Green Adelaide Rocky Reef Program: 2022–24 surveys for the southern blue devil, *Paraplesiops meleagris*

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Cover photo: Southern blue devil (*Paraplesiops meleagris*) at Seacliff Reef provided by Jamie Hicks, Marine Science Team, Department for Environment and Water.

Foreword

The Department for Environment and Water (DEW) is responsible for the management of the state's natural resources, ranging from policy leadership to on-ground delivery in consultation with government, industry and communities.

High-quality science and effective monitoring provides the foundation for the successful management of our environment and natural resources. This is achieved through undertaking appropriate research, investigations, assessments, monitoring and evaluation.

DEW's strong partnerships with educational and research institutions, industries, government agencies, Landscape Boards and the community ensures that there is continual capacity building across the sector, and that the best skills and expertise are used to inform decision making.

Ben Bruce
CHIEF EXECUTIVE
DEPARTMENT FOR ENVIRONMENT AND WATER

Acknowledgement of Country

We acknowledge and respect the Traditional Custodians whose ancestral lands we live and work upon and we pay our respects to their Elders past and present.

We acknowledge and respect their deep spiritual connection and the relationship that Aboriginal and Torres Strait Islanders people have to Country.

We also pay our respects to the cultural authority of Aboriginal and Torres Strait Islander people and their nations in South Australia, as well as those across Australia.

Acknowledgements

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Summary

The southern blue devil (*Paraplesiops meleagris*) is a small fish endemic to Australia's Great Southern Reef. Due to its spectacular appearance and inquisitive nature, the southern blue devil is an iconic species of significance to the recreational diving sector in South Australia, including the Adelaide region. It is also of significance to the conservation sector due to concerns raised about its population status and lack of fisheries regulations.

Between 2010 and 2013, divers surveyed four reefs off Adelaide using photo-identification (photo-ID) to establish baseline population data. From 2022 to 2024, three of these reefs were resurveyed through the Green Adelaide Rocky Reef (GARR) program, funded by the Green Adelaide Landscape Board in partnership with the Department for Environment and Water (DEW). These follow-up surveys assessed the status of southern blue devil populations at these reefs and the effectiveness of photo-ID for long term monitoring.

The 2022-2024 surveys confirmed that photo-ID remains an effective method for identifying individual fish over extended periods, with 15 individuals successfully photo-matched after 13 or 14 years. However, results from Seacliff Reef indicate a decline in abundance. In 2024, only half as many fish were observed compared to 2013, despite equivalent survey effort. The current population includes mostly older and larger individuals >25 cm total length (TL), with little evidence of juvenile recruitment. In contrast, the 2013 population was dominated by fish of 20–25 cm TL.

Surveys at Macs Ground and Milkies Reef were limited, but preliminary results were more encouraging. The cumulative count at Macs Ground in 2024 was higher than in 2013, and whilst there had also been a shift towards larger fish at both sites, several smaller juvenile fish were also detected for the first time in over a decade suggesting a recent recruitment event. Community divers also reported juveniles at other nearby reefs in 2024, though not at Seacliff Reef.

It remains unclear whether the reduced abundance at Seacliff Reef is cause for concern. The southern blue devil is a slow growing, long lived species that may rely on infrequent recruitment 'pulse' events to sustain small but stable populations. This strategy is common among marine species. The recent recruitment event at other sites offers cautious optimism. Continued surveys at Seacliff Reef are recommended to detect future recruitment. Future surveys should therefore continue to be conducted at Seacliff Reef to detect juvenile recruitment.

Improving the quality of the photo-ID catalogue, particularly ensuring clear images of both sides of each fish, would strengthen future data analysis. Monitoring the growth and site fidelity of juvenile fish at Macs Ground and Milkies Reef will also provide valuable insights into the early life stages of the species.

There is strong potential to develop a citizen science program for the southern blue devil across the Green Adelaide region and the Fleurieu Peninsula. The species is widely admired and frequently photographed by community divers, is present at many popular dive sites on natural and artificial reefs, and it responds well to photo-ID techniques. This approach supports the collection of important biological data including abundance, residency, movement, size structure, behaviour, recruitment, and growth.

1 Introduction

The southern blue devil (*Paraplesiops meleagris*) is a small (max. 36 cm total length (TL)) temperate demersal fish species that inhabits rocky reefs with caves and ledges in depths of <45 m. It is endemic to southern Australia's 'Great Southern Reef' with a distribution extending from southwest Western Australia, through South Australia, to central Victoria (Hutchins and Swainston 2002, Bennett et al. 2015) (Figure 1).

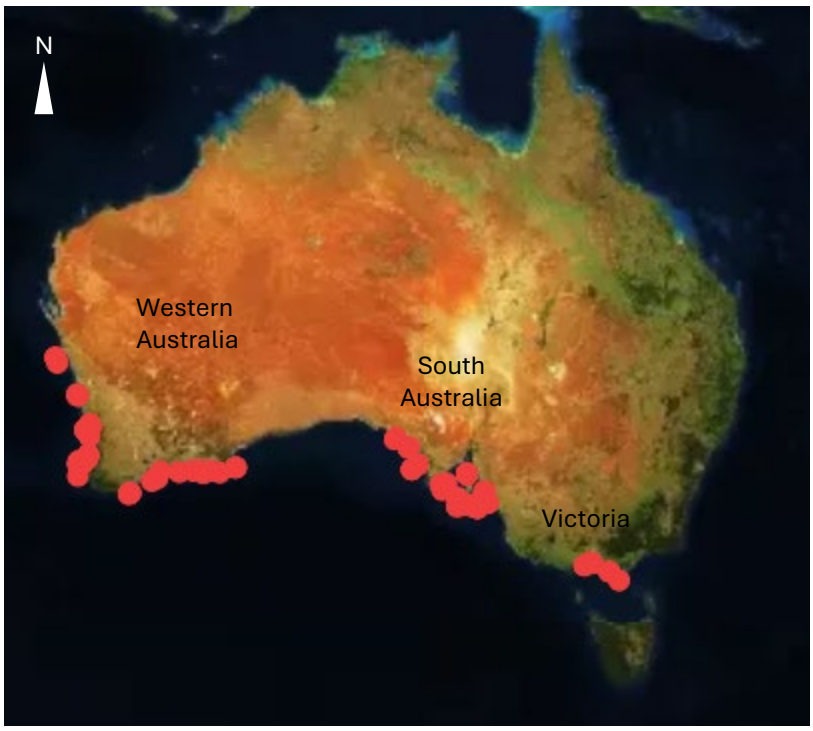

Figure 1. Distribution of the southern blue devil, *Paraplesiops meleagris*, along the Great Southern Reef based upon records from the Reef Life Survey database (shown as red dots). Base map image courtesy of Reef Life Survey (Paraplesiops meleagris - Western blue devil | Reef Life Survey).

Due to its spectacular appearance and inquisitive nature, the southern blue devil is an iconic species of significance to the recreational diving sector in South Australia, including the Adelaide region. It is also of significance to the conservation sector due to concerns raised about its population status and lack of fisheries regulations (Bryars 2011). It has an estimated maximum age of around 60 years, lacks any obvious sexual dimorphism or evidence of sequential sex change, and is susceptible to barotrauma when caught by fishers (Saunders et al. 2010). The species is slow-growing and shows a high degree of site fidelity or site-attachment making it particularly susceptible to fishing pressure. It has a pelagic larval phase and appears to rely on successful larval settlement and juvenile recruitment to replenish existing populations and colonise new sites (e.g., shipwrecks and artificial reefs, Bryars 2013); although the potential movement of post-larval and juvenile stages is unknown.

Bryars (2010, 2011, 2013) developed a photo-identification (photo-ID) technique using natural markings for identifying individual southern blue devils which enabled photo-capture and later photo-recapture of the same individual over time (Bryars et al. submitted, Figure 2, Appendix A-C). Using this photo-capture-recapture technique and a series of systematic underwater visual diving surveys, population estimates were determined at four discrete reefs found in Adelaide's metropolitan waters. These population baselines were used to assess historical and contemporary population status. In 2022, 2023 and 2024, the Green Adelaide Landscapes Board as part of the Green Adelaide Rocky Reef (GARR) program and iconic/focal species subprogram in partnership with the Department for Environment and Water (DEW) funded the re-survey of three of these reefs to assess the status of the southern blue devil populations resident on those reefs which had last been surveyed in 2013. This report summarises the results of the surveys and associated outreach and engagement activities.

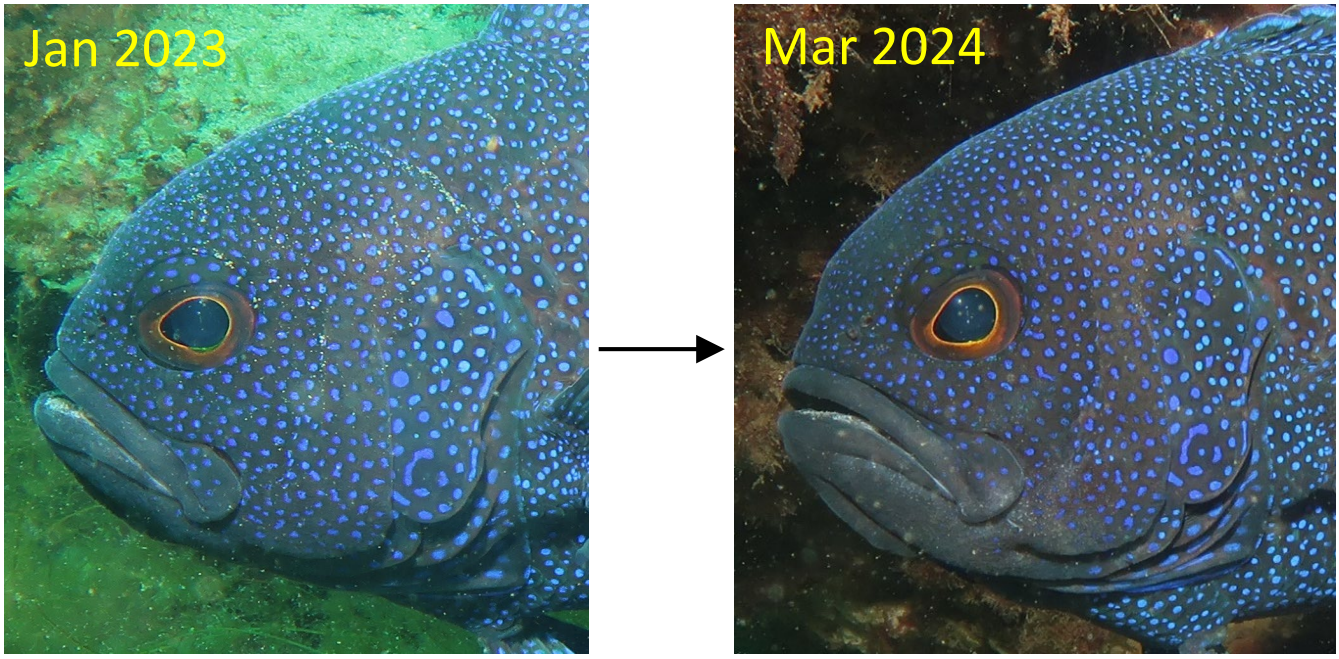

Figure 2. Example of photo-capture in January 2023 and photo-recapture in March 2024 of the same individual using photo-matching of the unique natural markings on the head. Photos: Simon Bryars.

2 Methodology

2.1 Blue devil surveys

2.1.1 Locations

During the summer/autumn of 2022, 2023 and 2024, 10 surveys were conducted at Seacliff Reef (Figure 3, Figure 4). In addition, during the summer/autumn of 2024, 3 surveys were conducted at Macs Ground and 2 at Milkies Reef. No surveys were conducted at the historical study site of Northern Outer (Figure 2, Table 1). The focus of the Seacliff Reef surveys was to derive a robust population estimate to compare with the baseline 2013 estimate. The focus of the surveys at Macs Ground and Milkies Reef was similar (although a lower number of surveys than planned was achieved) but also to search for juveniles which had been noted by community divers at those reefs.

These surveys used the same methodology and surveyed the same sections of reef as those surveyed in 2010–13 (see Bryars 2010, and Figure 4). The only difference at Seacliff Reef was that a new set of survey markers (star droppers) was installed at 50 m intervals in 2022 (rather than the original 20 m intervals used in 2010-13) as the original droppers were mostly corroded away and it was deemed unnecessary to have 20 m intervals for the more recent surveys (Figure 4). Surveys were conducted by Reef Life Survey (RLS) trained scientific and community (volunteer) divers.

Table 1. Number and date of surveys by site between 2022 – 2024.

Site	Survey number	Date
Seacliff Reef	Survey 1	5/04/2022
	Survey 2	20/01/2023
	Survey 3 & 4	31/01/2023
	Survey 5 & 6	9/02/2023
	Survey 7	3/04/2023
	Survey 8	13/05/2023
	Survey 9	8/02/2024
	Survey 10	7/03/2024
Macs Ground	Survey 1	8/02/2024
	Survey 2	7/03/2024
	Survey 3	8/05/2024
Milkies Reef	Survey 1	7/03/2024
	Survey 2	8/05/2024
Northern Outer	No surveys conducted	N/A

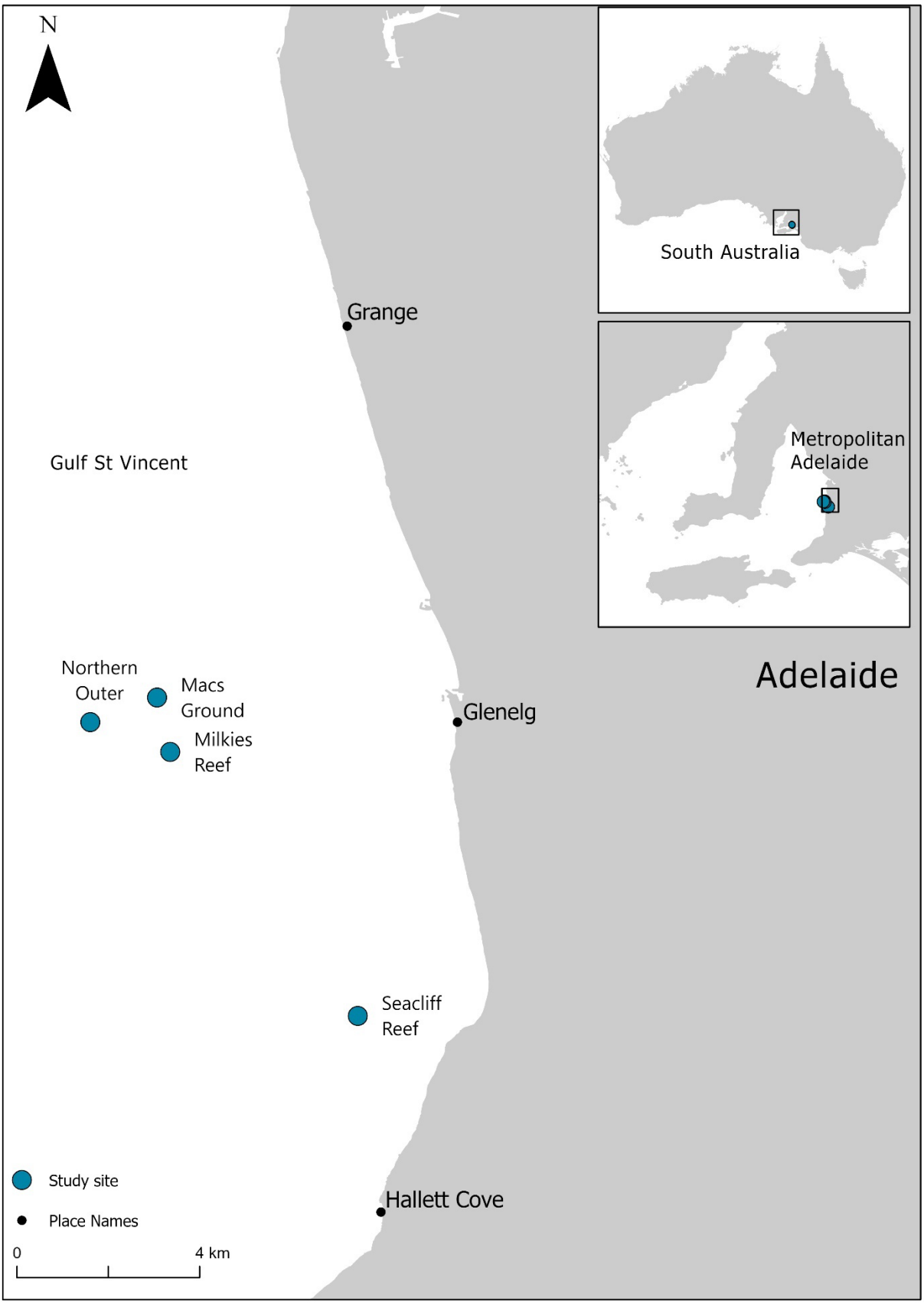

Figure 3. Map of survey sites in relation to metropolitan Adelaide, South Australia. Study sites are Seacliff Reef, Macs Ground, Milkies Reef and Northern Outer (not surveyed in current study).

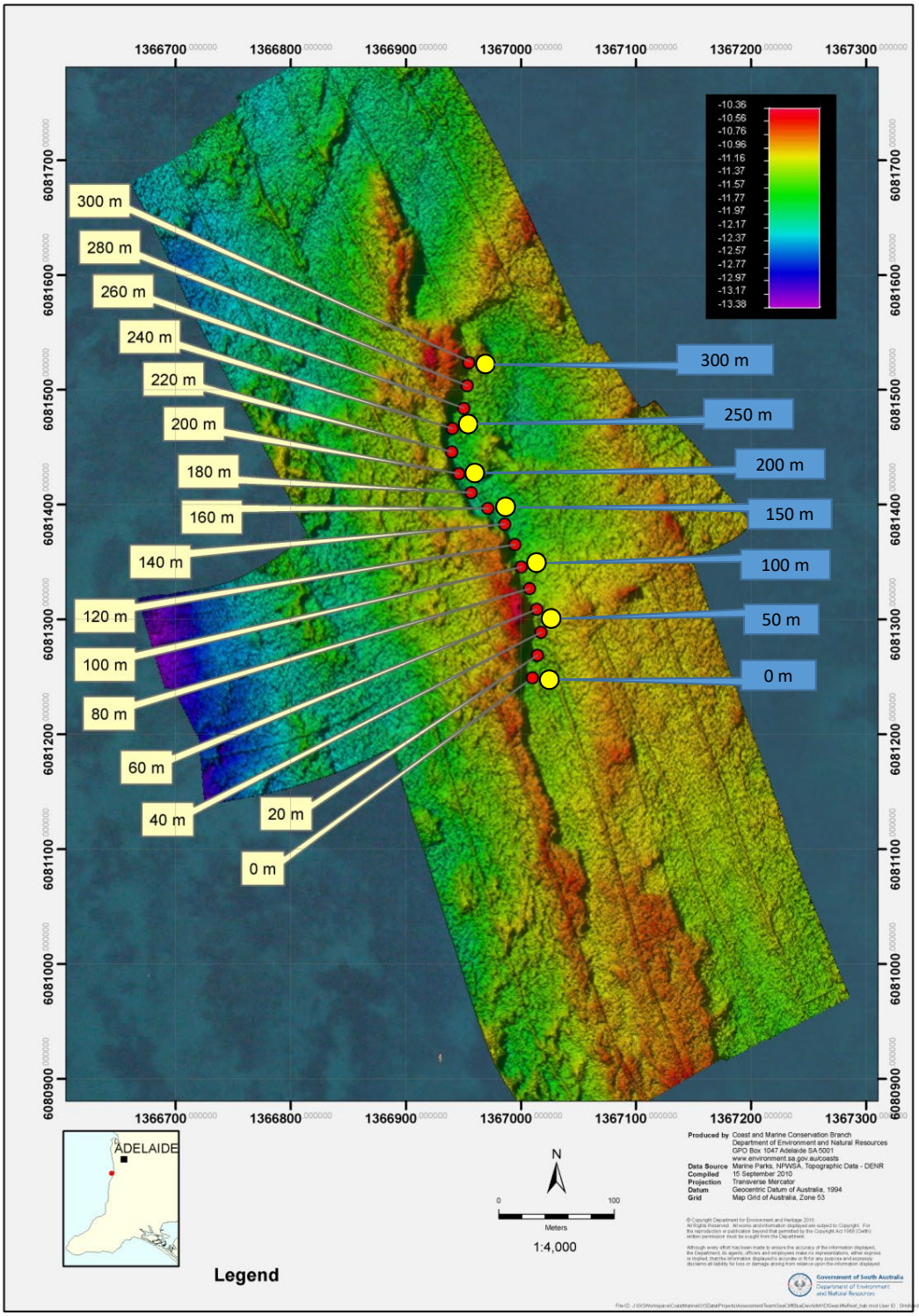

Figure 4. Seacliff Reef showing the location of the original 21 markers (red dots) positioned every 20 m in 2010 and the more recent 7 markers (yellow dots) positioned every 50 m in 2023 along the same 300 m section. The colours grading from red (shallowest) to purple (deepest) indicate depths (m) as 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. (NB This figure has been adapted from Figure 6 in Bryars 2010).

2.1.2 Individual and population estimates

When a fish was located during a survey an attempt was made to photograph both sides of the head, with particular focus on the operculum where unique markings can be used for individual identification. A photographic catalogue (photo-catalogue) of the left and right sides of each successfully photo-captured individual was then created. Photo-matching of previously photo-captured fish was undertaken by visual comparison of digital photographs (Appendix A-F). Due to the length of time since the 2010–13 surveys, a new photo-catalogue and cumulative population count was created from the 2022–24 survey data. Photo records and the cumulative population curves from 2024 were compared with those of 2013 (Bryars 2013).

For Seacliff Reef, the linear position of each fish was noted by assigning it to one of the six 50 m transects from south to north (designated as T1 to T6). This provided information on site fidelity and assisted with photo-matching. Most individuals at this site have small home ranges and often are re-sighted at the same location on the reef (Bryars 2011).

2.1.3 Fish size estimates

Total Length (TL) of each fish was visually estimated in 5 cm size class intervals between 0 and 35 cm (max documented length of 36 cm TL; Hutchins and Swainston 2002). Size estimates were periodically validated from photo records, measurements taken in situ, and by diver operated paired stereo cameras. Data for TL from 2013 and 2024 were plotted as size frequency distributions using the 5 cm size class intervals. For the purposes of the current study, small fish were defined as <15 cm, medium fish as 15–25 cm and large fish as >25 cm TL. A comparison of size was made for any individuals photo-matched in both the 2013 and 2024 photo-catalogues to provide an estimate of growth over that period.

2.2 Outreach and engagement

The benefits of community involvement in monitoring efforts have been well-documented through the successes of various citizen science projects, such as those carried out by Birds SA (https://birdssa.asn.au/) and RLS (Edgar et al. 2020). In South Australia, the local chapter of RLS has been actively engaging volunteer divers in data collection from subtidal rocky reefs as part of the GARR program since its inception in 2017 (Brock et al. 2017). In line with the objectives of the 2022/23 GARR project plan and the recommencement of blue devil surveys in South Australia, a deliverable was included to explore the potential for local dive volunteers to contribute meaningfully to conducting these surveys.

To facilitate community engagement and the integration of RLS volunteers into the program, Dr Simon Bryars presented at the annual end of year event for the volunteers (December 2022). This presentation covered information about the southern blue devil and showcased prior research and conservation efforts related to this species. Attendees were extended an invitation to actively participate in the survey program. To facilitate volunteer involvement and simplify the process of uploading data a modified datasheet, methodology, and database were developed. In addition, every year since 2019, Dr Bryars has given a presentation for the Coastal Ambassador's Program which is run by Green Adelaide. This presentation provides participants with insights on the unique biology of the southern blue devil and aims to inspire and empower participants with knowledge about this iconic species.

3 Results

3.1 Population count, size distribution, and behavioural observations

Using cumulative counts, the total number of individuals at Seacliff Reef, Macs Ground, and Milkies Reef in 2024 was 22, 14, and 7, respectively (Figure 5). The curve at Seacliff Reef suggests that close to the total population had been counted, but at Macs Ground and Milkies Reef there were insufficient surveys in 2022–24 and the curves had not tapered off yet. Nonetheless, the number of fish detected at Macs Ground in 2024 (n=14) was higher than in 2013 (n= 12). The number of fish at Seacliff Reef was substantially lower in 2024 (n=22) than in 2013 (n=42).

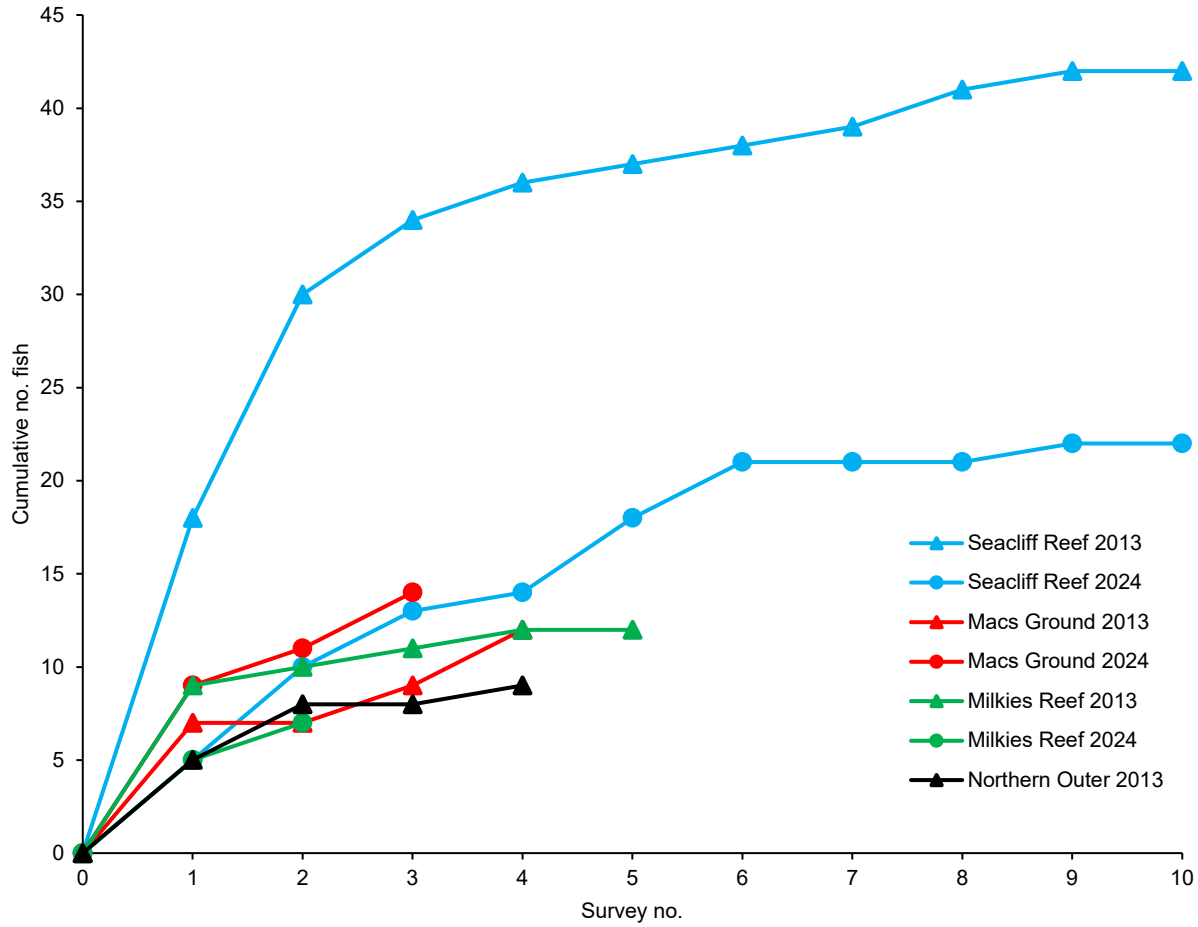

Figure 5. Cumulative number of *Paraplesiops meleagris* at Seacliff Reef, Macs Ground, and Milkies Reef in 2013 and 2024, and at Northern Outer in 2013 (2013 data from Bryars 2013).

Despite the long timespan, of the 22 fish photo-marked on the 2022–24 surveys at Seacliff Reef, 10 fish were successfully photo-matched with the original photo-catalogue of 2010-13 and which had first been photo-marked in 2010, i.e., 13 or 14 years later (Figure 6; Original fish Numbers 2, 12, 14, 15, 17, 18, 24, 26, 34, and 37, Appendix D). Fish No. 15, which was first photographed in May 2006 by a community diver, was photo-recaptured at Seacliff Reef 18 years later in 2024 (Appendix E). At Macs Ground, five individuals were able to be matched in 2024 with the 2013 photo-catalogue. In all individuals there had been some changes in the markings over the years (e.g., Figure 6), with dramatic changes in some fish which made photo-matching more challenging (e.g., RHS No 5, Appendix F). Each of the 10 individuals recaptured at Seacliff Reef in 2022–23 was within the same or adjacent 50 m section of reef to where they were originally reported as occurring in 2010–13.

Length estimates of the 10 photo-matched fish at Seacliff Reef across the 13–14 years between survey periods showed that five medium fish of 20–25 cm TL grew to large 30–35 cm TL (i.e., min. 5 cm and max. 15 cm growth), one medium fish of 20–25 cm TL grew to large 25–30 cm TL (min. 1 cm and max. 10 cm growth), one large fish remained at 25–30 cm TL (zero growth), and three large fish grew from 25–30 to 30–35 cm TL (min. 1 cm and max. 10 cm growth). For the five fish at Macs Ground photo-matched across the two study periods, two medium fish of 20–25 cm TL grew to large 25–30 cm TL (min. 1 cm and max. 10 cm growth), one large fish remained at 25–30 cm TL (zero growth), and two large fish grew from 25–30 to 30–35 cm TL (min. 1 cm and max. 10 cm growth).

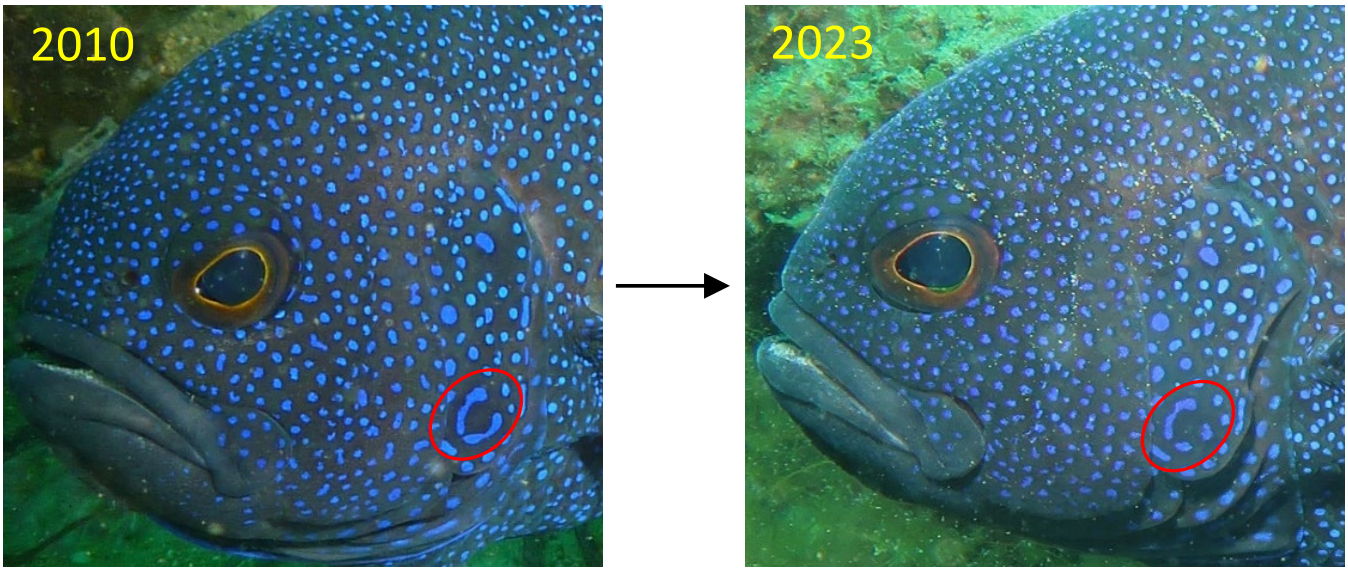

Figure 6. An example of photo-matching of an individual southern blue devil from 2010 and 2023. The red shapes highlight an area of note for photo-matching and demonstrates how the markings have changed across the years. Photos: Simon Bryars.

As with the 2010–13 surveys at Seacliff Reef the population size distribution in 2022–24 was dominated by medium and large fish with no fish <15 cm TL (Figure 7). However, in 2022–24 there had been a noticeable shift in the size distribution with a modal size class of 30–35 cm TL and relatively few fish present in the 20–25 cm TL size class (Figure 7). Despite the lower number of surveys, this pattern was also repeated at Macs Ground and Milkies Reef with a shift towards the larger size classes when compared to 2013, however, four small fish of 5–10 cm TL were detected at Macs Ground and three at Milkies Reef.

Two different individuals (assumed to be males as males guard the eggs) of 30–35 cm TL were observed guarding eggs during January of the 2023 surveys. One of these males (No. 7 = Original No. 14) was observed in an apparent courtship display with another individual (No 6 = Original No 15) on Survey 3 just 11 days after it had been guarding an egg mass on Survey 2; both fish were observed nine days later on Survey 5, but no egg mass could be located. The other of those males (No. 9) was observed guarding another egg mass in February 2024.

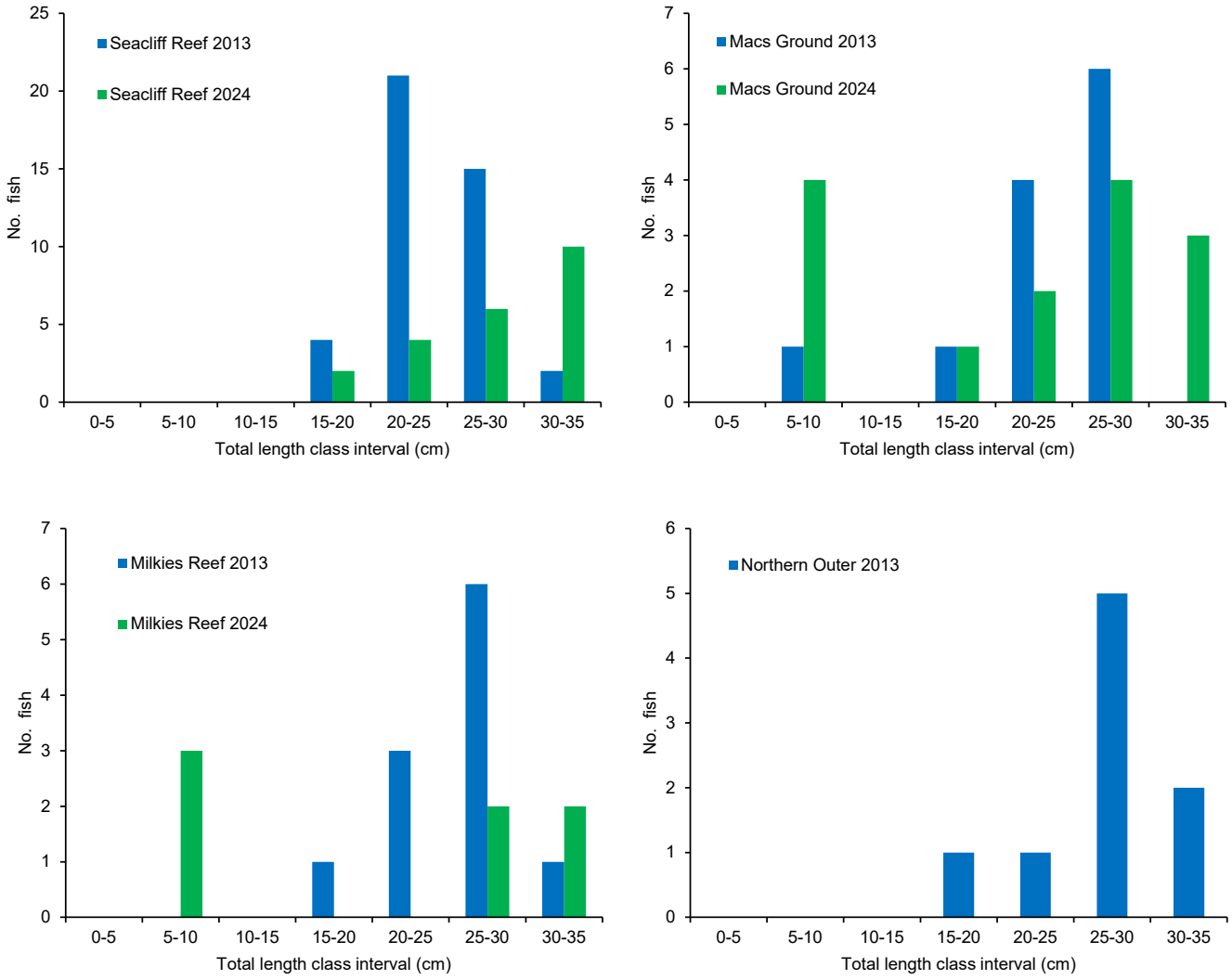

Figure 7. Size frequency distribution of photo-marked *Paraplesiops meleagris* at the four study sites from the 2010–13 (2013) and 2022–24 surveys (2024) (2013 data from Bryars 2013).

On Survey 6 at Seacliff Reef, two individuals of the same size (25–30 cm TL) were observed with superficial damage to their heads, bodies, and fins and that were engaged for many minutes in an apparently aggressive display: at times they were either locked together mouth to mouth or mouth to head, biting each other, or repeatedly circling each other (Figure 8). Such behaviour had never been observed on any other surveys or elsewhere by the authors.

Figure 8. Two southern blue devils engaged in an apparently aggressive display on 9-Feb-2023; upper panel showing one fish grasping the other fish in a mouth-head lock, lower panel showing the two fish grasping each other in a mouth-mouth lock. Note the superficial damage to their heads, bodies, and fins. Photos: Dan Easton.

3.2 Outreach and engagement

On 10 May 2023, a team of 10 South Australian RLS volunteers received training and actively participated in the final survey of the season, facilitated using a charter diving vessel. During this event, divers were divided into two groups, each responsible for surveying three of the six designated 50 m transects. This event showcased the enthusiasm of the volunteers but also highlighted the potential of volunteers contributing to monitoring initiatives and positive outcomes that can arise from engaging the local community in conservation efforts.

In February 2023 and March 2024, an additional effort to foster engagement was undertaken through presentations as part of the Green Adelaide Coastal Ambassadors program with attendances of 20–30 people per session. These presentations provided a platform to effectively communicate the program's outcomes, encompassing a

comprehensive understanding of blue devil biology, conservation significance, and life history. This approach played a pivotal role in bridging the gap between scientific insights and the broader community, promoting awareness and appreciation for this iconic species.

In September 2024, the results of the study were presented at the Australian Marine Sciences Association conference in Hobart. A journal paper on the results of the entire study since 2010 has been prepared for submission in 2025 (Bryars et al. submitted).

4 Discussion

4.1 Utility of photo-ID method

The recent surveys have proven the long-term effectiveness of the photo-ID method for identifying individual southern blue devils. Numerous fish were photo-matched after periods of 13-14 years and even up to 18 years in one individual. Overall, mature southern blue devil operculum markings are remarkably stable and despite some dramatic changes in the markings of some fish, it was still possible to photo-match 10 and five individuals at Seacliff Reef and Macs Ground, respectively, from the original 2010–13 surveys with those conducted in 2022–24.

Attempts at photo-matching reinforced the need to have quality photos of both sides (i.e., left-hand side (LHS) and right-hand side (RHS)) of an individual's head because sometimes there was little change on one side which allowed easy photo-matching, but dramatic changes on the other side which made photo-matching difficult (e.g., RHS No 5). It is apparent that in many cases the changes are due to growth/expansion of the operculum and the breaking up of the iridescent markings over time, especially in the most noticeable and unique shapes (which are often a variation of a circle or semi-circle) found on many fish at the lower part of the operculum (Appendix D, LHS No 1, LHS and RHS No 3, RHS No 4, RHS No 5, RHS No 7, LHS No 8; Appendix F, RHS No 5). In some fish, new spots had appeared after the 10-year period, which can also increase the complexity of photo-matching. The difficulties with photo-matching some fish using visual ID could potentially be assisted by using image recognition software which would increase the searchable pattern area compared to the human eye and is worth exploring if the project is to be continued and/or expanded.

4.2 Population status and trend

4.2.1 Seacliff Reef

Based upon the cumulative number of individual fish photo-marked after 10 surveys it is apparent that the population abundance at Seacliff Reef is markedly lower in 2024 than in 2013, with about half the number of fish being captured after the equivalent number of surveys (Figure 5). The population was comprised mainly of larger and older individuals in 2024, with about half of the population being long-term residents and the other half potentially new recruits. In 2024 there were very few fish <25 cm TL, whereas in 2013 the 20–25 cm TL size class was the most dominant (Figure 7). Collectively, this implies that the population is now less abundant and older in 2024 than in 2013 with little juvenile recruitment in that period.

4.2.2 Macs Ground and Milkies Reef

There were insufficient surveys at Macs Ground and Milkies Reef to get reliable population estimates with the cumulative curves still rising (Figure 5). Nonetheless, the cumulative count at Macs Ground was higher in 2024 than in 2013, and at both sites there had been a shift towards larger fish. However, several small fish were detected at both reefs in 2024 indicating a juvenile recruitment event (and noting that community divers reported juveniles at Northern Outer and other nearby reefs in 2024 but not at Seacliff Reef). The presence of these juveniles is significant

in the context of survey results across all sites from 2010–13 and 2022–24 in which just one small fish had only ever been detected at Macs Ground in 2013 (Bryars 2013, Figure 7).

4.2.3 Summary

Whether or not the lower abundance at Seacliff Reef in 2024 than 2013 is a cause for concern remains unclear. Current evidence suggests that the species relies upon infrequent juvenile recruitment events to replenish their small but long-lived populations. Such life history strategies are common in marine species, and it is possible that a successful 'pulse' recruitment event could occur as has recently happened at Macs Ground and Milkies Reef in 2024. Future surveys should therefore continue to be conducted at Seacliff Reef to detect juvenile recruitment. Further collection of photos at all reefs is also required as numerous individuals in the photo-catalogue do not have adequate photos of both sides of the head which can make interpretation and photo-matching difficult. It would also be useful to attempt to photo-recapture the juveniles at Macs Ground and Milkies Reef in 2025 to determine if juveniles are also site-attached and gain information on how the markings change in these smaller fish.

4.3 Outreach and engagement

There is good potential for further developing a long-term program on the southern blue devil in the Green Adelaide region and the wider Fleurieu Peninsula as:

- The species is much-loved and photographed by community divers.
- The species is present at many of the popular dive sites in the region, both on natural rocky reefs and artificial structures.
- Photo-ID is a proven technique for identifying individual fish over many years and even decades.
- Photo-ID enables the collection of a range of biological data including population abundance, site fidelity, home range, size distribution, behaviour, recruitment, and growth.

An initiative involving RLS volunteers and community divers to participate in the southern blue devil surveys was explored as part of the GARR program. Engaging volunteers and community divers for southern blue devil surveys has shown promise and yielded several positive outcomes, particularly in terms of the high level of engagement these volunteers experienced. With such engagement, these volunteers could become enthusiastic advocates for iconic species and custodians of long-term monitoring in Green Adelaide and the surrounding regions. While there are some challenges using volunteer divers, including requiring a higher skill level and knowledge of equipment in underwater photography which requires additional resourcing, the current volunteer RLS training and accreditation process embedded in the GARR program can facilitate this requirement to overcome these limitations and provide ongoing support to targeted blue devil surveys through this network of community divers.

There are also opportunities to consider greater community involvement and engagement on a broader scale. Outreach initiatives such as community presentations could raise awareness and educate a wider audience about the significance of reef ecosystems across Green Adelaide highlighting the importance of surveys of iconic species such as the southern blue devil, especially given the logistical and behavioural difficulties to capture information on the species (e.g., boat access, fish avoidance behaviours). Additionally, their life history (e.g., low recruitment) and the fact individuals are spatially sparce, makes collecting data intrinsically challenging but critical to determine their conservation status. Tapping into the local network of community divers, photographers, and naturalists could enhance participation (e.g., as occurs with iNaturalist). Encouraging individuals to contribute their underwater photographs for species identification could both expand the dataset and foster a sense of collective responsibility for reef health.

By considering these points and diversifying our engagement strategies to explore different opportunities to curate a wider photographic dataset, we could potentially harness the passion and interest of the broader diver community through citizen science to contribute to the current program. We could also increase the number of photo-marked fish and improve population estimates based upon cumulative counts and potentially identify new locations for

targeted surveys. Such an approach aligns with Green Adelaide's commitment to outreach and engagement, further solidifying the role of the community as stewards of our marine environment.

5 Recommendations

- Conduct further surveys at Macs Ground and Milkies Reef in 2025 to search and photograph juveniles that were photo-catalogued in 2024. This would provide novel information on survival, site fidelity, changes in markings, and growth rate of the juvenile life stage, which is currently limited.
- Investigate the potential for developing a photo-catalogue at popular dive sites where blue devils are found, e.g. Second Valley, Rapid Bay Jetty, Lasseter's Reef, ex-HMAS Hobart, and the Dredge and Barge off Adelaide. This could provide some comparative data for the current study sites by utilising citizen scientists and could be a useful mechanism for education and outreach.
- Investigate the potential for establishing some new monitoring sites in the core parts of the species range including inside and outside of South Australian marine park sanctuary zones. This could provide some comparative data to the current study sites which are all at the northern extent of the species range and subjected to relatively high recreational fishing pressure.
- Investigate the use of image recognition software for photo-ID of southern blue devils. This could provide a mechanism for processing larger numbers of photos and could potentially increase the accuracy of photo-ID.
- Undertake population modelling (e.g. Population Viability Analysis) to assess the likelihood of population decline over time based on longevity and juvenile recruitment patterns.
- Develop a citizen science project which educates and encourages local divers to take and upload photos of blue devils to a web-based tool (e.g., iNaturalist). This could increase the frequency and number of photo-marked fish (and thus improve cumulative population counts), improve the detection of juvenile recruitment and identify other potential sites of importance, whilst providing a platform for education and outreach.
- Interrogate current citizen science portals (i.e. Reef Life Survey, iNaturalist, Atlas of Living Australia) for blue devil sighting records and associated data for temporal patterns in abundance and size distribution of southern blue devils at sites across SA. This could provide context for the patterns being observed at existing study sites off Adelaide.
- Continue to involve RLS volunteers through the GARR program monitoring in blue devil surveys to build community capacity to conduct surveys and set up new sites for monitoring.

6 References

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7 Appendices

A. Terminology for photo-ID in the southern blue devil

Photo-identification: The unique pattern of natural iridescent light blue markings (i.e. spots and other shapes) on the head that allows identification of an individual fish using photos.

Photo-graphed: A photo is taken of an individual fish. The photo may or may not be suitable for photo-identification purposes.

Photo-captured: A photo is taken of at least one lateral side of the head with the markings in focus, lateral body symmetry/angle (i.e. 90 degrees where possible) and the head region displaying unique markings are visible to allow photo-identification of that individual.

Photo-marked: The photo-captured fish has distinguishing patterns of natural markings that enables photo-identification such that it can be 'photo-marked' and added to a photo-catalogue as a new individual (i.e. it was previously unmarked).

Photo-catalogued: A cropped photo of a newly photo-marked individual is added to the photo-catalogue for the left-hand side (LHS) and/or right-hand side (RHS) and allocated the next available sequential number for that individual at that site from the database. Noting that sometimes individuals may not have both sides available for the photo-catalogue. However, caution is required in allocating more than one new fish to the photo-catalogue when only one side is available; in these instances, there must be strong evidence that they are different fish, e.g. they were seen at different ends of a reef on the same survey, they were seen together at the time of photo-capture, they are clearly different in size. The objective for fish with only one side available or poorer quality photos is to add the missing photos or better-quality photos if they can be collected on subsequent surveys. In this way the photo-catalogue can be continually updated and improved.

Photo-matched: The process of using photo-identification to compare two different photos and assess if they are a match and therefore the same individual. Used to compare a photo-captured fish with a photo-catalogue and assigning as either not matching (i.e. it is a new unmarked fish which is then 'marked' and added to the photo-catalogue) or matching (i.e. it is a photo-recapture of a previously marked fish which is in the photo-catalogue).

Photo-recaptured: A photo-captured individual can be photo-matched with an existing photo-marked individual in the photo-catalogue.

B. Survey methodology in the southern blue devil

Equipment required

Scuba gear, digital underwater camera gear, dive slate and pencil, waterproof datasheet if preferred to writing on a hard slate, torch, and survey tapes (if measuring distance along a reef).

Site selection

Identify a discrete reef or section of reef that is inhabited by the southern blue devil and that is suitable for systematic searching of fish and which enables confidence in complete search effort (e.g. relatively non-complex ledge-like reef structures, isolated reefs that are surrounded by habitat(s) unsuitable for blue devils such as seagrass and sand, artificial reefs including shipwrecks). Preferably the reef can be searched on a single dive or two dives on a single day.

Preferably have permanent markers or some other means of spatially defining the start and end points of the search area underwater (e.g. GPS waypoints and the use of shot-lines, characteristic rock features, tapes). If the

specific location of the fish within the search area is required (e.g. for home range estimates) then additional markers or the use of tape measures will be needed to accurately estimate location.

Survey and image capture technique

Once the search area is defined then systematic searches can be undertaken using a pair of scuba divers. Prior to the survey, record the following information on your dive slate: Date, Time, Location, Diver name, Diver buddy name, and once underwater record the visibility in metres.

Survey the entire reef attempting to photo-capture all fish observed. The search effort should include looking in the surrounding open water, under ledges, and in caves and holes. The use of a torch is recommended for looking in dark places or at deeper sites. The pairs of divers can stagger their search along the reef whereby when one diver encounters a fish the other diver may proceed along the reef continuing to search whilst within sight of the other diver until they encounter a different fish.

Once a fish is encountered, attempt to photograph (and photo-capture) both sides of the head, and try to have the camera angle as close as possible to perpendicular and lateral with the head (i.e. 90 degrees).

If a fish is not out in the open, it may be necessary to allow time for the fish to emerge from a ledge/cave/hole such that a photo can be taken. Fish can sometimes be enticed out using unfamiliar objects such as a dive slate placed on the seabed as they are often inquisitive. If the fish does not emerge then photos will need to be attempted within the tighter confines of their hiding place. If the fish cannot be photographed, a note should be made and then searching recommenced for other fish along the survey trail. It is important to remember that the aim of the surveys is to photograph (and photo-capture) fish as opposed to obtaining high quality photogenic shots. Timing is key to conducting a complete underwater survey hence, once a fish is believed to be photo-captured it is ideal to promptly recommence searching.

Fish are usually encountered as solitary individuals which makes photo-capture easier. However, sometimes two fish will be found together, and in these instances, it is important to distinguish between them when undertaking photo-capture and recording details (see below).

The use of strobes in flash photography will usually assist in capturing better quality images. However, back scatter can be a major problem for successful photo-capture when the camera focuses on particles in the water column rather than the fish. In addition, with larger equipment (i.e. large strobe arms and camera housings) it can make it difficult to obtain images in tight spaces. Sometimes the use of a small camera/housing without strobe arms is particularly useful. Whilst videos can sometimes be utilised for screen grab still imagery this depends on the model of camera and often the angle of the photograph can be harder to verify leading to more oblique and less lateral side on images.

Once a fish has been photo-captured (preferably both LHS and RHS) the following details should be recorded on a dive slate: the sequential number of the different fish observed on the survey (starting with 1 upwards), an estimate of size (the total length TL of the fish), the location of the fish along the reef (if that information is possible and/or required for your study), if the LHS and/or RHS were photographed, and any unusual behavioural information (e.g. egg guarding, fighting). In the present study, size was estimated within 5 cm intervals from 0 up to 35 cm TL representing the maximum size class for this species. Reef Life Survey methodology uses estimates in the following size classes: 2.5, 5, 7.5, 10, 12.5, 15, 20, 25, 30 and 35 cm which may also be used depending on whichever size classification is most useful for your study. Once all information is recorded, take a photo of the slate and data sheet before moving on to search for the next fish to distinguish between sightings when processing the data post-dive.

C. Method of photo-matching in the southern blue devil

Image processing

All photos should be labelled and categorised consistently when downloaded to enable effective long term data management. All photos for our study were uploaded into individual folders per fish sighting correlating to the datasheet with the following naming scheme: Diver initials, Fish Sighting ID number and the Location on the Reef_ Date Site, e.g. JH_03T5_200123SeacliffReef. The same folder naming convention was used for the individual photos in the folder with the addition of an automatically assigned sequence number aligning to the time it was taken. Any photos that are not appropriate for photo-capture can be removed/deleted (e.g., out of focus, backscatter). All datasheets should be scanned and saved with diver initials, date and site of survey.

Photo-matching technique

If there is a series of photos of the same individual, then select the photo that is most side-on (i.e., perpendicular) to the head, and which has the best image sharpness showing the iridescent natural markings on the head. If there are photos of both sides of the head, then start photo-matching using the side which has the best quality photos (i.e., side-on, and sharp). Crop the chosen photo to the head area and assign as LHS or RHS. This photo can then be compared with photos in the photo-catalogue. Align the two photos for matching directly next to each other on a computer screen such that the orientation is as close to horizontal as possible (e.g., head not tilting downwards in one and upwards in the other), and the size of the head in each photo is similar in scale (by zooming in and out). Scroll through the photo-catalogue to see if there are any potential matches.

Concentrate on the following areas of the head (shown in Figure 9 below using coloured rings as examples on the same individual photographed 13 years apart):

- Lower part of the operculum (e.g., red rings below).
- Remainder of the operculum including the rear edge (e.g., yellow rings below).
- Remainder of the head and especially rearwards of the eye (e.g., green rings below).
- Basal part of the upper jaw (e.g., orange rings below).

Visually scan for areas that have:

- Distinctive individual markings other than the simple and most abundant small dots (e.g., ring-like shapes, unusual shapes, dashes, arcs, lines, larger dots) and,
- Distinctive groups or patterns of several or more markings.

If there is a matching spatial arrangement of a minimum of 3 separate areas between two photos, then it is assumed to be the same individual, as the chance of this happening with two different individuals is remote. In the photo below there are 7 areas highlighted that match and the spatial arrangement of those 7 areas is the same between the two photos. However, any 3 of those areas would have been sufficient to create a match.

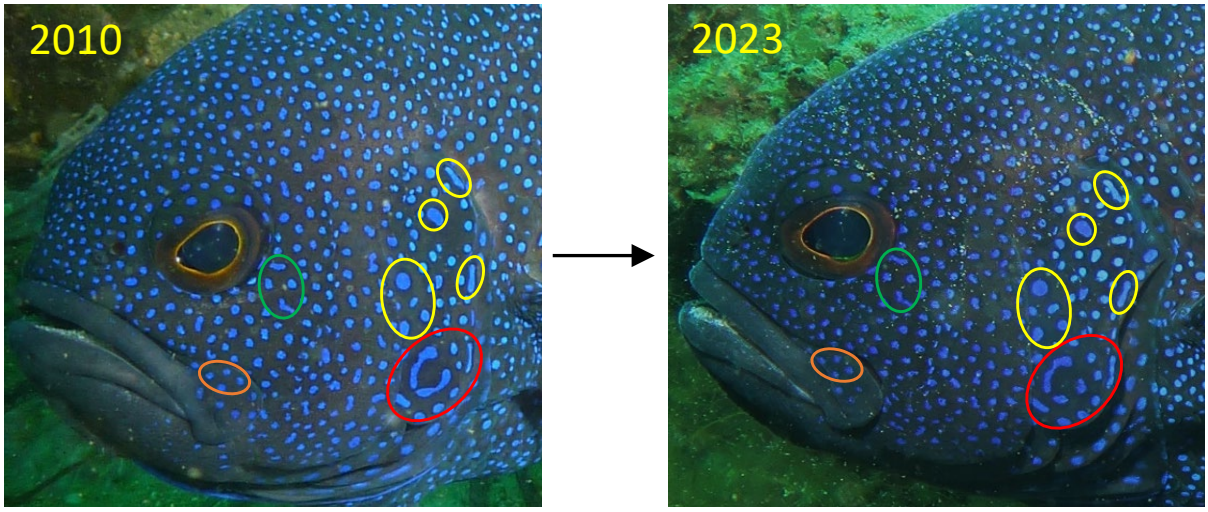


Figure 9. Coloured rings identify the same individual photographed 13 years apart

In cases where photos are available of both sides of a fish then:

- A double check of the photo-match with one side can be done using the opposite side,
- If there is uncertainty with one side of the fish (which can happen with poor quality photos) then use the opposite side, or
- If there are many years between photos and significant changes in markings have occurred, then both sides can assist with a positive match.

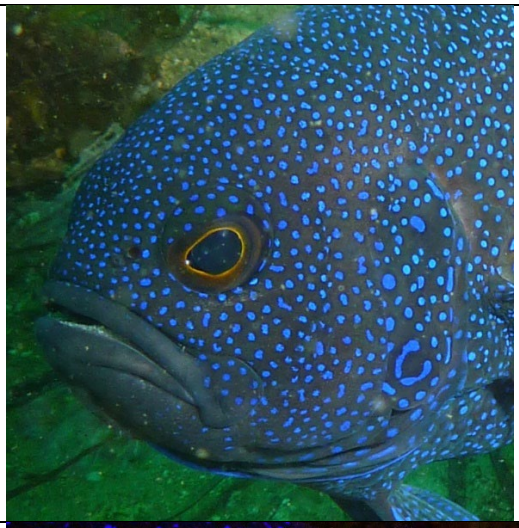
If there is uncertainty about a photo-match, then a second opinion should be sought. If there is still uncertainty, then a photo-match should not be assigned to prevent a false positive.

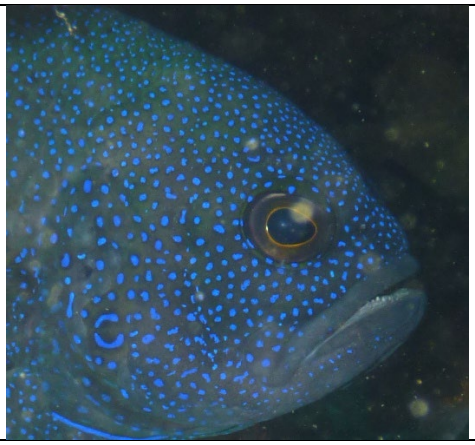
If using a Capture-Mark-Recapture method, then on the first survey all photo-captured individuals will be 'new fish' and therefore photo-marked and added to the photo-catalogue. Then on subsequent surveys all photo-captured individuals can be compared with the photo-catalogue and assigned as either not photo-matched (i.e. it is a new unmarked fish which is then 'marked' and added to the photo-catalogue) or photo-matched (i.e. it is a photo-recapture of a previously marked fish which is in the photo-catalogue).

Some other things to consider when photo-matching:

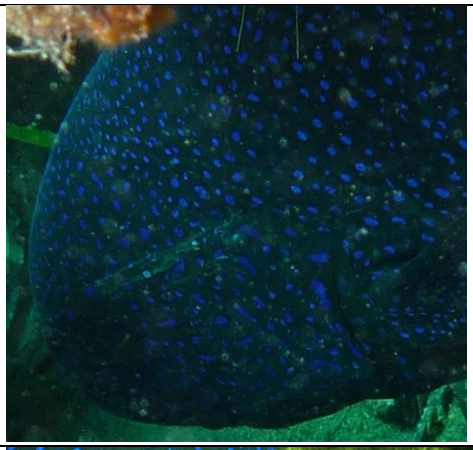
- In some instances, a newly photo-marked fish with only one side available cannot be added to the photo-catalogue if there are previously photo-marked fish in the photo-catalogue with the opposite side missing, i.e. they might be the same individual. In these cases, further surveys are required to photo-capture both sides of the fish at a single point in time to allow positive photo-matching (see earlier).
- There is often variation over time (years) in the more abundant small dots which can appear, disappear, or split; it is best to ignore many of these.
- The angle of the photo away from perpendicular to the side of the fish (e.g., front on) can appear to distort the shape of markings and obscure some of the markings around the gill cover area.
- Zooming in and out on specific areas of interest on the head can assist with photo-matching.
- Significant changes in markings can occur from medium- to large-sized fish as the fish grows and the head and gill cover expand (e.g., some of the markings in the red rings shown above); this can sometimes make photo-matching difficult.
- In some cases, it may assist if the photo is manipulated with computer software to highlight the markings. (e.g., In MS PowerPoint, Picture Format ➔ Artistic Effects ➔ Glow Edges; MS PowerPoint, Picture Format ➔ Contrast, etc., see examples below)
- Photos that capture only part of the head can still be used for positive photo-matching if there are particularly distinctive marks.

D. Photo-matching of 10 individuals between the 2010–13 surveys and 2022–24 surveys.

	No. 17 in 2010	= No. 1 in 2023
LHS		
RHS		

	No. 34 in 2013	= No. 2 in 2023
LHS	Not photo-captured	
RHS		

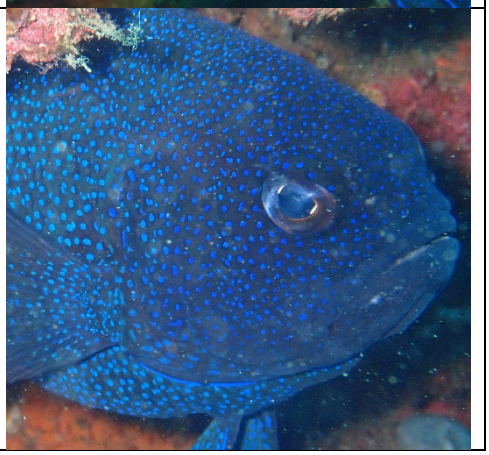
	No. 18 in 2010	= No. 3 in 2023
LHS		
RHS		

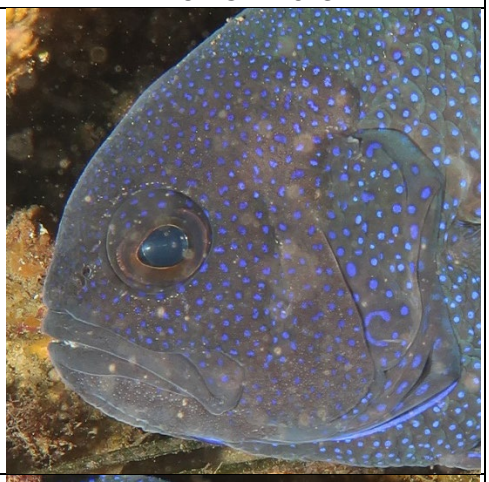
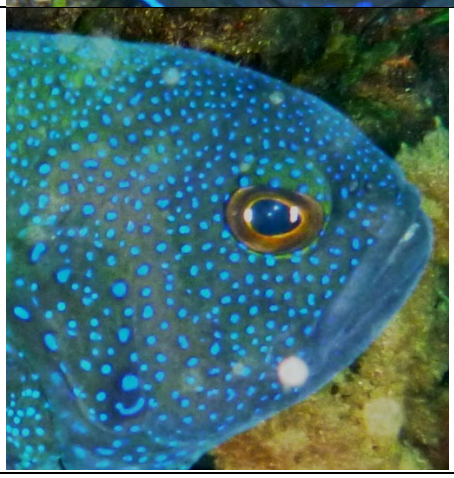
	No. 12 in 2010	= No. 4 in 2023
LHS		
RHS		

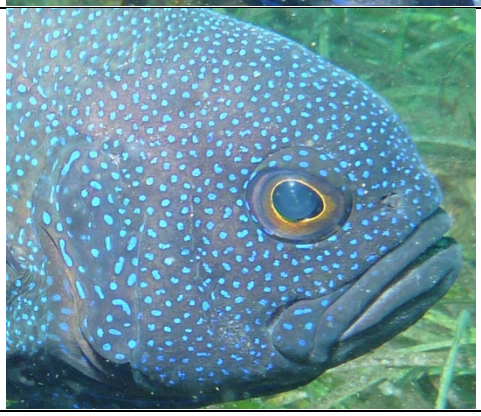
	No. 24 in 2010	= No. 5 in 2022
LHS		
RHS		

	No. 15 in 2010	= No. 6 in 2023
LHS		
RHS		

	No. 14 in 2010	= No. 7 in 2023
LHS		
RHS		

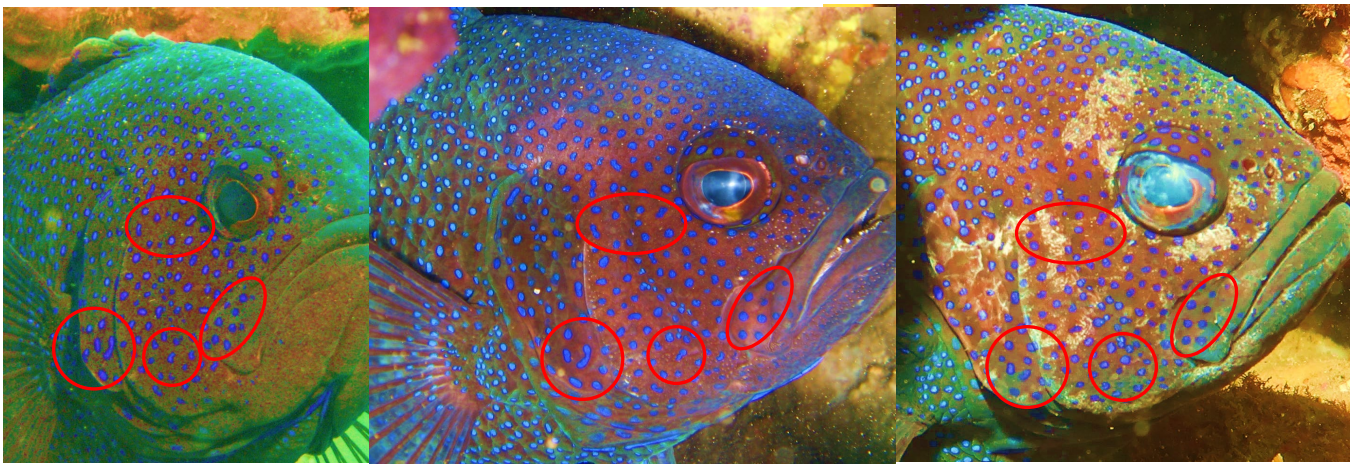
	No. 26 in 2010	= No. 8 in 2023
LHS		
RHS		

	No. 37 in 2010 (LHS) & 2012 (RHS)	= No. 15 in 2023
LHS		
RHS		

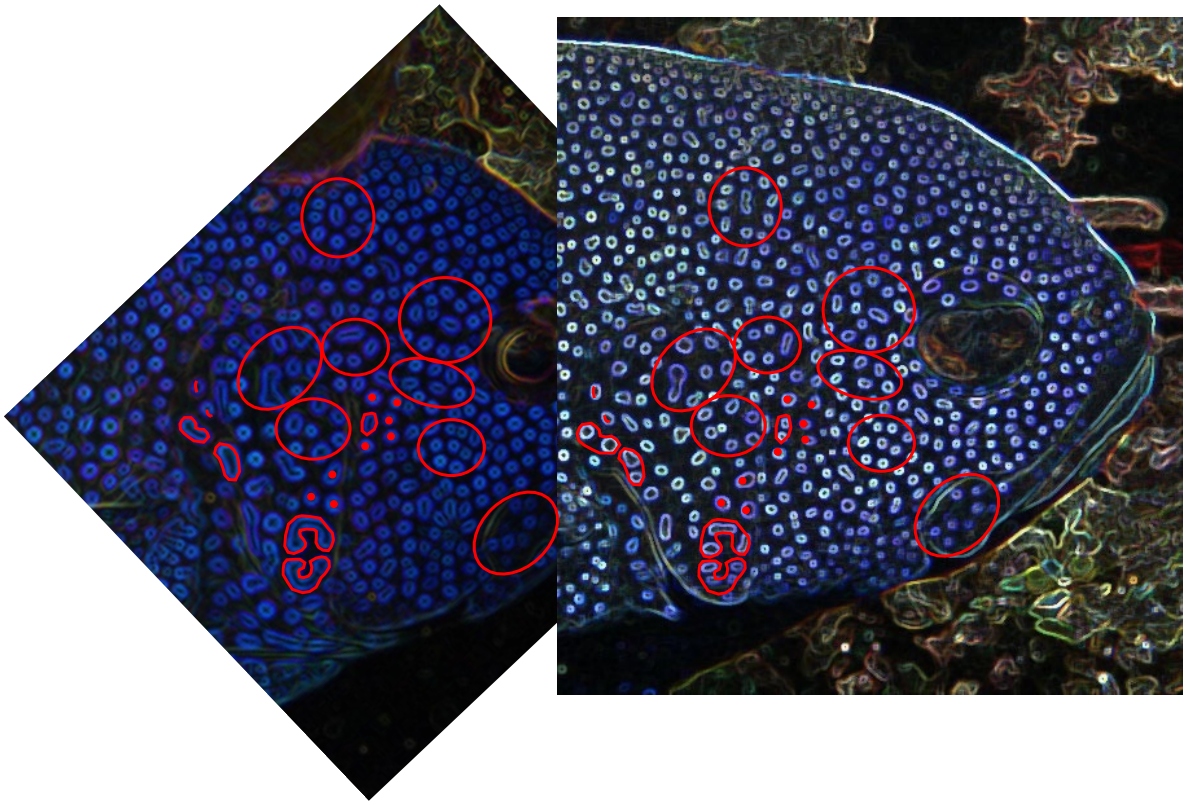
	No. 2 in 2010	= No. 18 in 2023
LHS		
RHS		

E. Photo-matching of fish No 6 (originally labelled as No 15 in 2010) in 2006, 2010 and 2023. Note that the colours have been modified to enhance the markings and red shapes highlight areas of note for photo-matching across the years.

2006 2010 2023



F. Photo-matching of fish No 5 (originally labelled as No 24 in 2010) in 2010 (left) and 2023 (right). Note that the colours have been modified to enhance the markings and red shapes highlight areas of note for photo-matching across the years.



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