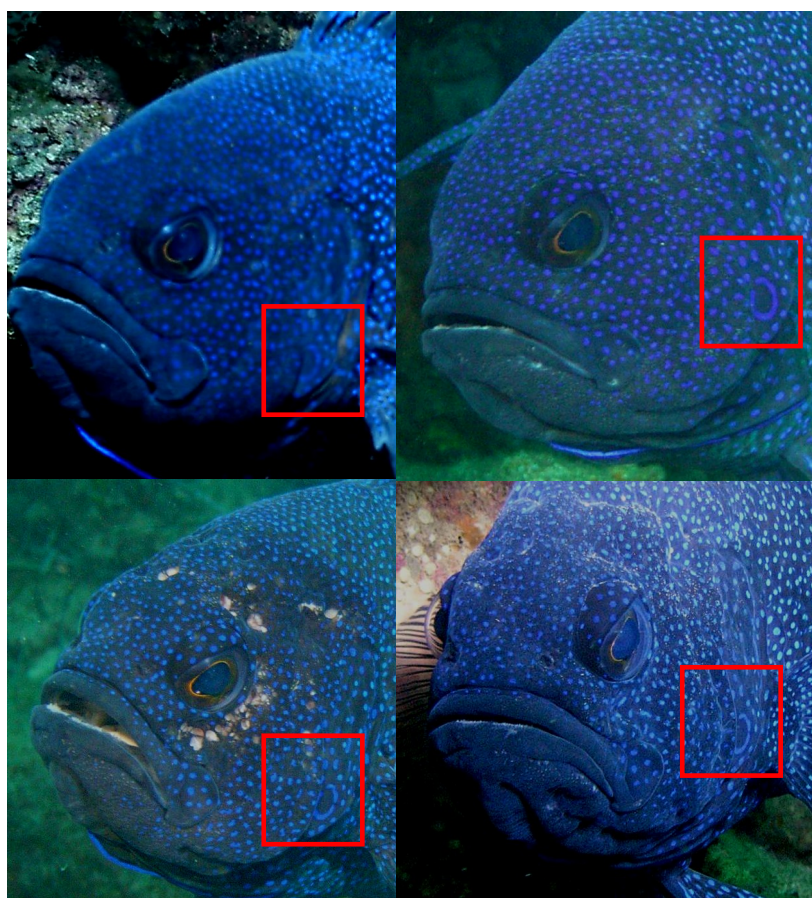


**Figure 7.** Time series photographs of the same blue devil at Seacliff Reef from 2006 to 2010. The inset boxes indicate the focus area for comparisons. Photographs: All by Antony King, except January 2010 by Simon Bryars.

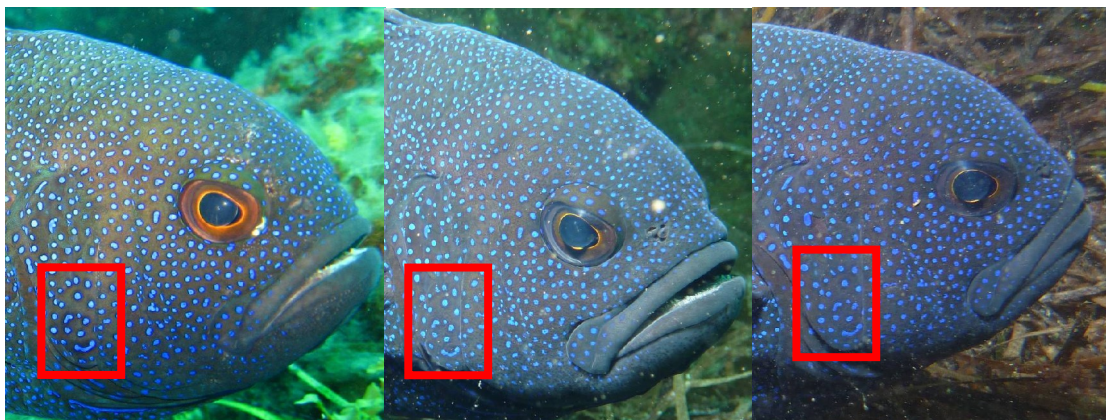




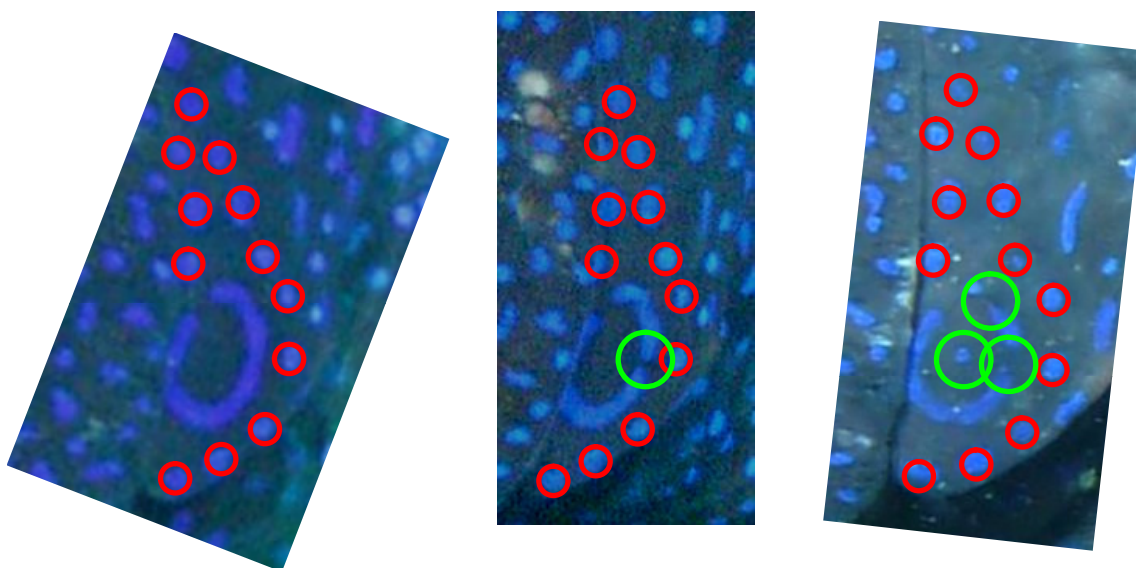
**Figure 8.** The same blue devil photographed at Macs Reef in February 2005 (left) and March 2006 (right). The inset boxes indicate the focus area for comparisons. Photographs: Paul Macdonald



**Figure 9.** 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

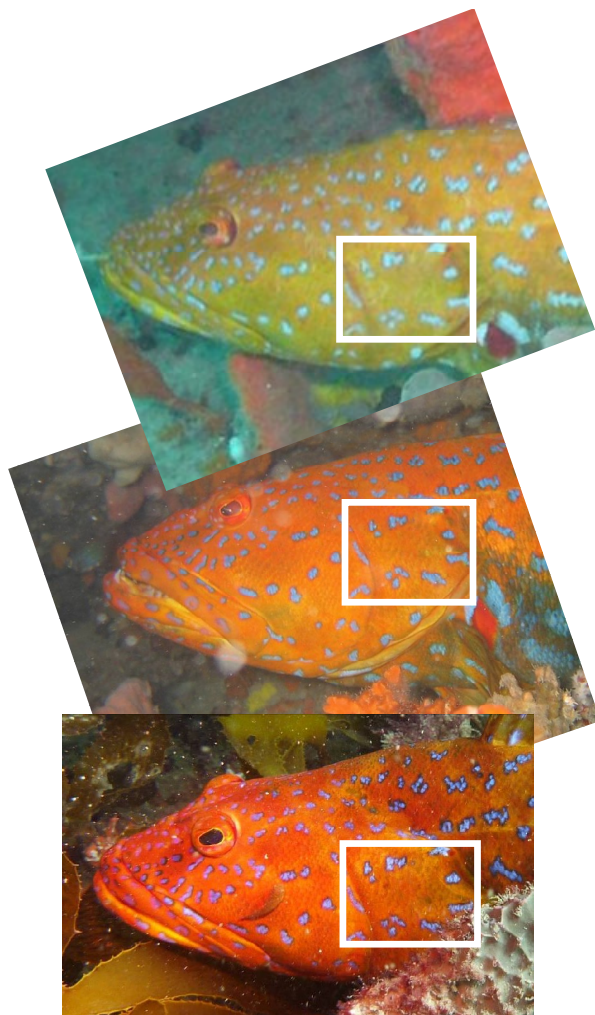


**Figure 10.** The same individual blue devil photographed at Seacliff Reef on Surveys 1–3 (left to right) during 2010 showing no change in markings on the operculum. The inset boxes indicate the focus area for comparisons. Photographs: Simon Bryars.

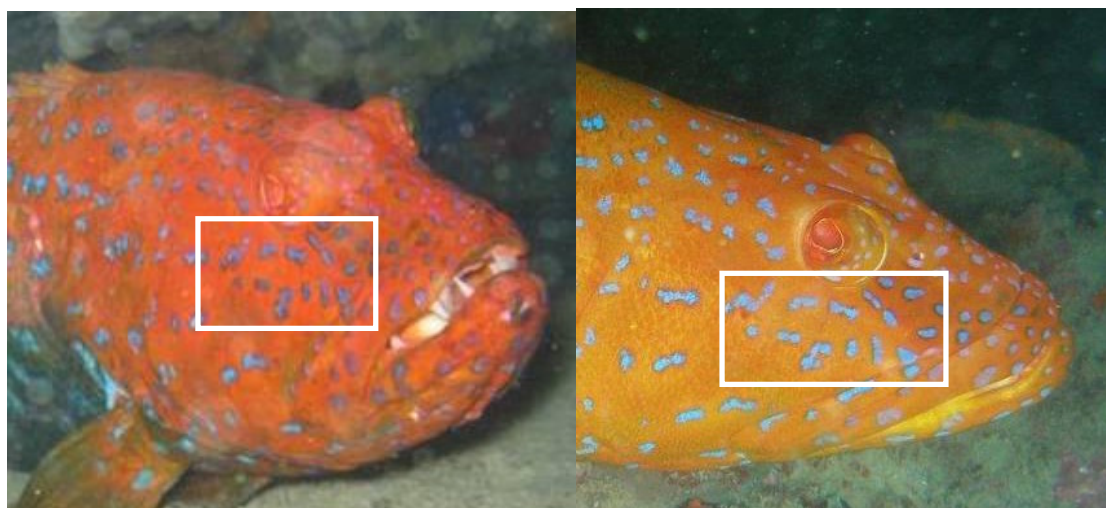


**Figure 11.** Close-up of the operculum of a blue devil photographed at Seacliff Reef in May 2006, April 2007 and January 2010 (from left to right), showing markings that were stable (red circles) and markings that changed (green circles).





**Figure 12.** The same harlequin fish photographed at Aldinga Reef in October 2008, January 2009, and December 2009 (from top to bottom). The inset boxes indicate the focus area for comparisons. Photographs: Paul Bierman (top), Gary Doubleday (middle), and David Pearce (bottom).



**Figure 13.** The same harlequin fish photographed at Aldinga Reef in November 2007 (left) and December 2009 (right). This is the same fish as shown in Fig. 12. The inset boxes indicate the focus area for comparisons. Photographs: Antony King (left) and Carl Charter (right).

### Aldinga Reef surveys

From a total of ~800 minutes searching time, just three harlequin fish were sighted (two on Survey 2 and one on Survey 3). All three fish were sighted in the vicinity of the drop-off, with the fish on Survey 3 occupying a fish cleaner station (see Shepherd et al. 2005) along with a blue devil; both fish were being tended by western cleaner clingfish, *Cochleocephalus bicolor*. Two of the three 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 the one previously sighted and photographed on the reef by community divers on four previous occasions (see *Historical photographic analyses*). The harlequin fish from Survey 3 could not be photo-matched with the historical photo-catalogue for the Adelaide coast. Both of the photo-marked fish from the Aldinga Reef surveys were estimated to be ~50 cm TL. Numerous blue devils were also sighted across Surveys 1–3 and 32 of these were reliably photo-marked for Aldinga Reef.

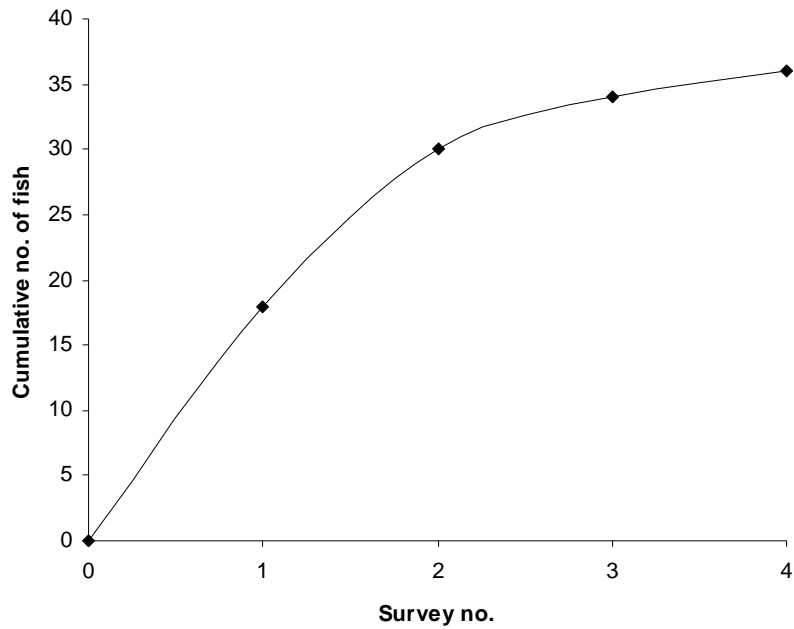
### Seacliff Reef surveys

A total of 36 blue devils were photo-marked across the four surveys (Fig. 14). The number of new fish being photo-marked on each successive survey rapidly declined (Table 1) and the total number of fish appeared to be reaching an asymptote (Fig. 14). The Lincoln-Petersen method gave population estimates of 34, 33 and 31 fish, which were all lower values than the minimum number of fish known to be in the study array (i.e.,  $n = 36$ ). The pseudo-removal method gave a population estimate of 39 fish (Fig. 15), while the Schnabel method gave a population estimate of 38 fish (95% CI 35–40). The proportion of photo-recaptures from Survey 1 was relatively constant across Surveys 2–4 (Table 1), indicating that the population was closed. The majority of photo-marked fish were in the size classes of 20–25 and 25–30 cm (Fig. 16). No fish of <15 cm or >35 cm were either photo-marked (Fig. 16) or sighted during any of the dives at Seacliff Reef.

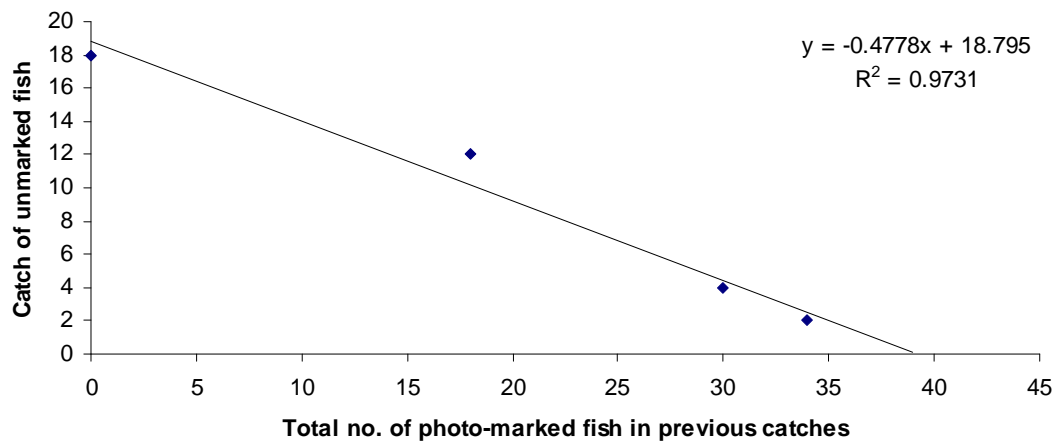
All photo-marked fish were either recaptured next to the same dropper or one of the adjacent droppers from where they were initially photo-marked. Three individuals were recaptured five times at the same dropper (including fish observed during the preliminary deployment dives). By using those fish that were recaptured at least three times, an estimate of home range length 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  $32 \pm 3$  m (mean  $\pm$  SE,  $n = 17$ ). 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. 17). Nonetheless, on average there was 1.2 fish per 10 linear metres of reef (using a total of 36 fish).

**Table 1.** Summary of photo-mark and photo-recapture data for blue devils at Seacliff Reef across Surveys 1–4 during 2010. \* assumes that total population = 36 and that fish sighted but not photographed were different individuals to those photographed on a given survey.

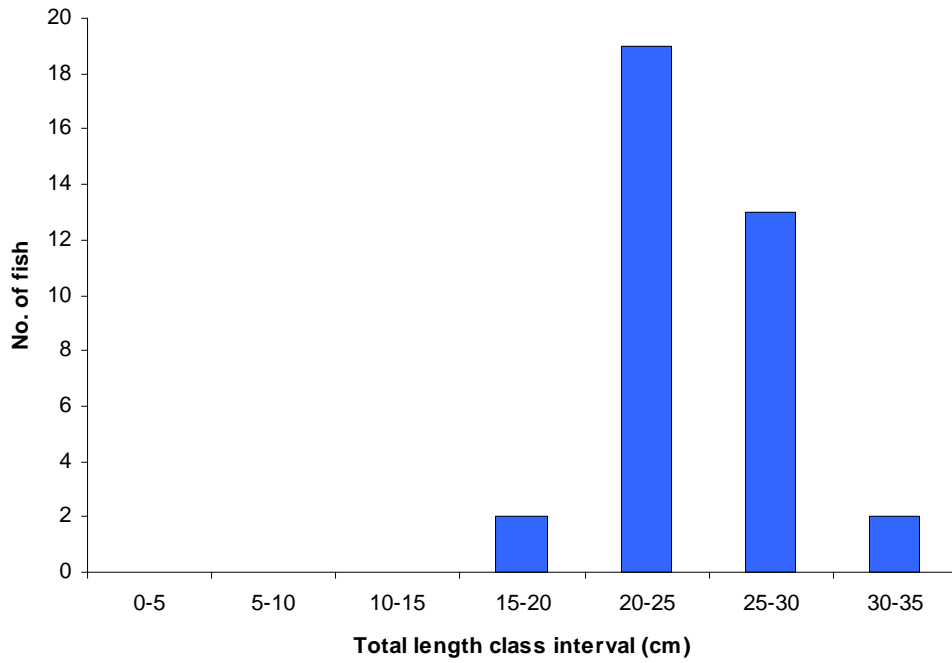
	Survey no.			
	1	2	3	4
No. fish photographed	18	25	17	21
No. new fish photo-marked	18	12	4	2
No. fish already photo-marked from survey 1	-	13	9	12
Proportion of photo-recaptures from survey 1 out of the total no. fish photographed	-	0.52	0.53	0.57
No. fish sighted	20	25	20	26
Proportion of total population sighted*	0.56	0.69	0.56	0.72



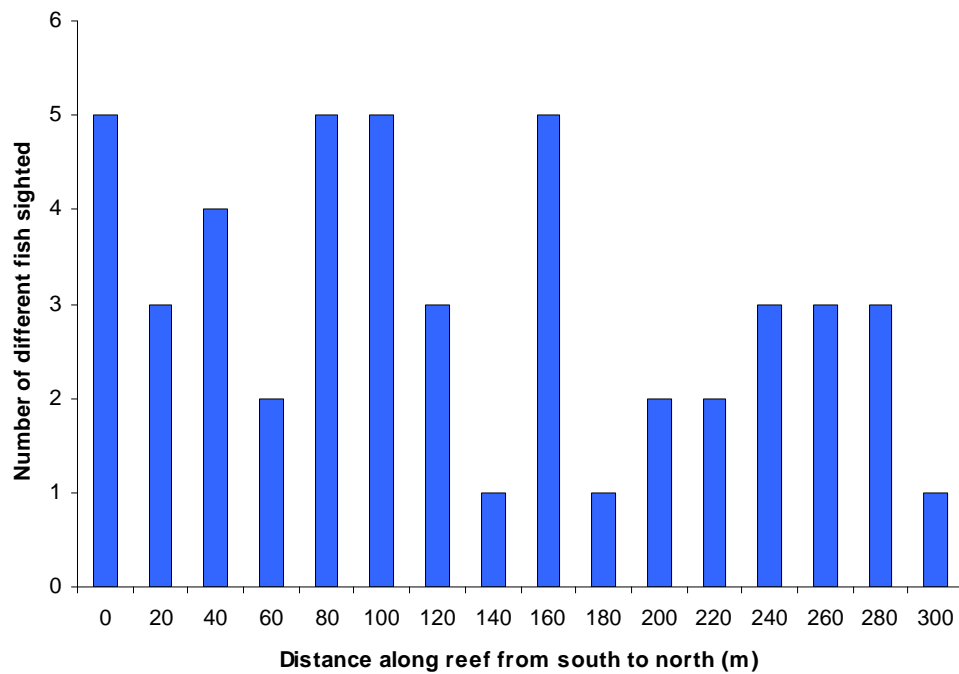
**Figure 14.** Cumulative and total number of blue devils photo-marked at Seacliff Reef during Surveys 1–4 in 2010.



**Figure 15.** Estimate of total population size using the pseudo-removal method. The intersection of the fitted regression line with the x-axis gives a total population estimate of 39 fish.



**Figure 16.** Size distribution of photo-marked blue devils at Seacliff Reef from Surveys 1–4 during 2010.



**Figure 17.** Spatial distribution of individual fish sightings along the length of Seacliff Reef from Surveys 1–4 and preliminary dives during 2010.

## Discussion

### *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 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 could be seen. Nonetheless, obtaining suitable photographs of blue devils and harlequin fish (and especially photographing both sides of the head) is at times difficult and sometimes impossible if the fish flees or hides in a small cave. 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 single harlequin fish with multiple photo-matches from Aldinga Reef was ~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. While a single harlequin fish showed no change in markings across several years, additional photographs are required to confirm temporal stability in this species.

### *Population demography of blue devils at Seacliff Reef*

Photo-ID was successfully used in a mark-recapture exercise for estimating the population size of blue devils at Seacliff Reef. The estimate of population size using the Lincoln-Petersen method gave values of 31–34 fish which were underestimates, given that the total population size was at least 36 fish. The pseudo-removal and Schnabel methods appeared to give more realistic estimates of 39 and 38 fish, respectively. In order to determine the absolute population size, further surveys are required until no new fish are being photo-marked on successive surveys. Until this is done, the effectiveness of each method cannot be fully assessed. Nonetheless, it may be the case that just two surveys using the simple Lincoln-Petersen method are all that is required to gain a useful population estimate (albeit a slight underestimate) for blue devils at a given reef. Once further survey data are collected it may also be informative to run them through a more sophisticated mark-recapture modelling program such as MARK.

The estimates of population size in blue devils using mark-recapture techniques assumed that the population was 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 study array during the study period. 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 array or any older fish died of natural causes during the study period. Due to the high recreational fishing activity at the site (pers. obs.), it is

possible that some mortality occurred from fishing. However, supporting the notion that the population was closed are the relatively stable values for the proportion of marked fish on subsequent surveys after the first survey, i.e. 0.52, 0.53 and 0.57 (Table 1). If the population was open then the proportion of marked animals on successive occasions would decline (Greenwood and Robinson 2006).

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 surveys that the smaller devils were sometimes shyer than larger fish. However, 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 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).

Around 30–40% of the total population of blue devils was unaccounted for on any given survey (Table 1, this assumed that the total population was 36). Thus it is apparent that a traditional survey technique of counting fish along a transect line would have underestimated the total population size by almost half on some occasions. While underestimation is inherent in fish count surveys, 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 was relatively constant between the four surveys (56–72%). Thus comparisons of relative abundance between sites using a standard fish count technique may still be useful for blue devils (however, this requires further testing). 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 lack of blue devils of >35 cm TL at Seacliff Reef 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 and the young (Baker 2010). If this is the case (and given the slow growth rate of blue devils) then I would have expected to observe some juveniles at Seacliff Reef. Possible explanations for the lack of juveniles at Seacliff Reef include, (1) the survey technique failed to locate them, (2) juveniles utilise different habitat or reefs to the adults, (3) there has been repeated recruitment failure, (4) breeding and recruitment are naturally infrequent, (5) there is high juvenile mortality, and/or (6) juveniles are forced out of the area due to the effects of density-dependence. The first explanation seems unlikely given the intensive searching that was conducted along the reef. The second explanation is also unlikely as observations by other divers indicate that juveniles 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.

#### *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 during the present surveys. At Aldinga Reef, only three 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; St Francis Isles, Shepherd and Brook 2003) indicates that the density of harlequin fish at Aldinga and Seacliff Reefs is relatively low. Whatever the population size of harlequins actually is at Aldinga and Seacliff Reefs, the low rate of encounters prevented the use of systematic surveys to derive population estimates for these two locations.

#### *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 may be 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.

#### *Advantages of photo-ID mark-recapture over other techniques*

If a photo-ID mark-recapture technique using two (or more) consecutive surveys could be further developed for the blue devil and harlequin fish, it may have several 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 (Kuitert 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.

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 mark-recapture technique being developed here offers the following potential advantages: (1) population estimates will be sufficiently large and reliable to be statistically useful, (2) double-counting is negated, and (3) absolute population size can be estimated. Knowing the absolute 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.

#### *Future work*

The 2009/2010 surveys for blue devils and harlequin fish have provided some useful preliminary observations and data. However, to meet the original aims of this project, the following work is required:

- Collection of further photographs of harlequin fish (both new and historic) is required to confirm the temporal stability of markings for use in population surveys.
- Additional surveys for blue devils at Seacliff Reef during 2010/2011 to: (1) verify the absolute population size, (2) monitor for population change across years, and (3) better define home ranges and possible relocations along the reef.
- A population survey for harlequin fish (similar to that conducted for blue devils at Seacliff Reef) at a site where they are relatively abundant (e.g. Dudley Peninsula on Kangaroo Island).

Ultimately it is hoped that this project can be 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 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 individuals 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).

## References

Baker, J. (2007) Marine and estuarine fishes of conservation concern in the Adelaide and Mount Lofty Ranges Natural Resources Management region. Prepared by Janine L. Baker for the Adelaide and Mount Lofty Ranges Natural Resources Management Board, 2007.

Baker, J.L. (2010) Marine Species of Conservation Concern in South Australia: Volume 1 - Bony and Cartilaginous Fishes. Report for the South Australian Working Group for Marine Species of Conservation Concern. J. Baker (consultant); Science and Conservation Division, and Coast and Marine Conservation branches of S.A. Department for Environment and Heritage (DEH); Marine and Coastal Community Network of S.A. (MCCN), and Threatened Species Network (TSN). Web version published by Reef Watch, South Australia. (<http://www.reefwatch.asn.au/pages/bin/view/Publications/SamsccHome>).

Baker, J., Shepherd, S., Brown, A., Crawford, H. and Muirhead, D. (2008) Uncommon and cryptic reef fishes: Results of pilot surveys along Fleurieu Peninsula. Report for Adelaide and Mount Lofty Ranges Natural Resources Management Board, 2008.

Baker, J., Crawford, H., Muirhead, D., Shepherd, S., Brook, J., Brown, A., and Hall, C. (2009a) Uncommon, cryptic and site-associated reef fishes: Results of surveys along Fleurieu Peninsula and in Encounter Bay, 2009. Report for Adelaide and Mount Lofty Ranges Natural Resources Management Board, August 2009.

Baker, J., Shepherd, S., Crawford, H., Brown, A., Smith, K., Lewis, J. and Hall, C. (2009b) Surveys of uncommon/rare and cryptic reef fishes in South Australia. Report to Commonwealth Department of the Environment, Water, Heritage and the Arts Envirofund Project 63120. 37 pp.

Barrett, N.S. (1995) Short- and long-term movement patterns of six temperate reef fishes (Families Labridae and Monacanthidae). *Marine and Freshwater Research*, 46: 853-860.

Brock, D.J. and Kinloch, M.A. (2007) Reef fish biodiversity on Kangaroo Island. KI NRM Board Coast and Marine Program Report No. CMP07/006. 39 pp.

Bryars, S., Wear, R. and Collings, G. (2008) Seagrasses of Gulf St Vincent and Investigator Strait. In: S.A. Shepherd, S. Bryars, I. Kirkegaard, P. Harbison & J.T. Jennings (eds) Natural History of Gulf St Vincent, Royal Society of South Australia Inc., Adelaide.

Connell, S.D. and Jones, G.P. (1991) The influence of habitat complexity on postrecruitment processes in a temperate reef fish population. *Journal of Experimental Marine Biology and Ecology*, 151: 271-294.

Connell, S. D., Russell, B. D., Turner, D. J., Shepherd, S. A., Kildea, T. et al. (2008). Recovering a lost baseline: missing kelp forests from a metropolitan coast. *Marine Ecology Progress Series*, 360: 63-72.

Connolly, R.M., Melville, A.J. and Keesing, J.K. (2002) Abundance, movement and individual identification of leafy seadragons, *Phycodurus eques* (Pisces: Syngnathidae). *Marine and Freshwater Research*, 53: 777-780.

Department for Environment and Heritage (2008) 'Marine Habitats in the Adelaide and Mount Lofty Ranges NRM Region.' Final Report to the Adelaide and Mount Lofty Ranges Natural Resources Management Board for the program: Facilitate Coast, Marine and Estuarine Planning and Management by Establishing Regional Baselines. Prepared by the Department for Environment and Heritage, Coast and Marine Conservation Branch.

Domeier, M.L. and Nasby-Lucas, N. (2007) Annual re-sightings of photographically identified white sharks (*Carcharodon carcharias*) at an eastern Pacific aggregation site (Guadalupe Island, Mexico). *Marine Biology*, 150: 977-984.

Edgar, G.J. (2008) Australian Marine Life. The plants and animals of temperate waters. Reed New Holland, Sydney.

Edgar, G., Barrett, N., Brook, J., McDonald, B. and Bloomfield, A. (2006) Ecosystem monitoring inside and outside proposed sanctuary zones with the Encounter marine park – 2005 baseline surveys. TAFI Internal Report, 36 pp.

Fowler, A.J., Lloyd, M. and Schmarr, D. (2009) A preliminary consideration of by-catch in the Marine Scalefish fishery of South Australia. South Australian Research and Development Institute (Aquatic Sciences), Adelaide, F2009/000097-1. SARDI Research Report Series No 365. 79 pp.

Gomon, M. (2001) Documenting change. In: C. Rasmussen (ed.) A Museum for the People: A History of Museum Victoria and its Predecessor Institutions, 1854–2000. Museum Victoria, Scribe Publications.

Gomon, M., Bray, D. and Kuitert, R. (2008) (Eds.) Fishes of Australia's Southern Coast. Reed New Holland, Sydney.

Greenwood, J.J.D. and Robinson, R.A. (2006) General census methods. In: W.J. Sutherland (ed.) Ecological Census Techniques: A Handbook. Cambridge University Press.

Hutchins, J.B. (2001) Biodiversity of shallow water reef fish assemblages in Western Australia using a rapid censusing technique. *Records of the Western Australian Museum*, 20: 247-270.

Hutchins, J.B. and Swainston, R. (2002) Sea fishes of southern Australia. Complete guide for anglers and divers. Swainston publishing, Perth.

Kendrick, G., Harvey, E., McDonald, J., Pattiaratchi, C., Cappel, M., Fromont, J., Shortis, M., Grove, S., Bickers, A., Baxter, K., Goldberg, N., Kleczkowski, M. and Butler, J. (2005) Characterising the fish habitats of the Recherche Archipelago. Fisheries Research and Development Corporation Report Project No. 2001/060.

Kleczkowski, M., Babcock, R.C. and Clapin, G. (2008) Density and size of reef fishes in and around a temperate marine reserve. *Marine and Freshwater Research*, 59: 165-176.

Kuitert, R.H. (1996) Guide to sea fishes of Australia: A comprehensive reference for divers and fishermen. New Holland Publishers, Sydney.

Lowe, C.G., Topping, D. T., Cartamil, D.P. and Papastamatiou, Y.P. (2003) Movements patterns, home range, and habitat utilization of adult kelp bass

*Paralabrax clathratus* in a temperate no-take marine reserve. *Marine Ecology Progress Series*, 256: 205-216.

Lowry, M.B. and Suthers, I.M. (1998) Home range, activity and distribution patterns of a temperate rocky-reef fish, *Cheilodactylus fuscus*. *Marine Biology*, 132: 569-578.

Meekan, M.G., Bradshaw, C.J.A., Press, M., McLean, C., Richards, A., Quasnicka, S. and Taylor, J.G. (2006) Population size and structure of whale sharks *Rhincodon typus* at Ningaloo Reef, Western Australia. *Marine Ecology Progress Series*, 319: 275-285.

Pirzl, R., Patenaude, N.J., Burnell, S. and Bannister, J. (2009) Movements of southern right whales (*Eubalaena australis*) between Australian and subantarctic New Zealand populations. *Marine Mammal Science*, 25(2): 455-461.

Samoilys, M.A. (1997) Movement in a large predatory fish: coral trout, *Plectropomus leopardus* (Pisces: Serranidae), on Heron Reef, Australia. *Coral Reefs*, 16: 151-158.

Saunders, R.J., Bryars, S.R. and Fowler, A.J. (2010) Preliminary consideration of the biology of several of South Australia's marine fish species that have conservation or management interest. Report to the Department for Environment and Heritage. South Australian Research and Development Institute (Aquatic Sciences), Adelaide, 41 pp. SARDI Publication Number F2009/000693-1. SARDI Research Report Series No. 426.

Shepherd, S.A. (2005) Ontogenetic changes in diet, feeding behaviour and activity of the western blue groper, *Achoerodus gouldii*. In: F.E. Wells, D.I. Walker and G.A. Kendrick (eds) *The Marine Flora and Fauna of Esperance, Western Australia*. Western Australian Museum, Perth.

Shepherd, S.A. (2005) Ontogenetic changes in diet, feeding behaviour and activity of the western blue groper, *Achoerodus gouldii*. In: F.E. Wells, D.I. Walker and G.A. Kendrick (eds) *The Marine Flora and Fauna of Esperance, Western Australia*. Western Australian Museum, Perth.

Shepherd, S.A. and Clarkson, P.S. (2001) Diet, feeding behaviour, activity and predation of the temperate blue-throated wrasse, *Notolabrus tetricus*. *Marine and Freshwater Research*, 52: 311-322.

Shepherd, S.A. and Brook, J.B. (2003) Encounter 2002 expedition to the Isles of St Francis, South Australia: reef fishes. *Transactions of the Royal Society of South Australia*, 127(2): 269-279.

Shepherd, S.A., Teale, J. and Muirhead, D. (2005) Cleaning symbiosis among inshore fishes at Althorpe Island, South Australia and elsewhere. *Transactions of the Royal Society of South Australia*, 129(2): 193-201.

Shepherd, S.A., Brook, J.B. and Xiao, Y. (2009) Environmental and fishing effects on the abundance, size and sex ratio of the blue-throated wrasse, *Notolabrus tetricus*, on South Australian coastal reefs. *Fisheries Management and Ecology*, 2009: 1-12.

Tolimieri, N., Andrews, K., Williams, G., Katz, S. and Levin, P.S. (2009) Home range size and patterns of space use by lingcod, copper rockfish and quillback rockfish in relation to diel and tidal cycles. *Marine Ecology Progress Series*, 380: 229-243.