Australia's National
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# Implementation of a survey program to monitor recovery of Conservation Dependent Southern Dogfish and Harrisson's Dogfish

## Final Report

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'Determining the status and recovery of depleted or declining fish species: a case study of southern dogfish and Harrison's dogfish in the context of AFMA's upper slope dogfish management strategy'.

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## Important disclaimer

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# Acknowledgments

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# Executive summary

**Management background:** This report details the results of the first field-based monitoring program for Harrisson's Dogfish and Southern Dogfish ('gulper sharks') undertaken by CSIRO, Fishwell and members of the fishing industry during 2022 and 2023. These species were listed under Threatened Species provisions of the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) in 2013 due to their widespread depletion by commercial fishing. The Threatened Species Scientific Committee (TSSC) listed them in the relatively low risk category of 'conservation dependent' because the TSSC: (1) considered the Upper Slope Dogfish Management Strategy (USDMS) (AFMA 2012; NSWDPI 2012) to have the potential to achieve its primary objective, "to halt further decline and support recovery of both species in order to maximise their chance of survival in nature"; and (2) required the effectiveness of the USDMS to be assessed via Research and Monitoring Workplans and a scientifically robust monitoring program (AFMA 2014, 2017). Two stakeholder workshops were convened in response to Workplan #2 (AFMA, 2017). Their purpose was to design a monitoring program aimed at producing standardised data to support a range of recovery indicators (Williams *et al.* 2018).

**Field program and baseline dataset:** Population baseline data for gulper sharks were generated in five reference areas (RA) – Flinders, Port MacDonnell, Hunter, Endeavour and Murray – by three successful auto-longline (ALL) fishing surveys scientifically supervised aboard the FV *Diana*. The data collected address four indicators of gulper shark population recovery: (1) relative abundance (standardised CPUE); (2) area of occupancy (geographical distribution); (3) size composition; and (4) sex composition; tag recaptures were also assessed. Non-extractive image-derived data from BRUVS (baited remote underwater video systems) were collected to compare to ALL catches. The ALL data proved to be very robust, whereas the BRUVS-generated data were not fit-for-purpose.

**Initial interpretation of data:** Interpretation of these baseline data in relation to recovery indicators is necessarily cautious in this report because time-series comparison is presently possible only at the Flinders RA (Table 4, Table 5), and not possible at the Port MacDonnell RA (non-standardised historical data), Hunter or Endeavour RA's (little historical data), or Murray (no historical data).

**Assessing the effectiveness of the USDMS:** Data from the five RA provide the means to assess the USDMS against its primary objective because these RAs contain remnant populations and stocks of both listed gulper shark species and have a variety of expected recovery trajectories. Catches during this survey suggested that there had been no decline of either species in the locations where they were expected to occur and showed male and female sharks co-occurred in every RA, indicating that breeding populations are protected (Table 6). Most importantly, in the Flinders RA, the large number (240) of Harrisson's Dogfish caught, and increase in mean CPUE (5.59 to 8.01) with relatively low SE (1.57 and 2.08, respectively) (Table 4, Table 5), was consistent with an expected upwards trajectory of relative abundance in an early stage of recovery following

protection of this population. This positive sign was further supported at the Flinders RA by an apparent expansion in the area of occupancy, a greater proportion and spatial range of juveniles, and co-occurrence of male and female sharks over a broad area (Table 6).

**Meeting requirements of Conservation Dependent listing:** In line with the TSSCs requirement, the monitoring program has been enacted, and the first phase of field sampling completed successfully. There is limited scope for performance assessment against rebuilding targets at this time because the data reported here are primarily establishing a baseline. Nonetheless, data suggest no further decline of either Harrisson's or Southern Dogfish, some evidence of early recovery of Harrisson's Dogfish in the Flinders RA, and no contra-indications to recovery for indicators (1 to 4). We note, however, one important RA was not sampled, Table 6.

**Recommendations for AFMA's future Research and Monitoring Workplans:** Requirements for future monitoring and management of Harrisson's and Southern Dogfish will be considered by the Upper Slope Dogfish Scientific Working Group (USDSWG), fishery RAGs, fishery managers and external stakeholders as part of developing AFMA's Workplan (WP) #3, following collection of these baseline data. We have used data and experience from this project to make recommendations in relation to the following four questions:

1. How will abundance measures (and other indicators) from the monitoring program be used to quantify the extent of rebuild? [Section 4.4.2]
2. How often, where, how intense and how to fund future surveys? [Section 4.4.3]
3. Is there erosion of the 25% of gulper habitat protected in closures by increased access for fishing, and if negative influences stem from this – including for interpreting monitoring data from key reference areas? [Section 4.4.4]
4. If fishing mortality outside closures is adequately monitored, and sustainable? [Section 4.4.5]

**Future field monitoring (gulper sharks and other depleted species):** This project developed the operational detail required for an effective ongoing ALL-based program of monitoring, and the standard operating procedures (SOP) required to ensure that the data collected can be standardised – an essential requisite for time-series data. A series of recommendations is made in relation to vessel suitability and experience of personnel; charter negotiations; operational planning and logistics; charter subsidy, particularly sale of catch; and the high and increasing burden of administrative overheads (particularly permits). In addition, SOP are fully detailed in relation to ALL (and BRUVS) equipment and operation; abundance metrics (standardised CPUE); and relevant environmental factors (particularly fishing depths).

There is very little scope to apply the methodology developed for monitoring gulper sharks to other depleted or declining SESSF species due mainly to operational factors (Table 7).

# 1 Introduction

## 1.1 Listing of gulper sharks

Harrisson's Dogfish (*Centrophorus harrisioni*) and Southern Dogfish (*C. uyato*, previously *C. zeehaani*; White et al., 2022), often referred to as 'gulper sharks', were listed under Threatened Species provisions of the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) in 2013 due to their historical widespread depletion by commercial fishing. The Threatened Species Scientific Committee (TSSC) listed Harrisson's Dogfish and Southern Dogfish in the relatively low risk category of 'conservation dependent' because the Upper Slope Dogfish Management Strategy (USDMS) (AFMA 2012; NSWDPI 2012) was considered by the TSSC to be potentially "effective in halting further decline and supporting recovery of both species in order to maximise their chance of survival in nature". Work conducted between 2009 and 2012 by CSIRO and other stakeholders, including the fishing industry and non-government organisations, in two FRDC, AFMA and CSIRO-funded projects (Williams *et al.* 2012, 2013), substantially informed the TSSC evaluation process and contributed to achieving the fishery-favourable conservation dependent listings. The listings were contingent on having "strategies for rigorous evaluation of the effectiveness of the collective management plans against their objectives, with a clear description of the monitoring and review process and its associated timelines" (TSSC 2013).

It was the TSSC's expectation that monitoring of gulper shark recovery would be progressed and reviewed during the first five years of implementation of the management strategy. In response, AFMA developed 'Research and Monitoring Workplans' in consultation with the Upper-Slope Dogfish Research Plan Working Group, a SESSF Resource Assessment Group (RAG) sub-committee (AFMA 2014, 2017).

## 1.2 Designing the monitoring program

Under Australia's Commonwealth Harvest Strategy Policy, stocks are considered to be overfished when they fall below 20% of pristine levels, and all targeted fishing must cease. This is usually achieved through strict management arrangements such as implementing a zero Total Allowable Catch (TAC) or, as was the case for gulper sharks, establishing a range of fishery closures over their preferred habitats. Such management arrangements heavily compromise the value of commercial catch per unit effort (CPUE) as an index of abundance. Without this standard CPUE method of monitoring abundance, there is a need to develop and operationalise other methods to establish a time series of fish abundance index to gauge management effectiveness and monitor change (recovery) of that stock over time. The first data point in such a time series is the 'baseline'.

A key element of the Upper-Slope Dogfish Research Plan was to develop "a cost-effective methodology for measuring gulper shark baseline relative abundance and recovery" (AFMA 2017). As outlined below, this was achieved in the consultative project -- managed by CSIRO and Fishwell (Williams *et al.* 2018) and developed during two stakeholder workshops that were well attended by scientists, fishery managers, and trawl and non-trawl fishing industry representatives.

The consultative project considered: (1) the types and quality of monitoring information that can be obtained; (2) the ways in which alternative types of information address the various needs of the USDMS (e.g. immediate versus long term needs); (3) the opportunities for the fishing industry to be involved in implementing the work; and (4) cost and cost-effectiveness.

The process to develop options for monitoring strategies explored several relevant topics: (1) the definition of recovery in the gulper shark context; (2) prospective indicators of recovery; (3) technical considerations for measuring recovery; (4) field operations and sampling; and (5) suitable reference areas. This background information, and its consideration by workshop attendees, is fully documented in the project report (Williams *et al.* 2018).

It was agreed by the stakeholders at both workshops that: (1) existing data do not constitute a baseline dataset, and that this needs to be established as the first step of the monitoring program; (2) a short list of six suitable reference areas could be identified; (3) commercial auto-longline fishing, with suitable fishing/handling practices, is the most reliable, cost-effective and immediately implementable option for measuring relative abundance (the top-ranked indicator of recovery); (4) a non-extractive (image-based) technique using conventional (short term deployments) and deep Baited Remote Underwater Video Systems (BRUVS) should be used in parallel with fishing to gauge its effectiveness and comparability to auto-longline (ALL) catches – noting that the novel aspects of deep BRUVs include having capability for long-term (weeks to months) data acquisition and being deployable from trawlers (Marouchos et al, 2011); and (5) there is a need and opportunity to continue tagging work to provide complementary data for population estimates, site fidelity, other range movements, and tissues for future genetic studies. On this basis and using three levels of sampling intensity (maximum, medium and minimum), five options for monitoring were identified and ranked by the stakeholders. Each option was costed by considering the indicative costs of vessel charter, scientific support and analysis, and applying off-sets from the sale of commercial bycatch.

Stakeholders ranked Option 1a (six reference areas, medium effort, four separate charters) as the preferred sampling plan for the baseline survey, as it was considered that this would provide the necessary data to inform ongoing monitoring. Using deep BRUVS to collect additional data over the same period was supported given its potential for long-term cost-effectiveness; this would be the first use of the system in a monitoring study.

## 1.3 Implementation of the monitoring program

The current project continued the consultation with industry and broader stakeholders to refine and implement the field-based monitoring program developed previously by Williams *et al.* (2018). Undertaken by CSIRO, Fishwell and the fishing industry between 2022 and 2023, here we report details on the implementation of monitoring Option 1a, the resultant baseline gulper shark abundance indices derived from the first implementation of the monitoring program, and recommendations for the future of the program.

# 2 Needs, Objectives, Planned Outcomes, Benefit

## 2.1 Needs

1. AFMA's Workplan (AFMA 2017) needs to assess the effectiveness of the USDMS in meeting its primary objective of "halting further decline of Harrisson's Dogfish and Southern Dogfish (gulper sharks) and supporting recovery of both species in order to maximise their chance of survival in nature".
2. A monitoring program needs to be implemented to meet the conditions of the conservation-dependent listings for these species.
3. The monitoring program needs to:
    a. address the immediate and long-term needs of the USDMS;
    b. measure gulper shark baseline relative abundance and recovery using scientifically robust methods; and
    c. involve the fishing industry to ensure it is efficient and cost-effective.
4. Other depleted/declining species lack methods and indicators to inform management plans aiming to halt declines and support and detect recovery.

## 2.2 Objectives

1. Complete the program to monitor the recovery of gulper sharks in the SESSF area by planning and implementing a cost-effective field survey program to measure gulper shark baseline relative abundance. [Section 3.1 to 3.3]
2. Effectively communicate the project's results to AFMA, the fishing industry and other stakeholder groups including the TSSC and SESSFRAG. [This report]
3. Contribute to formulating the next steps in the monitoring program in the context of AFMA's USDMS. [Section 4.3]
4. Evaluate the applicability of the research to other depleted/declining species, including species-specific requirements and modifications of methods if required. [Section 3.4]

## 2.3 Planned outcomes and benefits

1. The key outcome will be scientifically robust baseline estimates of gulper shark population relative abundance at key reference sites that support remnant populations of Harrisson's Dogfish and both geographic populations of Southern Dogfish. [Section 3.1 to 3.3]
2. A strategic outcome will be to evaluate the potential to apply two sampling (ALL catch and BRUVS) methods to other depleted/ declining species, particularly those with uncertain status. [Section 3.4]

3. The specific benefit will be to ensure that the USDMS is meeting its primary objective and complies with the TSSC requirement for conservation dependent listing of both gulper shark species. [Section 4]

# 3 The Field-based Monitoring program

## 3.1 Indicators of recovery and Reference Areas

The Reference Areas (RA) for monitoring gulper shark recovery (Williams *et al.* 2018) are locations where remnant gulper shark populations have been shown to exist (Williams *et al.* 2012), and which are now mostly closed to fishing under AFMA's USDMS (Figure 1).

Prospective indicators of gulper shark recovery were identified by the SESSFRAG chairs (SESSFRAG 2010) and adopted as an agreed set of indicators for the monitoring program (Table 1) (Williams *et al.* 2018). This monitoring program is designed to assess indicators 1 to 4 and provide information leading to assessment of indicator 6. Positive indications of population recovery in response to measures implemented by the USDMS are expected to be those below (Table 1). Of these, "an increase in relative abundance" was identified as the best indicator (SESSFRAG 2010), in part, because it is more readily quantified than other indicators.

**Table 1 Indicators of recovery and expected population responses to the USDMS (based on Williams et al. 2018, Table 1.)**

| | Indicator of recovery | Expected population change in response to the USDMS |
|---|---|---|
| **1** | Relative index of abundance in reference areas | Stable or increasing |
| **2** | Area of occupancy ('distribution') | Expanding |
| **3** | Size (age) composition | More larger sharks and presence of juveniles |
| **4** | Sex composition | Male and female populations co-occur (come together for breeding) |
| **5** | Abundance and distribution in commercial bycatch | Increasing and expanding |
| **6** | Genetic measures of connectivity and stock structure | Increasing complexity |

The potential for remnant populations to recover is likely to vary between individual RAs because the trajectory of expected increase in relative abundance depends on the estimated pre-fishery abundance and historical depletion, as well as the area of suitable habitat within the RA (Table 2).

**Table 2 Hypotheses for trajectories of Relative Abundance in relation to three 'types' of fishery Reference Areas (based on Williams *et al.* 2018, Table 2).**

| Type | Reference Area description | Hypothesis for trajectories of relative abundance |
|---|---|---|
| **1** | Not depleted (unfished, or very lightly fished), in suitable habitat, now closed to fishing. | Such areas should demonstrate relatively slow rates of increase in population relative abundance but show maintenance of populations. Large increases in population relative abundance are not expected. *Importantly, these areas could provide an indication of the "carrying capacity" of suitable habitat.* |
| **2** | Previously depleted, in suitable habitat, now closed to fishing. | Such areas should demonstrate relatively fast rates of increase in population relative abundance. Larger increases in population relative abundance are expected relative to (1). |
| **3** | Previously depleted, in suitable habitat, still open to fishing (noting that retention of gulper sharks is presently forbidden). | These areas may demonstrate no increase, low levels of increase, or even decline, in population relative abundance. |

The monitoring strategy was designed to measure population changes in a subset of six RAs representing both species of listed gulper shark (including the central and southern populations of Southern Dogfish), and a variety of recovery trajectories (Table 3) (Williams *et al.* 2018). Thus, for example, moderate to large changes in relative abundance are expected in the Flinders RA because this was an area of historically high abundance that experienced moderate depletion and is now closed to fishing.

**Table 3 Characteristics of gulper shark Reference Areas (based on Williams et al., 2018, Table 8). Each area supports gulper shark populations with different potential to recover and different trajectories of expected population increase depending on original shark abundance, historical depletion, area of suitable habitat, and exposure to continued fishing.**

| Reference Area (Figure 1) | Spatial region of core habitat[1] | Resident gulper species | Historic abundance[2] | Historic depletion[3] | Breeding success[4] | Anticipated trajectory of population increase[5] | Area type[6] |
|---|---|---|---|---|---|---|---|
| **Hunter** | Margin | Harrisson's | NA | Moderate | Many | Small change, or no change if still fished | 3 |
| **Endeavour** | Margin Harrisson's<br>Eastern Southern | Both | NA | Moderate - High | Some | Moderate change | 2 |
| **Flinders** | Margin Harrisson's<br>Eastern Southern | Both | High | Moderate | Some | Moderate to large change | 2 |
| **Pt-Mac** | Central | Southern | High | Low | Some | Moderate change | 2 |
| **Murray** | Central | Southern | NA | High | Unknown | Uncertain | 2 |
| **60-Mile** | Central | Southern | NA | Low | Some | None to small change | 1 |

[1]Based on distributional status defined by Figure 4.12 in Williams *et al.* (2013).
[2]Based on values from Table 1.3 in Williams *et al.* (2013).
[3]Based on estimated relative historic depletion values (approach 1) in Williams *et al.* (2013).
[4]Based on presence of juveniles using catch composition from fishery independent surveys reported in Williams *et al.* (2012).
[5]Hypothesised trajectory of recovery in gulper shark population under the USDMS considering Historic abundance[2], Historic depletion[3] and areal extent of local population (habitat size, km$^2$); see Table 2.
[6] See Table 2.

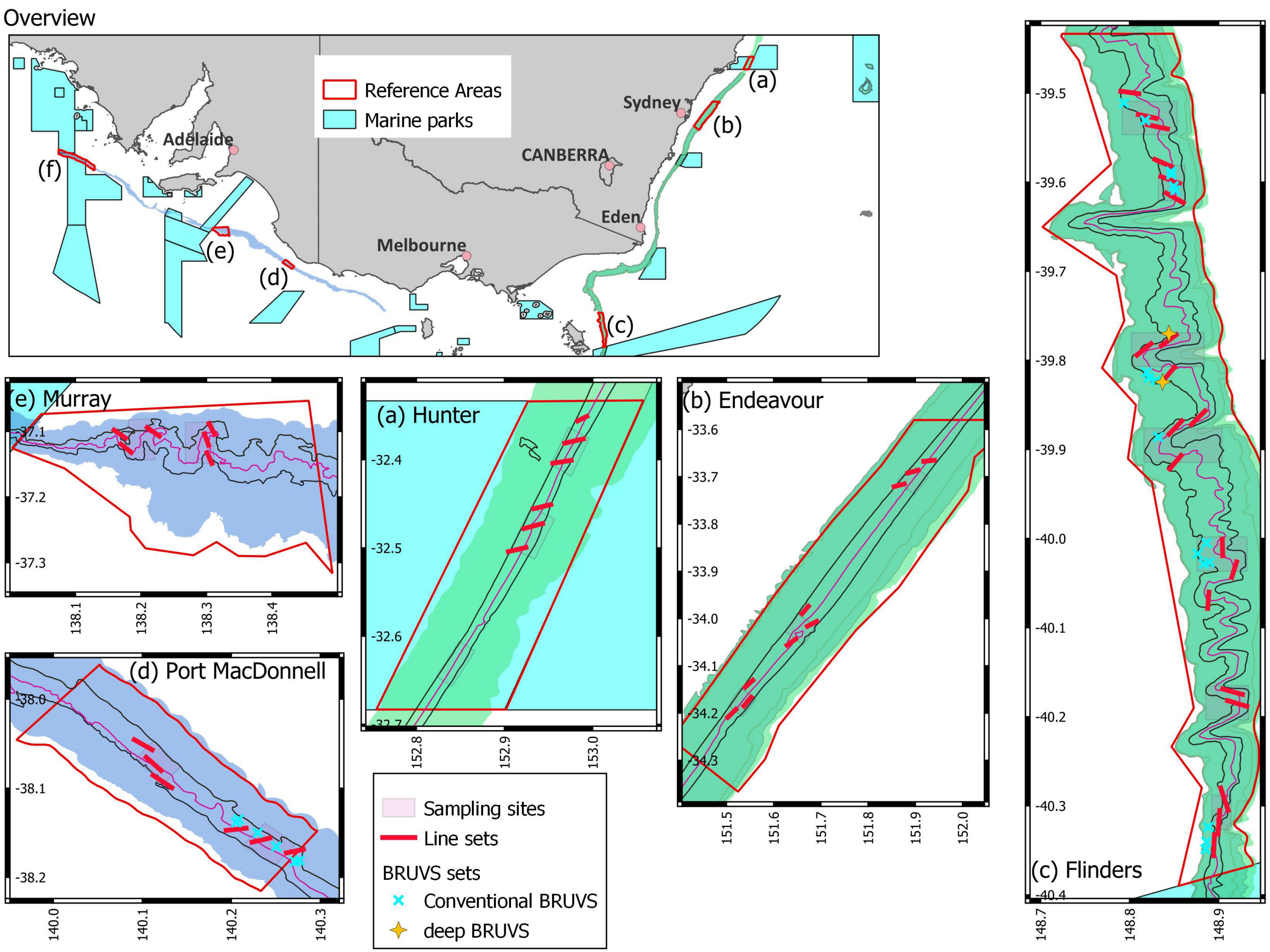


**Figure 1 Map of Australia's south-east coast showing an overview of the location of the Reference Areas (RAs) (a) to (f) on the core distribution of Harrisson's Dogfish (green shading) and Southern Dogfish (blue shading, overlaps green on eastern slope from c to southern border of a) – Williams *et al.* 2013. Inset maps (a) to (e) show the five sampled RAs with the distribution of successful auto longline sets and BRUVS operations over the sampling sites; the Sixty-mile RA (f) was not sampled.**

## 3.2 Overview of methods and data collection

Each survey used two sampling methods:

(1) Commercial auto-longline (ALL): used to catch gulper sharks to provide data on their biology and ecology (relative abundance, distribution, length and sex), as well as tag/recapture information, and tissue samples for future genetic analysis.

(2) Baited Remote Underwater Video Systems (BRUVS): trial of a non-extractive sampling method, i.e. it presents no risk of shark mortality. BRUVS were used to collect additional information on gulper shark ecology (routinely a maximum count per deployment and distribution, but size and sex for some individuals).

Because standardised methods and data are essential for robust time-series monitoring, we applied standard operating procedures (SOP) to our collection methods across surveys to the extent possible. We originally planned to use two auto-baited longline (ALL) vessels, the FV *Diana* and the FV *Candice K*, with somewhat different ALL set-ups (FV *Diana*: 1500 hooks at 1.4 m spacing, FV *Candice K*: 900 hooks at 4 m spacing), to survey individual RAs (FV *Diana* – Flinders, Hunter and Endeavour; FV *Candice K* – Murray, Port MacDonnell and 60-mile). The longline equipment and sounder on the FV *Candice K* were designed to target Gummy Shark in shelf waters but it was determined that modifications were required to adequately survey the deeper waters required for gulper sharks. Unfortunately, the time required to make these modifications was not available within the project timeframe. As a result, all surveys were conducted on the FV *Diana*. However, because of constraints on resources and the extra time and expenses involved in the FV *Diana* traveling to and from the Port MacDonnell and Murray RAs (refer to Section 3.4), the decision was made to exclude the 60-mile RA from the survey program. The baseline data for the remaining five RAs presented here were collected using the FV *Diana*. Having collected data using a single vessel helped considerably when applying SOPs across surveys.

Data were recorded for the catches of all teleost and elasmobranch species (including other gulper sharks) but are not reported here for brevity. Instead complete catch data can be found in the voyage reports (Scoulding *et al.* 2022; Untiedt *et al.* 2023 a&b, reproduced here in Appendix A1 to A3). BRUVS data is reported in the BRUVS analysis report (Althaus *et al.* 2024; reproduced in Appendix A.4).

### 3.2.1 Methods

#### Auto Long Line (ALL)

The ALL SOP included the following elements (details are provided in the survey reports, see Appendix A.1 to A.3):

- Surveys were specifically conducted in or close to winter (August/ September) to reduce heat stress on captured gulper sharks.
- Each RA was divided into equal along-slope segments. The number of segments corresponded to the number of sampling days (Figure 1), derived from the Option 1a sampling program (Williams *et al.* 2018).

- Daily sampling within a segment was standardised to 3 ALL sets and up to 6 BRUVS units, allowing sufficient distances between lines and BRUVS to ensure independence, while minimising the time between deployment and retrieval of longlines (Figure 1).
- Three ALL sets (each with 1500 baited hooks on 30 cm snoods separated by 1.4 m) were deployed within each segment. See Appendix A.1 (Scoulding *et al*. 2022) for a detailed description of the gear.
- A minimum distance of 500 m was kept between ALL sets.
- ALL sets were deployed between 350 and 625 m depth.
- ALL gear was set between 0300 and 0530, after which BRUVS units were deployed.
- ALL soak times ranged between 4 and 6 hours.
- Consistent fishing equipment was used e.g. hooks per set, bait type, snood length and separation of hooks.
- CPUE was calculated per ALL set as catch per 1000 hooks retrieved; where CPUE is reported for an area; the catch per 1000 hooks was averaged across all ALL sets ($N_L$).
- Compromised ALL sets (e.g. due to entanglement) were not considered in the analysis. Figure 1 shows only 'valid' operations.
- Strict gulper shark handling procedures were followed (see Appendix A.5).

### BRUVS

The BRUVS SOP included the following elements (detailed descriptions are provided in the BRUVS Analysis report, see Appendix A.4):

- Six conventional BRUVS units were available, although the number of BRUVS deployed at each site varied because of local sea conditions.
- BRUVS were deployed after setting the ALL gear. They were retrieved after ALL lines had been hauled.
- BRUVS were deployed at least 300 m away from any ALL set.
- BRUVs were deployed between 350 and 450 m depth.
- Video was vetted for suitability for analysis. To be considered valid, the BRUVS unit had to remain upright on the seafloor with minimal horizontal movement, and record at least 1 hour of footage. Figure 1 shows only 'valid' operations.
- Gulper sharks were identified and measured for the entire duration of the video (1-4 hours).
- A list of taxa (groupings of species that can be confidently and consistently identified in the video) observed from BRUVS was compiled.
- MaxN – a metric of local abundance based on the maximum number of individuals observed in a single frame – was recorded for the first hour of valid video recorded.

### 3.2.2 Data collection

Three surveys covering five of six RAs were successfully completed (Appendix A.1 to A.3). As stated above, the sixth RA, the 60-Mile closure in the GAB, was not sampled due to resource limitations and the greater importance of repeating the survey of Murray and Port MacDonnell.

#### Survey 1 – Flinders

The first survey (DI202201) took place in the Flinders RA onboard the FV *Diana* between 02/9/22 and 11/9/22. A detailed description of the 7-day survey (note three days transit time) is presented in the voyage report (Appendix A.1: voyage DI202201; Scoulding *et al.* 2022). In summary, the survey was very successful – noting that 20 ALL deployments (of the total of 21) yielded standardised data (one was lost due to a line entanglement), and 17 BRUVs deployments (of the total of 22) yielded standardised data (Appendix A.4).

#### Survey 2 - Murray and Port MacDonnell

The second survey was planned as a 6-day charter onboard the FV *Candice K* (5/5/23 to 12/5/23 with the aim of spending two days sampling in each of the Murray and Port MacDonnell RAs (with two transit days). A detailed voyage description is given in Appendix A.2 (voyage CK202301; Untiedt *et al.* 2023a). Unfortunately, the survey was abandoned after the first day of sampling within the Murray RA due to the vessel's hydraulic systems being unable to retrieve the ALL gear within the permitted soak time from the sampling depths. None of the 3 ALL deployments yielded standardised data and no BRUVS were deployed. As such we do not consider this data any further in this report.

#### Survey 3 - Hunter and Endeavour

The third survey took place in the Hunter and Endeavour RAs onboard the FV *Diana* between 24/8/23 and 1/9/23. A detailed description of the 7-day survey (five days sampling and two days transit) is given in Appendix A.3 (voyage DI202301; Untiedt *et al.* 2023b). In summary, the survey was successful, despite losing one sampling day at Endeavour due to weather. The 15 ALL deployments (nine in Hunter, six in Endeavour) yielded usable data, however data from the 11 BRUVS deployments (nine in Hunter, two in Endeavour) could not be used (Appendix A.4).

#### Survey 4 - Murray and Port MacDonnell (repeat)

The fourth survey was a repeat of the abandoned Murray and Port MacDonnell survey. The six-day survey (four sampling days and two transit days) was conducted onboard the FV *Diana* between 1/9/23 and 6/9/23. A detailed survey description is given in Appendix A.3 (voyage DI202302; Untiedt *et al.* 2023b). In summary, the survey was successful in that all 12 ALL deployments were valid, and the six BRUVs deployments at Port MacDonnell yielded standardised data, however, the four BRUVS deployments at Murray were unsuccessful due to adverse conditions (Appendix A.4).

#### BRUVS analyses

A dedicated report describing the BRUVS deployments is provided in Appendix A.4 (Althaus *et al.* 2024) but summarised here. Conventional BRUVS yielded valid, standardised data at just two of the five RAs: Flinders (17 deployments) and Port MacDonnell (six deployments) – see previous section. Eleven Harrisson's Dogfish were observed in the Flinders RA and two Southern Dogfish were observed in the Port MacDonnell RA. Interestingly, the IUCN Red-listed Whitefin Swellshark (*Cephaloscyllium albipinnum*) was commonly observed in BRUVS footage at both RAs (Appendix A.4).

Two Deep BRUVS units were deployed in the Flinders RA to evaluate their ability to detect gulpers over a 2-month deployment period (2/7/23 and 27/9/23). In total, 24 recording periods that were suitable for analysis were obtained from each unit. Harrisson's Dogfish were observed in four recording periods on one of the units (Appendix A.4).

Results from conventional and Deep BRUVS analyses show that while gulpers are observed in video footage, they are present in far lower numbers (greatest MaxN = 1) compared with longline catches. This means that many more BRUVS deployments (100s) would be needed to collect the data necessary to assess the abundance of gulper sharks in future monitoring surveys.

## 3.3 Baseline data (set)

### 3.3.1 Overview

This study acquired new data for Harrisson's Dogfish and Southern Dogfish (Table 4, Table 5) that can be considered baseline for future monitoring efforts. The spatial distribution of samples and catch rates for these baseline data and comparative historical catches are depicted in maps for each of the five RAs (Section 3.3.2, Figure 2 to Figure 8). On Australia's east coast, where the two species overlap, the data are mapped by species – Flinders (Figure 1), Hunter (Figure 6) and Endeavour (Figure 7); in the Great Australian Bight where only Southern Dogfish are found, the data are mapped by sex – Port MacDonnell (Figure 5) and Murray (Figure 8). Detailed interpretation of the baseline data is presented in reference to indicators of recovery listed in Section 3.1.

Historical data regarding gulper shark abundance were used to identify and design suitable reference areas for monitoring (Williams *et al.* 2012; 2013; 2018). However, historical data did not constitute a baseline because various non-standardised collection methods were used, and therefore the data do not have the statistical rigour against which future recovery could be measured (Williams *et al.* 2018).

Notwithstanding, there was scope to quantitatively compare relative abundance (and other indicators of recovery (Section 3.1), between the newly-collected baseline data and pre-existing historical data for Harrisson's Dogfish at the Flinders RA (Table 4, Table 5). Note, however, that much of the data are zero-inflated, i.e. a high percentage of sets did not catch any gulpers (zero catch; Table 4, Table 5). This means that the assumption of normal distribution of catches around the mean is violated and thus mean and standard error statistics (Table 4, Table 5) need to be viewed with caution.

Comparison with historical abundance would also have been possible in the 60-Mile Closure, but that RA was not sampled as planned due to resource limitations. Historical data also contain information about other indicators of recovery such as distribution, sex ratios and breeding success (presence of juveniles), but the data suffer the same lack of consistency with respect to collection methods. Thus, in other RAs there was some scope to compare selected indicators on a semi-quantitative basis, but this could only be done with high uncertainty.

**Table 4 Summary statistics from surveys of Harrisson's Dogfish: 2022/23 surveys are $T_0$ baseline data for monitoring; the historical data are shown for reference, but comparisons of relative abundance and other indicators is meaningful only at the Flinders Reference Area. NA = no data available. Historical data in grey = no comparison with baseline data possible.**

| Surveys | Baseline data (2022/23) | | | | | Historical data (2009/10[1]) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Reference Area | Flinders | Port MacDonnell | Hunter | Endeavour | Murray | Flinders | Port MacDonnell | Hunter | Endeavour | Murray |
| | Figure 2 to Figure 4 | Figure 5 | Figure 6 | Figure 7 | Figure 8 | Figure 2 to Figure 4 | Figure 5 | Figure 6 | Figure 7 | Figure 8 |
| Gulpers caught (total N) | 240 | | 47 | 194 | | 254 | | 46 | 5 | |
| Mean CPUE[2] | 8.01 | | 5.22 | 14.77 | | 5.29 | | 15.33 | 0.37 | |
| St.Error$_{CPUE}$ | 2.08 | | 0.50 | 3.44 | | 1.57 | | 10.67 | 0.16 | |
| $N_L$ = line sets | 20 | | 6 | 9 | | 21 | | 2 | 9 | |
| Zero catches of this species | 20% | | 0% | 0% | | 10% | | 0% | 56% | |
| $N_H$ = hooks retrieved | 31638 | | 9000 | 13100 | | 53000 | | 3000 | 13500 | |
| Tagged | 82 | | 29 | 97 | | 178 | | 14 | 5 | |
| Recaptures | 3 | | 0 | 0 | | NA | | NA | NA | |
| Age (juveniles present)? | Y | | Y | (Y) | | Y | | Y | Y | |
| Sexes co-occur? | Y | | Y | Y | | N | | Y | Y | |
| No. tissue samples | 77 | | 25 | 96 | | NA | | NA | NA | |

[1]Combined data from three surveys: Diana 2009-01, and Sarda 2010-01 and 2010-02 described in Appendices of Williams *et al.* (2012); data was standardised, excluding data from tangled lines or taken after 8am to maximise comparability.

[2] CPUE (catch per 1000 hooks per line) averaged over the total number of lines. (Note: mean and standard error statistics assume normal distribution – much of the data are zero-inflated, see "Zero catches of this species").

**Table 5 Summary statistics from surveys of Southern Dogfish: 2022/23 surveys are $T_0$ baseline data for monitoring; the historical data are shown for reference, but comparisons of relative abundance and other indicators is meaningful only at the Flinders Reference Area. NA = no data available. Historical data in grey = no comparison with baseline data possible.**

| Surveys | Baseline data (2022/23) | | | | | Historical data (2009/10[1]) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Reference Area | Flinders | Port MacDonnell | Hunter | Endeavour | Murray | Flinders | Port MacDonnell | Hunter | Endeavour | Murray |
| | Figure 2 to Figure 4 | Figure 5 | Figure 6 | Figure 7 | Figure 8 | Figure 2 to Figure 4 | Figure 5 | Figure 6 | Figure 7 | Figure 8 |
| Gulpers caught (total N) | 3 | 158 | 11 | 53 | 49 | 4 | 278 | 0 | 92 | NA |
| Mean CPUE[2] | 0.09 | 17.6 | 1.22 | 3.93 | 5.44 | 0.06 | 49.7 | 0.00 | 6.81 | NA |
| $St.Error_{CPUE}$ | 0.05 | 2.97 | 0.72 | 1.78 | 0.53 | 0.04 | 32.5 | 0.00 | 5.28 | NA |
| $N_L$ = line sets | 20 | 6 | 6 | 9 | 6 | 21 | 3 | 2 | 9 | NA |
| Zero catches of this species | 85% | 0% | 33% | 33% | 0% | 86% | 0% | 100% | 44% | NA |
| $N_H$ = hooks retrieved | 31638 | 9000 | 9000 | 13100 | 9000 | 53000 | 5000 | 3000 | 13500 | NA |
| Tagged | 2 | 74 | 9 | 30 | 37 | 4 | 200 | 0 | 49 | NA |
| Recaptures | 0 | 0 | 0 | 0 | NA | NA | NA | NA | NA | NA |
| Age (juveniles present)? | N | Y | N | N | Y | N | N | NA | N | NA |
| Sexes co-occur? | N | Y | N | Y (few f) | Y | Y | Y | NA | Y | NA |
| No. tissue samples | 2 | 74 | 9 | 30 | 37 | NA | NA | NA | NA | NA |

[1]Combined data from three surveys: Diana 2009-01, and Sarda 2010-01 and 2010-02 described in Appendices of Williams *et al.* (2012); data was standardised, excluding data from tangled lines or taken after 8am to maximise comparability.
[2] CPUE (catch per 1000 hooks per line) averaged over the total number of lines. (Note: mean and standard error statistics assume normal distribution – much of the data are zero-inflated, see "Zero catches of this species").

### 3.3.2 Spatial baselines (this study) and historical survey catches

**Flinders Reference Area**

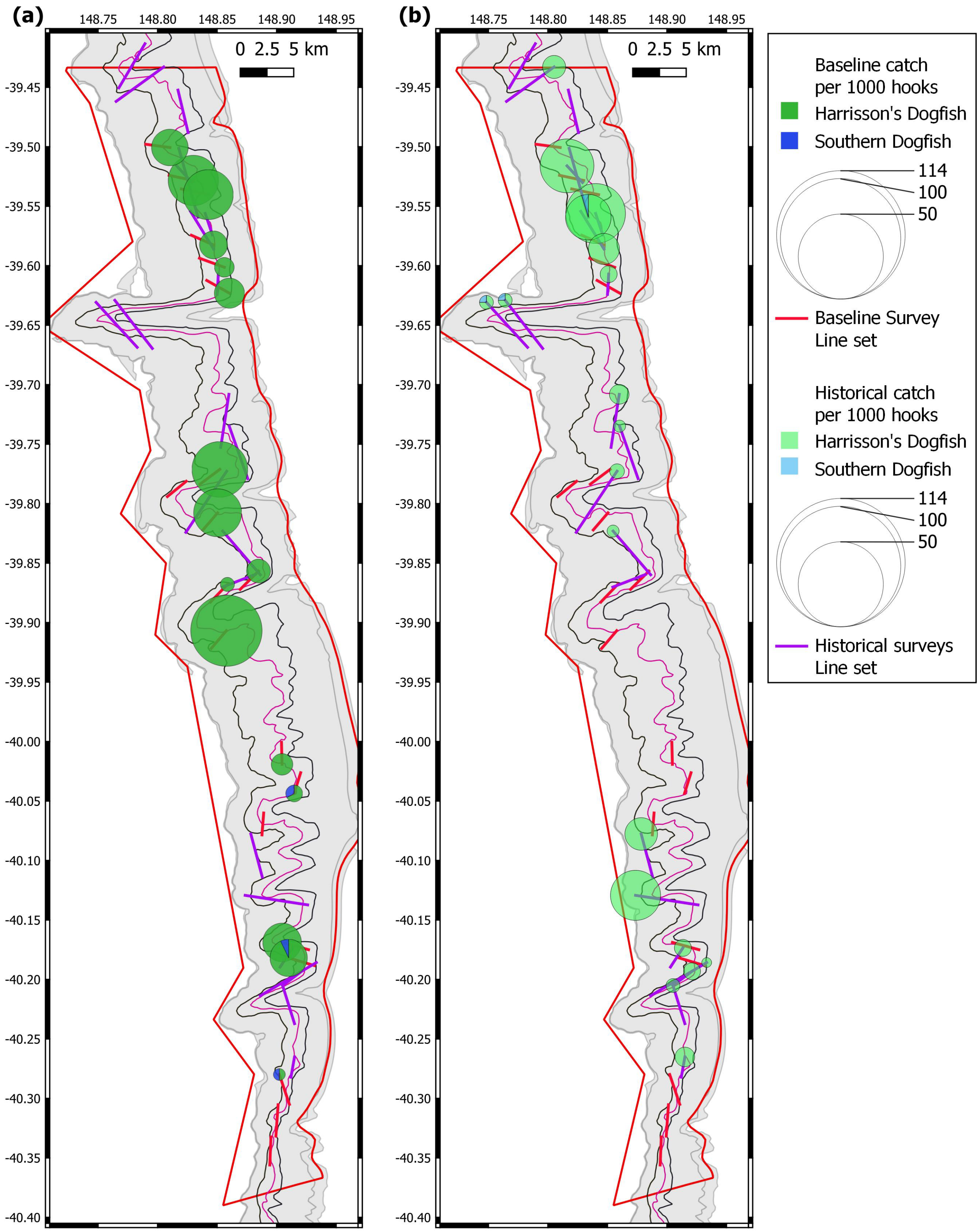


**Figure 2 Map of the Flinders RA showing the key properties of (a) the baseline data set for gulper sharks (abundance and distribution by species); (b) historical data for context; grey area: habitat range.**

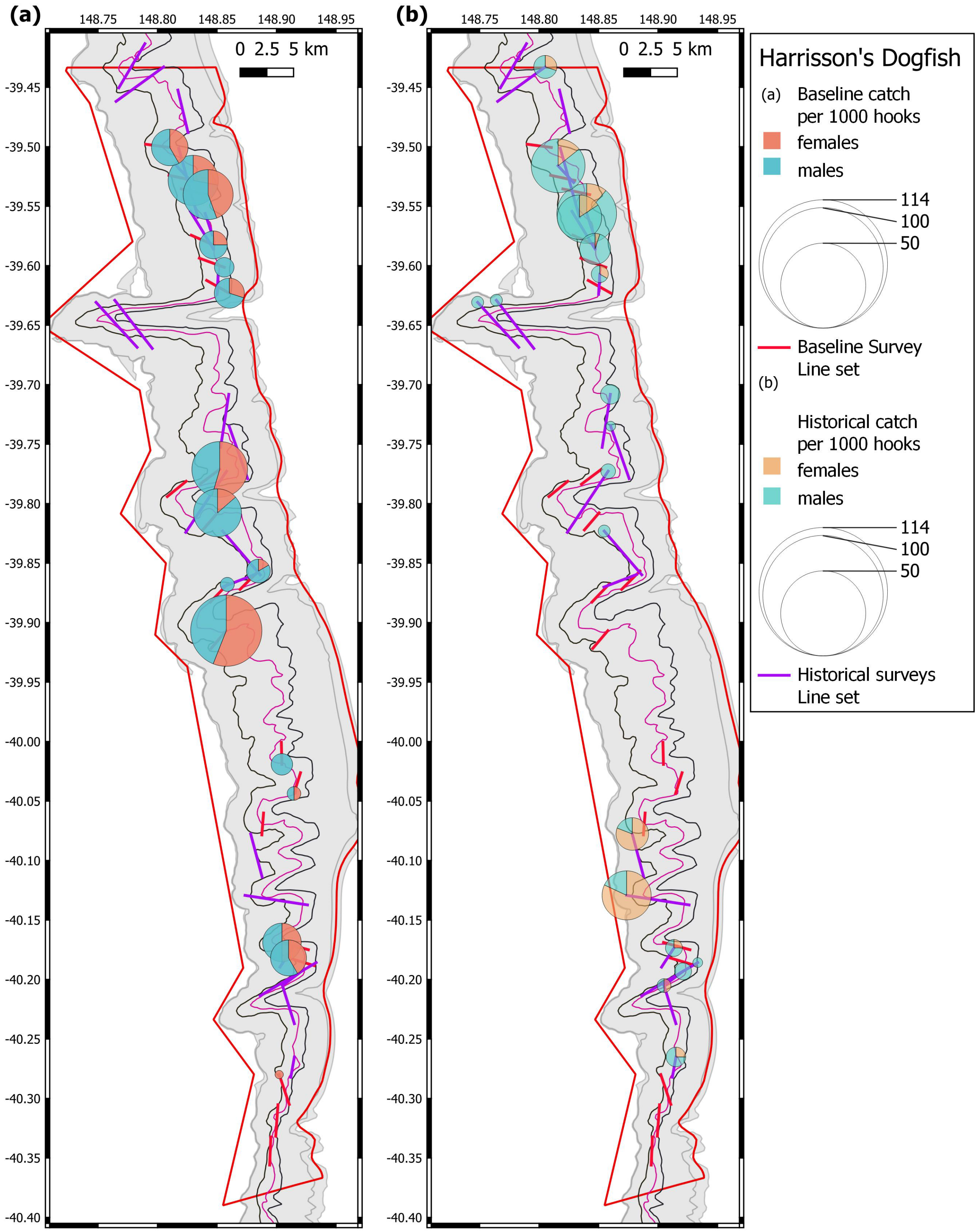


**Figure 3 Map of the Flinders RA showing (a) the abundance and sex ratio of the baseline data set for Harrisson's Dogfish; (b) historical data for context; grey area: habitat range. Maps of shark size (presence of juveniles) for data are shown in the survey report (Appendix A.1). Note: the northern 'Babel' and southern 'Barren' sub-areas in the Flinders RA were named by Williams *et al.* (2012) to designate spatially separated sexes; predominantly males in Babel and females in Barren (Figure 3b, 4b).**

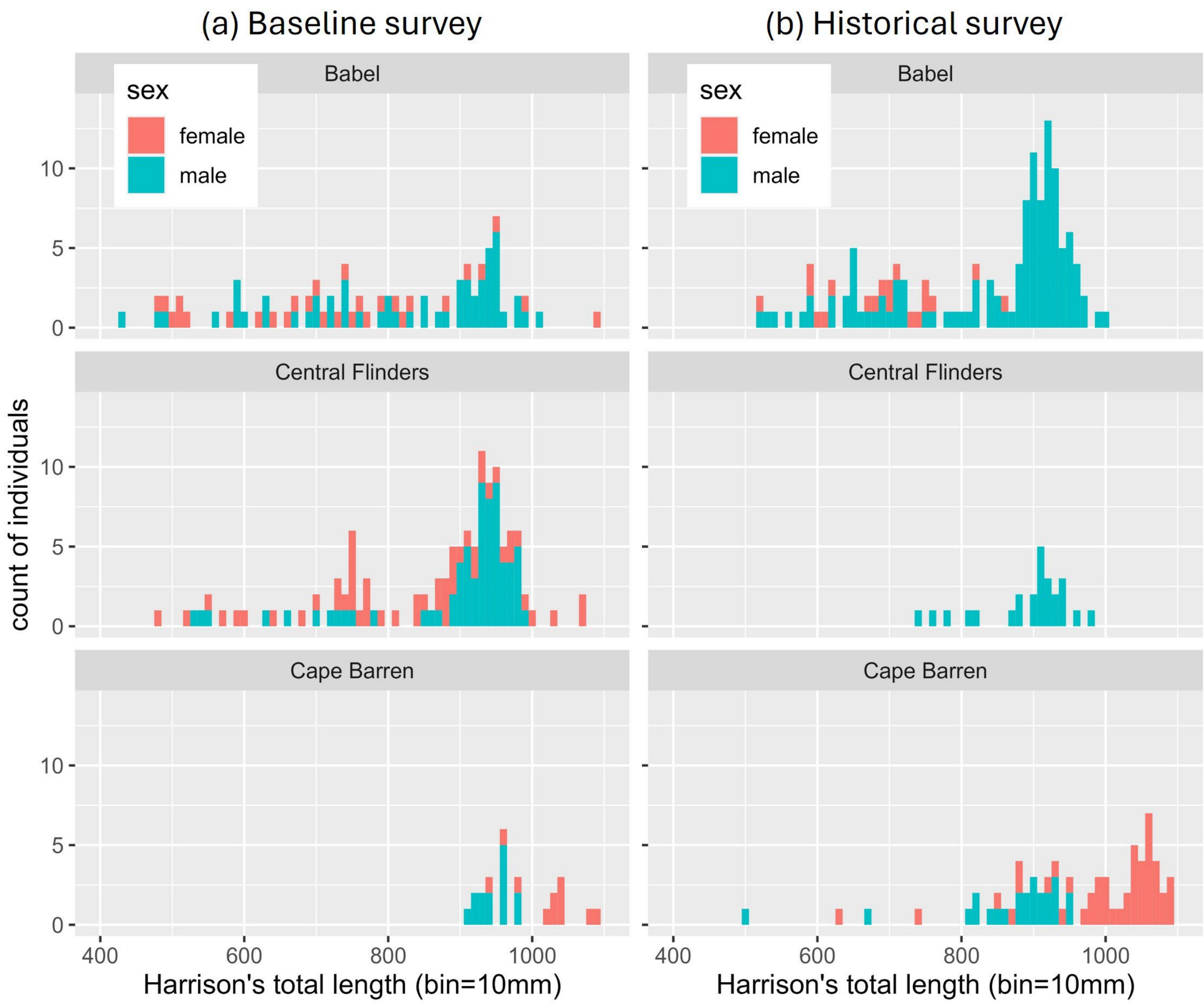


**Figure 4 Sex ratios and length frequencies for Harrisson's Dogfish in each of the three sub-areas in the Flinders RA (Babel, Cape Barren and central) identified in Figure 3**

## Port MacDonnell Reference Area

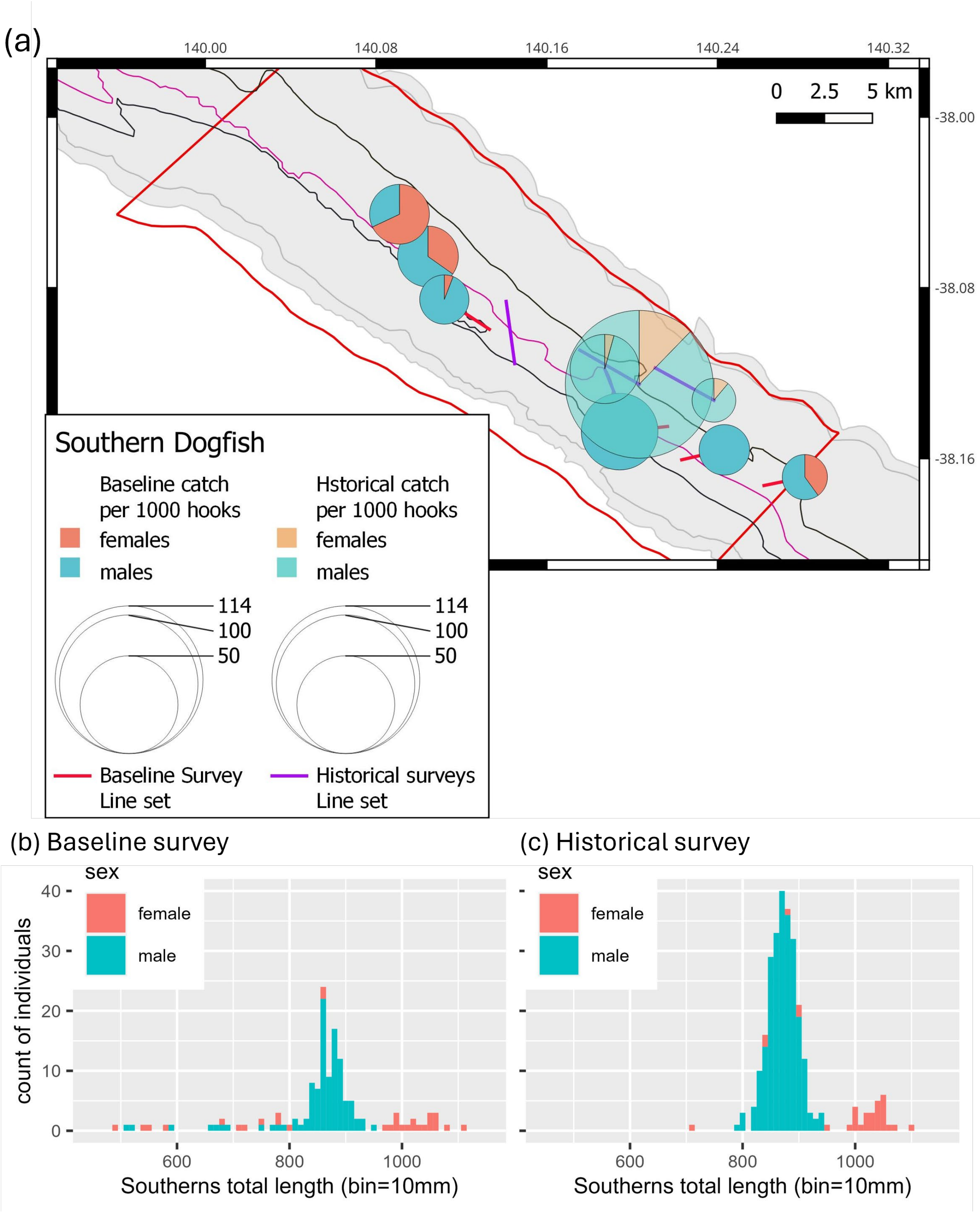


**Figure 5 Map of the Port MacDonnell RA showing (a) the abundance and sex ratio of the baseline data set for Southern Dogfish; historical data for context; grey area: habitat range. (b) and (c) sex ratios and length frequencies from baseline and historical data. Maps of shark size (presence of juveniles) data are shown in the survey report (Appendix A.3).**

## Hunter Reference Area

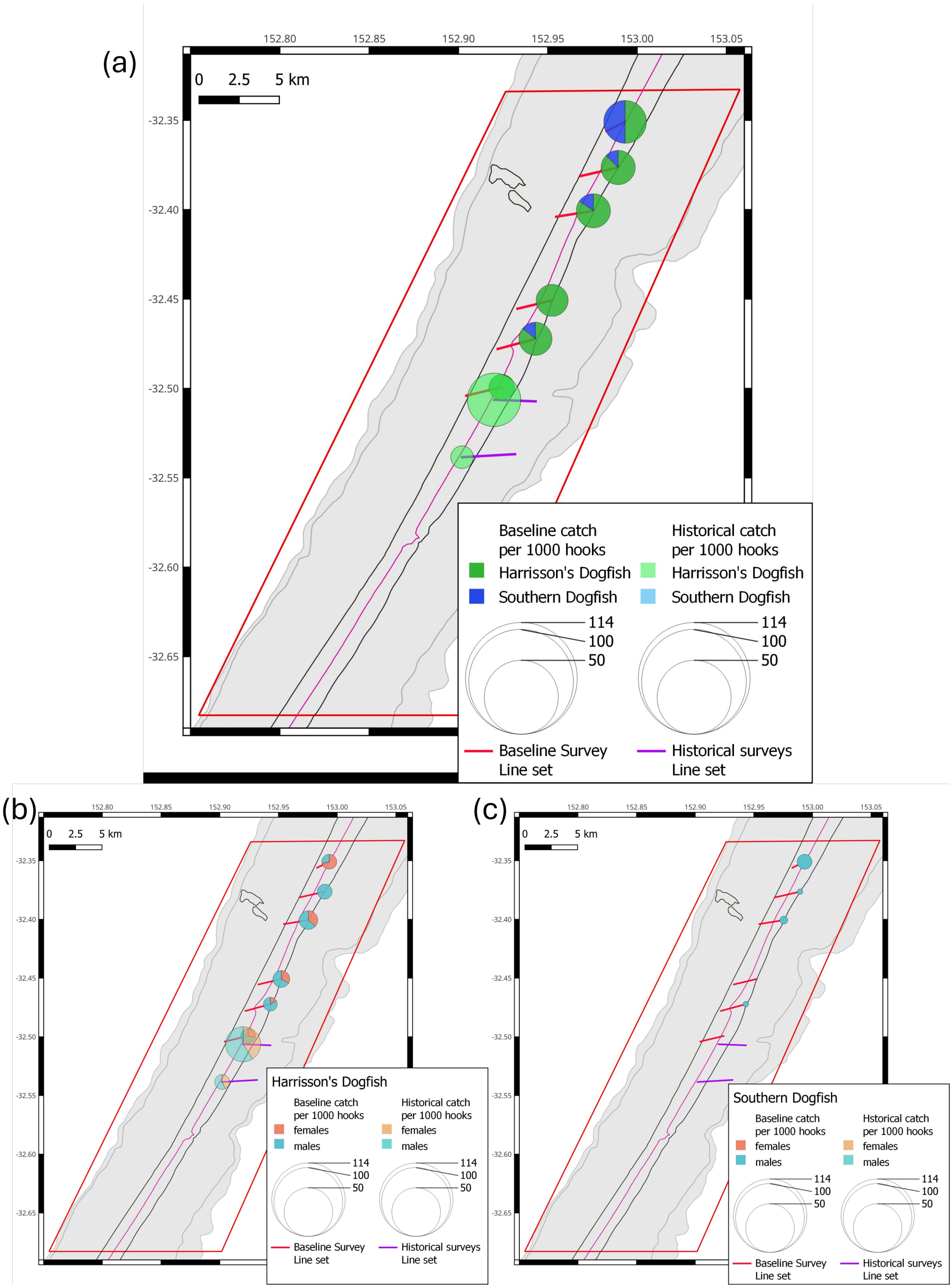


**Figure 6 Map of the Hunter RA showing the key properties of the baseline data set for gulper sharks (abundance and distribution) and overlay of historical data for context; grey area: habitat range. (a) Abundance by species, (b) sex ratio of Harrisson's Dogfish, (c) sex ratio of Southern Dogfish. Maps of shark size (presence of juveniles) data are shown in the survey report (Appendix A.3).**

## Endeavour Reference Area

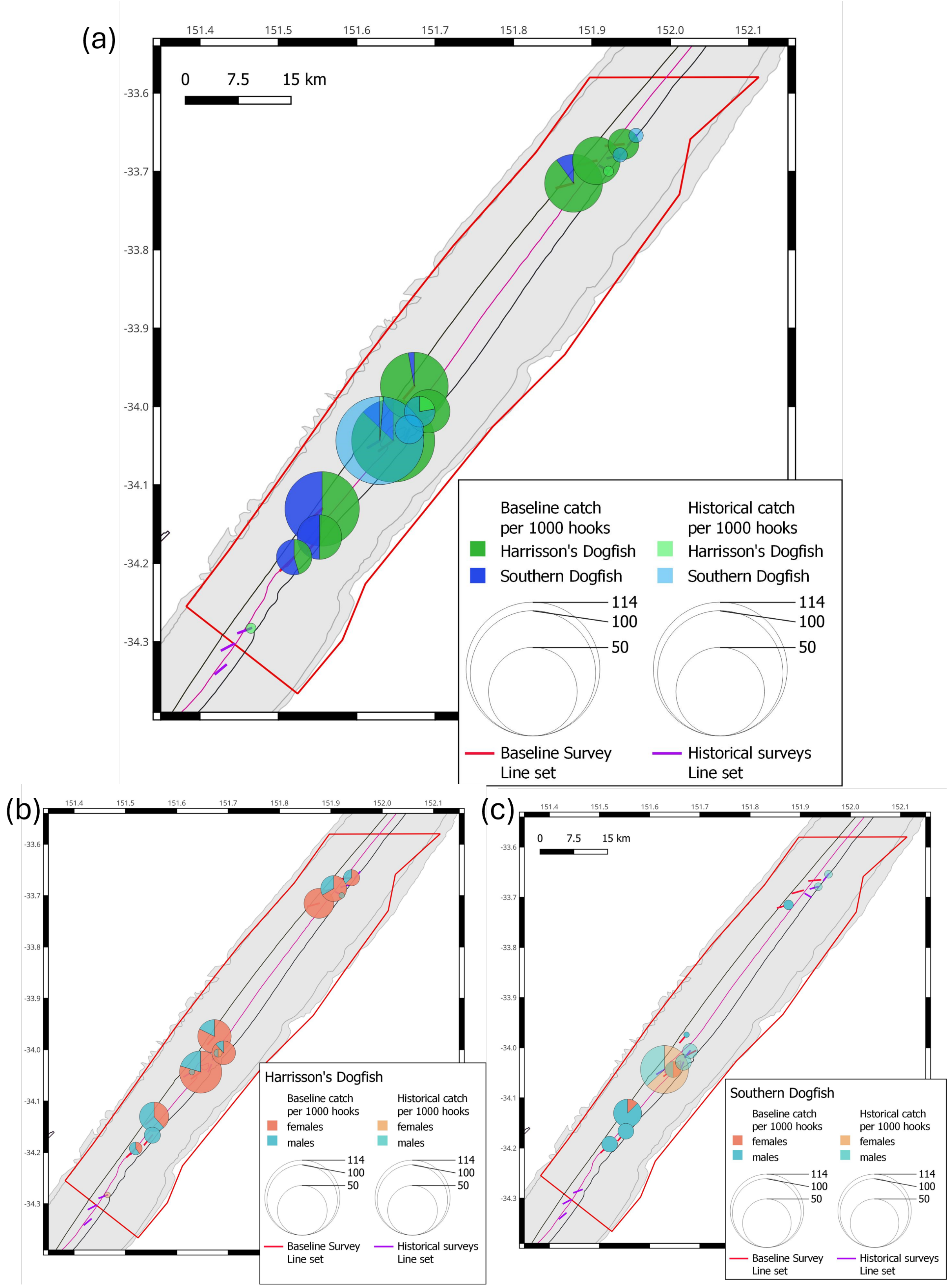


**Figure 7 Map of the Endeavour RA showing the key properties of the baseline data set for gulper sharks (abundance and distribution) and overlay of historical data for context; grey area: habitat range. (a) Abundance by species, (b) sex ratio of Harrisson's Dogfish, (c) sex ratio of Southern Dogfish. Maps of shark size (presence of juveniles) data are shown in the survey report (Appendix A.3).**

### Murray Reference Area

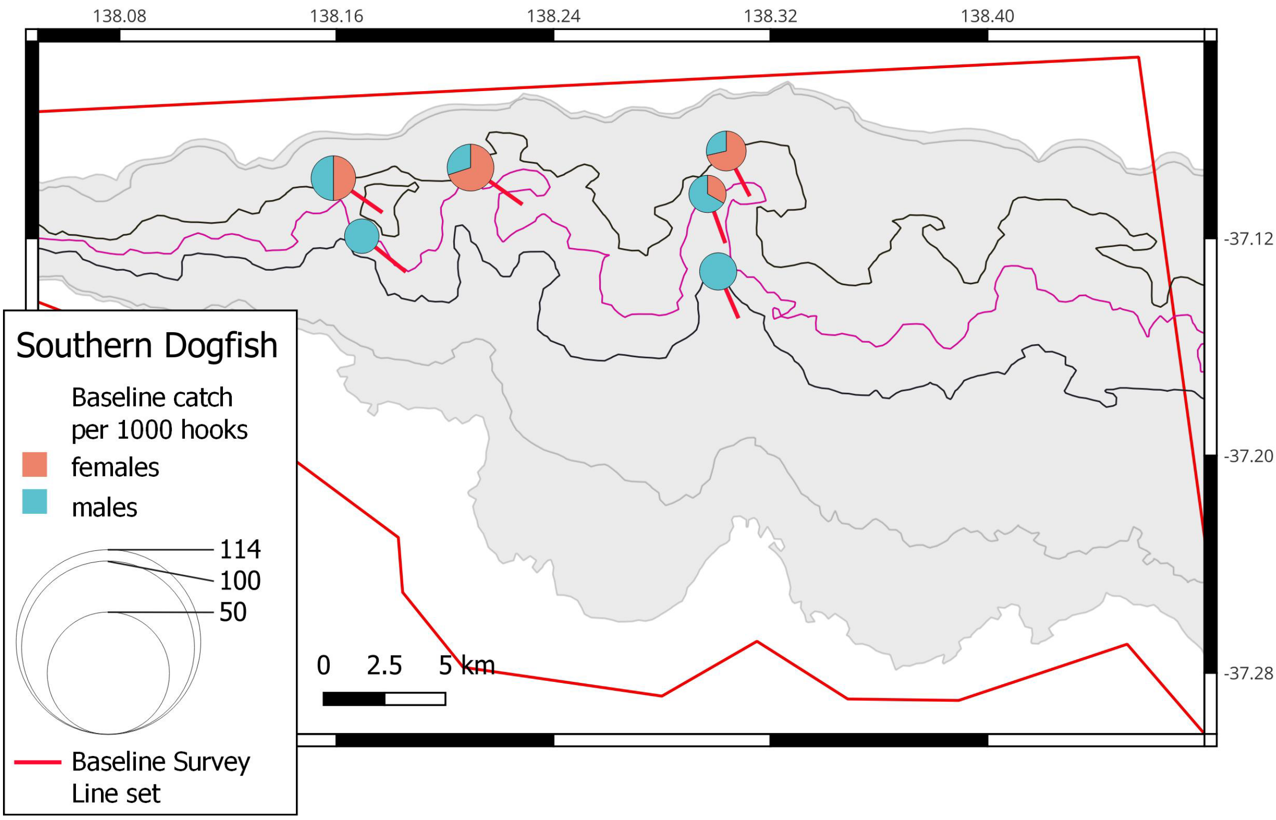


**Figure 8 Map of the Murray RA showing the key properties of the baseline data set for Southern Dogfish (abundance, distribution and sex ratio) (there are no historical data for this RA); grey area: habitat range. Maps of shark size (presence of juveniles) are shown in the survey report (Appendix A.3).**

## 3.3.3 Initial interpretation of indicators of recovery

### Indicator 1: Relative Abundance (standardised CPUE)

The most important positive indication that gulper shark populations are recovering would be an upward trajectory of relative abundance over time. While it is difficult to predict the rate of population increase, it can be assumed that the rates will be slow because gulper sharks have very low fecundity, slow growth and high age-at-maturity (Daley et al, 2002; Graham & Daley, 2011).

The Flinders RA (Figure 2, Figure 3) is the only area where the baseline data can be compared to historical data with any confidence. This is because standardised and considerable sampling effort was applied during both periods, and substantial numbers of Harrisson's Dogfish were caught each time (Table 4). Here, an increase in mean CPUE for Harrisson's Dogfish (5.59 to 8.01) and relatively low SE (1.57 and 2.08, respectively) is consistent with the expected trajectory of recovery following protection of this population by the USDMS. Southern Dogfish occurred at low abundance (mean CPUE = 0.09) in the Flinders RA in 2022/23 (Table 5, Figure 1.)

Substantial numbers of Southern Dogfish are also represented in both the current and historical datasets at the Port MacDonnell RA; however, direct comparison was not possible due to the non-randomised sampling design for the historical survey (which was specifically designed to locate and maximise the number of gulper sharks caught). This resulted in one extraordinarily high historical catch (114 gulpers/ 1000 hooks) from a single line set at a small rocky canyon/gully feature identified by a knowledgeable fisher which resulted in a high mean CPUE (49.7) and high SE (32.5) in the combined historical data (Table 5); this location was not re-sampled in the monitoring survey (Figure 5).

Robust time-series comparisons of relative abundance are not yet possible at the Hunter or Endeavour RAs because there are few historical data (Table 4, Table 5, Figure 6, Figure 7), or Murray, where there was no historical data (Table 5, Figure 8). It is, however, interesting to note that Southern Dogfish were caught at Hunter for the first time (11 adult individuals). This indicates a level of variability to be expected in future abundance data, possibly indicating that a greater number of ALL sets will be needed if surveys in that region are to have sufficient power to confidently detect signals of change. Recent capture of Southern Dogfish in the Murray RA confirms their presence in that area.

### Indicator 2: Area of Occupancy (distribution within individual RAs)

Gulper shark populations at both the Flinders RA (Harrisson's Dogfish) and Port MacDonnell RA (Southern Dogfish) were believed to have restricted distributions within these RAs based on spatial patterns of catch in the historical data. This was not due to historical under-sampling because the spatial distribution of samples within the RAs was broad (Figure 3, Figure 5). The baseline data show expanded distributions in each case: relatively larger numbers of individuals in the central area of the Flinders RA (Figure 3), and the areas away from the rocky canyon/gully habitat in the Port MacDonnell RA (Figure 5). These are apparent increases in areas of occupancy. If this is the case, it may be due to the sharks being less aggregated at restricted habitat features as fishing disturbance decreased and/or as relative abundance increases. These are initial interpretations, relatively robust for the Flinders RA but tentative for the Port MacDonnell RA given the limited data available. More notable is that individuals involved in these potential expansions include both sexes and also juveniles (see indicators 3 and 4 below).

As for comments made above in relation to relative abundance, no robust time-series comparisons of occupancy are possible at the Hunter, Endeavour (little historical data) or Murray (no historical data) RAs (Figure 6, Figure 7, Figure 8). However, the capture of Southern Dogfish at Hunter for the first time (11 adult individuals) represents an expansion of their extent of occurrence – significantly, into their 'extralimital' (vagrant) distributional range (Williams *et al.* 2013). This is an encouraging sign, but not necessarily related to recovery as historical sampling may not have detected them in the relatively low sampling effort in this area (Table 4, Table 5). This observation also indicates that sampling intensity in future surveys needs to be greater to have sufficient power to confidently detect signals of distributional changes.

### Indicator 3: Size composition

A longer time series is required to robustly establish changes in size distribution of gulper shark populations that might indicate recovery, i.e. greater proportions of larger (older) individuals. This is the case for both Harrisson's Dogfish in the Flinders RA (Figure 3 and Figure 4), the only location where some comparison of time-series data is possible, and Southern Dogfish in the Port MacDonnell RA (Figure 5), a second location where relatively large numbers of individuals have been caught. However, the increased presence of smaller fish classed as juveniles may be an early sign that populations are recovering. Both baseline and historical data show that modest numbers of juvenile Harrisson's Dogfish occurred in the northern (Babel) sub-area of the Flinders RA (virtually absent in the Barren sub-area), but baseline data show some juveniles also present among the population that expanded into the central sub-area (Figure 3 and Figure 4).

As for comments made above in relation to relative abundance and distribution, no robust comparisons are possible at the remaining RAs: there was a weak signal in the Port MacDonnell RA where a few juveniles were observed in the baseline data compared to zero in the historical data, but there are few historical data at the Hunter and Endeavour RAs and no historical data at the Murray RA (see Survey reports in Appendix A.3). However, we note that many juvenile Harrisson's Dogfish were caught at the Hunter RA in both the monitoring and historical surveys (but juvenile Southern Dogfish were absent). Curiously, while both species were caught at the Endeavour RA, juveniles of both were absent. Juvenile Southern Dogfish were caught at the Murray RA.

### Indicator 4: Sex composition

There have been previous studies that suggest that gulper shark populations may be spatially separated by sex for periods of time; for example historical surveys in the Flinders RA showed males were dominant in the northern 'Babel' sub-area and females in the southern 'Barren' sub-area (Williams *et al.* 2012; Figure 3b). These 'single-point-in-time' samples did not detect much mixing of sexes, but the observation of considerable mixing of males and females in the current survey is at odds with the previous findings but is nevertheless positive, as there is the potential for breeding.

The population of Harrisson's Dogfish in the Flinders RA baseline data was characterised by a mix of sexes in all areas where they were caught – including the central area where Harrison's Dogfish was largely absent in historical data (Figure 3a). The segregation of males in the northern 'Babel' sub-area and females in the southern 'Barren' sub-area was not apparent. This mixing of sexes, together with the relatively large numbers of juvenile Harrisson's Dogfish observed in the baseline data compared to historical data (Figure 3 and Figure 4) are interpreted as confirmation that there is successful breeding in the Flinders RA.

Male Southern Dogfish outnumbered females in the Port MacDonnell RA, and both sexes were mixed but patchily distributed in both the baseline and historical data (Figure 5). This is evidence that breeding is possible, and a few juveniles were observed in the baseline data compared to zero in the historical data.

Patterns of sex composition in the Hunter RA were complex: male and female Harrisson's Dogfish were present and mixed in all individual samples (line sets), both in the baseline and historical data, whereas Southern Dogfish, recorded in baseline data for the first time, were all males. As noted above for Indicator 3, both species of gulper sharks were present in the Endeavor RA and both species were represented by mixed populations of males and females (both historical and baseline data), but juveniles were curiously absent (see Survey reports in Appendix A.3). The population of Southern Dogfish in the Murray RA contained a mix of sexes in most individual samples (line sets) (Figure 8).

### Indicator 5: Catch and distribution in commercial bycatch

As noted by Williams *et al.* (2018), the efficacy of this indicator is highly dependent on correct identification of gulpers in bycatch by commercial fishers and consistent reporting of that bycatch in logbooks. Unfortunately, correct identification to species level of gulper shark is difficult and this is confounded by a code of practice that require longline vessels to cut all dogfishes off snoods before they are brought on board. Obviously, the commercial CPUE indicator is also compromised (intentionally) by the closures themselves, which preclude fishing in the habitat most likely to contain gulper sharks. While this indicator is not considered further in this report, its importance is discussed in the context of future work (Section 4.4.5).

#### Indicator 6: Genetic measures of connectivity and stock structure

An additional indicator of gulper shark recovery will be increasing complexity in population genetic structure. Insufficient samples exist for this purpose at this time, but tissues have and will be systematically accumulated for this purpose during the monitoring program (Table 4, Table 5).

#### Additional indicator: recapture of historically tagged gulper sharks

A tag-recapture program has the potential to add another indicator (recapture rate of tagged sharks) to the set of six indicators initially identified (Table 1). This program is ongoing, and additional sharks were tagged at all five RAs sampled for the baseline data (Table 4, Table 5).

There was a very low level of recapture of Harrisson's Dogfish (3 individuals) at the Flinders RA (182 tagged in 2009/10), no recaptures at Hunter (14 Harrisson's tagged in 2009) and Endeavour (5 Harrisson's and 49 Southern tagged in 2009), and no recaptures of Southern Dogfish at the Port MacDonnell RA (200 tagged in 2010) (Table 4, Table 5).

Recaptures at Flinders were within 2 km of the release points, indicating that these individuals may have moved only short distances in that time. However, if very restricted movement was typical, more recaptures would have been expected at both Flinders and Port MacDonnell where large numbers were tagged. It is more likely that individual sharks in these locations typically move over longer distances. This is consistent with (1) the need for mature individual Harrisson's Dogfish to make along-slope breeding migrations across the approximately 30-40 km gap separating sexually segregated populations in the Flinders RA, and (2) passive acoustic tracking data for Southern Dogfish (Daley *et al.* 2014) that showed average along-slope ranges of roughly 10 to 30 km, with a maximum of 75 km, while at liberty for roughly 18 months. Whilst low recapture rates could indicate a relatively high population size (an optimistic interpretation), they could equally indicate high dispersion, tagging mortality, or fishing mortality when sharks venture outside closed areas, e.g. at the Port MacDonnell RA which is relatively small and isolated by adjacent trawl grounds (the pessimistic interpretation). Additional surveys are required to add more certainty to interpretation of tagging data.

The tissue samples collected provide an additional opportunity for a tag-recapture indicator in that DNA sequencing would identify any individuals that might be sampled more than once i.e. 'gene tagging' (Preece and Bradford 2022). Although such an indicator would avoid the issue of tag loss, the other interpretational difficulties listed above would remain.

No relevant tagging information exists for the Murray RA.

## 3.4 Field monitoring program: reflections and lessons learned

The survey design described in the stakeholder workshop report (Williams *et al.* 2018) provided a framework to implement monitoring but was not able to fully consider the operational realities of conducting the field program. Much of that work has been undertaken as part of the current project. Here we identify the key challenges and lessons learned during the initial phases of this field monitoring program so that future surveys can be appropriately costed, efficiently implemented, and standardised with respect to the form of the scientific data.

### 3.4.1 Costings

- Charter fees: An early hurdle was the substantial increase in charter fees during the approximately five years between the project's conception and approval to commence surveys. A global surge in fuel prices added to the predictable rise in general costs over such a protracted period and this resulted in the actual charter expenses being more than double the originally allocated budget. This disparity in pricing imposed significant budgetary constraints. To overcome this, the contract was renegotiated and an increase to project funding was secured. However, the setback of a failed second survey made it necessary to exclude the 60-mile RA from the survey program.

  Lesson learned: This experience underscores the importance of up-to-date cost evaluation and management and ensuring fieldwork costs are accurately estimated. Consult the vessel owner/operator regarding charter fees during the scoping phase of the project. However, we do recognise that fuel price was particularly volatile due to international markets changing considerably during these years.

- Sale of catch: Charter cost offsets are potentially very cost-effective, but only in productive fishing areas. The initial costing of the project relied on offsetting charter costs through the sale of commercial catch (estimated $3,000 a day). Whilst this was exceeded in the Flinders RA, we achieved less than half this amount in the Murray and Port MacDonnell RAs. Furthermore, we were not permitted to sell the catch from Hunters and Endeavour RAs as they are within NSW line-fisheries jurisdiction and appropriate permission could not be obtained in time.

  Lesson learned: Cost field work appropriately and do not rely on the sale of catch to offset a large proportion of the charter fees. Revenue from the sale of catch should be considered separately and can be accounted for later with the funding body reimbursed at the conclusion of all field work. It is important to obtain permission from fisheries management agencies well in advance. Additionally, engage in discussions early regarding allocation of research quota (Commonwealth and State Fisheries).

- Management overheads and project administration: Conducting field programs within Australian waters, particularly in regions managed by multiple jurisdictions, carry significant overheads including lengthy Animal Ethics approvals, scientific permits, vessel procurement, and institutional HSE requirements.

Lesson learned: Do not underestimate the overheads of running a large field program. Carefully consider the time needed to administer the project and budget accordingly. As it would not be worthwhile to begin the administrative procedure before funding for the project is secured, it might be necessary to include a ‘planning year’ at the start of the project period, with at-sea sampling planned from the second year.

Operations and logistics

- Flexibility: Procurement of vessels had to be arranged well ahead of the survey, often scheduled outside of their primary fishing season. Consequently, there is limited or no flexibility regarding the timing of surveys and in some instances may be dictated by the vessel. In cases of adverse weather conditions, sampling days are inevitably forfeited without the opportunity for replacement.

  Lesson learned: Work closely with the vessel owner/operator to incorporate flexibility into the charter contract and operating plan to allow for bad weather. This may involve building contingency days into the budget to account for potential disruptions.

- Importance of local and appropriate fisher knowledge: The knowledge and skills of an experienced skipper and crew are critical to the success of the surveys and will ensure that standardisation and continuity are applied across surveys and RAs.

  Lesson learned: Success of future surveys will depend on the competency of an experienced skipper and crew.

- Survey requirements: Survey requirements of a charter vessel may be slightly different to the vessel’s normal commercial fishing location and activity. This difference may compromise the vessel’s ability to adequately conduct the survey.

  Lesson learned: Ensure vessels have conducted relatively recent fishing activities in suitable depths and/or locations using the required fishing gear.

- Availability of industry ALL vessels: The use of an industry ALL vessel was highly effective for the survey but there are only a few that operate in the region and there may be only one or two commercial vessels available to conduct a particular survey at the location or time required. This low pool of available vessels caused additional financial and logistic challenges that, when added to a budget limitation, ultimately resulted in the 60-mile RA survey being dropped. The shortage of ALL vessels provides no opportunity to reduce overall survey costs through fewer transit days and competitive pricing.

  Lesson learned: Future monitoring will depend critically on the availability of suitable ALL vessel(s).

- Standard Operating Procedures (SOPs) and best practice: The ALL SOP and best handling practices developed for this project were effective and appropriate. Of the 730 Harrissons and Southern dogfish captured, 99.5 % were returned to the water in good condition, with the remaining 0.5 % moribund on landing. Furthermore, the recapture of Harrison’s Dogfish from Flinders 12-13 years after tagging supports existing data showing gulper sharks are able survive the capture, handling and tagging process (although survival rate remains unknown).

  Lesson learned: Ongoing adoption of existing SOPs and best handling practices.

- Restrictions: Whilst necessary, restrictions set out in the animal ethics approval (e.g. number of hooks and the permitted length of time an animal can be on the hook) limited sampling to 4500 hooks per day which is less than the number proposed by Williams *et al.* (2018) based on statistical power analysis.

  Lesson learned: Consider current animal ethics requirements during the planning stages of future monitoring programs and challenge them if deemed inappropriate.

- At sea logistics: The sampling design drafted during the stakeholder workshops (Williams *et al.* 2018) did not fully account for at sea logistics of transit times between gear set and retrieval, and thus overrepresented the area that could be sampled in a day. Concessions were made to accommodate this in the survey design by creating sampling sites and a reduction in the number of ALL sets per day from four to three; the latter was counter-balanced by increasing the number of hooks per line.

  Lesson learned: Carefully consider the at sea realities of conducting field work and implications for survey design (e.g. spatial coverage).

- Work area: Sufficient space is required for storing BRUVS on deck. Further, the vessel layout needs to accommodate the safe deployment and retrieval of the units and provide enough space to work on them between operations.

  Lesson learned: Inspect vessels during the procurement phase and confirm that the required space is available for the planned field work.

Value adding

- Opportunities to sample other species: The field monitoring program resulted in the collection of many bycatch species, including from closed fishery areas. These data have the potential to contribute knowledge to stock assessment processes, e.g. recovery of other depleted species.

  Lesson learned: Explore the potential for the survey to collect additional samples, ensuring that such efforts do not compromise the primary objectives of the survey.

**BRUVS sampling**

The use of conventional BRUVS was identified as an integral part of the monitoring design, based on the recommendations from two stakeholder workshops (Williams *et al.* 2018). The purpose was to assess whether BRUVS would be a useful non-extractive addition to ongoing surveys, either as an alternative, or to augment longline surveys (Williams *et al.* 2018).

Our experience with BRUVS on the three surveys showed that they are not an alternative to using auto-longline for monitoring gulper sharks. There are considerable operational and environmental challenges in BRUVS deployments in the RAs and very few gulpers were observed by BRUVS. In summary, we found the use of BRUVS to be highly ineffective in this context and recommend they are not part of ongoing survey work.

# 4 Informing management

## 4.1 Background

AFMA initiated an ongoing program of Research and Monitoring Workplans (WP) to guide and assess research that provides AFMA and its stakeholders with information on how to improve the implementation and ongoing effectiveness of the Upper Slope Dogfish Management Strategy (USDMS, AFMA 2014, 2017). The primary objective of these workplans is to determine whether the USDMS is effective at “halting further decline of Harrisson’s Dogfish and Southern Dogfish (gulper sharks) and supporting recovery of both species in order to maximise their chance of survival in nature”, including whether management actions in the Strategy need to be amended in light of the WP reviews. Review of WPs also provides opportunities to identify additional research required for these purposes.

The key output of WP1 (AFMA 2014) was to develop a methodology for future monitoring. This was achieved successfully through consultative stakeholder workshops (Williams *et al.* 2018).

The key output of WP2 (AFMA 2017) was to implement the field-based monitoring strategy identified in WP1 to provide baseline data, particularly on relative abundance, for both listed gulper shark species. The results of that field program are presented in Section 3 of this report (above).

Here, we provide a summary of the results from the first phase of monitoring to enable performance assessment of WP2 and assist with developing WP3. The objective of both WPs is to determine the efficacy of management arrangements in the USDMS based on measures of recovery of both gulper species. Our summary provides:

- Advice in relation to the effectiveness of the USDMS (Project Need #1)
- Results in the context of stakeholder interests (Project Objective #2), including their alignment with the TSSC requirement for conservation dependent listing (Project Outcome #3)
- Contributions to formulating the next steps in the monitoring program (Project Objective #3)

## 4.2 Assessing the effectiveness of the USDMS

The six Reference Areas (RA) targeted by the monitoring program were selected because they collectively represent: populations and stocks of the two listed gulper shark species; areas having alternative hypothesised recovery trajectories; areas where remnant populations have been shown to exist; relative ease of accessibility; and areas with potential to produce a commercial bycatch to offset the costs of monitoring surveys (Williams *et al.* 2018). As such, monitoring data from these locations will provide the means of assessing whether or not AFMAs Upper Slope Dogfish Management Strategy (USDMS) (and complementary NSW Fisheries Strategy) is meeting its primary objective to halt further decline of both listed gulper shark species and support their recovery.

Our interpretation of these baseline data is made in relation to Indicators of Recovery 1 to 4 and is necessarily cautious because time-series comparison is possible only at the Flinders RA (Table 4, Table 5). Commentary on other aspects of the USDMS, including indicator 5 (abundance and distribution of gulper sharks in commercial bycatch), are outside the scope of this project. Historical data from other RAs contain indicator information, but there is limited scope to use it because the data was not collected systematically. Its scope is limited largely to making inferences in relation to Indicators 3 and 4 (Table 4, Table 5). Nonetheless, the data also support some other general comments to be made about the efficacy of the USDMS at present.

Our interpretations, in relation to Indicators 1 to 4, are:

1. Gulper sharks were collected in all five RAs sampled during the monitoring survey (Table 6). While the data support no general quantitative interpretation or comparison at this early stage in the collection of a time series, the raw numbers of individuals caught (and accounting for unstandardised historical data collection at the Endeavour and Port MacDonnell RAs), suggests that there has been no decline of either species in the locations where they were expected to occur; a relatively large increase in Harrisson's Dogfish was observed in the Endeavour RA. Male and female sharks co-occurred in every RA sampled, indicating that breeding was possible and sharks of both sexes are given protection (Table 6)
2. In the Flinders RA, the capture of a large number of Harrisson's Dogfish (240) and increase in mean CPUE (with relatively low SE) (Table 4, Table 5) is consistent with an expected upwards trajectory of relative abundance in an early stage of recovery following protection of this population. This positive sign of recovery in the Flinders RA is further supported by an apparent expansion in the area of occupancy, a stable size (age) composition as judged by a greater proportion and spatial range of juveniles, and co-occurrence of male and female sharks over a broad area to enable breeding (Table 6).
3. Robust time-series comparisons of the best indicator – i.e. relative abundance (SESSFRAG 2010) – is not yet possible at the Port MacDonnell RA (non-standardised historical data), Hunter or Endeavour RAs (little historical data), or Murray RA (no historical data).

Table 6 Summary interpretation of Indicators of Recovery 1 to 4 at the six Reference Areas for gulper shark monitoring. Note: there is scope to compare newly-collected baseline data and pre-existing historical data at the Flinders RA only. Square brackets = no. of individual sharks caught in historical and baseline surveys, respectively.

| Shark population response | |
|---|---|
| (dark green) | Positive (robust) |
| (light green) | Positive (weak) |
| (orange) | Baseline only |
| (grey) | Not applicable |
| (pink) | Baseline data not collected |

| **Indicator of recovery** | **1. Relative abundance** | **2. Area of occupancy** | **3. Size (age) composition** | **4. Sex composition** |
|---|---|---|---|---|
| **Expected shark population response under the USDMS** | Stable or increasing | Expanding | More larger sharks; presence of juveniles | Male and female populations co-occur (breeding possible) |
| Harrisson's Dogfish | | | | |
| **Hunter** [46, 47] | Baseline only | Baseline only | Baseline only | Positive (robust) |
| **Endeavour** [5,194] | Baseline only | Baseline only | Baseline only | Positive (robust) |
| **Flinders** [254, 240] | Positive (robust) | Positive (robust) | Juveniles (Positive (weak)) | Positive (robust) |
| **Port Macdonnell** [0, 0] | Not applicable | Not applicable | Not applicable | Not applicable |
| **Murray** [0,0] | Not applicable | Not applicable | Not applicable | Not applicable |
| **60-Mile** [0, --] | Not applicable | Not applicable | Not applicable | Not applicable |
| Southern Dogfish | | | | |
| **Hunter** [0, 11] | Baseline only | Baseline only | Baseline only | Baseline only |
| **Endeavour** [92, 53] | Baseline only | Baseline only | Baseline only | Positive (robust) |
| **Flinders** [4, 3] | Baseline only | Baseline only | Baseline only | Baseline only |
| **Port MacDonnell** [278, 158] | Baseline only | Positive (weak) | Juveniles (Positive (weak)) | Positive (robust) |
| **Murray** [--, 49] | Baseline only | Baseline only | Baseline only | Positive (robust) |
| **60-Mile** [Many[1], --] | Baseline data not collected | Baseline data not collected | Baseline data not collected | Baseline data not collected |

[1]Unconsolidated data from several historical surveys confirm a lightly fished population.

## 4.3 Alignment with requirements of Conservation Dependent listing

Harrisson's and Southern Dogfish were considered by the Threatened Species Scientific Committee (TSSC) to have met sufficient elements of Criterion 1 (A2) in section 178 of the EPBC Act (severe declines in population size) to make them eligible for listing as endangered.

The TSSC also considered that the collective plan of management (USDMS, AFMA 2012 and NSW Strategy, NSWDPI 2012) would be effective in halting further decline and supporting recovery of Harrisson's dogfish in order to maximise its chance of survival in nature, and therefore met the requirements of section 179(6)(b) of the EPBC Act for these species to be eligible for listing as conservation dependent – a listing category of lower concern. It was the TSSCs view that the conservation dependent category was likely to provide the best outcome for the two species for reasons including that plans of management had been developed with stakeholder consultation and engagement, and monitoring was required to meet specified rebuild targets, albeit over a long timeframe.

Data presented in this report demonstrate that the monitoring program has been enacted, and that the first phase of field sampling was completed successfully – although noting one important RA was not sampled (Table 6).

Because the data reported here are primarily the baseline, there is limited scope for further performance assessment of the USDMS (i.e. progress towards rebuilding targets), at this time.

We note, however, (see detail in previous section) that baseline data suggest:

- No further decline of either Harrisson's or Southern Dogfish – at least within remnant populations – as indicated by the raw numbers collected in all RAs where they were expected to occur.
- Some evidence of early recovery Harrisson's Dogfish in the Flinders RA based on the increase in catch rate, expansion in the area of occupancy, the greater proportion and spatial range of juveniles, and co-occurrence of male and female sharks over a broader area to enable breeding.
- No contra-indications to recovery for other indicators (1 to 4).

## 4.4 Future monitoring and management

### 4.4.1 Background

Reviewing the requirements for future monitoring and management of Harrisson's and Southern Dogfish will be considered by the Upper Slope Dogfish Scientific Working Group (USDSWG), fishery RAGs, fishery managers and external stakeholders as part of AFMAs Workplan (WP) #3. Assessing whether or not progress is being made towards rebuilding gulper shark stocks, and whether monitoring can measure this progress, needs to consider a variety of management and science issues.

This report identifies the following as relevant and important questions for WP#3 to consider:

1. How abundance measures (and other indicators) from the monitoring program will be used to quantify the extent of rebuild?
2. How often, where, and how intense should future surveys be – and how to fund them?
3. Whether there is erosion of the 25% of gulper habitat protected in closures by increased access for fishing, and if negative influences stem from this – including for interpreting monitoring data from key Reference Areas?
4. If fishing mortality outside closures is adequately monitored, and sustainable?

### 4.4.2 Fishery independent data and gulper shark population rebuilding

The key needs for fishery independent data from this monitoring program are that standard collection and analysis methods are maintained (Section 3.2.1), and that results are able to address the primary objective of the USDMS and the needs of the Conservation Dependent listing. Primarily, these are that rebuilding targets can be defined for populations of both listed gulper shark species, and that progress towards them can be measured against Recovery Indicators. The most important indicator is trajectory of relative abundance within the key Reference Areas (RA) that form part of the closure network implemented as part of the USDMS.

Rebuilding targets, such as those developed for commercially exploited species under Commonwealth Fisheries Harvest Strategy Policy (HSP) (DAFF, 2007), are difficult to formulate for gulper sharks because there are no measures of pre-fishery biomass, declines have been severe (67-96% across species and stocks), and timeframes for recovery are expected to be long (Harrisson's Dogfish roughly 86 years; Southern Dogfish, roughly 62 years: USDSWG, 2012). Furthermore, the foundation for the species' rebuild is based upon a novel 'habitat-proxy' method (Williams *et al.* 2013). The USDMS used this method to protect roughly 25% of the productive habitat of populations of both listed gulper shark species as an equivalent to the limit reference point ($B_{LIM}$) of B25 (25% of unfished biomass), with the aim that the biomass may reach the target reference point ($B_{TARG}$) of B50 (50% of unfished biomass), consistent with the HSP.

It is yet to be determined, however, how to formulate quantitative rebuilding target for each species at specific and representative spatial scales, e.g. within individual Reference Areas, or sub-regions of the SESSF, or sub-areas of population ranges. The estimates of depletion and natural environmental carrying capacity of both species vary greatly among regions of the SESSF (Williams *et al.* 2012).

The success of these baseline surveys has helped this process by confirming that the Reference Areas are suitable locations in which to formulate specific rebuilding targets that account for the differing trajectories of recovery expected (Table 2). Notwithstanding, it will also be worth exploring, as was suggested during review of the USDMS, whether sufficient demographic information is available for Harrisson's and Southern Dogfish to develop estimates of intrinsic rates of potential population increase (Cortes 2004, 2007, 2008, Garcia et. al. 2008, Smith et. al. 2008), that could be compared to abundance trends in the monitoring data.

Estimates of carrying capacity in the habitat-proxy study Williams *et al.* (2012) were based on trawl swept area (in $gm^{-2}$) so an equivalent metric will need to be developed for ALL data (based on CPUE of catch per hook), and perhaps translated to unsurveyed areas across the fishery region. One useful estimate should come from the 60-Mile Closure in the GAB because it was not heavily depleted (unfished, or very lightly fished), encloses areas of suitable and intact habitat, and is now fully closed to fishing (Area type 1; Table 2). Unfortunately, baseline data were not collected in this RA meaning it remains a future priority for survey.

### Recommended topics for WP#3

a. Review and evaluate the efficacy of the habitat-proxy method as a management and conservation recovery tool (as recommended by the TSSC) – including to refine the process of setting area-specific rebuilding targets.

b. Undertake a life history analysis of Harrisson's and Southern Dogfish, particularly age and growth, to help define recovery potential and provide a means to compare abundance trends in survey monitoring data.

### 4.4.3 Future surveys

Assessment of the requirements for collecting future fishery independent data will need to start with a focus on how to maintain a standardised survey method as this is paramount to generating monitoring data. Operationally, there will be full and ongoing reliance on auto-longline catch (ALL) for collection of relative abundance data because non-extractive (photographic, BRUVS) sampling has proven ineffective. This may be challenging in the future because collecting the ALL data requires a highly capable auto-longline vessel of which there are very few in the SESSF fleet. Attention to many finer scale operational aspects is also critical (detail in Section 3.4). Surveys are expensive, and to be cost-effective in the future it will remain necessary for management arrangements to better capitalise on the opportunities to offset vessel charter costs by sale of bycatch, and/or research quota.

Another key question for the monitoring program is the periodicity and intensity of sampling needed to underpin robust estimates of recovery trajectories, and how to balance this with the feasibility of running surveys with high project management and financial overheads. Additionally, the assumption of high post-capture survival should be validated before intense surveys are undertaken in small RAs, e.g. Port MacDonnell. Survey frequency was nominally proposed to be at 5-yearly intervals in the USDMS. This interval could be longer once sufficient baseline and time-series data are in place to provide confidence in trends (particularly relative abundance). Alternatively, the most informative RAs could be surveyed selectively. The GAB 60-Mile Closure is an important candidate because (1) it was missed from the first phase of baseline survey; and (2) it represents a strong prospect for determining the environmental (habitat) carrying capacity for Southern Dogfish by being a Type 1 Reference Area -- lightly depleted, known to have suitable habitat areas, and now fully closed to fishing. The Flinders RA is another strong candidate given the wealth of existing data (effectively two time-series data points), ease of access, and high potential to offset charter costs with commercial bycatch.

Sampling intensity – a balance between the need to maximise data and the need to minimise impact on shark populations will benefit from a review of the earlier power analysis for ALL sampling undertaken as part of the design of the monitoring program (Williams *et al.* 2018).

**Recommended topic for WP#3**

c. Review relevant factors, and specifically consider collecting baseline data in the GAB 60-Mile Closure at the earliest opportunity.

### 4.4.4 Fishing in the closure network

Relaxing restrictions on fishing in the closure network may be influentially negative since closures are the mainstay of the USDMS. If there are strong economic arguments for increasing fishery access to certain areas, further protection would be needed elsewhere in areas currently outside of the closure network. There are already a number of examples of increased fishery access, e.g. bottom trawling for Royal Red Prawns in the Endeavour RA, and for orange roughy in the Murray RA; access to others may possibly be negotiated in the future, e.g. Flinders RA (AFMA 2012). It is conceivable there could be rearrangements of closures that are also positive for gulper sharks, and which therefore provide win-win outcomes. Importantly, however, it should be noted that modifications within the six key RAs for monitoring will add further uncertainty to interpreting the results of the monitoring program. The results from the baseline survey strongly indicate that fishery access regulations for highly informative RAs – notably the Flinders RA – should not be weakened.

**Recommended topic for WP#3**

d. Summarise and review changes to fishing access and fishery use of the RAs since the USDMS was implemented and assess potential impacts on the strategy's efficacy, and future results of the monitoring program.

#### 4.4.5 Fishing mortality outside the closure network

Commercial fishery monitoring via logbook and observer data on bycatch of gulpers sharks is acknowledged as an important component of understanding gulper shark population rebuilding in the USDMS; arrangements were to record bycatch in logbooks and ensure 100% monitoring (electronic or observer) where line fishing methods are permitted in Commonwealth managed closures (AFMA, 2012b).

Fishery bycatch data are important: firstly because the sustainable fishing mortality on gulper sharks is not known and there is no estimate of absolute abundance for gulper sharks to enable a sustainable harvest rate to be calculated (Williams et al., 2012); and secondly, because increased abundance and distribution in commercial bycatch would be a positive indicator of recovery (Indicator #5, Table 1).

Sustainable harvest rates of gulper sharks have been estimated at between three and five percent of the population (Forrest and Walters, 2009), but these are regarded as maximal values (USDSWG, 2012). Thus, values less than three percent should be used in estimating the biomass that could support any targeted or incidental commercial catches. Small changes in this value can lead to large changes in population biomass, and localised depletion is possible even if catches are within the sustainable limits (USDSWG, 2012).

An addendum to these considerations is the efficacy of move-on provisions, i.e. whether vessels have reached maximum interaction limits of three gulper sharks per vessel triggering 12 month bans from the area for any vessel reaching this limit), and if move-on has been enforced.

**Recommended topics for WP#3**

e. Summarise and review logbook and observer data to determine fishing mortality outside the closure network (noting differential survival between trawl and non-trawl methods) and assess if commercial bycatch offers any prospect of being used as an indicator of recovery.

## 4.5 Applicability of methods to other depleted/declining species

Assessing the potential application of field monitoring methods (ALL and BRUVS) to other depleted or declining species needs to separately consider (1) the theoretical basis for the methodology, and (2) even if theoretically feasible, can it be made operational?

Many of the theoretical aspects of monitoring commercial fish species' responses to management intervention are generally similar, and therefore methods are transferrable. Thus, for any other species it will be necessary to identify a suite of biological indicators of recovery that can be measured; determine, a priori, expected recovery trajectories and timelines based on life-history traits and depletion history; and identify appropriate performance indicators for management measures, typically a target for increased population size against which monitoring observations can be compared.

There are, however, many different species-specific requirements at the operational level. The primary determinants for the likely success of our method with other species are the interactions between species' ecology and sampling tools. Primary considerations are: will the species take a baited hook and/or can enough BRUVs deployments be made to observe a sufficient number of the target species for indicators to be measured with confidence? Is the species too widespread and dispersed, including in the water column, to be measured at specific locations with confidence? Is it feasible to fund monitoring surveys on a regular (e.g. 5-10 yearly) basis?

In the context of making our (ALL and BRUV) methodology operational for other depleted or declining species in the SESSF region, the answers to the above questions are mostly negative – being not possible, or unlikely (Table 7). Out of eight species assessed for the "feasibility of applying our method to other species" the only realistic potential was the use of BRUVS for whitefin swellshark. Plausible options for the ALL method included for Eastern Gemfish, school sharks and Whitefin swellshark, while the only other plausible option for BRUVS was for school shark.

Importantly, the gulper monitoring (ALL) method is highly suited to some other species of interest to stock assessments, not assessed here,  particularly Blueeye Trevalla and Pink Ling. Because the gulper surveys generate excellent CPUE data from closed, i.e. 'rested', areas they potentially give some indications of population responses to reduced fishing pressure. Elevated catch rates or larger average body size of such species could indicate preference for areas undisturbed by the regular passage of fishing gear, and/or improved habitat quality as structural benthic faunal communities becomes more abundant. These types of biological responses are of high interest to AFMA given the increased reliance on spatial closures as a management tool on the deep continental shelf, e.g. for Eastern Redfish, Blue Warehou, Jackass Morwong and Eastern Gemfish (Table 7).

**Table 7 Summary assessment of the feasibility of applying the gulper shark monitoring methodology to other depleted/declining species in the SESSF (as identified by AFMA and IUCN).**

| Species | Agency | Capture by ALL[1] | Observe by BRUVS[2] | Amenable distribution[3] | Reference Areas[4] | **Gulper method feasible?** | Alternative method[5,6,7] | Cost effective[9] |
|---|---|---|---|---|---|---|---|---|
| Orange Roughy | AFMA | | | | | | 5 | |
| Eastern Redfish | AFMA | | | | | | 6 | Collective potential to offset cost |
| Blue Warehou | AFMA | | | | | | 6,7 | |
| Jackass Morwong | AFMA | | * | | | | 6,7 | |
| Eastern Gemfish | AFMA | | * | | | | 6,7 | |
| School Shark | AFMA | | | | | | 7 | |
| Deep-water sharks | AFMA | | | | | | 8 | |
| Whitefin Swellshark | IUCN | | | | | | | |

| Transfer operational methods? | |
|---|---|
| Realistic potential | |
| Plausible | |
| Unlikely | |
| Highly unlikely | |
| Not possible | |

[1]Will the species take a baited hook? Post-release survival high, or not an issue?
[2]Observed in sufficiently large nos.? N of BRUVs realistic for survey duration? *low nos. seen
[3]Species sedentary/resident, and/or benthic with habitat/site fidelity?
[4]Known or findable areas supporting remnant populations? Fishing prohibited?
[5]Optical-acoustic survey techniques well develped for this species when aggregated.
[6]Quantitative trawl survey or fishery independent data for CPUE (e.g. FIS).
[7]Quantitative non-trawl survey (line or gillnet) or fishery independent data for CPUE.
[8]Tow Camera or DeepBRUVs plausible if sharks are concentrated, e.g. on some seamounts
[9]Commercial bycatch taken and saleable? Research quota available? Industry funded?

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# Appendix

## A.1 FV Diana 2022 Survey report

Scoulding, B., Althaus, F., Untiedt, C., and Hudson, R. (2022). Gulper Shark Survey – Flinders Research Zone Closure (September 2022): Voyage report DI202201. CSIRO. Australia. (pg 1-20)

Australia's National
Science Agency

# Gulper Shark Survey - Flinders Research Zone Closure (September 2022)

## Voyage report DI202201

Ben Scoulding, Franzis Althaus, Candice Untiedt and Russell Hudson

October 14, 2022

Report to AFMA
Lara Ainsley

Oceans & Atmosphere

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# Acknowledgments

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# Executive summary

A 10-day survey of Harrisson's Dogfish (*Centrophorus harrissoni*) and Southern Dogfish (*C. uyato*, formally *C. zeehaani*) ('gulper sharks') in the Flinders Research Zone Closure was conducted between 2nd – 11th September 2022 onboard the FV *Diana*. During the 7-days of sampling 21 longline sets and 22 BRUVS were deployed. A total of 245 gulper shark (242 Harrison's and 3 Southern) were caught. Of these 236 (233 Harrison's and 3 Southern) were measured for length and sex. Male (138) and female (95) Harrison's dogfish were, in general, co-located, while smaller individuals (<60 cm length) were predominantly observed in the northern half of the survey area. In total 81 gulper shark were tagged, two Southern and 79 Harrison's. In addition, there were three recaptures of Harrison's dogfish tagged during a survey on board the FV *Sarda* in June 2010. In the 12 years and 3 months since being tagged the three males had grown between 1 to 2 cm and were recaptured within 0.4 and 2.3 km of the original capture site. Preliminary scans of the BRUV footage suggest at least 6 Harrison's dogfish were recorded.

# 1 Background and scientific objectives

Harrisson's Dogfish (*Centrophorus harrissoni*) and Southern Dogfish (*C. zeehaani*) ('gulper sharks') were listed under Threatened Species provisions of the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) in 2013 due to their widespread depletion by commercial fishing. The Threatened Species Scientific Committee (TSSC) listed them in the relatively low risk category of 'conservation dependent' because the Upper Slope Dogfish Management Strategy (USDMS) (AFMA 2012; NSWDPI 2012) was considered by the TSSC to be potentially effective in halting further decline and supporting recovery of both species to maximise their chance of survival in nature".

Work conducted between 2009 and 2012 by CSIRO and other stakeholders, including the fishing industry and non-government organisations, as part of two FRDC, AFMA and CSIRO-funded projects (Williams et al. 2012, 2013) substantially informed the TSSC evaluation process and helped achieve the fishery-favourable conservation dependent listings. The listings were contingent on having "strategies for rigorous evaluation of the effectiveness of the collective management plans against their objectives, with a clear description of the monitoring and review process and its associated timelines" (TSSC 2013). It was the TSSC's expectation that monitoring of gulper shark recovery would be progressed and reviewed during the first five years of implementation of the management strategy. In response, AFMA developed a 'Research and Monitoring Workplan' in consultation with the Upper-Slope Dogfish Research Plan Working Group (a SESSF RAG sub-committee) (AFMA 2014).

A key element of the plan was to develop "a cost-effective methodology for measuring gulper shark baseline relative abundance and recovery", (AFMA 2017). This was achieved in a consultative project undertaken by CSIRO and Fishwell (Williams et al. 2018). The project was built around two stakeholder workshops that were well attended by scientists, fishery managers, and trawl and non-trawl fishing industry representatives. It was agreed by the stakeholders at both workshops that: (1) existing data do not constitute a baseline dataset, and that this needs to be established as the first step of the monitoring program; (2) a short list of six suitable reference areas could be identified; (3) commercial auto-longline fishing, with suitable fishing/handling practices, is the most reliable, cost-effective and immediately implementable option for measuring relative abundance (the top-ranked indicator of recovery); (4) a non-extractive (image-based) technique using conventional baited remote underwater videos (BRUVS) should be used in parallel with fishing to gauge its effectiveness and comparability to auto-longline catches; and (5) there is a need and opportunity to continue tagging work to provide complementary data for population estimates, site fidelity, other range movements, and tissues for future genetic studies.

The current project, ‘*Determining the status and recovery of depleted or declining fish species: a case study of Southern Dogfish and Harrisson's Dogfish in the context of AFMA's upper slope dogfish management strategy’* is funded by AFMA and CSIRO. Its aim is to implement the highest ranked of the options considered at the stakeholder workshops (Option 1a, Williams et al. 2018). In short, Option 1a was to sample wild populations of Harrisson’s Dogfish, *Centrophorus harrissoni*, and Southern Dogfish, *Centrophorus uyato*, formerly *C. zeehaani* (White et al. 2022), on the continental slope from chartered commercial fishing vessels during four surveys, visiting six identified reference areas in fishery closures where remnant shark populations are known to exist. The six areas span the species' ranges (Figure 1).

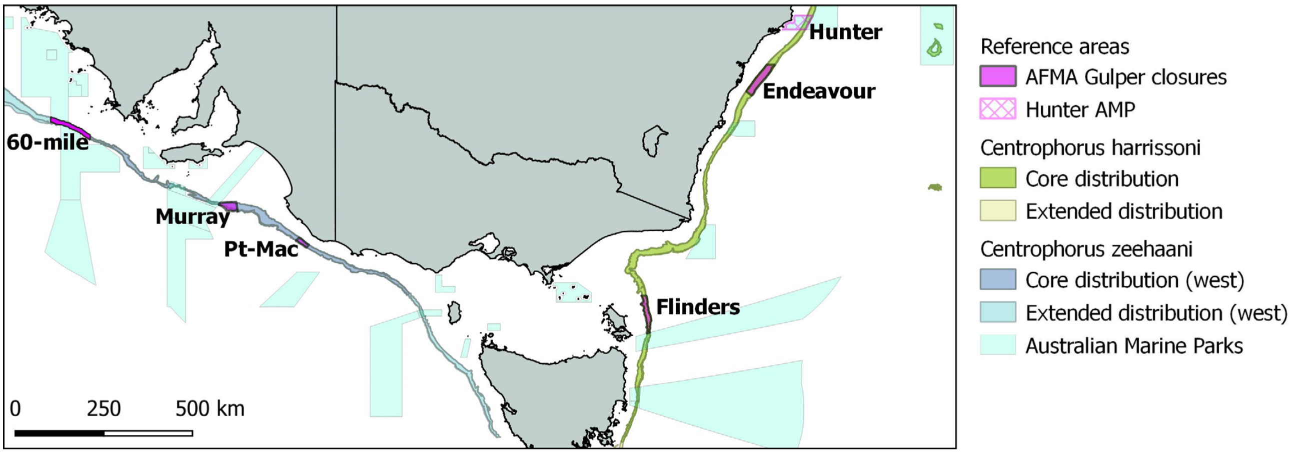


**Figure 1 Map showing locations of the six Reference Areas. Note *C.zeehaani* is now *C.uyato* (White et al., 2022)**

The six reference areas are referred to by shortened names in Figure 1, they are defined as follows by the Fisheries Management legislation (Anon. 2022):

- **60-mile**: Southern Dogfish Gulper Shark Closure: AFMA fishery closure: Schedule 10
- **Murray**: Murray Dogfish Closure: Schedule 33
- **Pt-Mac**: Port MacDonnell Closure: Schedule 32
- **Flinders**: Flinders Research Zone Closure: Schedule 39
- **Endeavour**: Endeavour Dogfish Gulper Shark Closure: AFMA fishery closure: Schedule 11
- **Hunter** Marine Park - Special Purpose Zone (trawl) defined by Australian Marine Parks Legislation (Director of National Parks, 2018a & b).

Here, we report on the first of the surveys under this project: the Flinders Survey conducted on the FV *Diana* from 2nd – 11th September 2022 (survey code DI202201).

# 2 Flinders Survey Report

## 2.1 Survey objectives

1. Charter the Fishing Vessel (FV) *Diana* for a 10-day return trip, conducting a 7-day sampling program in the Flinders Reference Area (Figure 1).
2. Use automatic longline fishing methods to sample *C. harrissoni* and *C. utayo* in the Flinders Reference Area. Effort to be concentrated in the 400-600 m depth range.
3. Collect catch composition (species, counts, catch-rate) data from each fishing operation.
4. Deploy replicate Baited Remote Underwater Video Systems (BRUVS).
5. Record shot details for each fishing line set (location, depth, hooks set) and BRUVS deployment (location, depth).
6. Record length and sex of all landed *C. harrissoni* and *C. utayo*.
7. Fit conventional tags onto as many vigorous *C. harrissoni* and *C. utayo* as practicable and release. Collect tissue samples from tagged sharks.

## 2.2 Survey Logistics

### Dates and timing of the charter

Departed Hobart 1640 hours, Friday 2nd September 2022
Docked at Hobart 1530 hours, Sunday 11th September 2022

### Staff

| Name | Affiliation | Role |
|---|---|---|
| **Dr Ben Scoulding** | CSIRO | Voyage leader |
| **Dr Candice Untiedt** | CSIRO | Biology/tagging |
| **Mr Russell Hudson** | Fishwell | Observer |
| **Mr Russell Porter** | FV Diana | Master |
| **Mr Jack Wallace** | FV Diana | Crew |
| **Mr Joshua O’Brien** | FV Diana | Crew |
| **Mr Huw Marchment** | FV Diana | Crew |

### Permits

- **Animal ethics:** Permit Franziska Althaus, Ref # 2022-02

- **AFMA Research fishing permit (sent to vessel)**:
    - Fishing permit using automatic longline in closures
    - Permit to retain dead gulper sharks (if dead or moribund on capture)

Catches of commercial species could be sold with proceeds going to the research project; catches of quota species are considered incidental research catch and are not counted towards quota (L. Ainsley, pers. comm.).

## Vessel details

The FV *Diana* – a Hobart based fishing vessel – was charted by CSIRO for this 10-day survey. The FV *Diana* is equipped with automatic longline gear and is licensed to fish in Commonwealth, SE non-trawl waters and the high seas. The master and crew are experienced longline fishers. The vessel was built in 2004 in Hobart, Tasmania. The vessel is 22.8 metres in length, constructed of steel and powered by a single 3406 Caterpillar Marine (460 hp) main engine. Auxiliary power is supplied by smaller engines (3056 Caterpillar) for hydraulics, 240-volt power, refrigeration and ice making machines. The vessel has berths for up to 8 and is owned by Mr Will Mure (Mures Fishing) and operated by Mr Russell Potter (Skippers 2, MED 2) who has 17 years' experience in auto longline and 23 years in all demersal line fishing in different parts of Australia.

## Fishing equipment

Setting and hauling the longline used a Mustad Coastal auto-line system with automatic baiting of 2 hooks per second whilst steaming at 5 knots. It took around 15 minutes to deploy 1500 hooks. The mainline used was 9 mm neutrally buoyant 4 strand Mustad roto line with fibre core (swivelled) with 300 mm snoods (2 mm monofilament) at 1.4 m intervals. The hooks used were 12/0 Mustad auto baiter circle hooks ('super baiters'). The mainline was anchored at each end with steel weights (approx. 25-28 kg) that had metal spikes to provide traction. Two weights were used at the start of each line and one weight at the end. Extra weights (10 kg) and floats (pressure buoys, 1100 m rating – 200 mm diameter) were deployed along the line (approx. 100 m apart) using shark clips and 1 m of 9 mm nylon rope. The typical sequence was three buoys followed by one weight. This was repeated down the length of the mainline. This resulted in a series of arches along the mainline with 40-50 m peaks, depending on tide (strong tide = low peak). The mainline was attached at both ends to 650 m of 9 mm downline which connected to large surface buoys (A5) which marked the start and end of the line and were used during retrieval. Squid (sourced from New Zealand and Tasmania) was used as the bait.

## Baited Remote Underwater Video Systems (BRUVS)

Six baited remote underwater video systems (BRUVS) were available during the voyage. BRUVS comprised two GoPro Hero 9 cameras housed in anodised aluminium pressure casings (rated to 550 m) fixed 70 cm apart, with an 8°angle of convergence, sitting 40 cm above the seabed in a steel frame. Each BRUVS had approx. 40 kg of lead weight attached. Light was provided by a single TWTEK depth rated (6000 m) LED light fitted between the two camera housings. Power to the GoPros and light was supplied through 25V lithium batteries located in the camera housings. Each BRUVS was calibrated in water using a SeaGIS calibration cube prior to the survey. Calibrated camera parameters were determined using the calibration facility software developed by SeaGIS. The BRUVS used ~1 kg of locally sourced frozen squid in a plastic bait saver at the end of a 1 m aluminium arm. The BRUVS were deployed/retrieved after the deployment/retrieval of the longline sets. Care was taken to ensure the BRUVS were at least 300 m from a longline set and from one another.

**Figure 2 Operational photos from the Gulper shark survey onboard the FV *Diana* in September 2022.**

## Survey design

The Flinders Reference Area was divided into 7 equal sectors (one sector per day, approx. 16 km long). Each day three longline sets and up to four BRUVS were deployed. To minimise soak time, and therefore maximise shark survival, the longline sets and BRUVS were deployed close together in randomly placed boxes within each sector. Each box was 4 km long (N-S) with a width that covered the 400-600 m depth contours (Figure 2). The longlines were set approx. 1.5 km apart. The start positions of each set depended on weather, tide, and local terrain. BRUVS were deployed near or between the longline sets at depths between 400-500 m, ensuring a distance of at least 300 m between equipment.

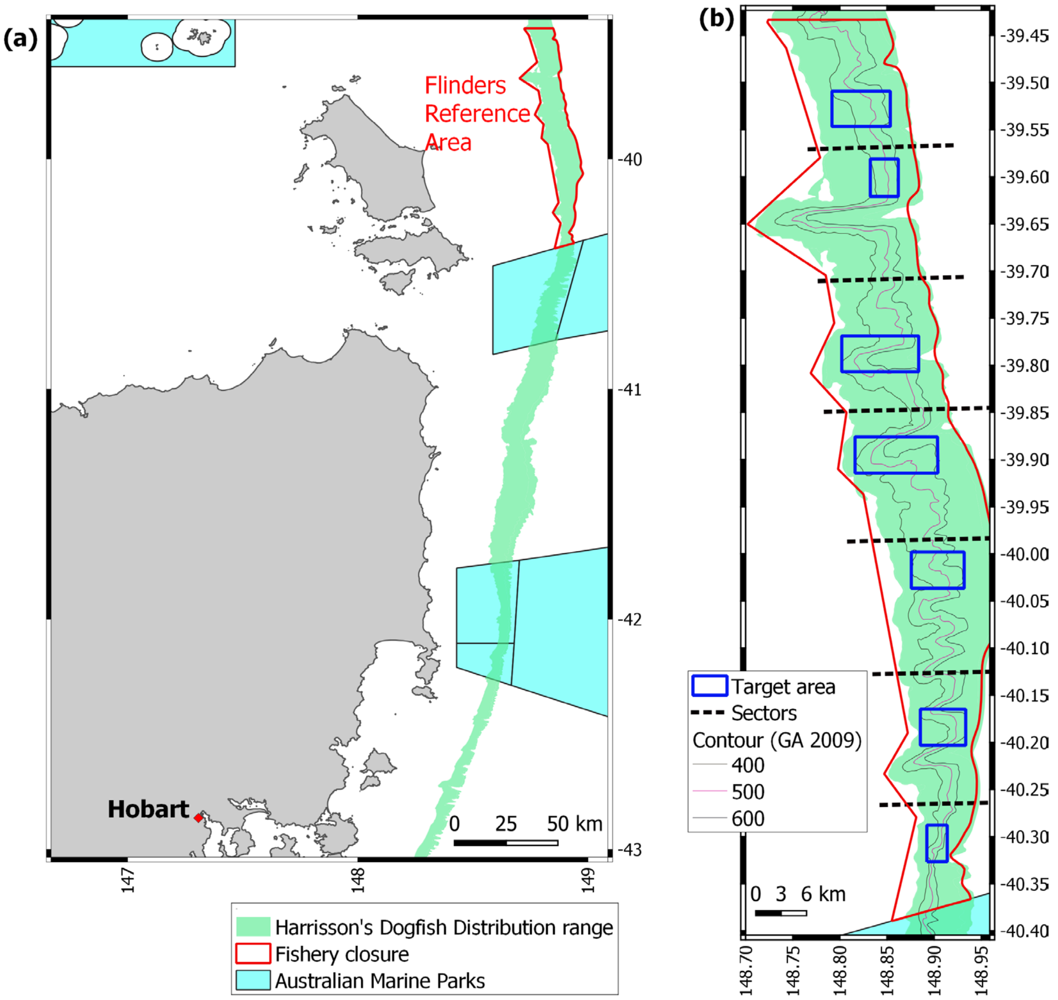


Figure 3 Maps showing (a) the location of the Flinders Reference Area in relation to Hobart and (b) the survey design with seven equal sectors (shown by the horizontal black dashed line). The randomly placed blue boxes show the target areas sampled by the longline sets and BRUVS.

## 2.3 Survey summary

The voyage was completed over 10 days. After departing Hobart at 1640 hours on 2nd September, the FV *Diana* steamed to the Flinders Reference Area (east of Flinders Island), arriving around 2200 hours on 3rd September. The sampling began at 0300 hours on 4th September and ended at 1100 hours on 10th September. The FV *Diana* arrived back in Hobart at 1530 hours on the 11th September. Twenty-one longline sets and 22 BRUVS were deployed during the survey (Table 1 and Figure 4a).

Longlines were set between 0300 and 0450 hours each morning and typically took 10-15 minutes to deploy each of the ~1500 hook sets (Table 1). On the first day, longer lines of ~2000 hooks were used to determine processing time (two gulper shark were caught this day). Longlines were hauled between 0600 and 1100 hours, typically taking 60 to 90 minutes to retrieve a line, depending on the number of sharks caught and the condition of the line (i.e., tangle or snag). The longest retrieval took 105 min (Table 1). Longline soak times ranged between 2 and 6 hours (Table 1), with the longer soak times associated with tangled lines.

The BRUVS were deployed between 0430 and 600 hours each day following deployment of the longline sets. BRUVS were retrieved between 1100 and 1300 hours after all longlines had been retrieved. This resulted in soak times of up to 8.5 hours (Table 1). Four BRUVS units were deployed on all days except day 6, when no BRUVS were deployed due to unfavourable conditions, and on day 7, when only two BRUVS were available because of damage to the other BRUVS.

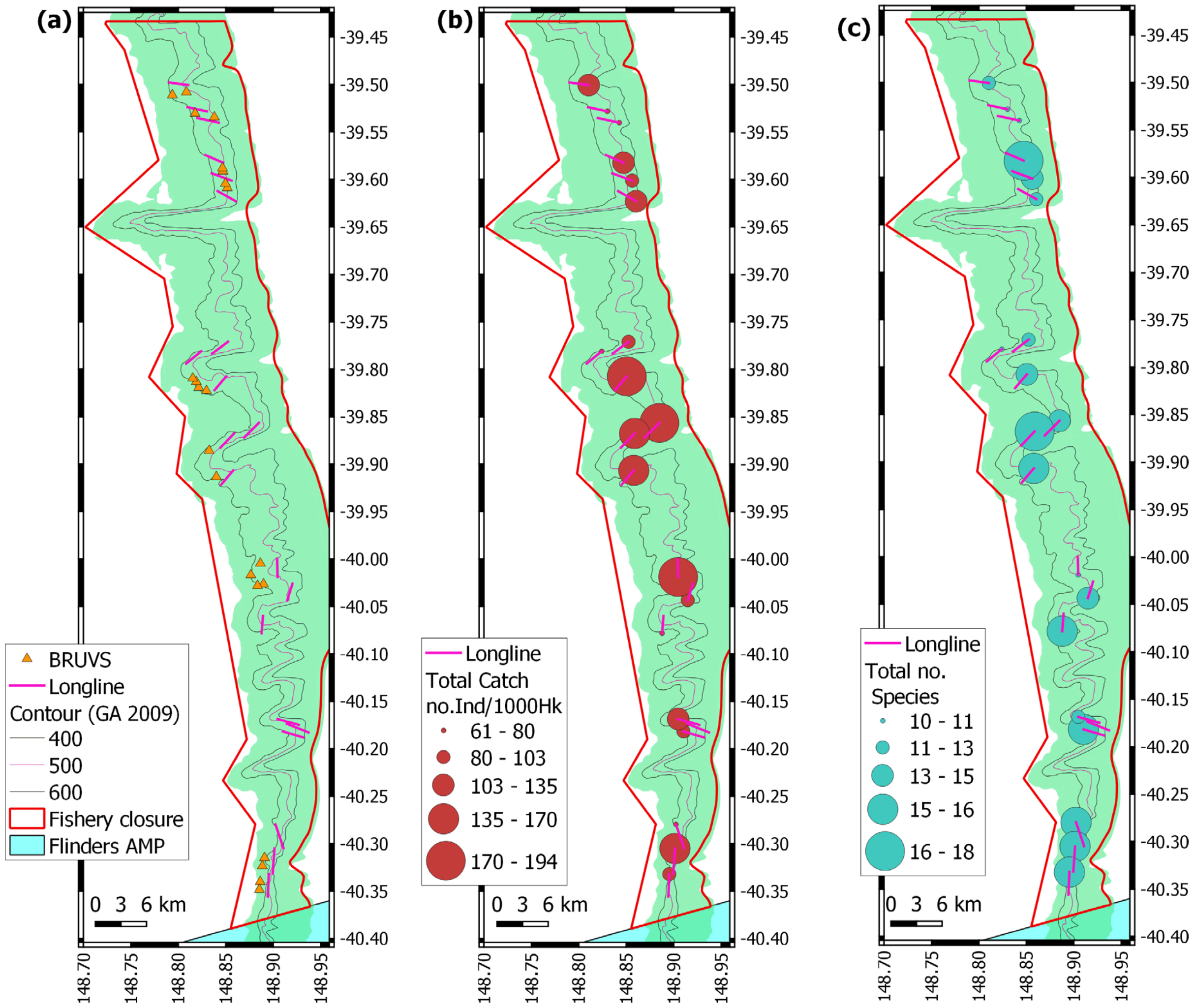


**Figure 4 Map of the Flinders Reference Area showing (a) the locations of the BRUV deployments and the auto-longline sets, (b) the total standardised catch (number of individuals per 1000 hooks) taken with each auto-longline set, and (c) the number of species caught with each set.**

**Table 1 Overview of the sampling deployments undertaken during the Flinders Survey DI202201. Summary data of catches from the longline sets are included.**

| Set Date Time | Gear | Set Longitude (°dec) | Set Latitude (°dec) | Set depth range (m) | Haul Time (hh:mm) | Soak Time (hh:mm) | Number of Hooks | Operation identifier | Comment | Total estimated catch weight (kg) | Total number of Individuals | Total number of species | Number of *C.harrissoni* | Number of *C.uyato* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 04/09/2022 03:10:10 | Longline | 148.902 | -40.280 | 401-585 | 01:43 | 02:28 | 2060 | DI202201_001 | | 544 | 165 | 16 | 1 | 1 |
| 04/09/2022 03:37:32 | Longline | 148.901 | -40.305 | 390-560 | 01:33 | 04:05 | 2075 | DI202201_002 | | 795 | 317 | 16 | 0 | 0 |
| 04/09/2022 04:03:10 | Longline | 148.895 | -40.332 | 400-530 | 01:51 | 06:16 | 1950 | DI202201_003 | Tangle in line | 751 | 199 | 16 | 0 | 0 |
| 04/09/2022 04:35:48 | BRUVS | -40.349 | 148.885 | 270 | | 08:21 | | DI202201_201 | | | | | | |
| 04/09/2022 04:43:11 | BRUVS | -40.340 | 148.886 | 200 | | 08:30 | | DI202201_202 | | | | | | |
| 04/09/2022 05:02:49 | BRUVS | -40.324 | 148.888 | 325 | | 08:30 | | DI202201_203 | | | | | | |
| 04/09/2022 05:08:59 | BRUVS | -40.315 | 148.891 | 370 | | 08:40 | | DI202201_204 | | | | | | |
| 05/09/2022 03:45:49 | Longline | 148.888 | -40.078 | 360-550 | 01:11 | 02:28 | 1580 | DI202201_004 | | 201 | 96 | 16 | 0 | 0 |
| 05/09/2022 04:11:15 | Longline | 148.915 | -40.044 | 450-540 | 01:13 | 03:48 | 1540 | DI202201_005 | | 339 | 152 | 15 | 2 | 1 |
| 05/09/2022 04:31:59 | Longline | 148.905 | -40.019 | 480-590 | 01:13 | 05:04 | 1560 | DI202201_006 | | 433 | 284 | 11 | 5 | 0 |
| 05/09/2022 05:05:17 | BRUVS | -40.005 | 148.886 | 445 | | 07:24 | | DI202201_205 | | | | | | |
| 05/09/2022 05:16:29 | BRUVS | -40.017 | 148.876 | 380 | | 06:55 | | DI202201_206 | | | | | | |
| 05/09/2022 05:25:24 | BRUVS | -40.028 | 148.883 | 364 | | 06:22 | | DI202201_207 | | | | | | |
| 05/09/2022 05:31:15 | BRUVS | -40.027 | 148.890 | 460 | | 06:00 | | DI202201_208 | | | | | | |
| 06/09/2022 03:36:25 | Longline | 148.860 | -39.623 | 405-580 | 01:14 | 02:53 | 1598 | DI202201_007 | | 335 | 201 | 13 | 10 | 0 |
| 06/09/2022 04:22:37 | Longline | 148.856 | -39.601 | 393-540 | 01:11 | 03:45 | 1500 | DI202201_008 | | 187 | 130 | 15 | 4 | 0 |
| 06/09/2022 04:44:42 | Longline | 148.847 | -39.582 | 405-490 | 01:06 | 05:00 | 1480 | DI202201_009 | | 424 | 200 | 18 | 8 | 0 |
| 06/09/2022 05:13:39 | BRUVS | -39.588 | 148.846 | 490 | | 06:36 | | DI202201_209 | | | | | | |
| 06/09/2022 05:21:34 | BRUVS | -39.591 | 148.847 | 490 | | 06:41 | | DI202201_210 | | | | | | |
| 06/09/2022 05:32:35 | BRUVS | -39.604 | 148.850 | 490 | | 06:42 | | DI202201_211 | | | | | | |
| 06/09/2022 05:38:54 | BRUVS | -39.609 | 148.852 | 497 | | 06:41 | | DI202201_212 | | | | | | |
| 07/09/2022 03:42:14 | Longline | 148.843 | -39.540 | 415-510 | 01:09 | 04:04 | 1565 | DI202201_010 | | 193 | 116 | 11 | 27 | 0 |
| 07/09/2022 04:04:12 | Longline | 148.830 | -39.528 | 395-477 | 01:13 | 02:14 | 1490 | DI202201_011 | | 239 | 98 | 11 | 26 | 0 |
| 07/09/2022 04:28:52 | Longline | 148.810 | -39.501 | 399-540 | 00:59 | 05:00 | 1410 | DI202201_012 | | 456 | 172 | 12 | 13 | 0 |
| 07/09/2022 04:53:51 | BRUVS | -39.508 | 148.808 | 490 | | 06:01 | | DI202201_213 | | | | | | |
| 07/09/2022 05:04:00 | BRUVS | -39.511 | 148.794 | 400 | | 06:10 | | DI202201_214 | | | | | | |
| 07/09/2022 05:24:25 | BRUVS | -39.534 | 148.838 | 494 | | 06:46 | | DI202201_215 | | | | | | |
| 07/09/2022 05:33:39 | BRUVS | -39.531 | 148.818 | 420 | | 06:10 | | DI202201_216 | | | | | | |
| 08/09/2022 03:44:40 | Longline | 148.852 | -39.771 | 451-470 | 01:11 | 02:29 | 1540 | DI202201_013 | | 312 | 143 | 13 | 33 | 0 |
| 08/09/2022 04:04:01 | Longline | 148.824 | -39.781 | 370-414 | 01:05 | 03:45 | 1450 | DI202201_014 | | 315 | 112 | 10 | 0 | 0 |
| 08/09/2022 04:33:53 | Longline | 148.850 | -39.808 | 425-450 | 01:08 | 04:49 | 1450 | DI202201_015 | | 898 | 281 | 15 | 23 | 0 |
| 08/09/2022 04:59:02 | BRUVS | -39.823 | 148.830 | 425 | | 06:18 | | DI202201_217 | | | | | | |
| 08/09/2022 05:09:16 | BRUVS | -39.819 | 148.821 | 410 | | 06:31 | | DI202201_218 | | | | | | |
| 08/09/2022 05:17:17 | BRUVS | -39.813 | 148.819 | 427 | | 06:45 | | DI202201_219 | | | | | | |
| 08/09/2022 05:25:53 | BRUVS | -39.810 | 148.815 | 420 | | 06:55 | | DI202201_220 | | | | | | |
| 09/09/2022 03:43:39 | Longline | 148.885 | -39.857 | 450-500 | 01:24 | 03:10 | 1530 | DI202201_016 | | 784 | 292 | 14 | 6 | 0 |
| 09/09/2022 04:06:40 | Longline | 148.859 | -39.868 | 430-485 | 01:06 | 04:52 | 1460 | DI202201_017 | | 493 | 225 | 18 | 2 | 0 |
| 09/09/2022 04:32:49 | Longline | 148.858 | -39.907 | 420-503 | 01:08 | 06:16 | 1480 | DI202201_018 | | 486 | 251 | 16 | 52 | 0 |
| 09/09/2022 05:03:45 | BRUVS | -39.914 | 148.840 | 400 | | 07:26 | | DI202201_221 | | | | | | |
| 09/09/2022 06:04:05 | BRUVS | -39.886 | 148.832 | 410 | | 06:58 | | DI202201_222 | | | | | | |
| 10/09/2022 03:42:51 | Longline | 148.914 | -40.174 | 430-630 | 01:29 | 02:25 | 1570 | DI202201_019 | Tangle in line | 138 | 104 | 12 | 2 | 0 |
| 10/09/2022 04:11:51 | Longline | 148.910 | -40.182 | 350-565 | 01:16 | 03:46 | 1460 | DI202201_020 | | 348 | 150 | 16 | 13 | 1 |
| 10/09/2022 04:49:07 | Longline | 148.905 | -40.169 | 440-530 | 01:09 | 04:47 | 1460 | DI202201_021 | | 309 | 177 | 13 | 15 | 0 |

## Catch summary

The longlines caught between 10 and 18 species per set and catch rates range between 61 and 194 fish per 1000 hooks (Figure 4b & c and Table 1). The total catch by species over the 7-day sampling period is summarised in Table 2. In total 35 different species were caught. The most common commercial species caught were Ribaldo (861), Blue-Eye Trevalla (633), Ocean Perch (552), and Pink Ling (327). The most common bycatch species was the Whitefin Swell Shark (625), that were returned to the water in good condition (Table 2).

**Table 2. Total catch by species for the DI202201 survey, including a list of the retained catch. Species with ^ are commercial species under AFMA Quota.**

| Common Name | Scientific Name | CAAB | ^ | Total number individuals | Total number retained |
|---|---|---|---|---|---|
| Harrisson's dogfish | *Centrophorus harrissoni* | 37020010 | | 242 | 2 |
| Southern dogfish | *Centrophorus uyato* | 37020011 | | 3 | 0 |
| Ribaldo | *Mora moro* | 37224002 | ^ | 861 | 845 |
| Blue-eye trevalla | Hyperoglyphe antarctica | 37445001 | ^ | 633 | 633 |
| Whitefin swell shark | Cephaloscyllium albipinnum | 37015013 | | 625 | 2 |
| Ocean perch | Helicolenus percoides & *H.barathri* | 37287901 | ^ | 552 | 550 |
| Pink ling | Genypterus blacodes | 37228002 | ^ | 327 | 326 |
| Lantern shark | Etmopterus spp. | 37020907 | ^ | 172 | 37 |
| Sawtail catshark | Figaro boardmani | 37015009 | | 72 | 0 |
| Bight skate | Dipturus gudgeri | 37031010 | | 61 | 5 |
| Southern whiptail | Coelorinchus australis | 37232001 | | 51 | 1 |
| Spikey dogfish | Squalus megalops | 37020006 | | 47 | 0 |
| Southern chimaera | Chimaera fulva | 37042005 | | 47 | 44 |
| Grey skate | Dipturus canutus | 37031028 | | 26 | 0 |
| Gemfish | Rexea solandri | 37439002 | ^ | 24 | 21 |
| Conger eel | Conger verreauxi & *Conger wilsoni* | 37067900 | | 24 | 0 |
| Blackfin ghostshark | Chimaera ogilbyi | 37042001 | | 17 | 17 |
| Platypus shark | Deania calceus & *Deania quadrispinosa* | 37020905 | ^ | 13 | 0 |
| Alfonsino | Beryx splendens | 37258002 | ^ | 9 | 9 |
| Spikey oreodory | Neocyttus rhomboidalis | 37266001 | ^ | 9 | 9 |
| Sharpnose sevengill shark | Heptranchias perlo | 37005001 | | 8 | 0 |
| Gummy shark | Mustelus antarcticus | 37017001 | ^ | 7 | 0 |
| Black shark | Dalatias licha | 37020002 | ^ | 5 | 1 |
| Peacock skate | Pavoraja nitida | 37031009 | | 5 | 0 |
| Jackass morwong | Nemadactylus macropterus | 37377003 | ^ | 4 | 4 |
| School shark | Galeorhinus galeus | 37017008 | ^ | 4 | 0 |
| Imperador | Beryx decadactylus | 37258001 | | 4 | 2 |
| Greeneye dogfish | Squalus chloroculus | 37020048 | | 3 | 1 |
| Toothed whiptail | Lepidorhynchus denticulatus | 37232004 | | 3 | 1 |
| Blue grenadier | Macruronus novaezelandiae | 37227001 | ^ | 2 | 2 |
| Dusky whaler | Carcharhinus obscurus | 37018003 | | 1 | 0 |
| Blue shark | Prionace glauca | 37018004 | | 1 | 0 |
| Unknown shark | Sharks - undifferentiated | 37990016 | | 1 | 0 |
| Schmidt's Cod | Lepidion schmidti | 37224017 | | 1 | 0 |
| Bass groper | Polyprion americanus | 37311170 | | 1 | 1 |

## Gulper shark data

A total of 245 gulper shark (242 *C. harrisoni* and 3 *C. uatyo*) were observed. Of these 236 (233 *C. harrisoni* and 3 *C. utayo*) were measured for length and sex. The other nine were not landed as they fell off the hook. Four lines caught no gulper sharks and the 3 *C. uatyo* were caught in three separate locations (Figure 5a). Males and females were, in general, co-located (Figure 5b), unlike the observation made in previous survey conducted in June 2010, where the sexes were segregated (Williams et al., 2012). Smaller, potentially juvenile individuals were mostly observed in the northern half of the survey area (Figure 5c).

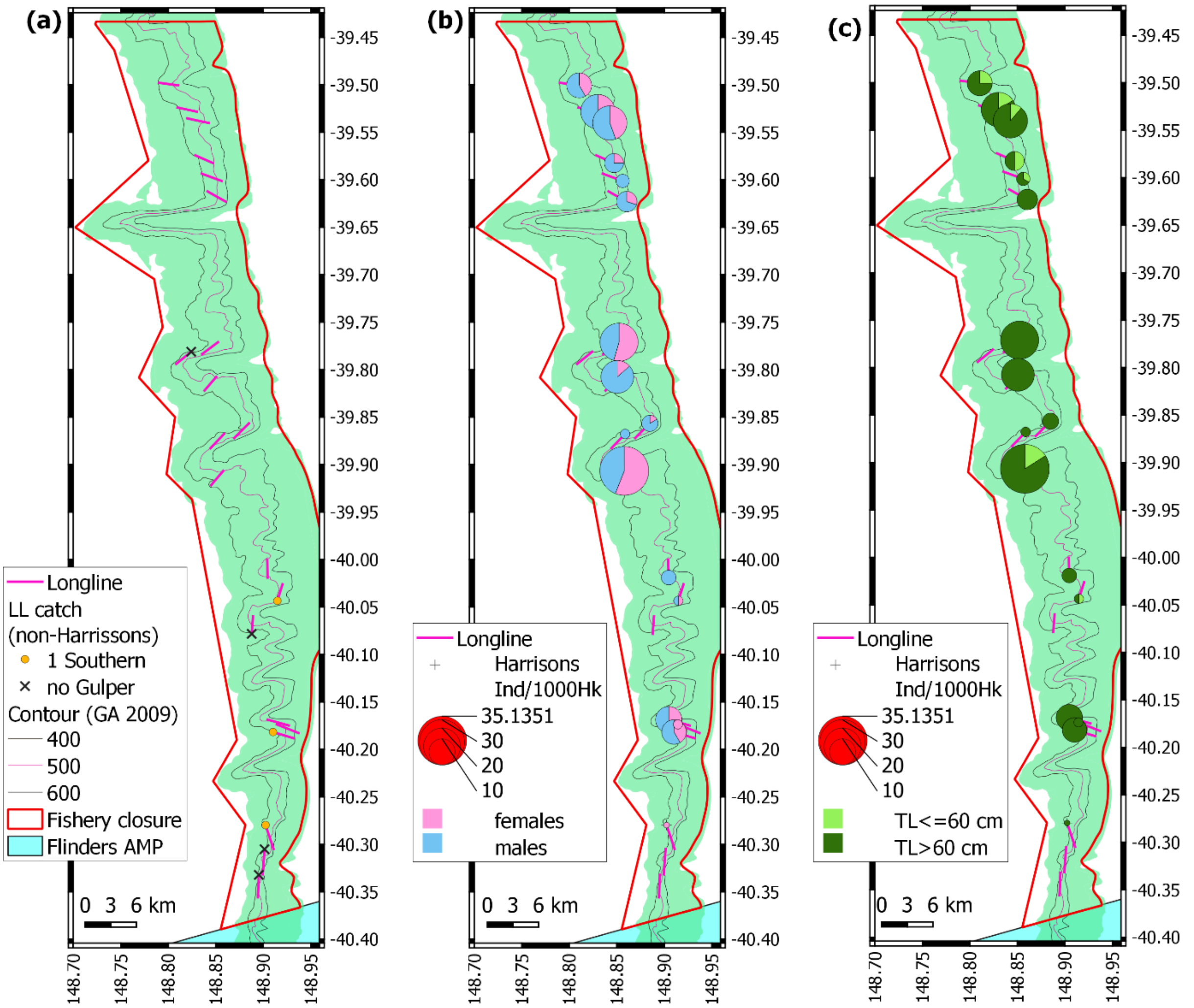


**Figure 5 Distribution of Gulper shark catches during the survey. (a) shows the locations of the longline sets (pink lines). The black crosses show lines where no gulper shark was caught, and the orange dots show where individual *C. uyato* was caught; (b) and (c) show the standardised catch per 1000 hooks of *C. harrissoni* broken down by (b) sex and (c) indicative maturity based on total length >/<= 60 cm.**

There were fewer female Harrison's Dogfish (95) caught than males (138) (Figure 5). Of the individuals greater than 100 cm in length all but one were female. The 24 individuals that were smaller than 60 cm were evenly divided between the sexes (Figure 6). The three Southern Dogfish were all adult males of sizes 90 cm, 96 cm, and 99 cm.

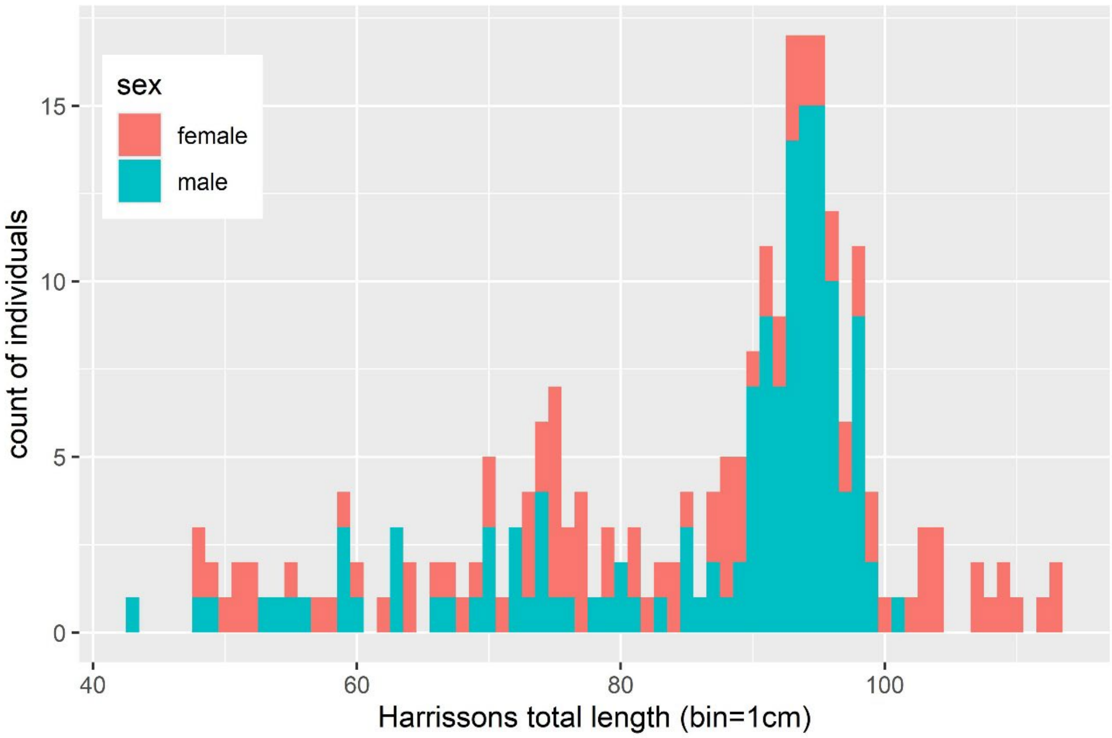


**Figure 6 Length frequency distribution of male (blue) and female (red) Harrisson's Dogfish captured during the survey.**

In total 81 gulper shark were tagged, two Southern and 79 Harrisson's Dogfish. In addition, there were three recaptures of Harrisson's Dogfish tagged during a survey on board the FV *Sarda* in June 2010 (Williams et al., 2012). In the 12 years and 3 mouths since being tagged the three males had grown between 1 to 2 cm (Table 3) and were recaptured within 0.4 and 2.3 km of the original capture site (Table 3 and Figure 7). Tagging data were delivered to the national tagging data base maintained at CSIRO.

**Table 3. Information on the three recaptured Harrison's gulper shark.**

| Tagging | Survey | Survey_Ops | Tag_No | CAAB | sex | TL (cm) | Growth (cm) | Distance (km) | Date | Depth range (m) | Line set Longitude | Line set Latitude |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Taged | SA201002 | SA201002_019 | 12533 | 37020010 | m | 93 | | | 1/06/2010 | 487-457 | 148.847 | -39.5859 |
| Recapture | DI202201 | DI202201_009 | 12533 | 37020010 | m | 95 | 2 | 0.38 | 6/09/2022 | 405-490 | 148.847 | -39.5824 |
| Taged | SA201002 | SA201002_020 | 12553 | 37020010 | m | 89 | | | 1/06/2010 | 498-561 | 148.8339 | -39.5592 |
| Recapture | DI202201 | DI202201_010 | 12553 | 37020010 | m | 90 | 1 | 2.32 | 7/09/2022 | 415-510 | 148.8425 | -39.5402 |
| Taged | SA201002 | SA201002_032 | 12877 | 37020010 | m | 91 | | | 4/06/2010 | 311-424 | 148.9133 | -40.1733 |
| Recapture | DI202201 | DI202201_020 | 12877 | 37020010 | m | 92 | 1 | 1.01 | 10/09/2022 | 350-565 | 148.9101 | -40.1817 |

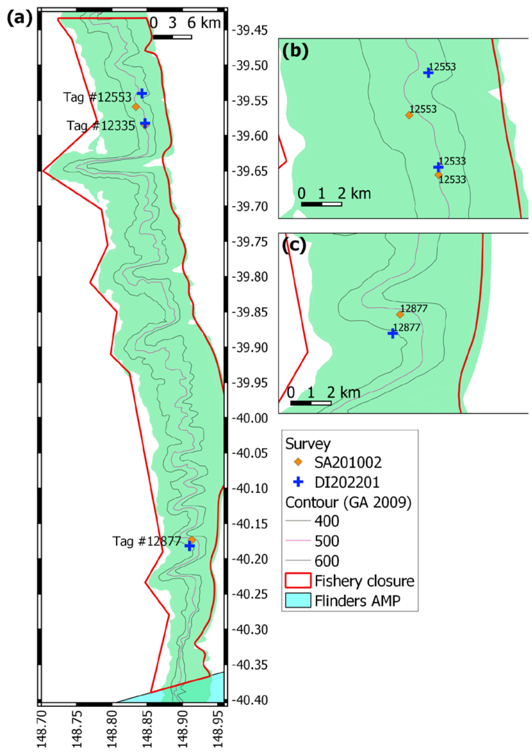


**Figure 7 Map showing (a) the location of original capture and tagging location from the 2010 FV *Sarda* survey (SA201002) and the recapture location from the 2022 FV *Diana* survey (DI202201); (b) and (c) show close-ups of the individual capture-recapture sites.**

## BRUVS preliminary observations

BRUVS footage was briefly scanned during the survey. At least six Harrison's dogfish were observed during these preliminary scans of the 22 BRUVS deployments (example shown in Figure 8). Detailed analyses of the BRUVS data will be done as part of the project.

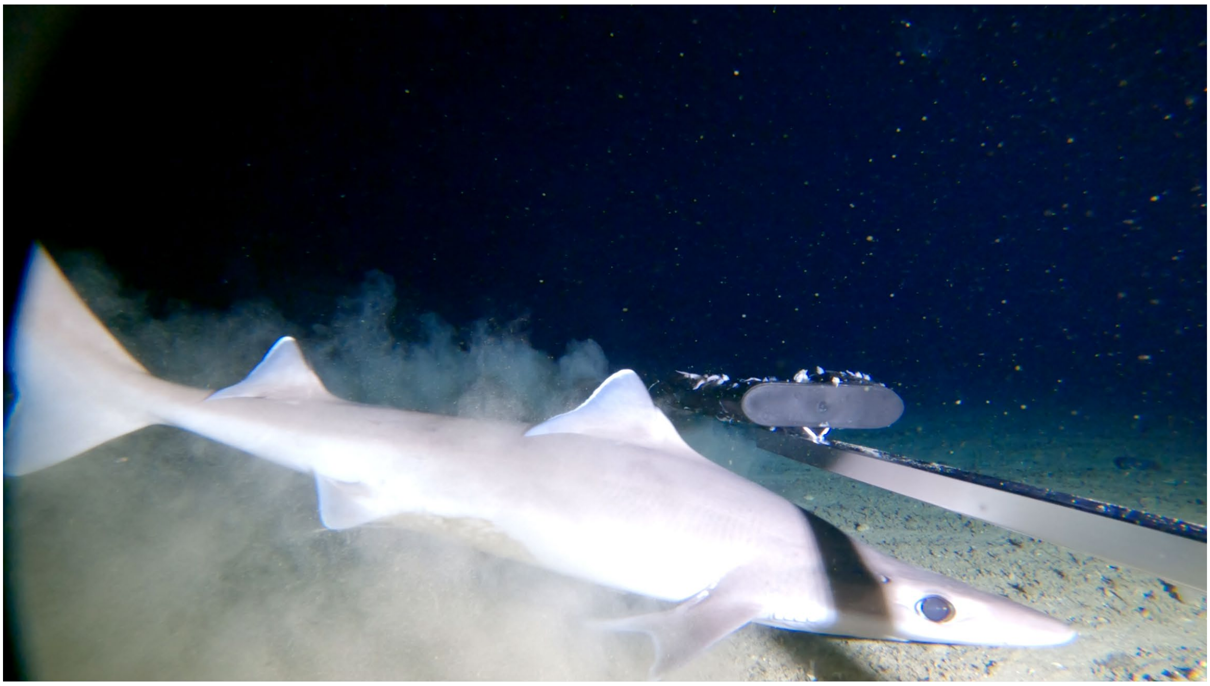

**Figure 8 Example of a Harrison's Dogfish observed in BRUVS footage taken during the survey.**

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## A.2 FV *Candice K* 2023 Survey report

Untiedt, C., Green, M. Scoulding, B., Althaus, F. and Dorter, M. (2023a) Gulper Shark Survey – Murray Research Zone Closure (May 2023): Voyage Report CK202301. Hobart, Australia: CSIRO. (pg 1-18)

Australia's National
Science Agency

# Gulper Shark Survey – Murray and Port MacDonnell Research Zone Closures (May 2023)

## Voyage report CK202301

Candice Untiedt, Mark Green, Ben Scoulding, Franzis Althaus, and Matthew Dorter

June 2023

Report to AFMA
Lara Ainsley

CSIRO

Environment: Sustainable Marine Futures

## Citation

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## Copyright



## Important disclaimer

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# Figures



# Tables

# Acknowledgments

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Many thanks to the Southern Fisheries company and to the Master Pio Llesis and crew of fishing vessel Candice K who provided a happy and safe work and living environment.

# Executive summary

An 8-day survey of Harrisson's Dogfish (*Centrophorus harrissoni*) and Southern Dogfish (*C. uyato*, formally *C. zeehaani*) ('gulper sharks') in the Murray and Port MacDonnell Closures was commenced on the 5th May onboard the FV *Candice K*. During the first day of sampling three longline sets of 900 hooks were deployed. Hauling time was much longer than anticipated due to issues with the hauling equipment which was not functioning correctly. There were also issues with the sounder, which stopped working sometime between setting and hauling of the gear. A total of 3 gulper sharks (Southern) were caught and processed. Due to the equipment issues and haul time (3-5 hours) it was decided to abandon the remainder of sampling and return to port on the 8th May as the vessel is not currently suitable to perform the fishing work required. Given the space and layout of equipment on the deck this vessel is also not suitable for BRUV work. The fisheries company, skipper and crew of the vessel were exceptional during the survey but unfortunately the vessel is not suitable at this time to perform the work required for this project.

# 1 Background and scientific objectives

Detailed Background and scientific objectives are provided in Scoulding et al., 2022 (EP2022-4954).

The current project, '*Determining the status and recovery of depleted or declining fish species: a case study of Southern Dogfish and Harrisson's Dogfish in the context of AFMA's upper slope dogfish management strategy'* is funded by AFMA and CSIRO. Its aim is to implement the highest ranked of the options considered at the stakeholder workshops (Option 1a, Williams et al. 2018). In short, Option 1a was to sample wild populations of Harrisson's Dogfish, *Centrophorus harrissoni*, and Southern Dogfish, *Centrophorus uyato*, formerly *C. zeehaani* (White et al. 2022), on the continental slope from chartered commercial fishing vessels during four surveys, visiting six identified reference areas in fishery closures where remnant shark populations are known to exist. The six areas span the main known species' ranges (**Error! Reference source not found.**).

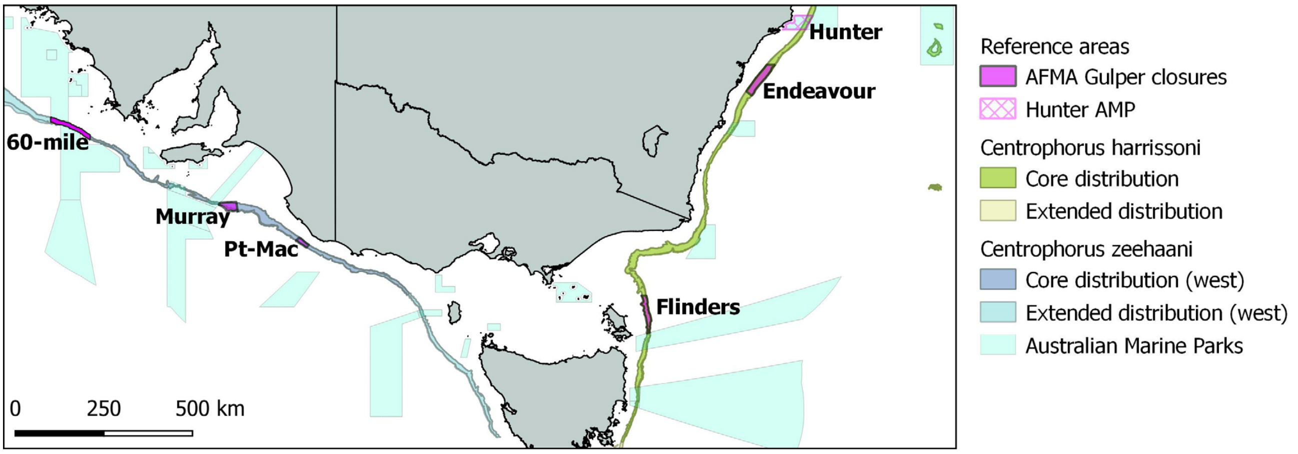


**Figure 1. Map showing locations of the six Reference Areas. Note *C. zeehaani* is now *C.uyato* (White et al., 2022)**

The six reference areas are referred to by shortened names in **Error! Reference source not found.**, they are defined as follows by the Fisheries Management legislation (Anon. 2022):

- **60-mile**: Southern Dogfish Gulper Shark Closure: AFMA fishery closure: Schedule 10
- **Murray**: Murray Dogfish Closure: Schedule 33
- **Pt-Mac**: Port MacDonnell Closure: Schedule 32
- **Flinders**: Flinders Research Zone Closure: Schedule 39
- **Endeavour**: Endeavour Dogfish Gulper Shark Closure: AFMA fishery closure: Schedule 11
- **Hunter** Marine Park – Special Purpose Zone (trawl) defined by Australian Marine Parks Legislation (Director of National Parks, 2018a & b).

Here, we report on the second of the surveys under this project: the Murray and Port MacDonnell surveys conducted on the FV *Candice K* from 5th May 2023 (survey code CK202301).

# 2 Survey Report

## 2.1 Survey objectives

1. Charter the Fishing Vessel (FV) *Candice K* for an 8-day return trip, conducting a 2-day sampling program in each of the Murray and Pt-Mac Reference Areas (**Error! Reference source not found.**).
2. Use automatic longline fishing methods to sample *C. harrissoni* and *C. utayo* in the Murray and Pt-Mac Reference Areas. Effort to be concentrated in the 400-600 m depth range.
3. Collect catch composition (species, counts, catch-rate) data from each fishing operation.
4. Record shot details for each fishing line set (location, depth, hooks set).
5. Record length and sex of all landed *C. harrissoni* and *C. utayo*.
6. Fit conventional tags onto as many vigorous *C. harrissoni* and *C. utayo* as practicable and release. Collect tissue samples from tagged sharks.

## 2.2 Survey Logistics

### Dates and timing of the charter

Departed Port Adelaide 19:00 hours, Friday 5th May 2023
Docked at Port Adelaide 11:00 hours, Tuesday 9th May 2023

### Staff

| Name | Affiliation | Role |
|---|---|---|
| **Dr Candice Untiedt** | CSIRO | Voyage leader |
| **Mr Mark Green** | CSIRO | Biology/tagging |
| **Mr Matthew Dorter** | Fishwell | Observer |
| **Mr Pio Llesis** | FV Candice K | Master |
| **Mr Amando Lastimado** | FV Candice K | Crew |
| **Mr Alvin Ursua** | FV Candice K | Crew |

### Permits

- **Animal ethics:** Permit Franziska Althaus, Ref # 2022-02
- **AFMA Research fishing permit (sent to vessel)**: Permit # 1005629
    - Fishing permit using automatic longline in closures
    - Permit to retain dead gulper sharks (if dead or moribund on capture)

Catches of commercial species could be sold with proceeds going to the research project; catches of quota species are considered incidental research catch and are not counted towards the vessel owner's commercial quota, and are covered by research quota allowance (L. Ainsley, pers. comm.).

## Vessel details

The FV *Candice K*– a Port Adelaide based fishing vessel – was charted by CSIRO for this 8-day survey. The FV *Candice K* is equipped with automatic longline gear and is licensed to fish in Commonwealth, SE non-trawl waters and the high seas. The master and crew are experienced shallow water longline fishers. The vessel was built in 1979. The vessel is 22 metres in length, constructed of steel and powered by a single 3406 Caterpillar Marine (460 hp) main engine. Auxiliary power is supplied by smaller engines (3056 Caterpillar) for hydraulics, 240-volt power, refrigeration and ice making machines. The vessel has berths for up to 4 and is owned by Southern Fisheries and operated by Mr Pio Llesis (Skippers 2, MED 2) who has 10 years' experience in auto longline fishing in South Australia and other Australian waters.

## Fishing equipment

Setting and hauling the longline used a Mustad Coastal auto-line system with automatic baiting of 1 hook per second whilst steaming at 3 knots. It took around 30 minutes to deploy 900 hooks. The mainline used was 9 mm neutrally buoyant 4 strand Mustad roto line with fibre core (swivelled) with 300 mm snoods (2 mm monofilament) at 4 m intervals. The hooks used were 12/0 Mustad auto baiter circle hooks ('super baiters') (Figure 2). The mainline was anchored at each end with two steel weights (approx. 15-20 kg each). No extra weights and/or floats were deployed along the line. The mainline was attached at both ends to 650 m of 9 mm downline which connected to large surface buoys (A5) which marked the start and end of the line and were used during retrieval. Locally sourced mackerel was used as bait.


**Figure 2. Images of gear and hauler: a) roller with main fishing line hauler on left, b) secondary hauler and hook storage, c) main hauler showing gap between sheaves, apparently worn, d) float line hauler showing smaller gap between sheaves for comparison.**

## Survey design

Two days of fishing were planned in each the Murray and Port-Mac Reference Areas (red boxes, Figure 3), with three longline sets in the 400-600 m depth range per day. To minimise soak time, and therefore maximise shark survival, the longline sets each day were planned within an area approximately 5 km wide (blue box, Figure 3). Longlines sets were planned to be approx. 1.5 km apart, with start positions within the box, but adjusted to account for weather, tide, and local terrain. To representatively sample the reference areas, these were divided into 2 equal sectors along the main direction of the slope (sector width Murray ~25 km, Port-Pac ~18 km), and a sampling box was randomly placed within each sector. (Figure 3).

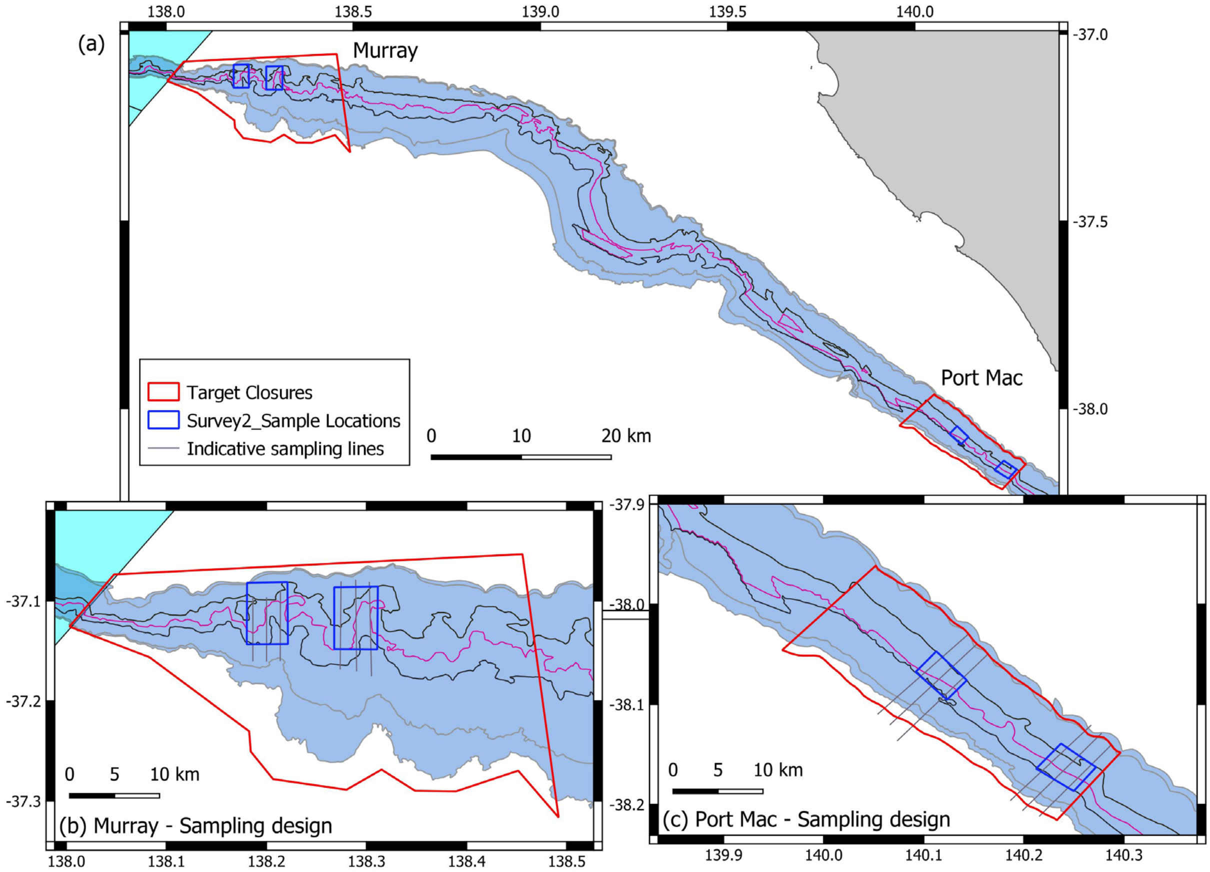


**Figure 3. Maps showing (a) the survey design with randomly placed blue boxes showing the target areas identified for sampling with longline sets (indicative grey lines).**

## 2.3 Survey summary

An 8-day survey of Harrisson's Dogfish (*Centrophorus harrissoni*) and Southern Dogfish (*C. uyato*, formally *C. zeehaani*) ('gulper sharks') in the Murray and Port MacDonnell Closure sites was planned between 5$^{th}$–12$^{th}$ May 2023 onboard the FV *Candice K*. The sampling plan was to deploy 3 sets of longlines (900 hooks) in two sectors at both sites over four days of sampling. No BRUVS were taken on this voyage as we had not worked on the vessel before and wanted to ensure that the fishing operations were adequate and refined prior to introducing this additional sampling gear.

The vessel steamed from Port Adelaide at 19:00 on the 5$^{th}$ May. We arrived on site at 02:00 on Sunday 07 May. The first fishing operation comprised 3 longline sets, each of 900 hooks, in the Murray 2 site on the morning of Sunday 07 May from 04:00–06:10 (Table 1).

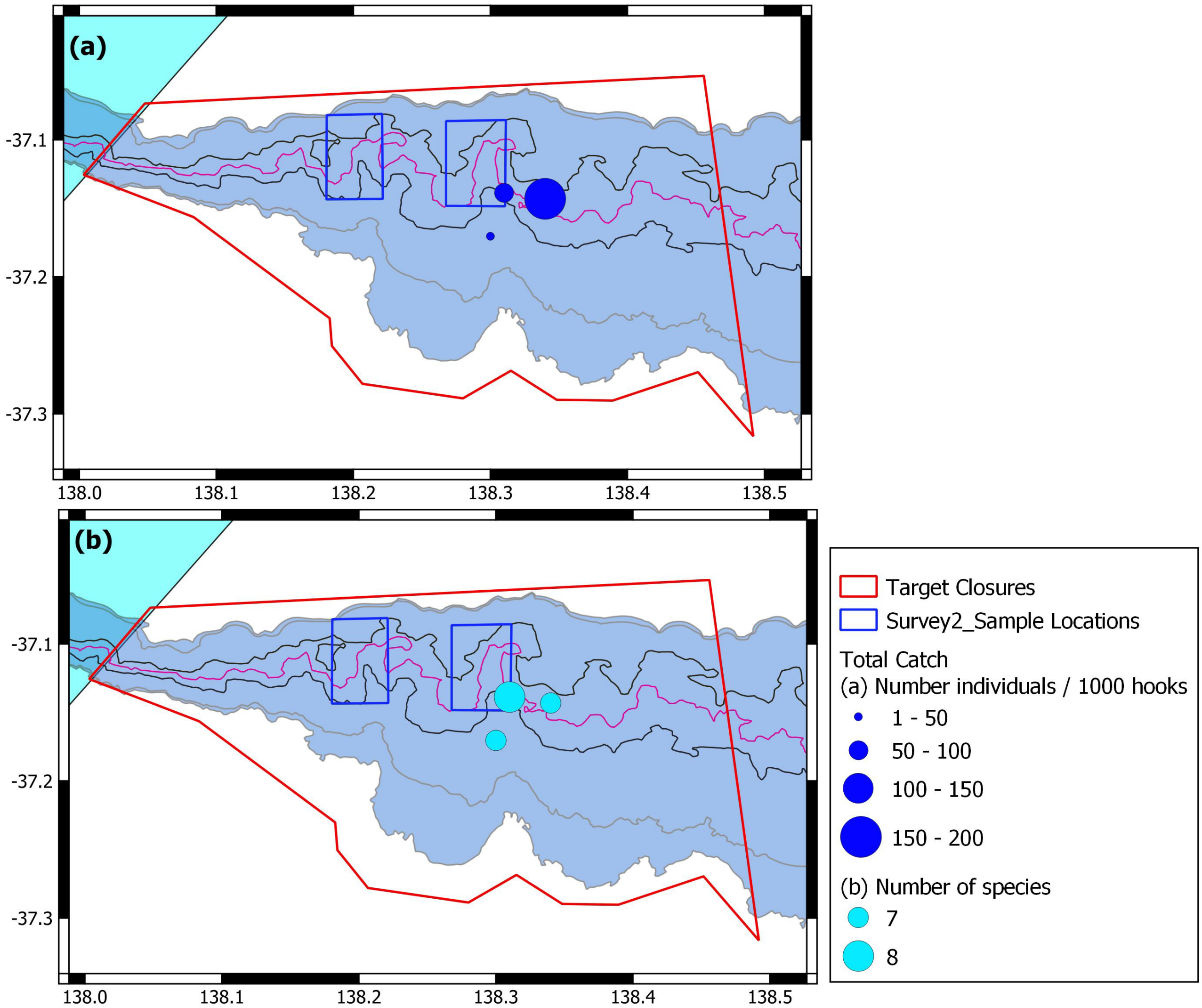


**Figure 4. Map of the Murray Reference Area showing (a) the locations of the auto-longline sets sized by the total standardised catch (number of individuals per 900 hooks) taken with each auto-longline set, and (b) the number of species caught with each set.**

The first longline set was hauled at 07:00, three hours after it had been deployed. The echosounder, operational during line setting, enabling depth data to be recorded and the lines to be set in the target depth ranges, failed sometime during these three hours. There were some issues during hauling in that the line had snapped about 20-30 hooks in and throughout most of the retrieval it appeared that the hauler had insufficient power to retrieve the heavy line and at times the line appeared to have snagged on the bottom. These issues resulted in the skipper having to manoeuvre the vessel in several directions to achieve the traction needed to haul the line. Consequently, retrieval took 5 hours, far longer than planned (Figure 3) delaying the retrieval of the remaining lines and reducing the survival prospects of any captured sharks. A total of 3 gulper sharks (*C. uyato*) were captured in this operation with 2 individuals landed, processed and released in good condition.

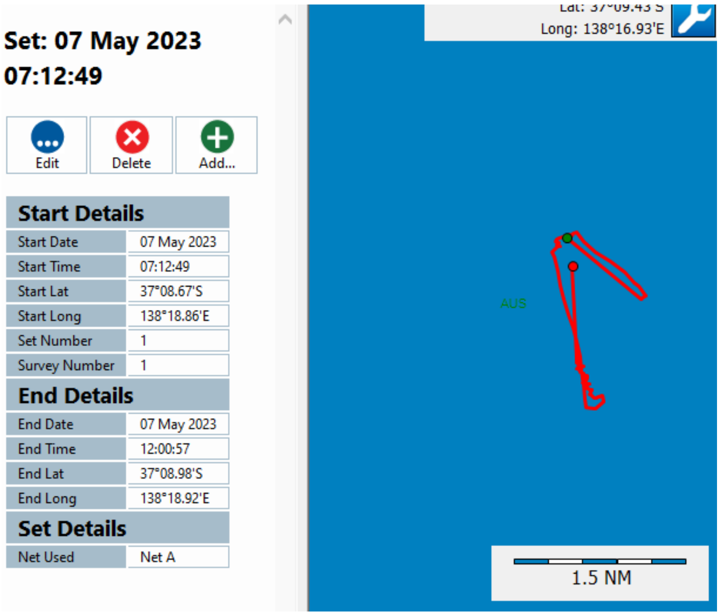


Figure 5. Haul track for first operation (CK202301_001)

As a result of the long haul time and the concern that gulper sharks may have been captured on the shallowest line of the set it was decided to retrieve line three (Table 1: CK202301_003) next. Retrieval commenced at 12:20 (Figure 4). The hauling issues were worse for this line and it was discovered that while the hauler was rotating, the main fishing line was slipping between the sheeves. This resulted in a haul time of over 6 hours, which was complete at 18:32 on Sunday evening.

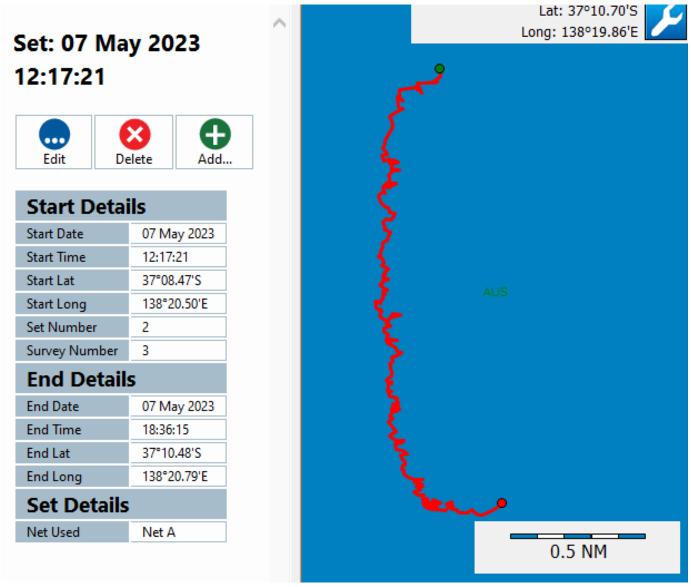


Figure 6. Haul track for third operation (CK202301_003)

As the remaining long line (Table 1: CK202301_002) was the deepest line of the set and staff and crew had been working since 03:00 it was decided for safety reasons that this set would be retrieved the following morning. The base contact and the project Principal Investigator were informed of the challenges and the proposed by field trip leader, with support from the on-vessel science staff, to abandon the remainder of the survey and return to port as the vessel is not currently fit to perform the scientific work required. Both base contact (Franzis Althaus) and project/team leader (Ben Scoulding) were in support of this decision.

The remaining longline was hauled on the morning of Monday 08 May commencing at 08:37 and being completed at four and a half hours later at 13:00 (Figure 5). During the retrieval of this line, crew were manually assisting the hauler to bring in the main line in more quickly and reduce the haul time somewhat

(Figure 6). One gulper shark was caught on this line, it was a lively specimen and was processed and released in good condition and observed to dive and swim away (Table 1).

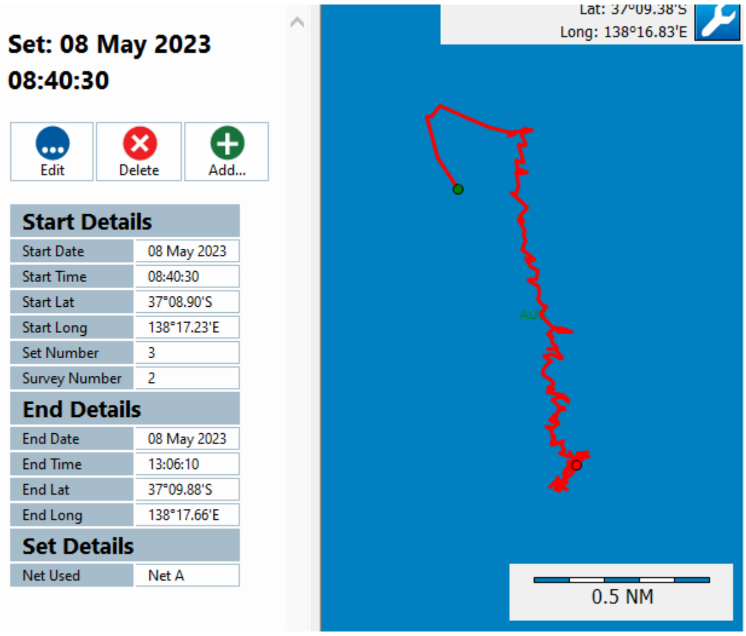


Figure 7. Haul track for second operation (CK202301_002)

Figure 8. Gulper shark processing area showing manual assistance of the hauler in the background

The vessel began steaming back to port on Monday at 14:00 and we arrived in Port Adelaide at 11:00 on Tuesday the 9th of May. The skipper and crew on board were exceptionally helpful, hardworking and skilled, managing to retrieve all the gear without loss. Southern fisheries representatives, Kyri and Philios Toumazos provided support and assistance to the science staff prior to, and following the voyage and, like the skipper and crew, were a pleasure to interact and work with during this time.

The CSIRO staff onboard the vessel have made an initial determination that there is insufficient space on this vessel to accommodate and safely deploy and retrieve BRUVS units. The longlines are organised and stored in pods of 300 hooks and these pods are moved around the deck, leaving inadequate space to store the BRUVS units. There is also insufficient space on the side of the vessel to safely deploy and retrieve BRUVS.

**Table 1. Overview of the sampling deployments undertaken during the CK202301 Survey. Summary data of catches from the longline sets are included.**

| Set Date Time (UTC) | Set Longitude (°dec) | Set Latitude (°dec) | Set depth range (m) | Haul Date Time (UTC) | Soak Time (d:hh:mm) | Number of Hooks | Operation identifier | Total number of Individuals | Total number of species | Number of *C.harrissoni* | Number of *C.uyato* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 6/05/2023 18:31:00 PM | 138.31215 | 37.13867 | 557-730 | 6/05/2023 21:32:00 PM | 3:01 | 900 | CK202301_001 | 75 | 8 | 0 | 2 |
| 6/05/2023 19:36:00 PM | 138.3003 | 37.17035 | 633-726 | 7/05/2023 23:03:00 PM | 1 day 03:27 | 900 | CK202301_002 | 38 | 7 | 0 | 1 |
| 6/05/2023 20:17:00 PM | 138.337983 | 37.14303 | 464-553 | 07/05/2023 02:54:00 AM | 6:37 | 900 | CK202301_003 | 161 | 7 | 0 | 0 |

## Catch summary

The longlines caught between 7-8 species per set and catch rates range between 38 and 161 fish per 900 hooks (Table 1). The total catch by species over the 1-day sampling period is summarised in Table 2. In total 12 different species were caught. The most common commercial species caught were Ribaldo (46). The most common bycatch species was the Greeneye dogfish (112), that were returned to the water in good condition (Table 2).

**Table 2. Total catch by species for the CK2022301 survey, including a list of the retained catch. Species with ^ are commercial species under AFMA Quota.**

| Common Name | Scientific Name | CAAB | ^ | Total number individuals | Total number retained |
|---|---|---|---|---|---|
| Southern dogfish | *Centrophorus uyato* | 37020011 | | 3 | 0 |
| | | | | | |
| Ribaldo | *Mora moro* | 37224002 | ^ | 46 | 39 |
| Whitefin swell shark | *Cephaloscyllium albipinnum* | 37015013 | | 22 | 0 |
| Ocean perch | *Helicolenus percoides & H.barathri* | 37287901 | ^ | 2 | 2 |
| Pink ling | *Genypterus blacodes* | 37228002 | ^ | 17 | 17 |
| Sawtail catshark | *Figaro boardmani* | 37015009 | | 22 | 0 |
| Bight skate | *Dipturus gudgeri* | 37031010 | | 1 | 0 |
| Platypus shark | *Deania calceus & Deania quadrispinosa* | 37020905 | ^ | 36 | 0 |
| School shark | *Galeorhinus galeus* | 37017008 | ^ | 2 | 2 |
| Greeneye dogfish | *Squalus chloroculus* | 37020048 | | 112 | 0 |
| Skate - undifferentiated | Rajiformes | 37990030 | | 1 | 0 |
| Shortfin eel | *Anguilla australis* | 37056001 | | 10 | 9 |

## Gulper shark data

A total of 4 gulper sharks (all *C. uyato*) were observed. Of these 3 were measured for length, sexed and tagged. The other individual was not landed as it fell off the hook. The shallowest line set (CK202301_003: 464-553 m) caught no gulper sharks and only mature males (>81 cm TL) were observed during the survey.

**Table 3. Information on the Southern gulper sharks captured during CK202301.**

| Operation | Specimen # | species | sex | Life stage | TL (mm) | Tag # |
|---|---|---|---|---|---|---|
| CK202301_001 | 001 | *C. uyato* | M | 3 | 815 | 13089 |
| CK202301_001 | 002 | *C. uyato* | M | 3 | 875 | 13090 |
| CK202301_001 | | *C. uyato* | | | | |
| CK202301_002 | 003 | *C. uyato* | M | 3 | 910 | 13088 |

# References


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White W, Guallart J, Ebert DA, Naylor GJP, Veríssimo A, Cotton CF, Harris M, Serena F, and Iglésias SP (2020) Revision of the genus Centrophorus (Squaliformes: Centrophoridae): Part 3—Redescription of *Centrophorus uyato* (Rafinesque) with a discussion of its complicated nomenclatural history. Zootaxa 5155(1), 1-51.

Williams A, Green MA, Althaus F, Knuckey I, McLean D and M. Koopman M (2018) Research to support the upper slope dogfish management strategy: options for monitoring the recovery of Southern Dogfish and Harrisson's Dogfish. Report to AFMA. CSIRO, Hobart, Australia.

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## A.3 FV *Diana* 2023 Surveys report

Untiedt, C., Green, M., Hudson, R., Althaus, F., and Scoulding, B. (2023b). Gulper Shark Survey 3: Hunter and Endeavour and Survey 4: Port MacDonnell and Murray Areas; Voyage Report Di202301 and DI202302 Hobart, Australia: CSIRO. (pg 1-41)

Australia's National
Science Agency

# Gulper Shark Survey 3: Hunter and Endeavour and Survey 4: Port MacDonnell and Murray areas

## Voyage report DI202301 and DI202302

Candice Untiedt, Mark Green, Russell Hudson, Franzis Althaus and Ben Scoulding

October 03, 2023

Report to AFMA
Lara Ainley

CSIRO Environment

## Citation

Untiedt, C., Green, M., Hudson R., Althaus, F. and Scoulding, B., (2023). Gulper Shark Survey 3: Hunter and Endeavour and Survey 4: Port MacDonnell and Murray areas. CSIRO, Australia.



## Important disclaimer

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# Figures

# Tables

# Acknowledgments

Funding was provided by AFMA and CSIRO.

Many thanks to the Mures Fishing company and particularly to the Master Russell Potter and crew of fishing vessel Diana who have provided a happy and safe work area and shared their knowledge and experience of the fishing operations and the fishery area.

# Executive summary

Two surveys were conducted onboard the FV *Diana* in late August – early September 2023: DI202301 and DI202302.

A 5-day survey (DI202301) of Harrison's (*Centrophorus harrissoni*) and Southern Dogfish (*C*. *uyato*, formally *C. zeehaani*) ('gulper sharks') in the Hunter (2 days) and Endeavour (3 days) Research Zone Closures was conducted between 24th August to 1st September 2023. During the 5-days of sampling fifteen longline sets (6 in the Hunter and 9 in the Endeavour Reference Areas) and eleven BRUVS (9 in the Hunter and 2 in the Endeavour Reference Areas) were deployed. A total of 631 gulper shark, across three species were observed from the Hunter Reference Area. Of the 594 gulper sharks landed, the vast majority (537 or 90%) were Endeavour dogfish (*Centrophorus moluccensis*), followed by Harrison's dogfish (*C. harrissoni*) (47 or 8%), with a small number of Southern dogfish (*C. uyato*) (10 or 2%) also being captured. Mature (>60cm TL) male Endeavour dogfish dominated, with only two females caught from one set in this area, one of which was the only juvenile of this species caught. For Harrison's dogfish, males and females were generally co-located and males were generally more abundant than females. Adults and possible juvenile individuals were also co-located with most males (78%) being mature adults, while almost 50% of captured females of this species were possible juvenile (<60cm TL) individuals. All individuals of Southern dogfish were mature (>60cm TL) males.

A total of 295 gulper shark, across three species were observed from the Endeavour Reference Area. Of the 274 landed gulper sharks, the vast majority (193 or 70%) were Harrison's dogfish (*C. harrissoni*), followed by Southern dogfish (*C. uyato*) (51 or 19%) and a smaller number of Endeavour dogfish (*C. moluccensis*) (30 or 11%). Males and females of this species were, in general, co-located and there were fewer male (54) Harrison's dogfish caught than females (140), except for the southern sampling sector, where males were more abundant in all three longline sets. Of the 193 individuals, only 1 individual (male) was a possible juvenile (<60cm TL). Only seven (14%) of the 51 Southern dogfish caught were females, and all were larger than 60cm TL. For Endeavour dogfish, only two of the 29 landed individuals were females and no smaller, possible juvenile (<60cm TL) individuals were caught.

In total, 204 gulper shark across the three species were tagged from the Hunter (37 Endeavour dogfish, 29 Harrison's dogfish and 9 Southern dogfish) and Endeavour Reference Area (2 Endeavour dogfish, 97 Harrison's dogfish and 30 Southern dogfish). There were no recaptures of dogfish for either area during the survey. Preliminary scans of the BRUV footage suggest that several Endeavour dogfish were recorded.

The second, 4-day survey (DI202302) of Southern Dogfish (*C. uyato*, formally *C. zeehaani*) ('gulper sharks') in the Port MacDonnell (2 days) and Murray (2 days) Research Zone Closures was conducted between 1st August to 6th September 2023. During the 4-days of sampling twelve longline sets (6 in each of the Port MacDonnell and Murray Reference Areas) and ten BRUVS (6 in the Port MacDonnell and 4 in the Murray Reference Areas) were deployed.

A total of 157 Southern dogfish (*C. uyato*) were observed from the Port MacDonnell Reference Area. Of the 138 landed Southern dogfish, the majority (106 or 77%) were males, and while co-location of sexes was common, no females were caught on two of the three sets in the eastern sampling sector. Only 7 (4%) individuals were juveniles (<69cm TL)

A total of 47 Southern dogfish (*C. uyato*) were observed from the Murray Reference Area. Of the 43 Southern dogfish landed, the majority (25 or 66%) were males, and while co-location of sexes was common, no females were caught on the deepest set in both the eastern and western sampling sectors. Most (35 or 81%) of the Southern dogfish landed were large (>60cm TL) individuals. In total, 108 Southern dogfish were tagged from the Port MacDonnell (74) and Murray (34) Reference Area. There were no recaptures of dogfish from Port MacDonnell. Preliminary scans of the BRUV footage suggest that  Southern dogfish were recorded.

# 1 Background and scientific objectives

Harrisson's Dogfish (*Centrophorus harrissoni*) and Southern Dogfish (*C. zeehaani*) ('gulper sharks') were listed under Threatened Species provisions of the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) in 2013 due to their widespread depletion by commercial fishing. The Threatened Species Scientific Committee (TSSC) listed them in the relatively low risk category of 'conservation dependent' because the Upper Slope Dogfish Management Strategy (USDMS) (AFMA 2012; NSWDPI 2012) was considered by the TSSC to be potentially effective in halting further decline and supporting recovery of both species to maximise their chance of survival in nature".

Work conducted between 2009 and 2012 by CSIRO and other stakeholders, including the fishing industry and non-government organisations, as part of two FRDC, AFMA and CSIRO-funded projects (Williams et al. 2012, 2013) substantially informed the TSSC evaluation process and helped achieve the fishery-favourable conservation dependent listings. The listings were contingent on having "strategies for rigorous evaluation of the effectiveness of the collective management plans against their objectives, with a clear description of the monitoring and review process and its associated timelines" (TSSC 2013). It was the TSSC's expectation that monitoring of gulper shark recovery would be progressed and reviewed during the first five years of implementation of the management strategy. In response, AFMA developed a 'Research and Monitoring Workplan' in consultation with the Upper-Slope Dogfish Research Plan Working Group (a SESSF RAG sub-committee) (AFMA 2014).

A key element of the plan was to develop "a cost-effective methodology for measuring gulper shark baseline relative abundance and recovery", (AFMA 2017). This was achieved in a consultative project undertaken by CSIRO and Fishwell (Williams et al. 2018). The project was built around two stakeholder workshops that were well attended by scientists, fishery managers, and trawl and non-trawl fishing industry representatives. It was agreed by the stakeholders at both workshops that: (1) existing data do not constitute a baseline dataset, and that this needs to be established as the first step of the monitoring program; (2) a short list of six suitable reference areas could be identified; (3) commercial auto-longline fishing, with suitable fishing/handling practices, is the most reliable, cost-effective and immediately implementable option for measuring relative abundance (the top-ranked indicator of recovery); (4) a non-extractive (image-based) technique using conventional baited remote underwater videos (BRUVS) should be used in parallel with fishing to gauge its effectiveness and comparability to auto-longline catches; and (5) there is a need and opportunity to continue tagging work to provide complementary data for population estimates, site fidelity, other range movements, and tissues for future genetic studies.

The current project, '*Determining the status and recovery of depleted or declining fish species: a case study of Southern Dogfish and Harrisson's Dogfish in the context of AFMA's upper slope dogfish management strategy'* is funded by AFMA and CSIRO. Its aim is to implement the highest ranked of the options considered at the stakeholder workshops (Option 1a, Williams et al. 2018). In short, Option 1a was to sample wild populations of Harrisson's Dogfish, *Centrophorus harrissoni*, and Southern Dogfish, *Centrophorus uyato*, formerly *C. zeehaani* (White et al. 2022), on the continental slope from chartered commercial fishing vessels during four surveys, visiting six identified reference areas in fishery closures where remnant shark populations are known to exist. The six areas span the species' ranges (Figure 1).

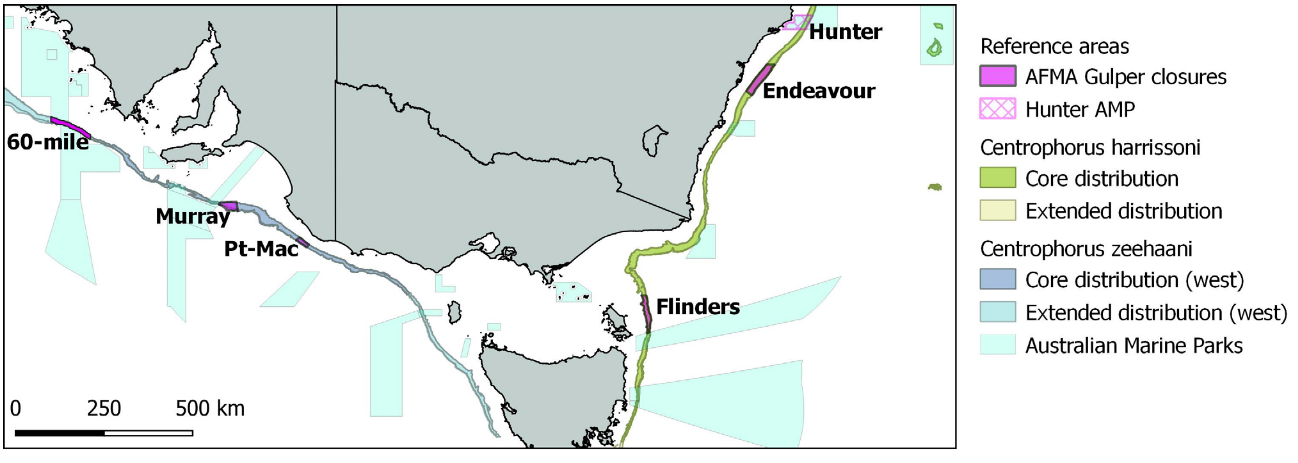


**Figure 1 Map showing locations of the six Reference Areas. Note *C. zeehaani* is now *C. uyato* (White et al., 2022)**

The six reference areas are referred to by shortened names in Figure 1, they are defined as follows by the Fisheries Management legislation (Anon. 2022):

- **60-mile**: Southern Dogfish Gulper Shark Closure: AFMA fishery closure: Schedule 10
- **Murray**: Murray Dogfish Closure: Schedule 33
- **Pt-Mac**: Port MacDonnell Closure: Schedule 32
- **Flinders**: Flinders Research Zone Closure: Schedule 39
- **Endeavour**: Endeavour Dogfish Gulper Shark Closure: AFMA fishery closure: Schedule 11
- **Hunter** Marine Park - Special Purpose Zone (trawl) defined by Australian Marine Parks Legislation (Director of National Parks, 2018a & b).

The first survey under this project was conducted on the FV *Diana* in September 2022 in the Flinders Reference Area. The second survey was undertaken on the FV *Candice K* to the Murray and Port MacDonnell areas in May 2023 but due to operational reasons this survey trip was abandoned with only three longline sets (900 hooks) conducted in the Murray area. The 60 mile area was deemed to have sufficient prior knowledge of Gulper shark populations and due to constraints around sampling times and project costings it was decided to drop the 60 mile closure area from the project.

Here, we report on the third and fourth surveys under this project: Survey 3 to the Hunter and Endeavour reference areas conducted on the FV *Diana* from 24$^{th}$ – 31$^{st}$ August 2023 (survey code DI202301) and Survey 4 to the Murray and Port MacDonnell reference areas conducted from the 1$^{st}$ to the 5$^{th}$ September 2023 (survey code DI202302).

# 2 Surveys 3&4: Vessel, staff and equipment details

## Staff

| Name | Affiliation | Role |
|---|---|---|
| **Dr Candice Untiedt** | CSIRO | Voyage leader |
| **Mark Green** | CSIRO Contractor | Biology/tagging |
| **Mr Russell Hudson** | Fishwell | Observer |
| **Mr Russell Potter** | FV Diana | Master |
| **Mr Wilson Mure** | FV Diana | Crew |
| **Mr Joshua O'Brien** | FV Diana | Crew |
| **Mr Huw Marchment** | FV Diana | Crew |

## Vessel details

The FV *Diana* – a Hobart based fishing vessel – was charted by CSIRO for these surveys. The FV *Diana* is equipped with automatic longline gear and is licensed to fish in Commonwealth, SE non-trawl waters and the high seas. The master and crew are experienced longline fishers. The vessel was built in 2004 in Hobart, Tasmania. The vessel is 22.8 metres in length, constructed of steel and powered by a single 3406 Caterpillar Marine (460 hp) main engine. Auxiliary power is supplied by smaller engines (3056 Caterpillar) for hydraulics, 240-volt power, refrigeration and ice making machines. The vessel has berths for up to 8 and is owned by Mr Will Mure (Mures Fishing) and operated by Mr Russell Potter (Skippers 2, MED 2) who has 19 years' experience in auto longline and 30 years in all demersal line fishing in different parts of Australia.

## Fishing equipment

Setting and hauling the longline used a Mustad Coastal auto-line system with automatic baiting of 2 hooks per second whilst steaming at 5 knots. It took around 15 minutes to deploy 1500 hooks. The mainline used was 9 mm neutrally buoyant 4 strand Mustad roto line with fibre core (swivelled) with 300 mm snoods (2 mm monofilament) at 1.4 m intervals. The hooks used were 12/0 Mustad auto baiter circle hooks ('super baiters') (Figure 2). The mainline was anchored at each end with steel weights (approx. 25-28 kg) that had metal spikes to provide traction. Two weights were used at the start of each line and one weight at the end. Extra weights (10 kg) and floats (pressure buoys, 1100 m rating – 200 mm diameter) were deployed along the line (approx. 100 m apart) using shark clips and 1 m of 9 mm nylon rope. The typical sequence was two to three buoys followed by one weight. This was repeated down the length of the mainline. This resulted in a series of arches along the mainline with 40-50 m peaks, depending on tide (strong tide = low peak). The mainline was attached at both ends to 650 m of 9 mm downline which connected to large surface buoys (A5) which marked the start and end of the line and were used during retrieval. Squid and mackerel (sourced from New Zealand and Tasmania) was used as the bait.

## Baited Remote Underwater Video Systems (BRUVS)

Six baited remote underwater video systems (BRUVS) were available during the voyage. BRUVS comprised two GoPro Hero 9 cameras housed in anodised aluminium pressure casings (rated to 550 m) fixed 70 cm apart, with an 8° angle of convergence, sitting 40 cm above the seabed in a steel frame. Each BRUVS had approx. 40 kg of lead weight attached. Light was provided by a single Blue Robotics Lumen Subsea, 500 m depth rated LED light fitted between the two camera housings. Power to the GoPros and light was supplied through 25V lithium batteries located in the camera housings. The BRUVS used ~1 kg of locally sourced frozen squid and/or mackerel in a plastic bait saver at the end of a 1 m aluminium arm and a 1 m plastic conduit. The BRUVS were deployed/retrieved after the deployment/retrieval of the longline sets. Care was taken to ensure the BRUVS were at least 300 m from a longline set and from one another.

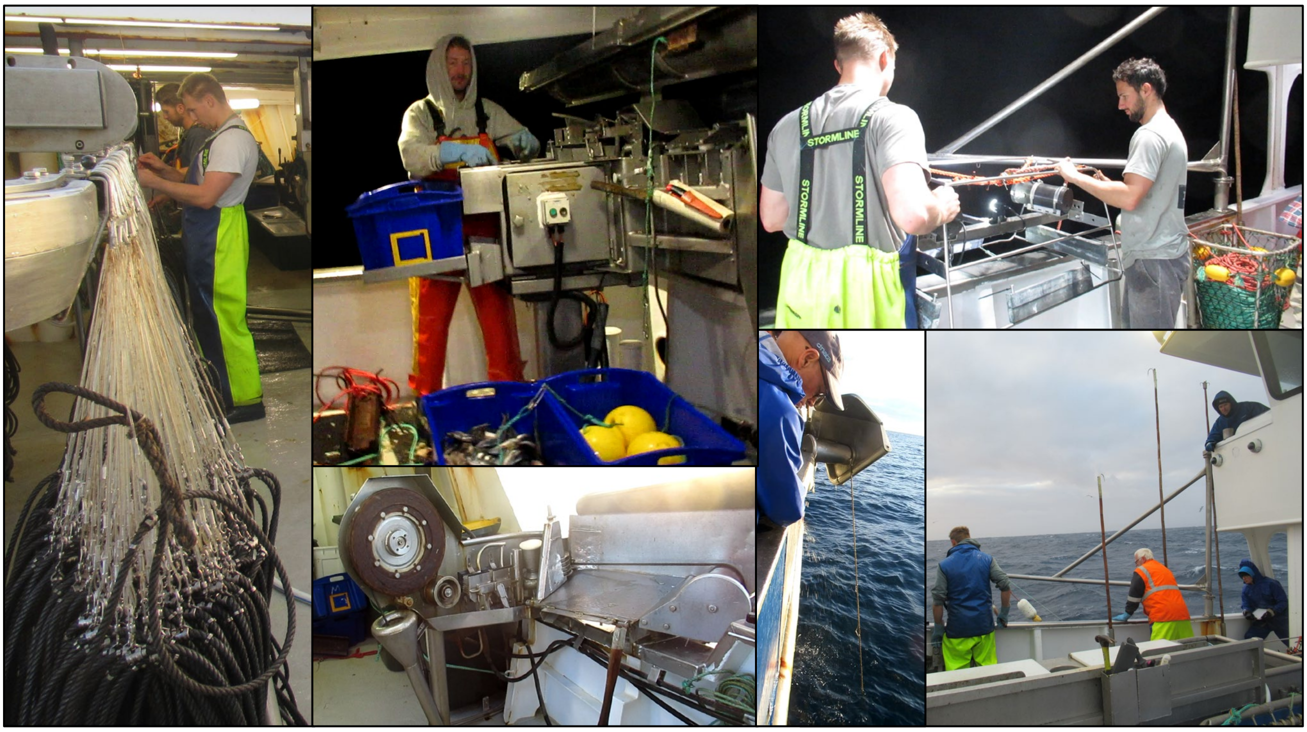


**Figure 2 Operational photos from the Gulper shark survey onboard the FV *Diana* in September 2023.**

# 3 Survey 3: Hunter and Endeavour Reference Areas

## 3.1 Survey objectives

1. Charter the Fishing Vessel FV *Diana* for an 8-day trip, conducting a 6-day sampling program in the Hunter and Endeavour Reference Areas (Figure 1). Transit to Portland at the end of the sampling program.
2. Use automatic longline fishing methods to sample *C. harrissoni* and *C. uyato* in the Hunter and Endeavour Reference Areas. Effort to be concentrated in the 400-600 m depth range.
3. Collect catch composition (species, counts, catch-rate) data from each fishing operation.
4. Deploy replicate Baited Remote Underwater Video Systems (BRUVS).
5. Record shot details for each fishing line set (location, depth, hooks set) and BRUVS deployment (location, depth).
6. Record length and sex of all landed *C. harrissoni* and *C. uyato*.
7. Fit conventional tags onto as many vigorous *C. harrissoni* and *C. uyato* as practicable and release. Representative individuals of *C. moluccensis* will also be tagged. Collect tissue samples from tagged sharks.
8. Where time and space allows, retain scientific specimens of Pink Ling (*Genypterus blacodes*) and Blue-eye Trevalla (*Hyperoglyphe antarctica*) for a separate study.

## 3.2 Survey Logistics

### Dates and timing of the charter

Departed Sydney 09:30 hours, Thursday 24th August 2023
Reached Portland at 14:00 hours, Friday 01 September 2023

### Permits

- **Animal ethics:** Permit Franziska Althaus, Ref # 2022-02
- **NSW DPI:** Ref # FP22/46
  - As per the conditions S37 of the Research Permit, commercial species may be retained for research purposes only and cannot be sold or consumed.
- **Access to Biological Resources:** Ref # AU-COM2022-551
- **Parks Australia**: Ref # PA2022-00018-2

**Survey design**

The Hunter and Endeavour Reference Areas were divided into three equal sectors (one sector per day; approx. 14 km long for Hunter and 34 km long for Endeavour). Each day three longline sets and up to six BRUVS were planned. To minimise soak time, and therefore maximise shark survival, the longline sets and BRUVS were deployed close together in randomly placed boxes within each sector. Each box was approximately 5 km long (N-S) with a width that covered the 400-600 m depth contours (Figure 3). The longlines were set approx. 1.5 km apart. The start positions of each set depended on weather, tide, and local terrain. BRUVS were deployed near or between the longline sets at depths between 400-500 m, ensuring a distance of at least 300 m between equipment and considering tide and weather conditions.

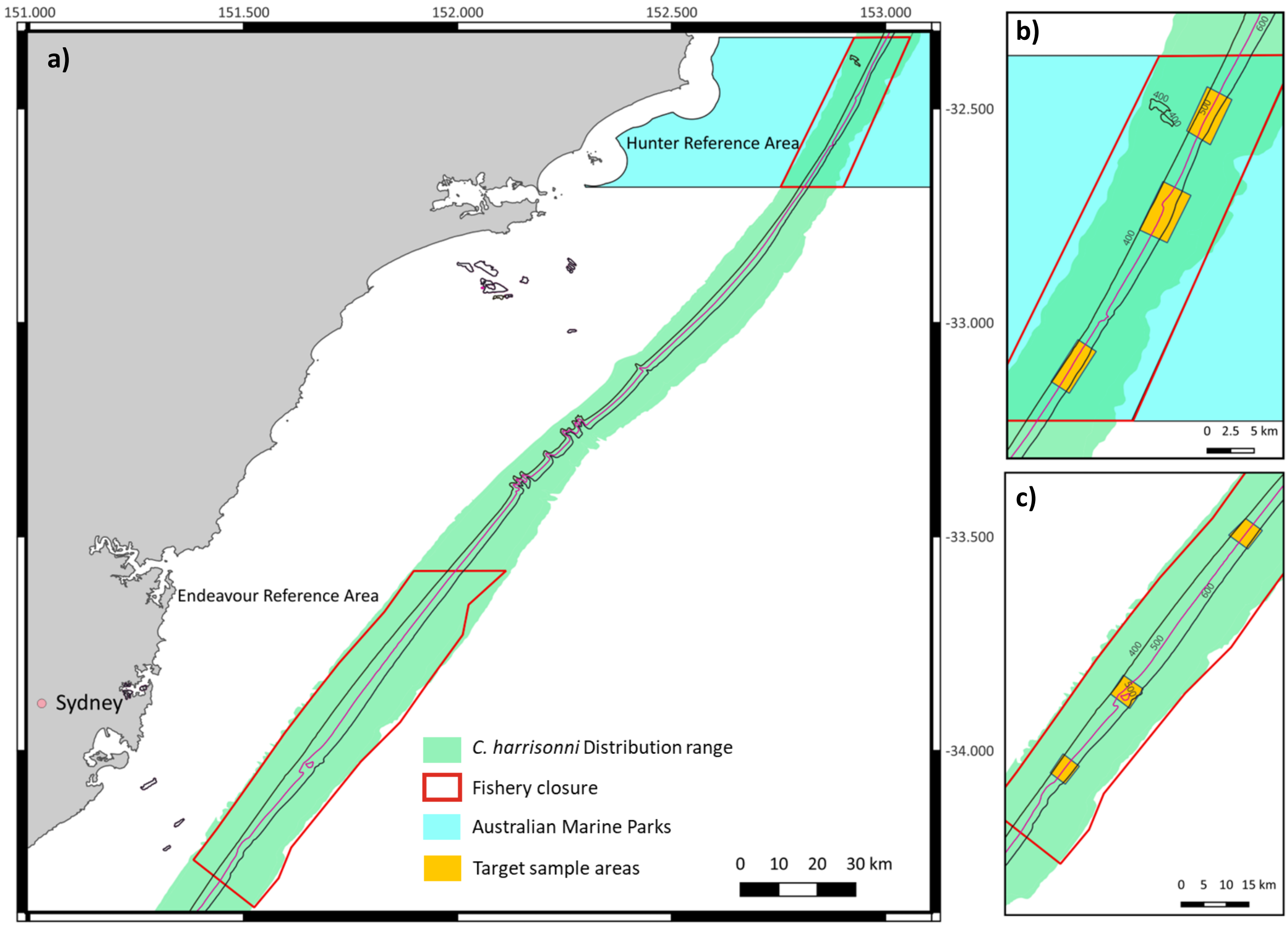


**Figure 3 Maps showing (a) the location of the NSW Hunter and Endeavour Reference Areas in relation to Sydney and the randomly placed target areas for longline sets and BRUVS sampling in the (b) Hunter and (c) Endeavour Reference Areas.**

## 3.3 Survey summary

The voyage was completed over 9 days. Due to constraints on the amount of charter days for this survey one sample sector was dropped from the Hunter region. After departing Sydney at 09:30 hours on 24$^{th}$ August, the FV *Diana* steamed to the Hunter Reference Area arriving at the central sample sector around 01:00 on the 25$^{th}$ August. Sampling began at 03:17 hours on the 25$^{th}$ August and was completed at the northernmost sampling sector in the Hunter Reference Area at 14:00

hours on the 26th August (Figure 3). The vessel then steamed to the northernmost sampling sector in the Endeavour Reference Area to commence sampling at 03:10 hours on the 27th August (Figure 3). Sampling in this Reference Area was completed at 12:00 on the 29th August. The vessel then began steaming to Portland, arriving at 14:00 on the 1st September. Fifteen longline sets (6 in the Hunter and 9 in the Endeavour Reference Areas) and eleven BRUVS (9 in the Hunter and 2 in the Endeavour Reference Areas) were deployed during the survey (Table 1 and Figure 4a, Figure 5a).

Longlines were set between 03:10 and 04:22 hours each morning and typically took 12-15 minutes to deploy each of the ~1500 hook sets (Table 1). Longlines were hauled between 06:12 and 11:22 hours, typically taking 50-80 minutes to retrieve a line, depending on the number of sharks caught and the condition of the line (i.e., tangle or snag). The longest retrieval took 97 min (Table 1). Longline soak times ranged between 3.5 and 6.5 hours (Table 1), with the longer soak times associated with tangled lines.

The BRUVS were deployed between 04:33 and 05:25 hours each day following deployment of the longline sets. BRUVS were retrieved between 10:42 and 12:25 hours after all longlines had been retrieved. This resulted in soak times of up to 7.5 hours (Table 1). Operation of the BRUVS units was adjusted for this survey to include the use of QR codes to minimise the handling of sensitive battery and SD card components during deployment. Six BRUVS units were deployed on the first day in the Hunter Reference Area, but only the right-hand cameras collected data because of problems associated with the QR code procedure. Further, due to bottom currents, the units only remained on the bottom for around 20 minutes before the action of tides and currents on the float, ropes and BRUVS unit itself were strong enough to displace and move them (Figure 6). Three BRUVS units were deployed on the second sampling day in the Hunter Reference Area to refine operation of the units and ascertain whether similar bottom currents were present. All units were fully operational, with both left and right-hand cameras collecting data, but as with the previous days deployments the units only remained on the bottom for a short period of time before being moved off. This did not allow for the proper functioning of the unit where it should be stationary, having an extended deployment time over which the bait plume can be effectively distributed in the surrounding waters, attracting nearby fishes and invertebrates. Only two BRUVS units were deployed in the Endeavour Reference Area on the first day of sampling there, with the same results (Figure 6). As tidal and current conditions were stronger in this area compared with the Hunter region, no BRUVS were deployed on the remaining two days of sampling in the Endeavour Reference Area.

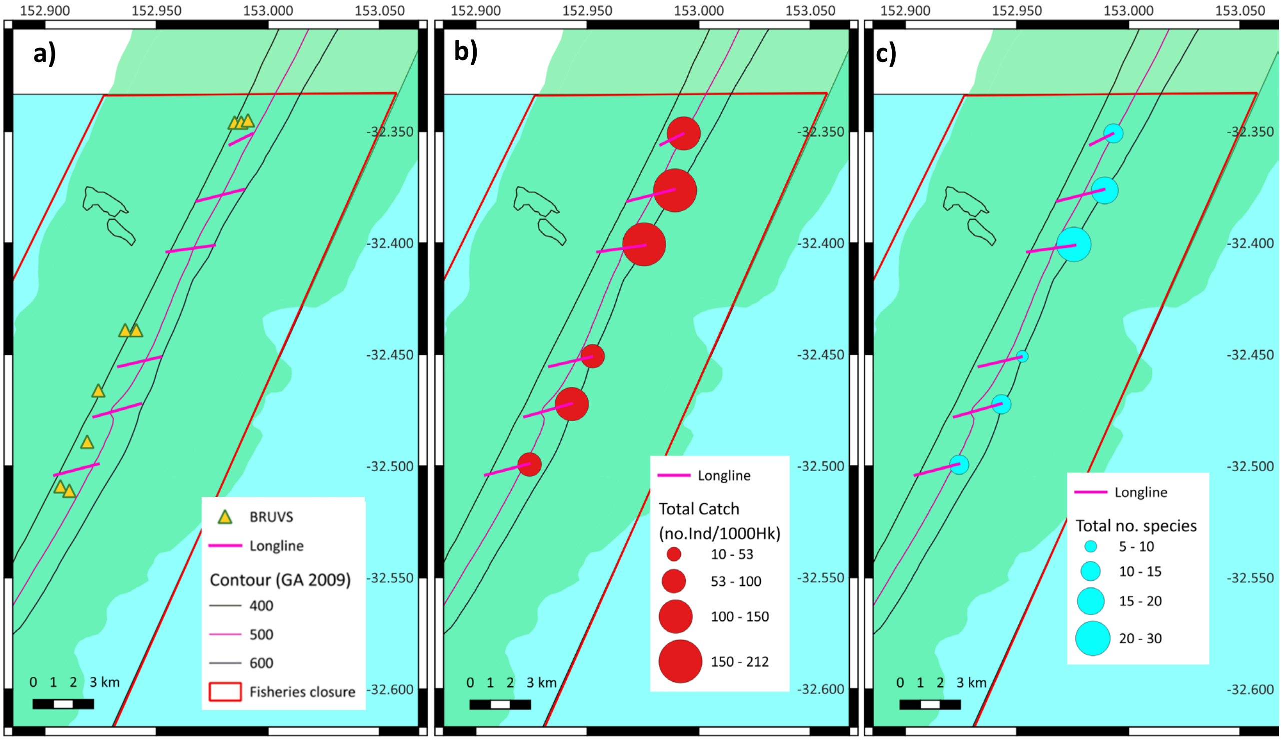


**Figure 4 Map of the Hunter Reference Area showing (a) the locations of the BRUV deployments and the auto-longline sets, (b) the total standardised catch (number of individuals per 1000 hooks) taken with each auto-longline set, and (c) the number of species caught with each set.**

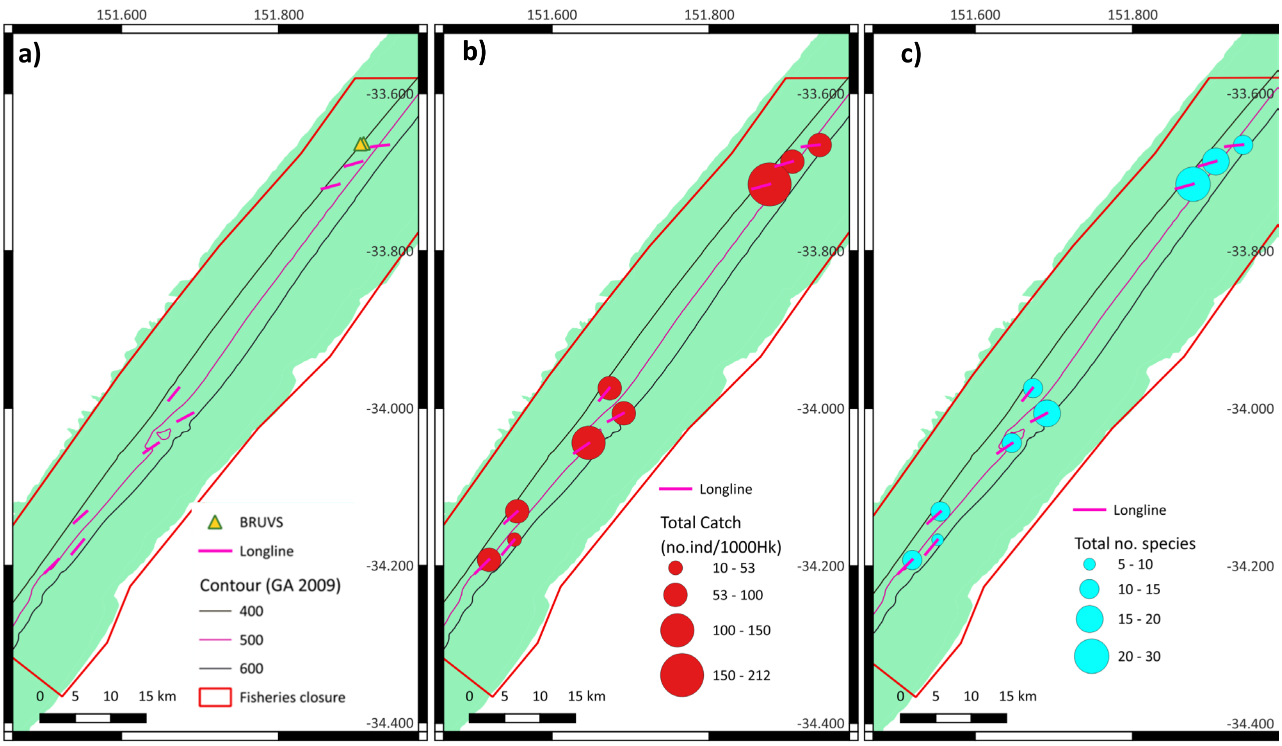


**Figure 5 Map of the Endeavour Reference Area showing (a) the locations of the BRUVS deployments and the auto-longline sets, (b) the total standardised catch (number of individuals per 1000 hooks) taken with each auto-longline set, and (c) the number of species caught with each set.**

**Table 1 Overview of the sampling deployments undertaken during Survey 3: DI202301: Hunter and Endeavour Reference Areas. Summary data of catches from the longline sets are included.**

| Set Date Time | Gear | Reference Area | Set Start Longitude (dec) | Set Start Latitude (dec) | Set depth range (m) | Haul time (hh:mm) | Soak time (hh:mm) | Number of Hooks | Operation Identifier | Comment | Total estimated catch weight (kg) | Total number of Individuals | Individuals per 1000 hooks | Total number of species | Number of *C.harrissoni* | Number of *C. uyato* | Number of *C.moluccensis* | Number of *Centrophorus (Not landed)* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 25/08/2023 03:17:39 | Longline | Hunter 2 | 152.952 | -32.451 | 407-590 | 01:12 | 03:30 | 1500 | DI202301_001 | | 276.3 | 132 | 88.00 | 10 | 9 | 0 | 70 | 5 |
| 25/08/2023 03:39:04 | Longline | Hunter 2 | 152.943 | -32.472 | 405-580 | 01:07 | 04:36 | 1500 | DI202301_002 | | 339.5 | 156 | 104.00 | 11 | 6 | 1 | 82 | 8 |
| 25/08/2023 04:05:43 | Longline | Hunter 2 | 152.924 | -32.499 | 420-550 | 01:06 | 05:35 | 1500 | DI202301_003 | | 222.5 | 135 | 90.00 | 11 | 7 | 0 | 38 | 2 |
| 25/08/2023 04:33:03 | BRUVS | Hunter 2 | 152.907 | -32.509 | 417 | 00:08 | 06:12 | | DI202301_004 | | | | | | | | | |
| 25/08/2023 04:42:09 | BRUVS | Hunter 2 | 152.911 | -32.511 | 460 | 00:09 | 06:14 | | DI202301_005 | | | | | | | | | |
| 25/08/2023 04:54:08 | BRUVS | Hunter 2 | 152.919 | -32.489 | 425 | 00:08 | 06:31 | | DI202301_006 | | | | | | | | | |
| 25/08/2023 05:05:38 | BRUVS | Hunter 2 | 152.924 | -32.466 | 390 | 00:08 | 06:40 | | DI202301_007 | | | | | | | | | |
| 25/08/2023 05:20:22 | BRUVS | Hunter 2 | 152.936 | -32.439 | 380 | 00:08 | 06:49 | | DI202301_008 | | | | | | | | | |
| 25/08/2023 05:25:06 | BRUVS | Hunter 2 | 152.941 | -32.439 | 405 | 00:02 | 06:54 | | DI202301_009 | | | | | | | | | |
| 26/08/2023 03:14:39 | Longline | Hunter 3 | 152.993 | -32.351 | 410-590 | 01:19 | 03:46 | 1500 | DI202301_010 | | 454.4 | 219 | 146.00 | 14 | 7 | 6 | 82 | 11 |
| 26/08/2023 03:36:19 | Longline | Hunter 3 | 152.989 | -32.376 | 400-590 | 01:21 | 05:01 | 1500 | DI202301_011 | | 590.9 | 287 | 191.33 | 19 | 7 | 1 | 142 | 8 |
| 26/08/2023 03:58:01 | Longline | Hunter 3 | 152.976 | -32.401 | 388-590 | 01:37 | 06:28 | 1500 | DI202301_012 | Tangle in line | 602.8 | 317 | 211.33 | 21 | 11 | 2 | 123 | 3 |
| 26/08/2023 04:39:41 | BRUVS | Hunter 3 | 152.985 | -32.346 | 390 | 00:03 | 07:10 | | DI202301_013 | | | | | | | | | |
| 26/08/2023 04:43:04 | BRUVS | Hunter 3 | 152.988 | -32.346 | 415 | 00:06 | 07:26 | | DI202301_014 | | | | | | | | | |
| 26/08/2023 04:48:40 | BRUVS | Hunter 3 | 152.991 | -32.345 | 440 | 00:04 | 07:33 | | DI202301_015 | | | | | | | | | |
| 27/08/2023 03:24:02 | Longline | Endeavour 3 | 151.940 | -33.665 | 460-590 | 00:58 | 03:30 | 1500 | DI202301_016 | | 111.7 | 101 | 67.33 | 13 | 8 | 0 | 1 | 0 |
| 27/08/2023 03:46:15 | Longline | Endeavour 3 | 151.906 | -33.686 | 405-470 | 00:51 | 04:27 | 1100 | DI202301_017 | Lost 400 hooks | 186.3 | 83 | 55.33 | 16 | 15 | 0 | 4 | 0 |
| 27/08/2023 04:08:40 | Longline | Endeavour 3 | 151.877 | -33.715 | 387-448 | 01:12 | 06:03 | 1500 | DI202301_018 | Break in line | 580.3 | 272 | 181.33 | 26 | 27 | 3 | 4 | 2 |
| 27/08/2023 04:55:37 | BRUVS | Endeavour 3 | 151.908 | -33.663 | 400 | 00:04 | 06:51 | | DI202301_019 | | | | | | | | | |
| 27/08/2023 04:59:30 | BRUVS | Endeavour 3 | 151.904 | -33.664 | 385 | 00:02 | 07:06 | | DI202301_020 | | | | | | | | | |
| 28/08/2023 03:10:11 | Longline | Endeavour 2 | 151.673 | -33.974 | 410-425 | 01:04 | 03:27 | 1500 | DI202301_021 | | 306.8 | 85 | 56.67 | 15 | 34 | 1 | 7 | 9 |
| 28/08/2023 03:36:38 | Longline | Endeavour 2 | 151.691 | -34.006 | 545-580 | 01:21 | 04:34 | 1500 | DI202301_022 | | 293.5 | 118 | 78.67 | 17 | 17 | 0 | 1 | 0 |
| 28/08/2023 04:05:32 | Longline | Endeavour 2 | 151.647 | -34.044 | 480-510 | 01:19 | 06:11 | 1500 | DI202301_023 | | 343.8 | 215 | 143.33 | 13 | 54 | 8 | 1 | 4 |
| 29/08/2023 03:15:23 | Longline | Endeavour 1 | 151.556 | -34.131 | 410-425 | 01:12 | 03:31 | 1500 | DI202301_024 | | 254.3 | 100 | 66.67 | 15 | 26 | 25 | 6 | 2 |
| 29/08/2023 03:39:18 | Longline | Endeavour 1 | 151.552 | -34.167 | 550-580 | 01:00 | 04:46 | 1500 | DI202301_025 | | 123 | 77 | 51.33 | 10 | 8 | 8 | 1 | 3 |
| 29/08/2023 04:02:32 | Longline | Endeavour 1 | 151.520 | -34.192 | 485-490 | 01:00 | 05:42 | 1500 | DI202301_026 | Rubbish on line | 132.4 | 94 | 62.67 | 13 | 4 | 6 | 5 | 1 |

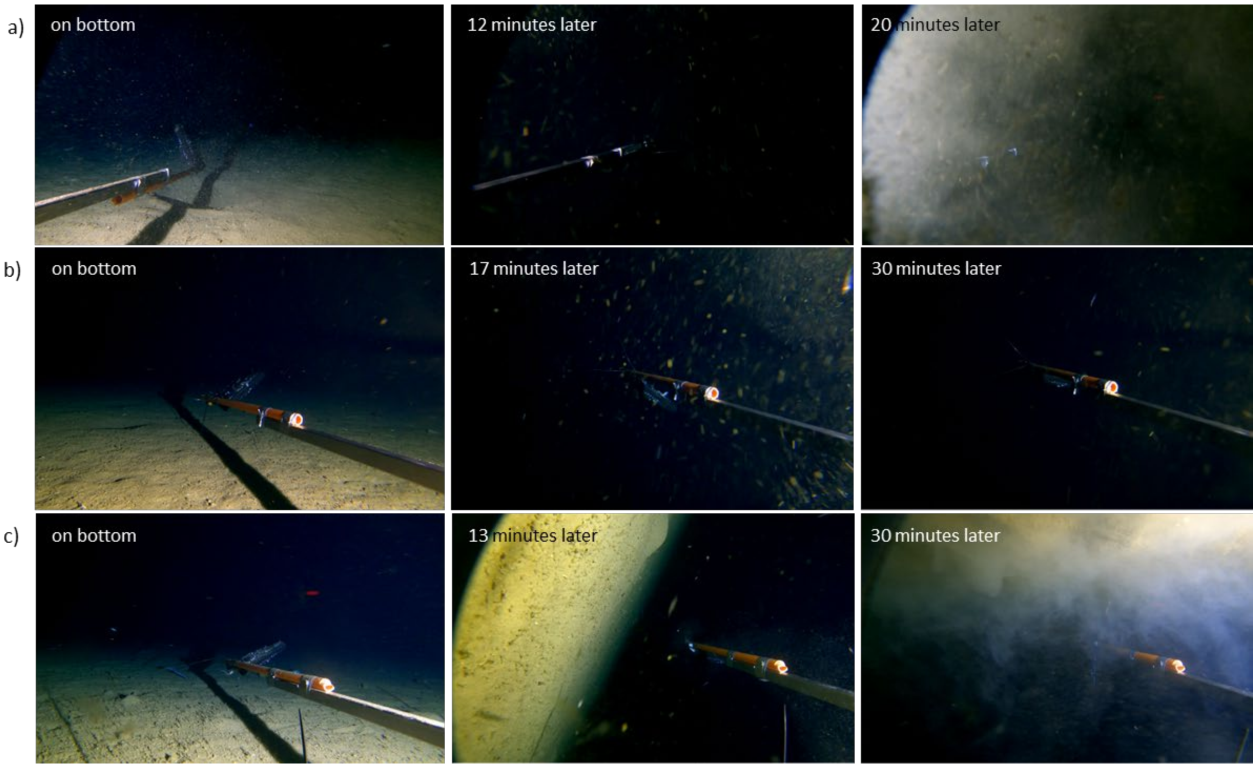


**Figure 6 Selected frames from BRUVS deployments in the a,b) Hunter and c) Endeavour Reference Areas showing the movement of BRUVS units with time after landing on the bottom.**

## Catch summary

In the Hunter Reference Area the longlines caught between 10 and 21 species per set and catch rates ranged between 88 to 211 fish per 1000 hooks (Figure 4b & c and Table 1). The total catch by species over the 2-day sampling period is summarised in Table 2. In total 22 different species were caught. The most common commercial species caught was Ocean Perch (17). The most common bycatch species were the Eastern highfin spurdog (299) and the Phillipine spurdog (109), that were returned to the water in good condition (Table 2).

In the Endeavour Reference Area the longlines caught between 10 and 26 species per set and catch rates ranged between 55 to 181 fish per 1000 hooks (Figure 5b & c and Table 1). The total catch by species over the 3-day sampling period is summarised in Table 3. In total 28 different species were caught, including spider crab. The most common commercial species caught was Ocean Perch (355). The most common bycatch species were the Phillipine spurdog (116) and the Grey skate (67), that were returned to the water in good condition (Table 3).

Due to conditions associated with the NSW DPI S37 Research Permit obtained to conduct this survey, retaining commercial species for the purposes of sales or consumption was not permitted in the NSW reference areas. Ten individuals of Pink ling captured in the Endeavour Reference Area were retained for scientific purposes, the remainder of the catch was released or discarded.

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**Table 2. Total catch by species or higher-level taxonomic group for the Hunter Reference Area (DI202301), including a list of the retained catch. Species with ^ are commercial species under AFMA Quota.**

| Common Name | Scientific Name | CAAB code | ^ | Total number of individuals | Total number retained |
|---|---|---|---|---|---|
| Endeavour dogfish | *Centrophorus moluccensis* | 37020001 | | 537 | 2 |
| Harrisson dogfish | *Centrophorus harrissoni* | 37020010 | | 47 | 2 |
| Southern dogfish | *Centrophorus uyato* | 37020011 | | 10 | 0 |
| Gulper sharks (not landed) | *Centrophorus* | 37020902 | | 37 | 0 |
| Bigeye ocean perch | *Helicolenus barathri* | 37287093 | ^ | 17 | 0 |
| Bight skate | *Dipturus gudgeri* | 37031010 | | 19 | 0 |
| Blackbelly lanternshark | *Etmopterus lucifer* | 37020005 | | 2 | 0 |
| Common sawshark | *Pristiophorus cirratus* | 37023002 | | 2 | 0 |
| Deepsea flathead | *Hoplichthys haswelli* | 37297001 | ^ | 5 | 0 |
| Eastern highfin spurdog | *Squalus albifrons* | 37020038 | | 299 | 0 |
| Eastern longnose spurdog | *Squalus grahami* | 37020041 | | 81 | 0 |
| Grahams skate | *Dipturus grahami* | 37031029 | | 9 | 0 |
| Grey skate | *Dipturus canutus* | 37031028 | | 4 | 0 |
| Ogilbys Ghostshark | *Chimaera ogilbyi* | 37042001 | | 14 | 0 |
| Painted latchet | *Pterygotrigla andertoni* | 37288005 | | 10 | 0 |
| Peacock skate | *Pavoraja nitida* | 37031009 | | 1 | 0 |
| Philippine Spurdog | *Squalus montalbani* | 37020047 | | 109 | 0 |
| Pink ling | *Genypterus blacodes* | 37228002 | ^ | 1 | 0 |
| Plunket dogfish | *Scymnodon plunketi* | 37020013 | | 1 | 0 |
| Saddled swellshark | *Cephaloscyllium variegatum* | 37015031 | | 1 | 0 |
| Sandtiger shark | *Odontaspis ferox* | 37008003 | | 1 | 0 |
| Sawtail catshark | *Figaro boardmani* | 37015009 | | 38 | 0 |
| Whitefin swell shark | *Cephaloscyllium albipinnum* | 37015013 | | 1 | 0 |

**Table 3 Total catch by species or higher-level taxonomic group for the Endeavour Reference Area (DI202301), including a list of the retained catch. Species with ^ are commercial species under AFMA Quota.**

| Common Name | Scientific Name | CAAB code | ^ | Total number of individuals | Total number retained |
|---|---|---|---|---|---|
| Endeavour dogfish | *Centrophorus moluccensis* | 37020001 | | 30 | 0 |
| Harrisson dogfish | *Centrophorus harrissoni* | 37020010 | | 193 | 0 |
| Southern dogfish | *Centrophorus uyato* | 37020011 | | 51 | 0 |
| Gulper sharks (not landed) | *Centrophorus* | 37020902 | | 21 | 0 |
| Bigeye ocean perch | *Helicolenus barathri* | 37287093 | ^ | 355 | 0 |
| Bight skate | *Dipturus gudgeri* | 37031010 | | 59 | 0 |
| Blackbelly lanternshark | *Etmopterus lucifer* | 37020005 | | 17 | 0 |
| Blacktip cucumberfish | *Paraulopus nigripinnis* | 37120001 | | 1 | 0 |
| Blue-eye trevalla | *Hyperoglyphe antarctica* | 37445001 | ^ | 26 | 0 |
| Deepsea conger | *Bassanago hirsutus* | 37067013 | | 1 | 0 |
| Deepsea flathead | *Hoplichthys haswelli* | 37297001 | ^ | 3 | 0 |
| Eastern highfin spurdog | *Squalus albifrons* | 37020038 | | 29 | 0 |
| Eastern longnose spurdog | *Squalus grahami* | 37020041 | | 59 | 0 |
| Gemfish | *Rexea solandri* | 37439002 | ^ | 1 | 0 |
| Grahams skate | *Dipturus grahami* | 37031029 | | 4 | 0 |
| Greeneye dogfish | *Squalus chloroculus* | 37020048 | | 6 | 0 |
| Grey skate | *Dipturus canutus* | 37031028 | | 67 | 0 |
| Mandarin shark | *Cirrhigaleus australis* | 37020026 | | 1 | 0 |
| Ogilbys Ghostshark | *Chimaera ogilbyi* | 37042001 | | 3 | 0 |
| Painted latchet | *Pterygotrigla andertoni* | 37288005 | | 28 | 0 |
| Pelagic armourhead | *Pseudopentaceros richardsoni* | 37367009 | | 3 | 0 |
| Philippine Spurdog | *Squalus montalbani* | 37020047 | | 116 | 0 |
| Pink ling | *Genypterus blacodes* | 37228002 | ^ | 29 | 10 |
| Red cod | *Pseudophycis palmata* | 37224006 | | 1 | 0 |
| Saddled swellshark | *Cephaloscyllium variegatum* | 37015031 | | 29 | 0 |
| Sharpnose sevengill shark | *Heptranchias perlo* | 37005001 | | 7 | 0 |
| Smooth Golden Toadfish | *Lagocephalus inermis* | 37467008 | | 1 | 0 |
| Spider crab spp | *Majidae & related families* | 28880000 | ^ | 3 | 0 |
| Whitefin swell shark | *Cephaloscyllium albipinnum* | 37015013 | | 1 | 0 |

## Gulper shark data

A total of 631 gulper shark, across three species were observed from the Hunter Reference Area. Of these 594 were measured for length and sex. The remaining 37 were not landed as they fell off the hook and were not able to be identified to species level with confidence (Table 2). Of the 594 landed gulper sharks, the vast majority (537 or 90%) were Endeavour dogfish (*Centrophorus moluccensis*), followed by Harrison's dogfish (*C. harrissoni*) (47 or 8%) with a small number of Southern dogfish (*C. uyato*) (10 or 2%) also captured in both Reference Areas (Table 2, Figure 7). Endeavour dogfish and Harrison's were caught on every longline, but *C. uyato* were not caught in two of the three longline sets deployed in the southern Hunter sample sector.

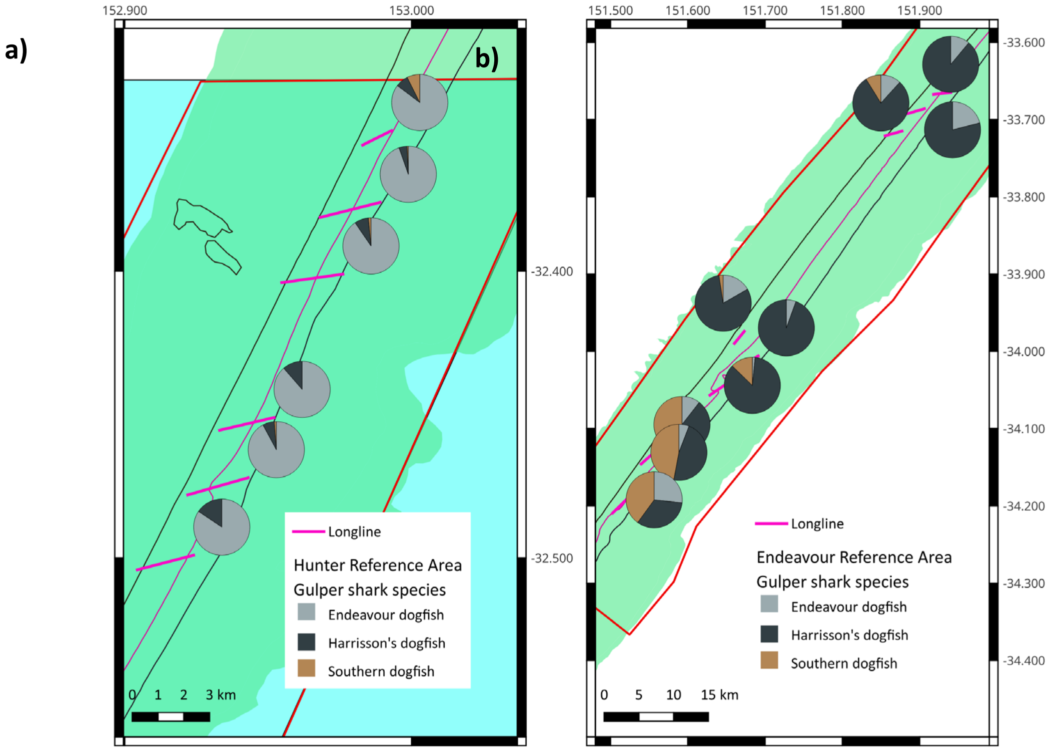
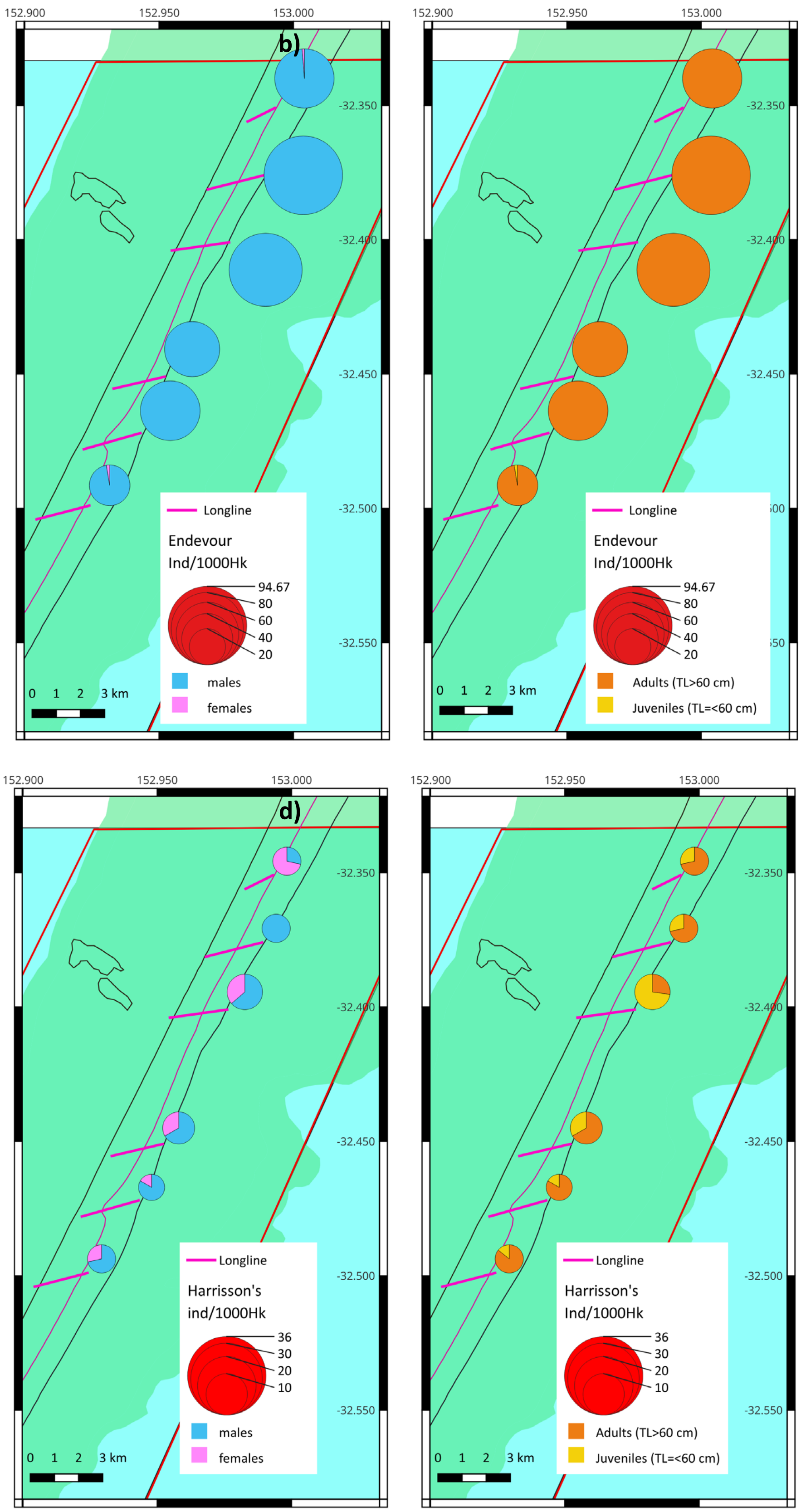



**Figure 7 Distribution and proportion of the three Gulper shark species: Endeavour dogfish (*C. moluccensis*), Harrisson's dogfish (*C. harrissoni*) and Southern dogfish (*C. uyato*) caught from the a) Hunter and b) Endeavour Reference Areas. Longline set locations are shown by the pink lines.**

Gulper shark catch rates in the Hunter Reference Area were highest for Endeavour dogfish varying between 25 to 95 shark per 1000 hooks in the southern and northern sampling sites, respectively. Mature males dominated, with just two females caught, one from each of the two sampling sectors (Figure 8a, b). The female caught in the southern sampling site was a juvenile (41 cm TL) while the specimen from the northern site was a mature female (96 cm TL) (Figure 10). Catch rates for Harrison's dogfish varied between 4 to 7 sharks per 1000 hooks across the two sample sites in the Hunter Reference Area. Males and females were generally co-located and males were generally more abundant than females. Adults and possible juvenile individuals were also co-located, with a slightly higher abundance of possible juvenile individuals in the northern sample sector. Most males (78%) were mature adults, while almost 50% of captured females of this species were possible juvenile individuals (based on size)(Figure 8c, d). The highest catch rates for Southern dogfish were obtained for the northern sampling site, with a maximum of 5 sharks per 1000 hooks. All individuals of this species were mature males (Figure 8e, f).

a)

c)


b)
d)
152.900
152.950
153.000
-32.350
-32.400
-32.450
-32.500
-32.550
Longline
Endevour
Ind/1000Hk
94.67
80
60
40
20
males
females
Adults (TL>60 cm)
Juveniles (TL=<60 cm)
Harrisson's
ind/1000Hk
Ind/1000Hk
36
30
20
10
0 1 2 3 km

e)

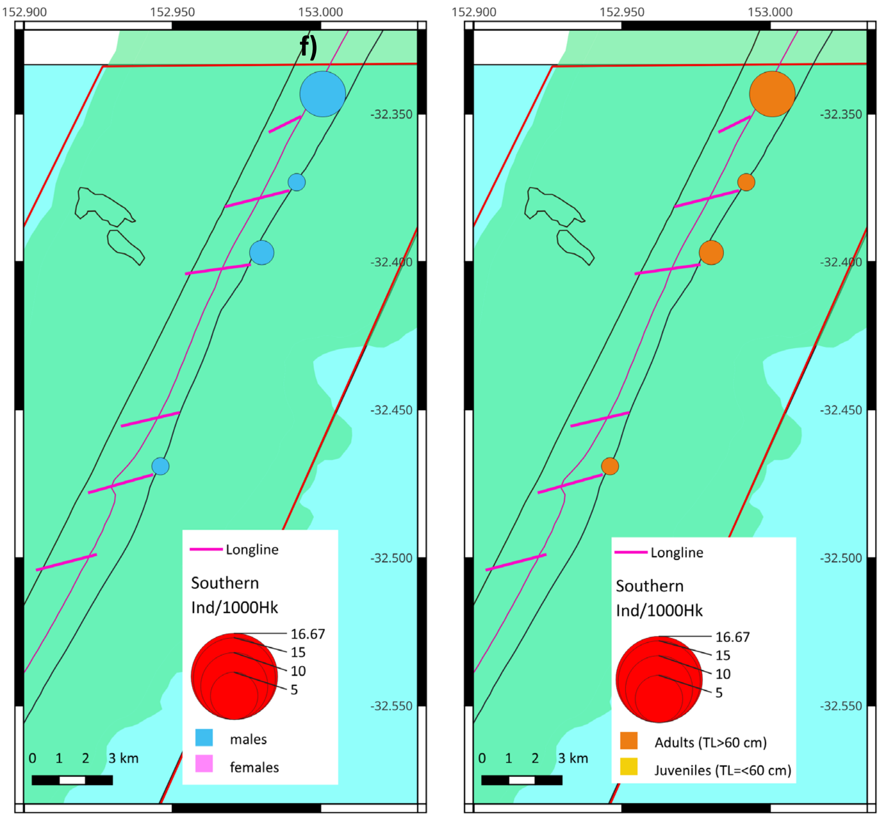
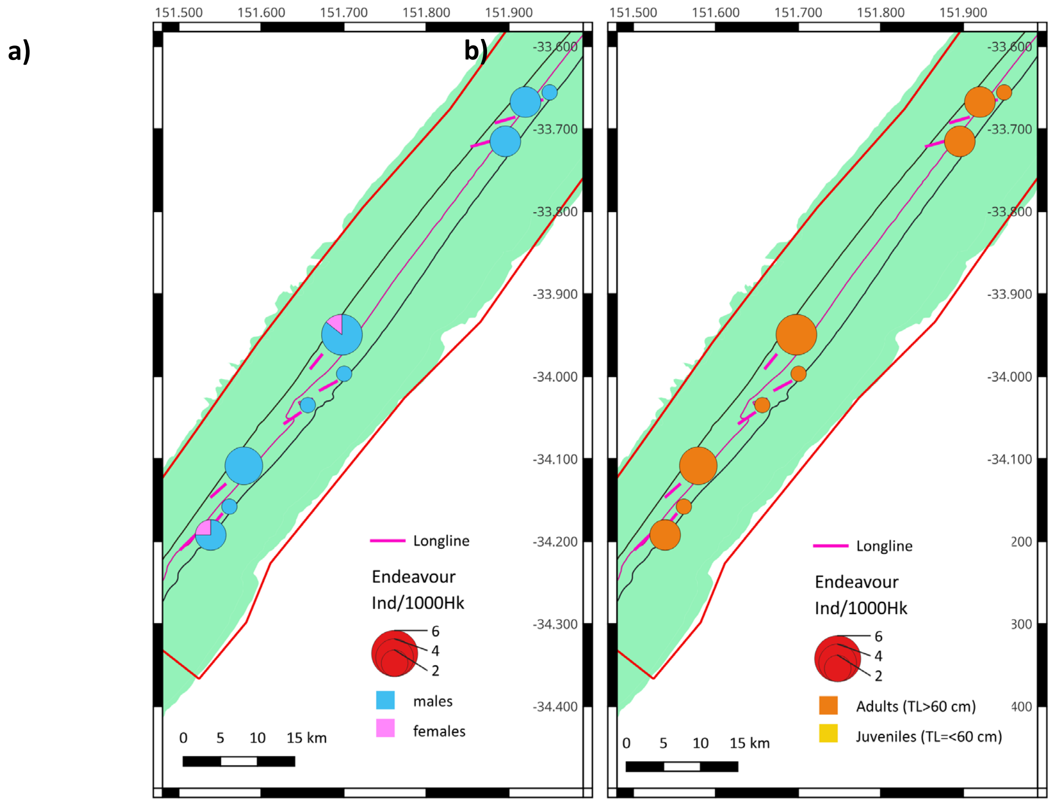



**Figure 8 Distribution of Gulper shark for each of the three species from the Hunter Reference Area. Longline set locations are shown by the pink lines. Standardised catch per 1000 hooks, broken down by sex and indicative maturity based on total length >/=< 60 cm for (a), (b): Endeavour dogfish (*C. moluccensis*); (c) (d): Harrisson's dogfish (*C. harrissoni*); (e), (f): Southern dogfish (*C. uyato*).**

A total of 295 gulper shark, across three species were observed from the Endeavour Reference Area. Of these 274 were measured for length and sex. The remaining 21 were not landed as they fell off the hook and were not able to be definitively assigned to a single species. Of the 274 landed gulper sharks, the vast majority (193 or 70%) were Harrison's dogfish (*C. harrissoni*), followed by Southern dogfish (*C. uyato*) (51 or 19%) and a smaller number of Endeavour dogfish (*C. moluccensis*) (30 or 11%). Gulper shark were caught on every longline, but *C. uyato* were not caught in two of the three longline sets deployed in the northern, and in one of the three longline sets deployed in the central sample sector in the Endeavour Reference Area.

Gulper shark catch rates in the Endeavour Reference Area were highest for Harrison's dogfish varying between 3 and 36 sharks per 1000 hooks, with the highest catch rates recorded for the central sample site. Males and females of this species were, in general, co-located (Figure 9c, d) and there were fewer male (54) Harrison's dogfish caught than females (140), except for the southern sampling site, where males were more abundant in all three longline sets (total male count vesus females summed over all sets?). Of the 193 individuals, only 1 male was smaller than 60 cm TL (Figure 10). Catch rates for Southern dogfish increased from an average of 0.67 in the northern, to 9 sharks per 1000 hooks in the southern sampling site of the Endeavour Reference Area. Of the 51 Southern dogfish caught, only seven (14%) were females, from two longline sets;

one in the central and one in the southern sample sector (Figure 9e, f). There was one individual (DI202301_024_039) for which sex could not be determined as the animal had a badly damaged anal fins. There were no smaller, possible juvenile individuals of this species caught from the Endeavour Reference Area. Catch rates for Endeavour dogfish were low (0.67 to 5 sharks per 1000 hooks) across all sample sectors in the Endeavour Reference Area. Of the 30 individuals, only two were females, and all individuals were probable adults, larger than 60 cm TL (Figure 9a, b).



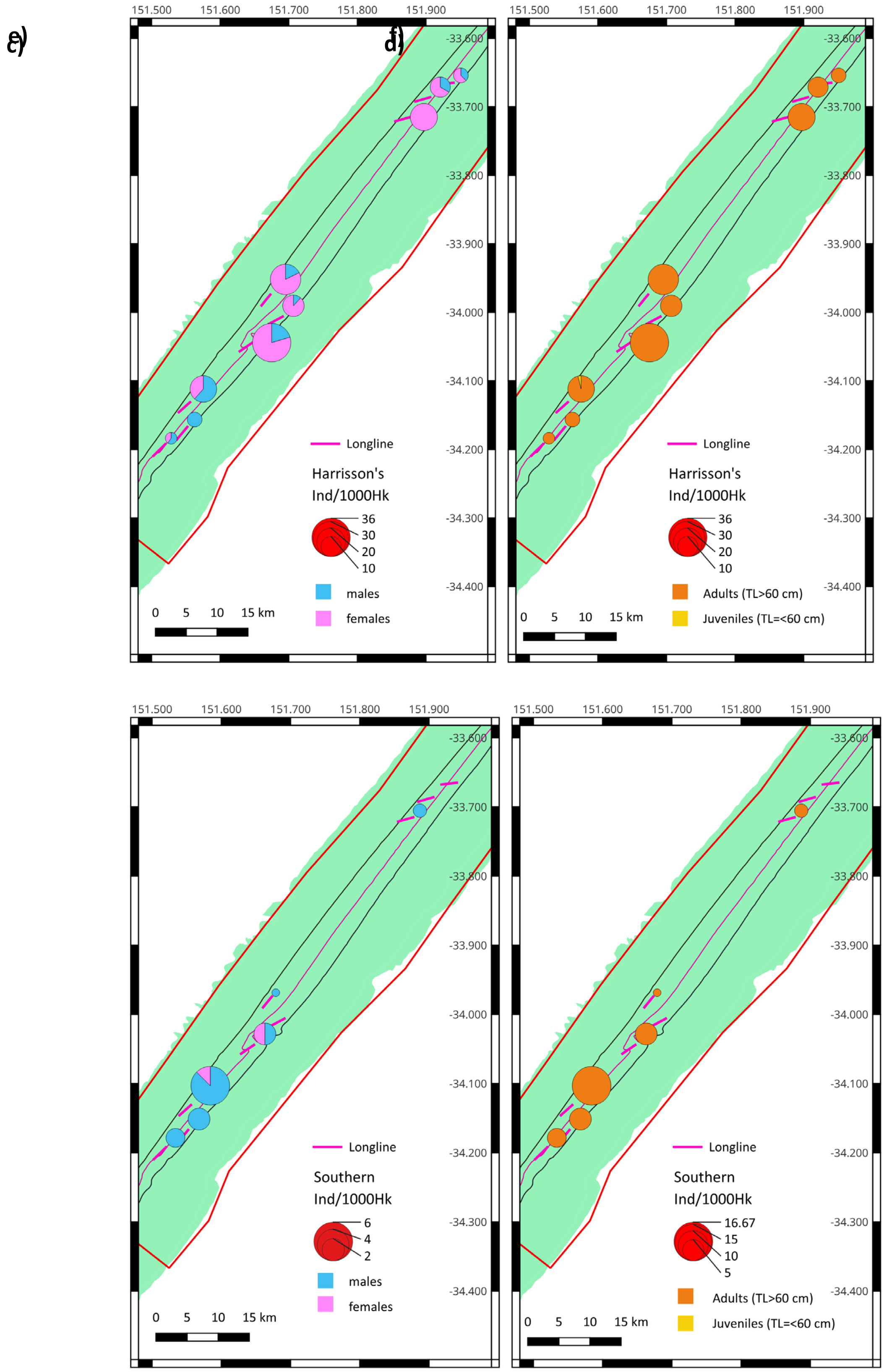


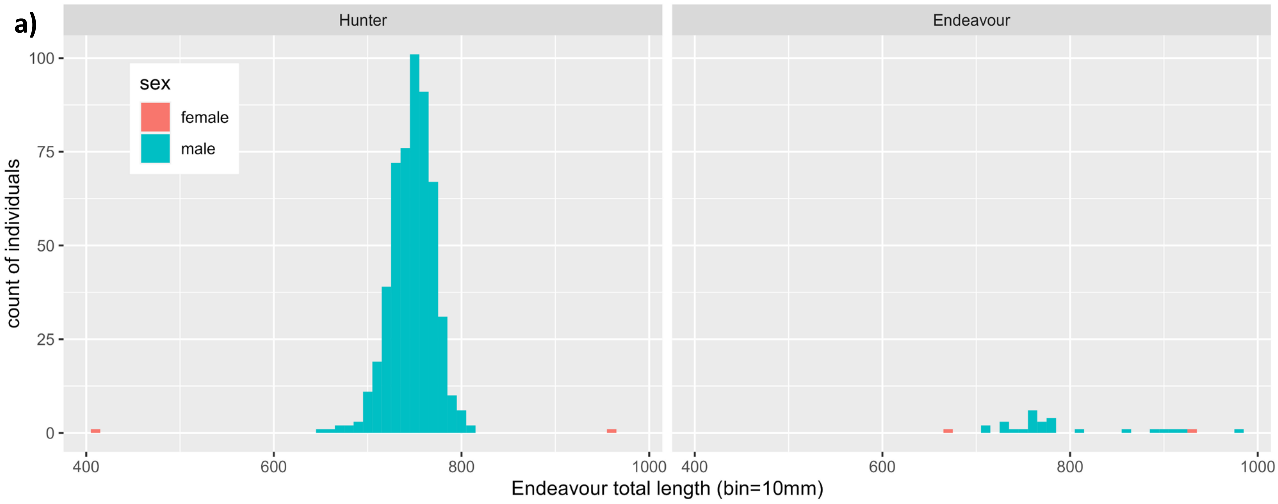

**Figure 9 Distribution of Gulper shark for each of the three species from the Endeavour Reference Area. Longline set locations are shown by the pink lines. Standardised catch per 1000 hooks, broken down by sex and indicative maturity based on total length >/=< 60 cm for (a), (b): Endeavour dogfish (*C. moluccensis*); (c) (d): Harrisson's dogfish (*C. harrissoni*); (e), (f): Southern dogfish (*C. uyato*).**

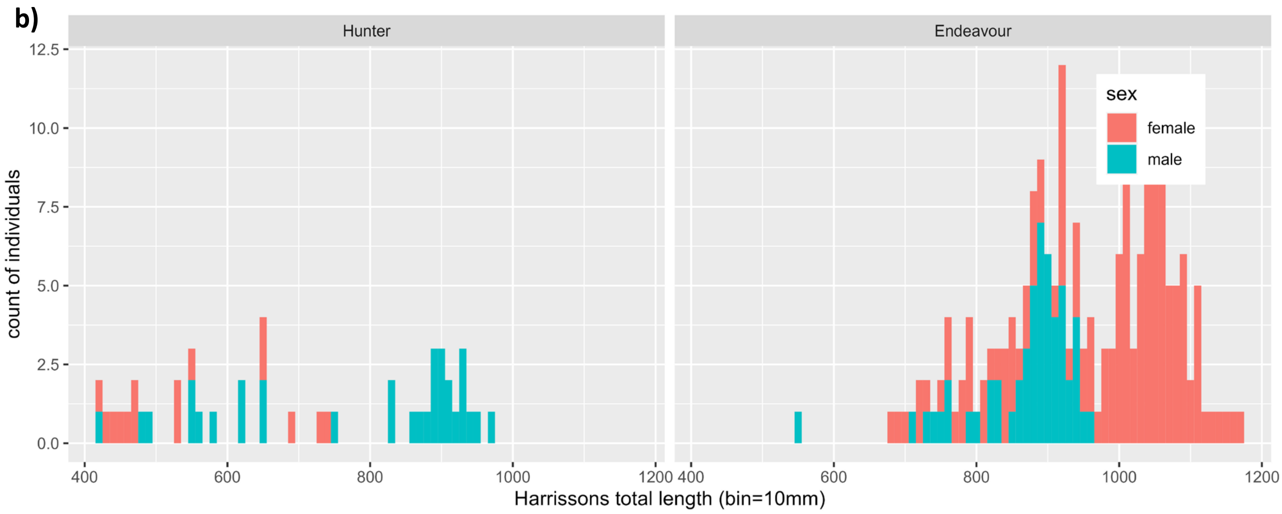
When comparing the Hunter and Endeavour Reference Areas, much higher numbers of Endeavour dogfish were present in the Hunter Area (Figure 10). There were far fewer females than males in each area, and several males captured in the Endeavour area were larger (> 80 cm TL) than those caught in the Hunter area, where most males were between 70 and 80 cm TL. Only one juvenile of the species was recorded in the Endeavour Reference Area (Figure 10a).

There were fewer Harrison's dogfish caught in the Hunter than the Endeavour Reference Area and males were more abundant than females in the Hunter, while the opposite trend (females more abundant than males) occurred in the Endeavour Reference Area (Figure 10b). Many females caught in the Endeavour area were of a larger size (>100 cm TL) than males or individuals of this species caught in the Hunter area. Only one individual from the Endeavour area was smaller than 60 cm TL, whereas in the Hunter area there were 17 individuals in this size class, with a relatively equal distribution of males and females (Figure 10b).

A much higher number of Southern dogfish were caught in the Endeavour Reference Area (Figure 10c). Males and females were caught in this area, whereas only males were present in the Hunter area, although several of these individuals were larger (>90 cm TL) than males in the Endeavour area. A few larger females were caught in the Endeavour area and no smaller, possible juvenile individuals of this species were caught in either reference area (Figure 10c).

a)





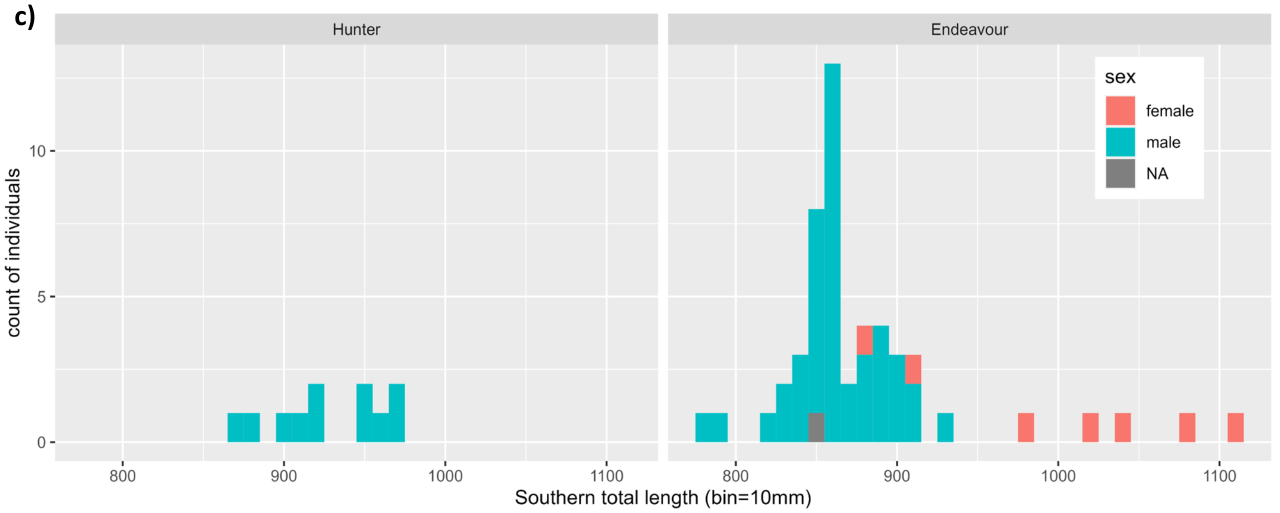




**Figure 10 Length frequency distribution of male (blue) and female (red) a) Endeavour, b) Harrisons and c) Southern dogfish captured during the survey.**

In total 75 gulper shark across the three species were tagged from the Hunter Reference Area; 37 Endeavour dogfish, 29 Harrison's dogfish and 9 Southern dogfish. In total, 129 gulper sharks across the three species were tagged from the Endeavour Reference Area; 2 Endeavour dogfish, 97 Harrison's dogfish and 30 Southern dogfish. There were no recaptures of dogfish for either area during the survey.

## BRUVS preliminary observations

BRUVS footage was briefly scanned during the survey. Several Endeavour dogfish were observed from preliminary scans of the 11 BRUVS deployments in the Hunter Reference Area. No gulper sharks were observed during preliminary scans of the 2 BRUVS deployments in the Endeavour Reference Area. Detailed analyses of the BRUVS data will be done as part of the project.

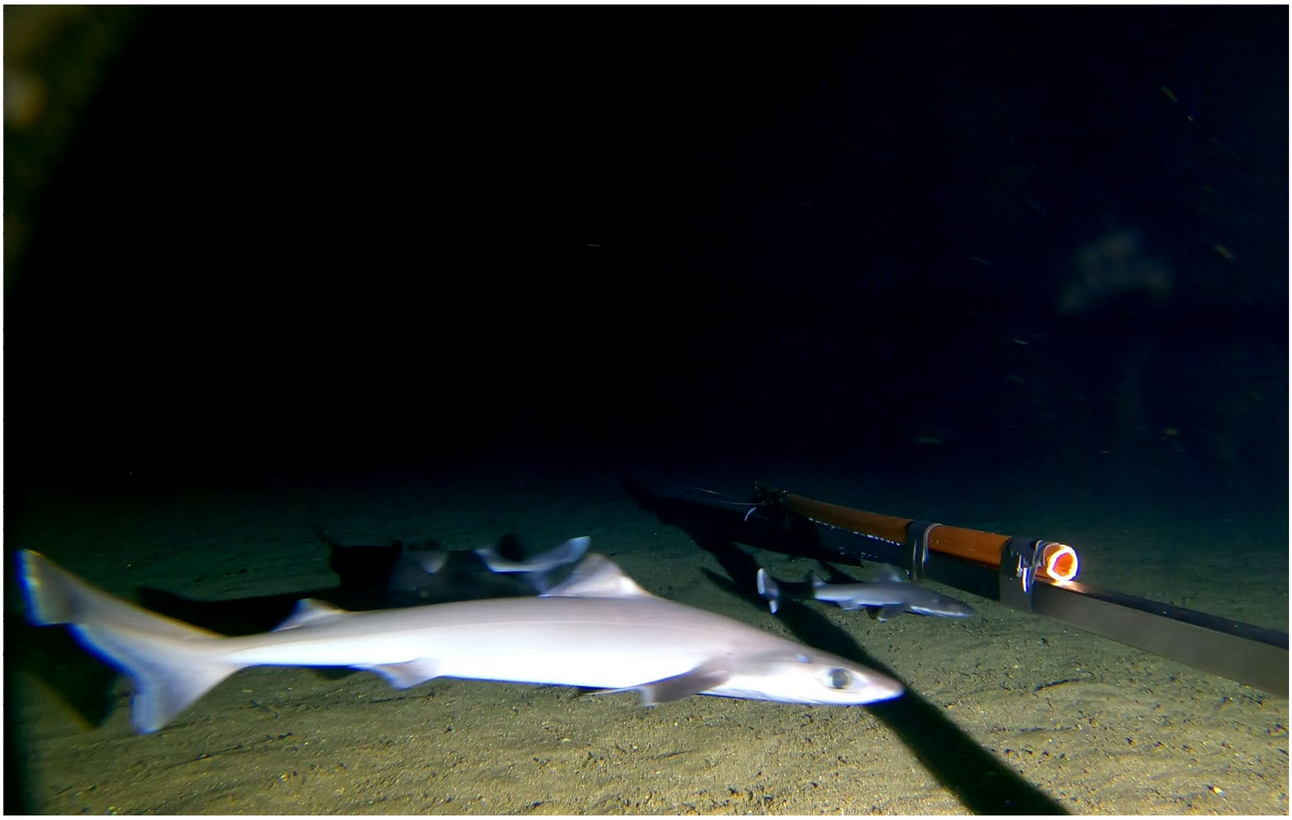


**Figure 11 Example of an Endeavour Dogfish observed in BRUVS footage taken in the Hunter Reference Area during the survey.**

# 4 Survey 4: Port MacDonnell and Murray Reference Areas

## 4.1 Survey objectives

9. Charter the Fishing Vessel FV *Diana* for a 6-day trip, conducting a 4-day sampling program in the Port MacDonnell and Murray Reference Areas (Figure 12).
10. Use automatic longline fishing methods to sample *C. uyato* in the Port MacDonnell and Murray Reference Areas. Effort to be concentrated in the 400-600 m depth range.
11. Collect catch composition (species, counts, catch-rate) data from each fishing operation.
12. Deploy replicate Baited Remote Underwater Video Systems (BRUVS).
13. Record shot details for each fishing line set (location, depth, hooks set) and BRUVS deployment (location, depth).
14. Record length and sex of all landed *C. uyato*.
15. Fit conventional tags onto as many vigorous *C. uyato* as practicable and release. Collect tissue samples from tagged sharks.

## 4.2 Survey Logistics

### Dates and timing of the charter

Departed Portland 1730 hours, Friday 1st September 2023
Reached Portland at 2100 hours, Wednesday 6th September 2023

### Permits

- **Animal ethics:** Permit Franziska Althaus, Ref # 2022-02
- **AFMA Research fishing permit (sent to vessel)**: Ref # 1005631
    - Fishing permit using automatic longline in closures
    - Permit to retain dead gulper sharks (if dead or moribund on capture)

Catches of commercial species could be sold, with proceeds going to the research project; catches of quota species are considered incidental research catch and are not counted towards quota (L. Ainsley, pers. comm.).

### Survey design

The Port MacDonnell and Murray Reference Areas were divided into two equal sectors (one sector per day; approx. 35 km long for Port MacDonnell and 52 km long for Murray). Each day three longline sets and up to six BRUVS were planned. To minimise soak time, and therefore maximise shark survival, the longline sets and BRUVS were deployed close together in randomly placed boxes within each sector. Each box was approximately 4.5-5 km long (N-S) with a width that covered the 400-600 m depth contours (Figure 12). The longlines were set approx. 1.5 km apart. The start positions of each set depended on weather, tide, and local terrain. BRUVS were deployed near or between the longline sets at depths between 400-500 m, ensuring a distance of at least 300 m between equipment and considering tide and weather conditions.

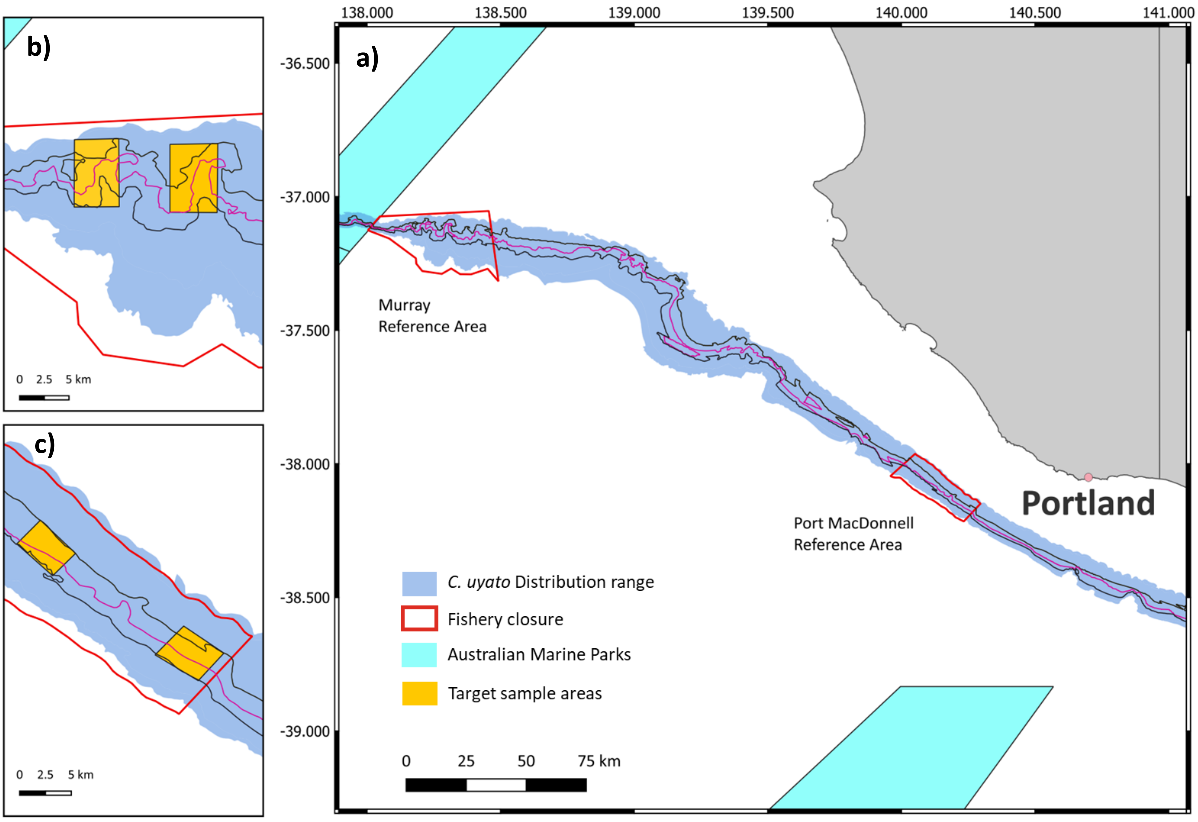



**Figure 12 Maps showing (a) the location of the Port MacDonnell and Murray Reference Areas in relation to Portland and the randomly placed target areas for longline sets and BRUVS sampling in the (b) Port MacDonnell and (c) Murray Reference Areas.**

## 4.3 Survey summary

The voyage was completed over 6 days. After departing Portland at 17:30 hours on the 1st September the FV Diana steamed to the Port MacDonnell Reference Area, arriving at the northernmost sampling sector at around 01:00 on 2nd September. The sampling began in the Port MacDonnell Reference Area at approximately 03:00 hours on 2nd September. Due to the arrival of a front bringing strong wind and high swell conditions, the vessel steamed to the Murray Reference Area at around 14:00 hours on the 2nd September. The sampling began in the Murray Reference Area at 03:35 hours on 3rd September and ended at 12:00 hours 4th September, after which the vessel steamed back to the Port MacDonnell reference area to complete sampling there. Due to unfavourable weather conditions (>30 knots of wind and >5 m swell), no sampling was undertaken on the 5th September. Longline sets were completed at the Port MacDonnell area on 6th September at 12:30 hours, after which the FV Diana steamed back to Portland, arriving at

21:00. Twelve longline sets (6 in both the Port MacDonnell and Murray Reference Areas) and ten BRUVS (6 in the Port MacDonnell and 4 in the Murray Reference Areas) were deployed during the survey (Table 4 and Figure 13a, Figure 14a).

Longlines were set between 03:00 and 04:26 hours each morning and typically took 13-15 minutes to deploy each of the ~1500 hook sets (Table 4). Longlines were hauled between 06:34 and 11:05, typically taking 60 to 70 minutes to retrieve a line, depending on the number of sharks caught and the condition of the line (i.e., tangle or snag). The longest retrieval took 79 min (Table 1). Longline soak times ranged between 3.5 and 6 hours (Table 4), with the longer soak times associated with tangled lines.

The BRUVS were deployed between 04:13 and 05:32 hours each day following deployment of the longline sets. BRUVS were retrieved between 09:51 and 12:27 hours after all longlines had been retrieved. This resulted in soak times of up to 7.5 hours (Table 4). Six BRUVS units were deployed on the first sample day in the Port MacDonnell Reference Area. These BRUVS deployments were successful; the units remained stationary on the seafloor and both cameras (left and right) collected a full suite of video data for all deployments. Wind and sea state conditions on the first sample day in the Murray area were not suitable for the deployment of BRUVS units. On the following day the weather and sea state conditions had improved slightly and it was decided to deploy 4 BRUVS units as this was the last sample day in the Murray Reference Area. One of the units travelled some distance into a canyon and no bottom footage was collected. The remaining 3 units were on the bottom for around 10-20 minutes before the action of wind, swell and waves on the float, ropes and BRUVS unit itself were strong enough to displace their position several times over the remaining deployment. As weather conditions remained much the same, no BRUVS were deployed on the remaining day of sampling in the Port MacDonnell Reference Area.

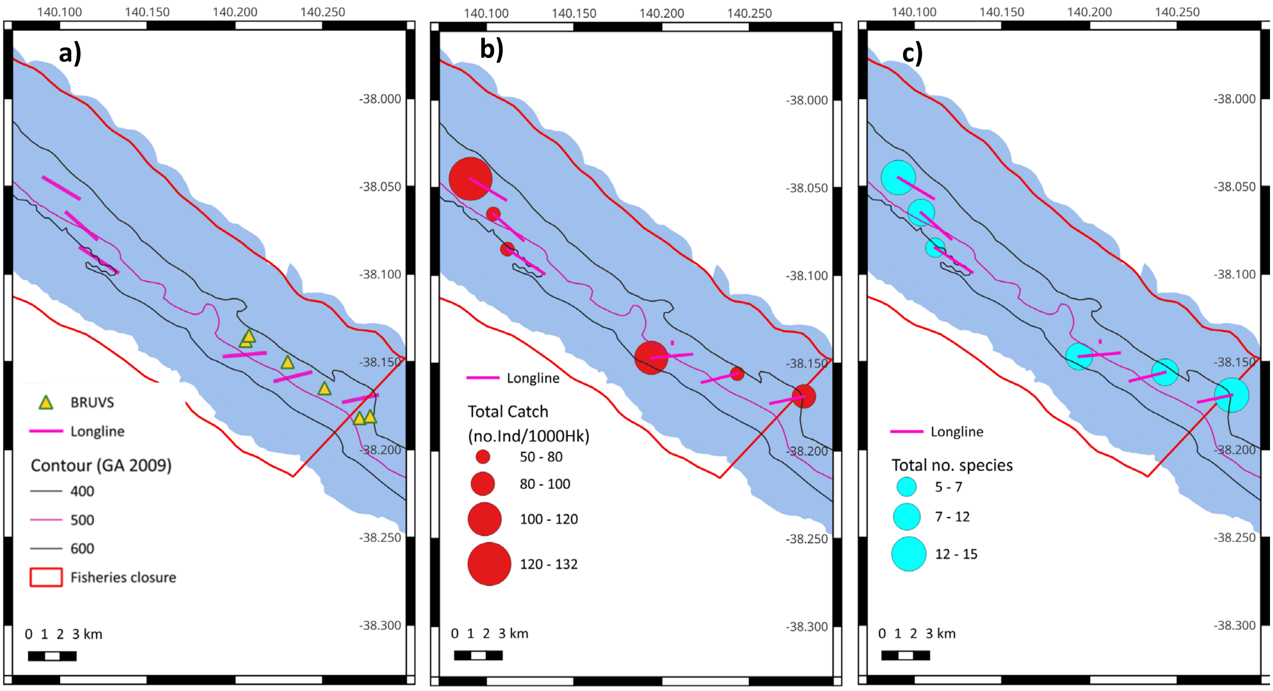



**Figure 13 Map of the Port MacDonnell Reference Area showing (a) the locations of the BRUVS deployments and the auto-longline sets, (b) the total standardised catch (number of individuals per 1000 hooks) taken with each auto-longline set, and (c) the number of species caught with each set.**

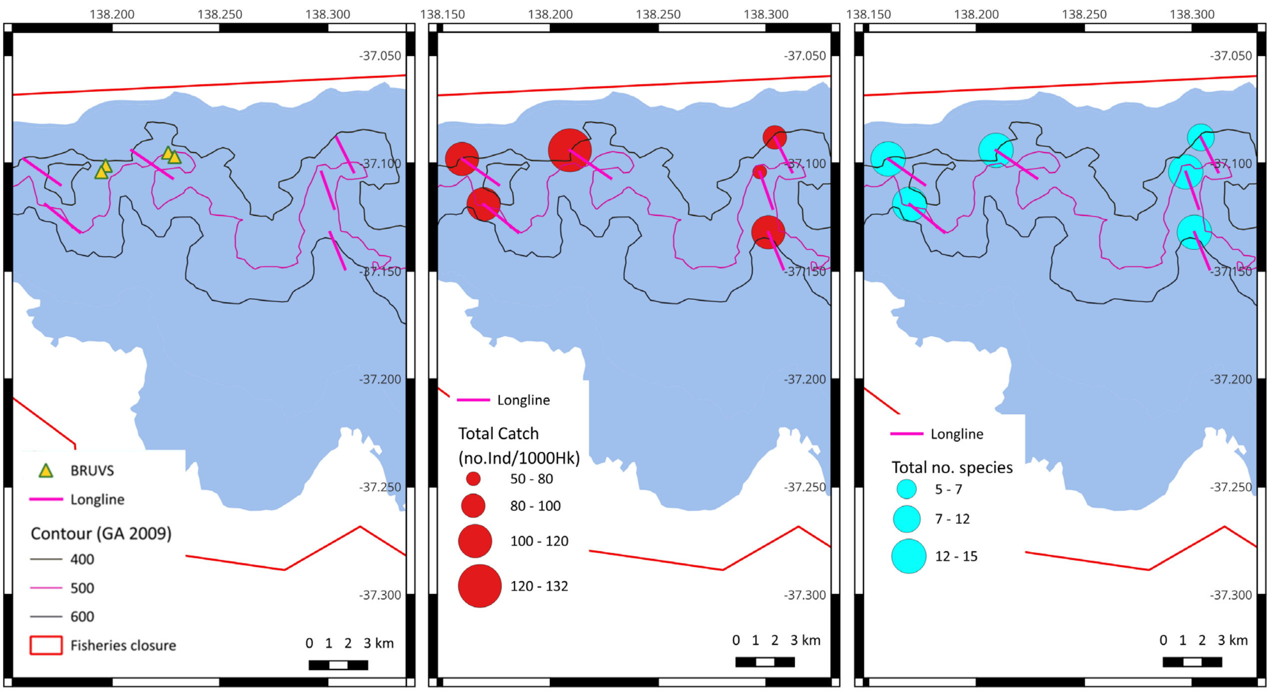



**Figure 14 Map of the Murray Reference Area showing (a) the locations of the BRUVS deployments and the auto-longline sets, (b) the total standardised catch (number of individuals per 1000 hooks) taken with each auto-longline set, and (c) the number of species caught with each set.**

**Table 4 Overview of the sampling deployments undertaken during Survey 4: DI202302: Port MacDonnell and Murray Reference Areas. Summary data of catches from the longline sets are included.**

| Set Date Time | Gear | Reference Area | Set Start Longitude (dec) | Set Start Latitude (dec) | Set End Longitude (dec) | Set End Latitude (dec) | Set depth range (m) | Haul time (hh:mm) | Soak time (hh:mm) | Number of Hooks | Operation Identifier | Comment | Total estimated catch weight (kg) | Total number of Individuals | Individuals per 1000 hooks | Total number of species | Number of *C. uyato* | Number of *Centrophorus (Not landed)* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 02/09/2023 02:54:20 | Longline | Port MacDonnell 2 | 140.281 | -38.169 | 140.262 | -38.173 | 390-450 | 01:00 | 04:03 | 1500 | DI202302_001 | | 313.9 | 126 | 84.00 | 14 | 15 | |
| 02/09/2023 03:24:58 | Longline | Port MacDonnell 2 | 140.243 | -38.156 | 140.223 | -38.161 | 430-530 | 01:04 | 05:01 | 1500 | DI202302_002 | | 251.1 | 114 | 76.00 | 12 | 17 | 3 |
| 02/09/2023 03:50:38 | Longline | Port MacDonnell 2 | 140.194 | -38.147 | 140.217 | -38.145 | 470-580 | 01:00 | 06:02 | 1500 | DI202302_003 | | 391 | 162 | 108.00 | 12 | 41 | 5 |
| 02/09/2023 04:13:00 | BRUVS | Port MacDonnell 2 | 140.206 | -38.138 | 140.206 | -38.139 | 456 | 00:03 | 06:39 | | DI202302_004 | | | | | | | |
| 02/09/2023 04:17:46 | BRUVS | Port MacDonnell 2 | 140.208 | -38.135 | 140.208 | -38.135 | 425 | 00:03 | 06:45 | | DI202302_005 | | | | | | | |
| 02/09/2023 04:28:55 | BRUVS | Port MacDonnell 2 | 140.230 | -38.150 | 140.230 | -38.150 | 460 | 00:03 | 06:55 | | DI202302_006 | | | | | | | |
| 02/09/2023 04:38:32 | BRUVS | Port MacDonnell 2 | 140.251 | -38.165 | 140.251 | -38.165 | 450 | 00:16 | 07:10 | | DI202302_007 | | | | | | | |
| 02/09/2023 04:51:52 | BRUVS | Port MacDonnell 2 | 140.271 | -38.182 | 140.271 | -38.182 | 450 | 00:03 | 07:10 | | DI202302_008 | | | | | | | |
| 02/09/2023 04:56:07 | BRUVS | Port MacDonnell 2 | 140.277 | -38.181 | 140.277 | -38.181 | 415 | 00:15 | 07:24 | | DI202302_009 | | | | | | | |
| 03/09/2023 03:35:12 | Longline | Murray 2 | 138.304 | -37.088 | 138.312 | -37.104 | 380-390 | 01:09 | 03:25 | 1500 | DI202302_010 | | 280.9 | 138 | 92.00 | 11 | 7 | |
| 03/09/2023 03:57:43 | Longline | Murray 2 | 138.297 | -37.104 | 138.303 | -37.121 | 510-510 | 01:09 | 04:28 | 1500 | DI202302_011 | Tangle in line | 189.1 | 118 | 78.67 | 13 | 6 | |
| 03/09/2023 04:19:18 | Longline | Murray 2 | 138.301 | -37.132 | 138.308 | -37.149 | 570-625 | 00:57 | 05:35 | 1500 | DI202302_012 | | 301.6 | 168 | 112.00 | 14 | 7 | 3 |
| 04/09/2023 03:33:58 | Longline | Murray 1 | 138.159 | -37.098 | 138.176 | -37.110 | 350-450 | 01:03 | 03:28 | 1500 | DI202302_013 | | 332.4 | 158 | 105.33 | 13 | 8 | 1 |
| 04/09/2023 03:52:41 | Longline | Murray 1 | 138.169 | -37.119 | 138.185 | -37.132 | 480-490 | 01:18 | 04:30 | 1500 | DI202302_014 | | 363.9 | 165 | 110.00 | 14 | 5 | |
| 04/09/2023 04:26:08 | Longline | Murray 1 | 138.209 | -37.094 | 138.228 | -37.107 | 420-580 | 00:58 | 05:57 | 1500 | DI202302_015 | | 442.8 | 193 | 128.67 | 15 | 10 | |
| 04/09/2023 04:57:59 | BRUVS | Murray 1 | 138.226 | -37.095 | 138.226 | -37.095 | 390 | 00:03 | 06:30 | | DI202302_016 | | | | | | | |
| 04/09/2023 05:03:32 | BRUVS | Murray 1 | 138.229 | -37.097 | 138.229 | -37.097 | 380 | 00:04 | 06:09 | | DI202302_017 | | | | | | | |
| 04/09/2023 05:22:32 | BRUVS | Murray 1 | 138.197 | -37.101 | 138.197 | -37.101 | 380 | 00:06 | 06:29 | | DI202302_018 | | | | | | | |
| 04/09/2023 05:32:07 | BRUVS | Murray 1 | 138.195 | -37.104 | 138.195 | -37.104 | 410 | 00:06 | 04:21 | | DI202302_019 | | | | | | | |
| 06/09/2023 03:36:43 | Longline | Port MacDonnell 1 | 140.091 | -38.045 | 140.111 | -38.057 | 435-440 | 01:19 | 03:32 | 1500 | DI202302_020 | Tangle in line | 473.2 | 196 | 130.67 | 13 | 25 | 3 |
| 06/09/2023 03:56:58 | Longline | Port MacDonnell 1 | 140.104 | -38.065 | 140.121 | -38.080 | 475-508 | 01:03 | 05:02 | 1500 | DI202302_021 | | 230.8 | 97 | 64.67 | 10 | 23 | 6 |
| 06/09/2023 04:17:44 | Longline | Port MacDonnell 1 | 140.112 | -38.085 | 140.133 | -38.099 | 547-590 | 01:04 | 06:07 | 1500 | DI202302_022 | Tangle in line | 170.2 | 86 | 57.33 | 7 | 17 | 2 |

## Catch summary

In the Port MacDonnell Reference Area the longlines caught between 7 and 14 species per set and catch rates range between 57 to 131 fish per 1000 hooks (Figure 13b & c and Table 4). The total catch by species over the 2-day sampling period is summarised in Table 5. In total, 23 different species were caught. The most common commercial species caught were Pink ling (68) and Ocean Perch (58). The most common bycatch species were the Greeneye dogfish (184) and the Whitefin swell shark (86), that were returned to the water in good condition (Table 5).

In the Murray Reference Area the longlines caught between 11 and 15 species per set and catch rates ranged between 79 to 129 fish per 1000 hooks (Figure 14b & c and Table 6). The total catch by species over the 2-day sampling period is summarised in Table 6. In total 23 different species were caught. The most common commercial species caught were Ribaldo (146) and Pink ling (111). The most common bycatch species were the Greeney dogfish (263) and the Whitefin swell shark (101), that were returned to the water in good condition (Table 6).

**Table 5 Total catch by species or higher-level taxonomic group for the Port MacDonnell Reference Area (DI202302), including a list of the retained catch. Species with ^ are commercial species under AFMA Quota.**

| Common Name | Scientific Name | CAAB code | ^ | Total number of individuals | Total number retained |
|---|---|---|---|---|---|
| Southern dogfish | *Centrophorus uyato* | 37020011 | | 138 | 0 |
| Southern dogfish (not landed) | *Centrophorus uyato* | 37020011 | | 19 | 0 |
| Bigeye ocean perch | *Helicolenus barathri* | 37287093 | ^ | 58 | 58 |
| Bight skate | *Dipturus gudgeri* | 37031010 | | 2 | 0 |
| Blue grenadier | *Macruronus novaezelandiae* | 37227001 | ^ | 3 | 2 |
| Blue-eye trevalla | *Hyperoglyphe antarctica* | 37445001 | ^ | 11 | 11 |
| Common sawshark | *Pristiophorus cirratus* | 37023002 | | 1 | 0 |
| Deepsea conger | *Bassanago hirsutus* | 37067013 | ^ | 54 | 34 |
| Gemfish | *Rexea solandri* | 37439002 | ^ | 43 | 37 |
| Greeneye dogfish | *Squalus chloroculus* | 37020048 | | 184 | 0 |
| Gummy shark | *Mustelus antarcticus* | 37017001 | ^ | 31 | 16 |
| Hapuku | *Polyprion oxygeneios* | 37311006 | ^ | 2 | 2 |
| Knifejaw | *Oplegnathus woodwardi* | 37369002 | ^ | 2 | 2 |
| Ocean jacket | *Nelusetta ayraud* | 37465006 | ^ | 4 | 0 |
| Ogilbys Ghostshark | *Chimaera ogilbyi* | 37042001 | | 1 | 1 |
| Pink ling | *Genypterus blacodes* | 37228002 | ^ | 68 | 68 |
| Ribaldo | *Mora moro* | 37224002 | ^ | 49 | 44 |
| Sawtail catshark | *Figaro boardmani* | 37015009 | | 9 | 0 |
| School shark | *Galeorhinus galeus* | 37017008 | ^ | 6 | 1 |
| Sharpnose sevengill shark | *Heptranchias perlo* | 37005001 | | 2 | 0 |
| Southern whiptail | *Coelorinchus australis* | 37232001 | | 4 | 0 |
| Spikey dogfish | *Squalus megalops* | 37020006 | | 3 | 0 |
| Tusk | *Dannevigia tusca* | 37228001 | ^ | 1 | 1 |
| Whitefin swell shark | *Cephaloscyllium albipinnum* | 37015013 | | 86 | 0 |

**Table 6 Total catch by species or higher-level taxonomic group for the Murray Reference Area (DI202302), including a list of the retained catch. Species with ^ are commercial species under AFMA Quota.**

| Common Name | Scientific Name | CAAB code | ^ | Total number of individuals | Total number retained |
|---|---|---|---|---|---|
| Southern dogfish | *Centrophorus uyato* | 37020011 | | 43 | 0 |
| Southern dogfish (not landed) | *Centrophorus uyato* | 37020011 | | 4 | 0 |
| Bigeye ocean perch | *Helicolenus barathri* | 37287093 | ^ | 29 | 29 |
| Bight skate | *Dipturus gudgeri* | 37031010 | | 7 | 0 |
| Black shark | *Dalatias licha* | 37020002 | | 4 | 0 |
| Blacktip cucumberfish | *Paraulopus nigripinnis* | 37120001 | | 1 | 0 |
| Blue grenadier | *Macruronus novaezelandiae* | 37227001 | | 2 | 0 |
| Blue shark | *Prionace glauca* | 37018004 | | 1 | 0 |
| Blue-eye trevalla | *Hyperoglyphe antarctica* | 37445001 | ^ | 89 | 86 |
| Brier shark | *Deania calceus* | 37020003 | | 1 | 0 |
| Common sawshark | *Pristiophorus cirratus* | 37023002 | | 2 | 0 |
| Deepsea conger | *Bassanago hirsutus* | 37067013 | ^ | 27 | 21 |
| Gemfish | *Rexea solandri* | 37439002 | ^ | 9 | 7 |
| Greeneye dogfish | *Squalus chloroculus* | 37020048 | | 263 | 0 |
| Grey skate | *Dipturus canutus* | 37031028 | | 5 | 0 |
| Knifejaw | *Oplegnathus woodwardi* | 37369002 | ^ | 5 | 5 |
| Pink ling | *Genypterus blacodes* | 37228002 | ^ | 111 | 109 |
| Ribaldo | *Mora moro* | 37224002 | ^ | 146 | 121 |
| Sawtail catshark | *Figaro boardmani* | 37015009 | | 67 | 0 |
| School shark | *Galeorhinus galeus* | 37017008 | | 4 | 0 |
| Sharpnose sevengill shark | *Heptranchias perlo* | 37005001 | | 16 | 0 |
| Southern chimaera | *Chimaera fulva* | 37042005 | ^ | 2 | 2 |
| Southern whiptail | *Coelorinchus australis* | 37232001 | | 1 | 0 |
| Whitefin swell shark | *Cephaloscyllium albipinnum* | 37015013 | | 101 | 0 |

## Gulper shark data

A total of 157 Southern dogfish (*C. uyato*) were observed from the Port MacDonnell Reference Area. Of these, the length and sex were recorded for 138 individuals. The other 19 were not landed as they fell off the hook (Table 5). All longlines set in the Port MacDonnell area caught gulper sharks. Gulper shark catch rates varied between 10 to 27 sharks per 1000 hooks. Of the 138 Southern dogfish landed, the majority (106 or 77%) were males, and while co-location of sexes was common, no females were caught on two of the three sets in the eastern sampling sector (Figure 15a). Most (131 or 95%) of the landed Southern dogfish were large adults. The 7 small, possible juvenile individuals were caught from one longline set in each sampling sector and were almost evenly divided between sexes (Figure 15b; Figure 17).

A total of 47 Southern dogfish (*C. uyato*) were observed from the Murray Reference Area. Of these, 43 were measured for length and sex. The other four were not landed as they fell off the hook (Table 5). All longlines set in the Murray area caught gulper sharks. Gulper shark catch rates ranged between 4 and 7 sharks per 1000 hooks. Of the 43 Southern dogfish landed, the majority (25 or 66%) were males, and while co-location of sexes was common, no females were caught on the deepest set in both the eastern and western sampling sector (Figure 16a). Most (35 or 81%) of the landed Southern dogfish were large adults. The 8 small, possible juvenile individuals were caught from the shallowest longline set in each sampling sector and all but one were females (Figure 16b; Figure 17).

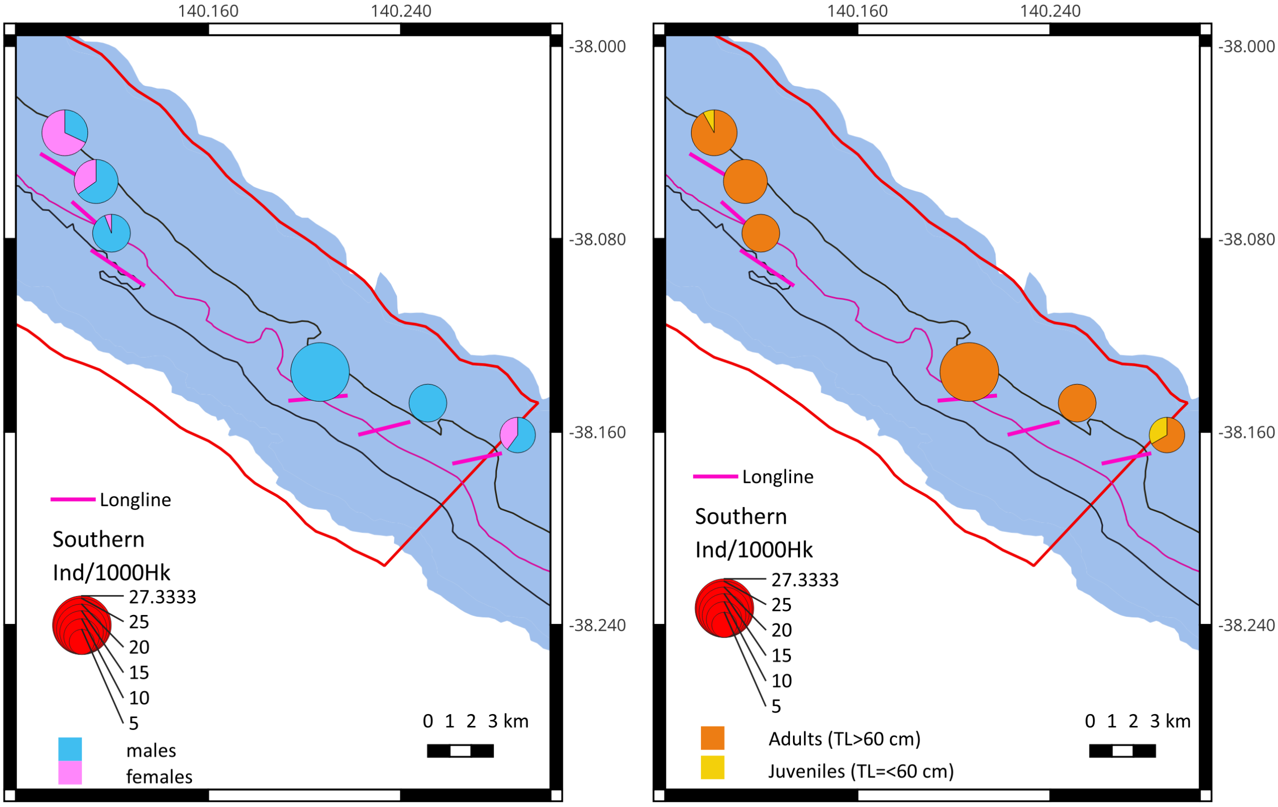



**Figure 15 Distribution of Southern dogfish (C uyato) from the Port MacDonnell Reference Area. Longline sets locations are shown by the pink lines. Standardised catch per 1000 hooks, broken down by sex and indicative maturity based on total length >/=< 60 cm.**

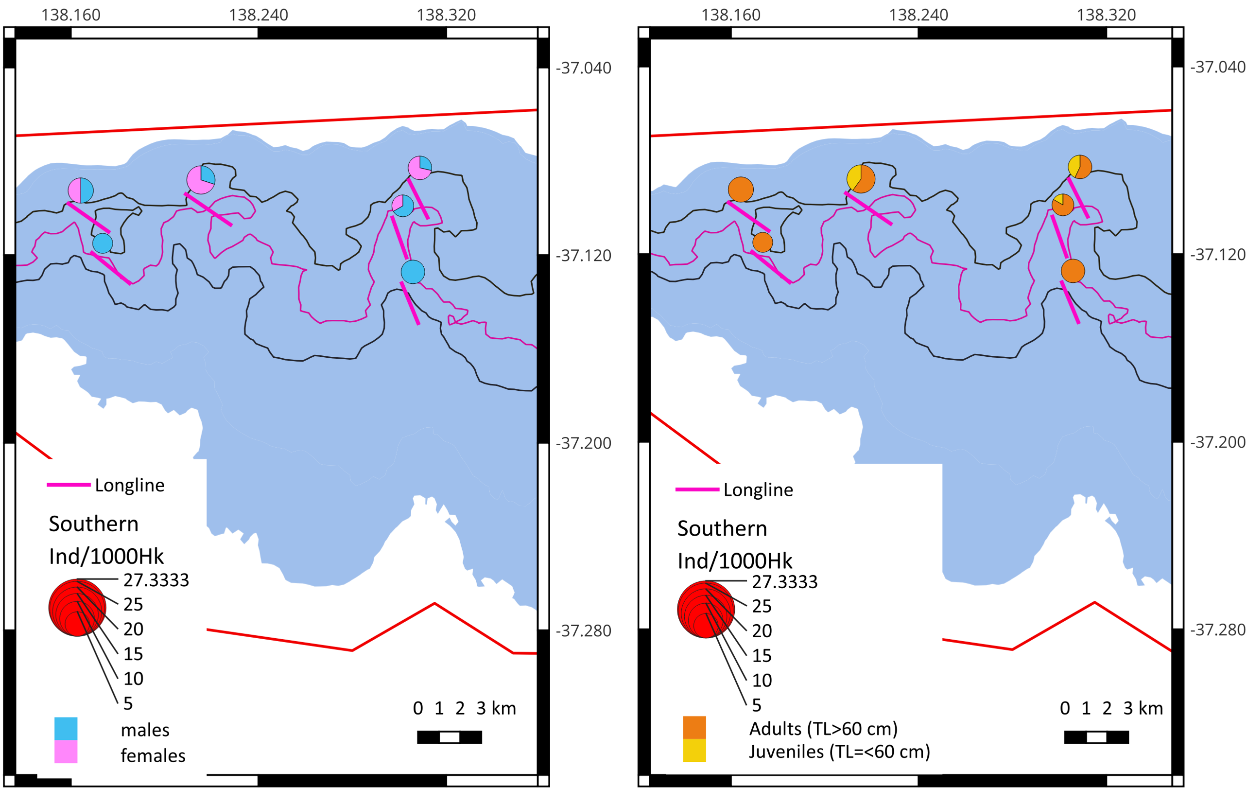


Figure 16 Distribution of Southern dogfish (C uyato) from the Murray Reference Area. Longline sets locations are shown by the pink lines. Standardised catch per 1000 hooks, broken down by sex and indicative maturity based on total length >/=< 60 cm.

Higher numbers of Southern dogfish were present in the Port MacDonnell Area compared to the Murray Reference Area (Figure 10). There were fewer females than males in each area, but there was a higher proportion of females in the Murray Area. While the number of smaller, possible juvenile individuals was similar for both areas, the proportion of juveniles was higher in the Murray Area. Males in both areas were generally of mature size (>80 cm TL), while mature females (>96 cm TL) were more abundant in the Port MacDonnell area.

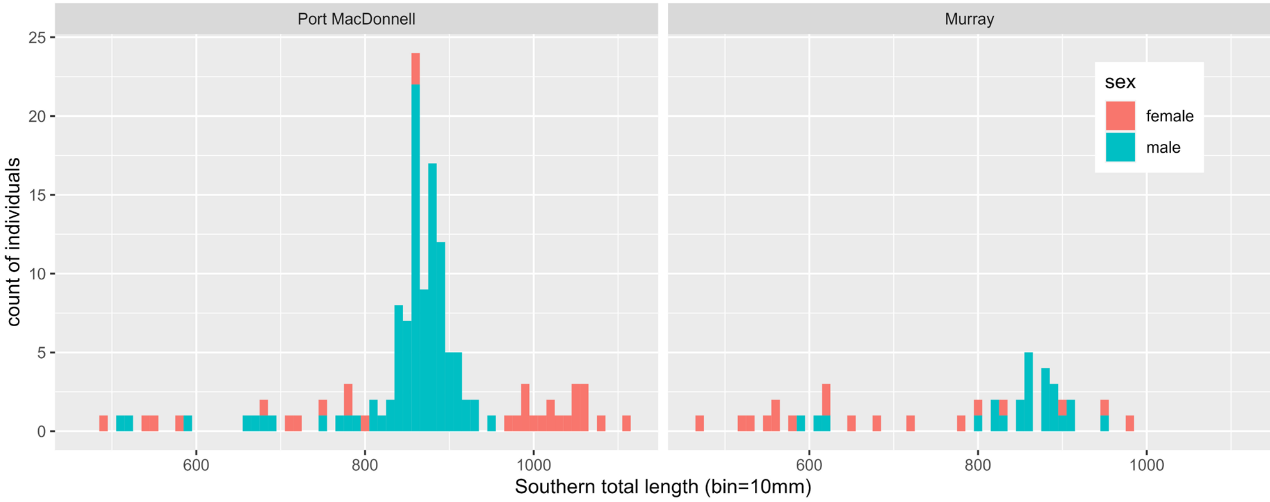



Figure 17 Length frequency distribution of male (blue) and female (red) Southern dogfish captured during the survey.

In total, 74 Southern dogfish were tagged from the Port MacDonnell Reference Area and a total of 34 Southern dogfish were tagged from the Murray Reference Area. There were no recaptures of dogfish from Port MacDonnell.

## BRUVS preliminary observations

BRUVS footage was briefly scanned during the survey. A few Southern dogfish were observed from preliminary scans of the 6 BRUVS deployments in the Port MacDonnell Reference Area (Figure 18). No gulper sharks were observed during preliminary scans of the 4 BRUVS deployments in the Murray Reference Area. Detailed analyses of the BRUVS data will be done as part of the project.

**Figure 18 Example of a Southern Dogfish observed in BRUVS footage taken in the Port MacDonnell Reference Area during the survey.**

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## A.4 BRUVS Analyses Report

Althaus, F., James, A., Untiedt, C. and Scoulding, B. (2024). Gulper Shark Monitoring: Baited Remote Underwater Video System (BRUVS). Hobart, Australia: CSIRO. 9 (pg 1-38)

Australia's National
Science Agency

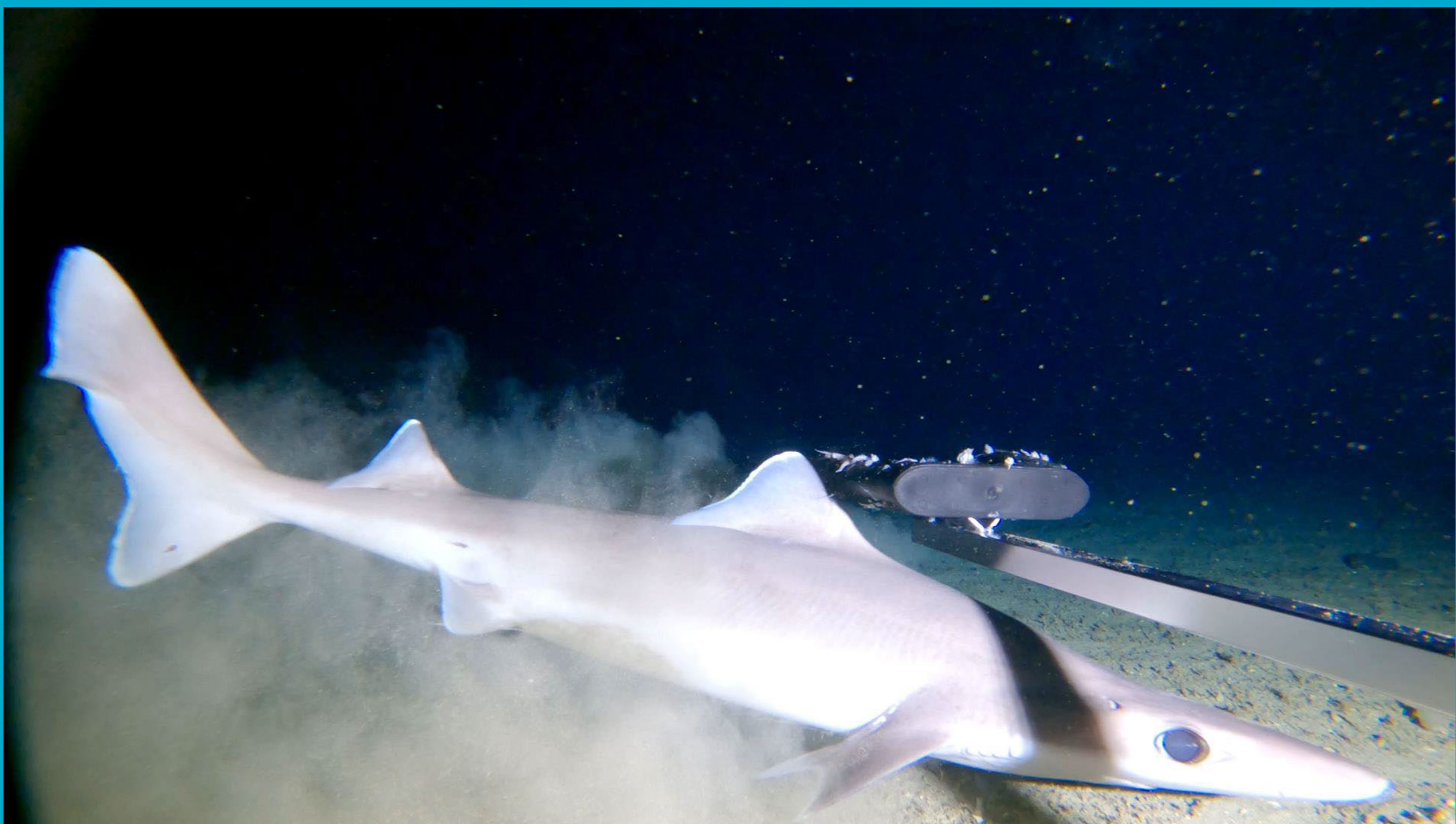
# Gulper Shark Monitoring: Baited remote underwater video system (BRUVS)

PROJECT: 'Determining the status and recovery of depleted or declining fish species: a case study of Southern Dogfish and Harrisson's Dogfish in the context of AFMA's upper slope dogfish management strategy'

Franzis Althaus, Amarina James, Candice Untiedt, and Ben Scoulding

February 19, 2024

Report to AFMA
Cate Coddington



CSIRO Environment

## Citation

Althaus, F., James, A., Untiedt, C. and Scoulding, B., (2024). Gulper Shark Monitoring: Baited remote underwater video system (BRUVS). CSIRO, Australia.



## Important disclaimer

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# Acknowledgments

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Many thanks to the Mures Fishing company and particularly to the Master Russell Potter and crew of fishing vessel *Diana* who provided a happy and safe work area and shared their knowledge and experience of the fishing operations and the fishery area.

Thank you to John Pogonoski and Will White from CSIRO for their expertise in identifying the species represented in our annotation taxa.

# Executive summary

The current project, '*Determining the status and recovery of depleted or declining fish species: a case study of Southern Dogfish and Harrisson's Dogfish in the context of AFMA's upper slope dogfish management strategy'* is funded by the Australian Fisheries Management Authority (AFMA) and CSIRO. Its aim was to sample wild populations of gulper sharks – Harrisson's Dogfish, *Centrophorus harrissoni*, and Southern Dogfish, *Centrophorus uyato*, formerly *C. zeehaani* (White et al., 2022) – on the continental slope from chartered commercial fishing vessels with hook-and-line, and to complement the data collection using a non-extractive (image-based) technique, baited remote underwater video system (BRUVS), to gauge its effectiveness and comparability to auto-longline catches. In addition, two unbaited Deep BRUVS, designed for long-term deployment, were trialled.

Conventional BRUVS were deployed in five reference areas during three surveys: Flinders Research Zone Closure (DI202201), Endeavour Dogfish Closure and Hunter Australian Marine Park (AMP) – special purpose zone (DI202301), and Murray Dogfish Closure and Port MacDonnell Closure (DI202302). Succes rate for the BRUVS varied with valid deployments made only in the Flinders and Port MacDonnell Reference Areas. Strong currents at the Endeavour, Hunter and Murray Reference Areas caused the units to bounce and move along the seafloor, rendering the video footage unsuitable for analysis. The two Deep BRUVS recorded 24 events each over a three-month deployment.

Gulper sharks were observed in six of 17 successful operations at Flinders and in two of six operations at Port MacDonnell. In total 11 Harrisson's Dogfish were observed Flinders and two Southern Dogfish were seen at Port MacDonnell. A further four gulper sharks were observed in the 24 recording periods of Deep BRUV1 but no gulper sharks were seen on Deep BRUV2.

In total 20 other taxa were identified in the BRUVS footage, including several shark species of interest to conservation and management: school shark (*Galeorhinus galeus*), longsnout dogfish (*Deania quadrispinosa*), lantern sharks (*Etmopterus spp.*), and whitefin swellshark (*Cephaloscyllium albipinnum*). Whitefin swellsharks were seen in all successful operations, with a MaxN of seven in one deployment.

Results from conventional and Deep BRUVS analysis show that while gulper sharks are observed in video (presence) recorded by both baited and unbaited platforms, they are observed in much lower numbers (MaxN = 1) compared with catch data. This means that many more BRUVS operations (likely many 100s) would be needed to collect the data necessary to assess the abundance of gulper sharks during future monitoring surveys.

# 1 Background and scientific objectives

Harrisson's Dogfish (*Centrophorus harrissoni*) and Southern Dogfish (*C. zeehaani*) ('gulper sharks') were listed under Threatened Species provisions of the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) in 2013 due to their widespread depletion by commercial fishing. The Threatened Species Scientific Committee (TSSC) listed them in the relatively low risk category of 'conservation dependent' because the Upper Slope Dogfish Management Strategy (USDMS) (AFMA 2012; NSWDPI 2012) was considered by the TSSC to be "potentially effective in halting further decline and supporting recovery of both species to maximise their chance of survival in nature".

The current project, '*Determining the status and recovery of depleted or declining fish species: a case study of Southern Dogfish and Harrisson's Dogfish in the context of AFMA's upper slope dogfish management strategy'* is funded by the Australian Fisheries Management Authority (AFMA) and CSIRO. Its aim was to sample wild populations of Harrisson's Dogfish, *Centrophorus harrissoni*, and Southern Dogfish, *Centrophorus uyato*, formerly *C. zeehaani* (White et al., 2022), on the continental slope from chartered commercial fishing vessels during four surveys, visiting six identified reference areas in fishery closures where remnant shark populations are known to exist. The six areas span the species' ranges (Figure 1).

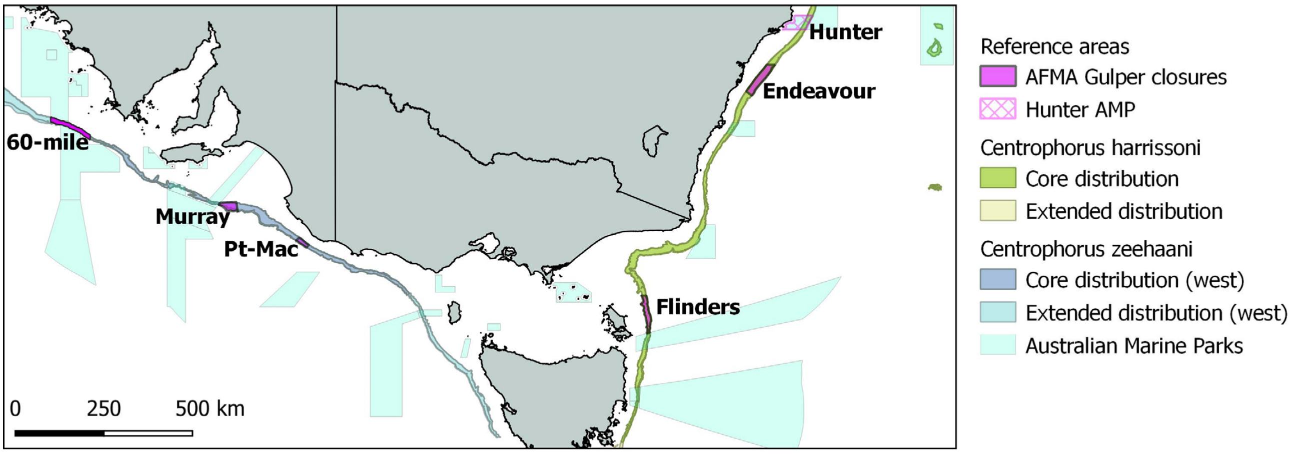


**Figure 1 Map showing locations of the six reference areas. Note *C. zeehaani* is now *C. uyato* (White et al., 2022)**

The six reference areas are referred to by shortened names in Figure 1, they are defined as follows by the Fisheries Management legislation (Anon. 2022):

- **Hunter** Marine Park - Special Purpose Zone (trawl) defined by Australian Marine Parks Legislation (Director of National Parks, 2018a & b).
- **Endeavour**: Endeavour Dogfish Gulper Shark Closure: AFMA fishery closure: Schedule 11

- **Flinders**: Flinders Research Zone Closure: Schedule 39
- **Pt-Mac**: Port MacDonnell Closure: Schedule 32
- **Murray**: Murray Dogfish Closure: Schedule 33
- **60-mile**: Southern Dogfish Gulper Shark Closure: AFMA fishery closure: Schedule 10

Due to funding constraints the 60-mile closure was not surveyed as part of this project and may be considered in future work.

The main sampling tool was commercial auto-longline fishing, with appropriate fishing/handling practices (Scoulding et al., 2022; Untiedt et al., 2023). In addition, a non-extractive (image-based) technique using conventional baited remote underwater video system (BRUVS) was used in combination with fishing to gauge its effectiveness and comparability to auto-longline catches.

Conventional BRUVS were deployed in five reference areas during three surveys (DI202201 – Scoulding et al., 2022; DI202301 & DI202302 – Untiedt et al., 2023). In addition, programmable and unbaited Deep BRUVS units designed for long-term deployments, were operating in the Flinders Reference Area between July 2 and September 27, 2023. Here, we report on the data collected from these BRUVS operations.

# 2 Methods

## 2.1 BRUVS Details & Deployments

### 2.1.1 Conventional BRUVS units

Conventional BRUVS units (Figure 2) comprised two GoPro Hero 9 cameras housed in anodised aluminium pressure casings (rated to 550 m) fixed 70 cm apart, with an 8° angle of convergence, sitting 40 cm above the seabed in a steel frame. Illumination was supplied by a light fitted between the two camera housings. Power to the GoPros and light was supplied through 25V lithium batteries located in the camera housings. Units used during the 2022 survey had a single TWTEK depth rated (6000 m) LED light; units used during the 2023 surveys had a single Blue Robotics Lumen Subsea, 500 m depth rated LED light. The BRUVS used ~1 kg of locally sourced frozen squid and/or mackerel in a bait saver at the end of a 1 m aluminium arm; this arm was extended using a 1 m plastic conduit during the 2023 surveys. Each BRUVS was weighted with approximately 40 kg of lead for deployment and was attached by a rope to a rope-basket and surface floats for recovery. Each BRUVS was calibrated in water using a SeaGIS calibration cube prior to the survey. Calibrated camera parameters were determined using the calibration facility software developed by SeaGIS. Recording time was up to 3 hours but varied between units depending on battery time and available memory (one to four hours).

Six BRUVS units were available during the surveys. BRUVS were deployed close to longlines, no less than 300m away. They were deployed/retrieved by the fishing crew after the deployment/retrieval of the longline sets. The number and position of BRUVS deployed was determined by local conditions and care was taken to avoid setting the units in areas where they could potentially interact (e.g. due to currents and tides) with each other or the longline sets.

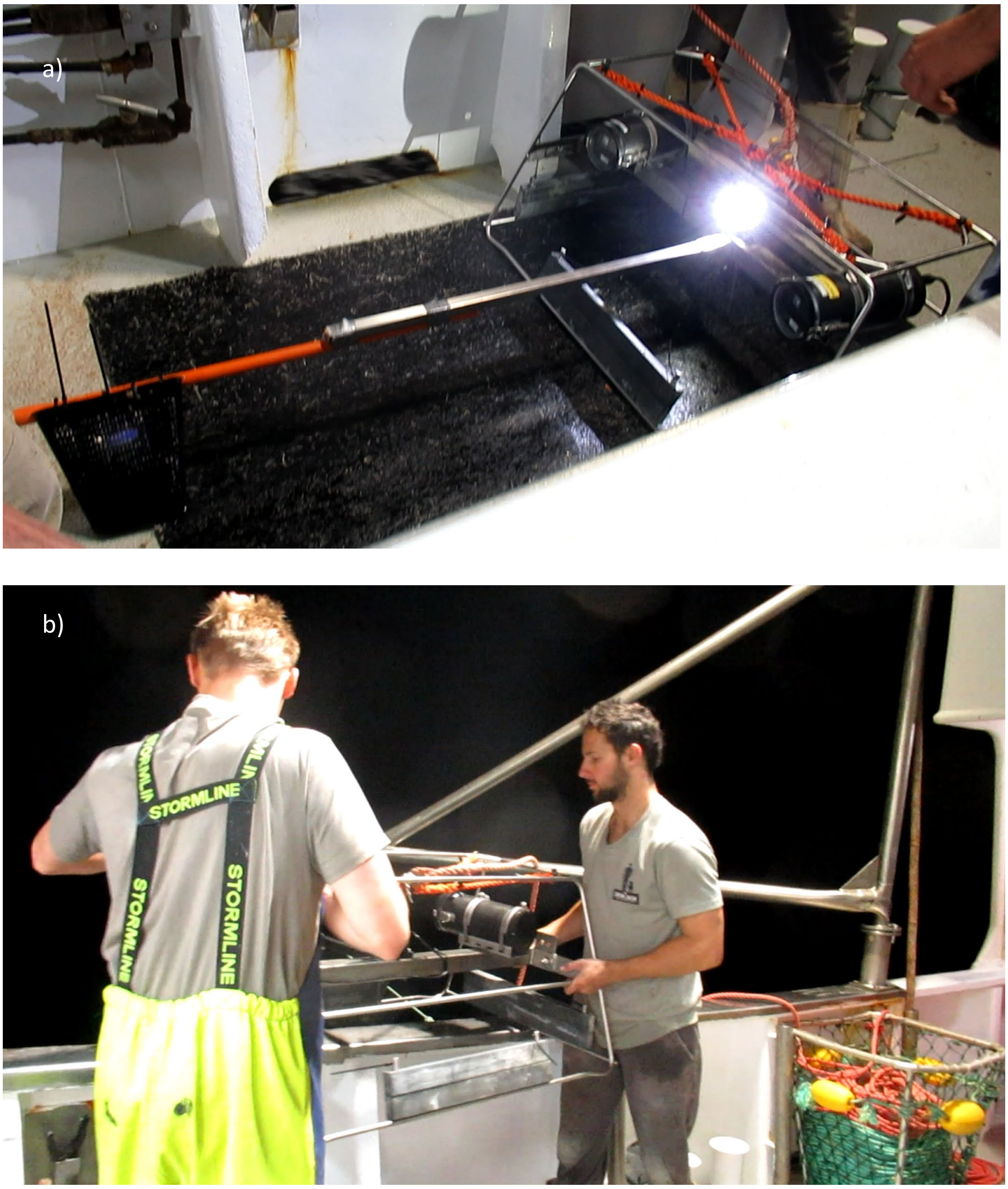


**Figure 2 Conventional BRUVS unit deployed during the longline surveys. A). BRUVS unit showing two cameras and a light on a steel frame, with weights and a bait arm; b). Deployment of the BRUVS unit by fishing crew showing the surface rope basket.**

### 2.1.2 Deep BRUVS

The Deep BRUVS platforms (Figure 3a) are capable of deep deployments (1000 m) and allow for user configurable recording schedules via an Intel NUC computer – the Deep BRUVS controller – to achieve long-term deployments. Deep BRUVS units comprise two network connected GBO Technology S1080 cameras each fitted with a fixed focus and fixed aperture 6 mm LM6HC Kowa lens. Power is supplied through a custom designed low power supervisory circuit board which acts as timer and switch to turn power on to the Deep BRUVS controller when required. Cameras are housed in pressure casings (rated to 1000 m) fixed to a frame with DWTEK LED lights, weights, small floats and an acoustic release mechanism on the platform. The acoustic release enables the BRUVS unit to be deployed on the seabed without a surface float. The unit is negatively buoyant when deployed, sinking to the seafloor where it resides, collecting video recordings according to the user defined schedule until the acoustic release is activated to decouple the frame from a sacrificial weight (90 kg) attached to the bottom of the platform. Reserve buoyancy, in the form of depth rated trawl floats, brings the platform back to the surface for recovery (Sherlock 2002).

Two Deep BRUVS units were deployed in the Flinders Reference Area to evaluate their ability to detect gulpers. They were deployed off the RV *Investigator* on 2nd July 2023 as the ship transited through the Flinders Research Area during the CSIRO SEA-MES voyage (IN2023_V05). The units were retrieved on 27th September 2023 during a two-day charter of FV *Nina* (an 11 m commercial crayfish boat) out of St. Helens. The two units were programmed to turn on for 30 min (Deep BRUV1) or 1 hour (Deep BRUV2) at 06:00 daily (Figure 3b). No bait was used during the Deep BRUVS operations. The difference in recording period between the cameras was intended to increase total recording days for one of the units. Video cameras were turned on five seconds before the lights were activated, to capture animals that might be deterred by the light.

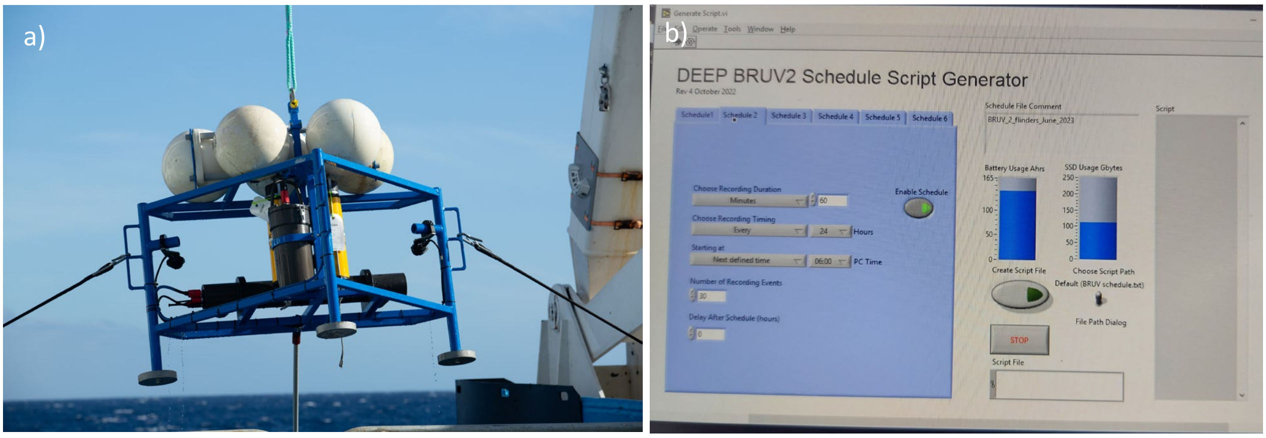


**Figure 3 Deep BRUVS : a) Deep BRUVS unit being deployed from the RV *Investigator*. Photo credit: Fred Olivier; b) screen shot of the Deep BRUVS controller user interface with program settings for Deep BRUV2.**

## 2.2 Analyses

### 2.2.1 Annotation method

The SeaGIS software EventMeasure version 6.22 (https://www.seagis.com.au/event.html ) was used to collect species and abundance data from video imagery.

**Species abundance: Point annotations and MaxN**

Prior to video analysis and annotation of the video footage a list of expected species was compiled based on long-line catch data collected during the 2022 and 2023 surveys (Scoulding et al., 2022; Untiedt et al., 2023), and on previous BRUVS observations (Williams et al., 2012). These species were grouped into annotation taxa which can be accurately and consistently identified from the imagery (Table 1).

Gulper shark (*Centrophorus harrissoni and C. uyato*) abundance was quantified by the point metric, which ensured every individual was included for analysis. For all other elasmobranchs and all teleosts abundance was quantified by the MaxN metric. MaxN is a conservative method, recording the maximum number of individuals present in a single video frame over the annotation period, ensuring individuals are not counted twice (Langlois et al., 2018). For teleosts, MaxN was recorded for the first hour, while for elasmobranchs (including gulpers) MaxN was recorded for both, the first hour and the entire duration of BRUVS operations. One observer annotated all imagery to reduce identification bias; two taxonomists, John Pogonski and Will White from CSIRO, were consulted to identify which species were contained in each annotation taxon group (Table 1).

**Length Measurements: 3D point size measurements**

Calibrated stereo imagery was used to obtain elasmobranch length measurements with the 3D point function in the EventMeasure software. For *C. harrissoni* and *C. uyato* two measurements were taken per individual: standardised fork length (FL – the central point of the snout to the fork of the tail (caudal fin)), and either the snout to pectoral length (SP) or snout to dorsal fin length (SD). Both measurements were taken in triplicate for each individual, by stepping forward / backward one video frame either side of the point annotation; the average and range from the triplicate measurements were used to compare multiple sightings of the target species in a single operation, and thus corroborate total abundance counts (as opposed to MaxN). A single measurement of fork length was made for individuals of all other elasmobranchs at the MaxN observation. Length measurements could not be obtained from Deep BRUVS stereo video due to frame rate inconsistencies which caused an error in the calibration of the stereo imagery in the SEAGIS software, because synchronisation between the stereo cameras was not maintained.

**Table 1 Complete list of the annotation taxa observed in conventional BRUVS and Deep BRUVS, detailing the species identifications by experts included in within each of the taxa.**

| Annotation Taxon | Identification of species included | Sum of MaxN | Caught on hooks |
|---|---|---|---|
| **Eel** | *Bassanago spp.* | 8 | Y |
| **Eellike** | Only identifiable as eel-like | 3 | |
| **Bellows fish** | *Centriscops humerosus* | 90 | N |
| | *Macroramphosus scolopax* | | N |
| **Berycidae** | Berycidae | 1 | Y |
| **Blue grenadier** | *Macruronus novaezelandiae* | 17 | Y |

| Annotation Taxon | Identification of species included | Sum of MaxN | Caught on hooks |
|---|---|---|---|
| **Cardinal fish** | *Verilus anomalus* | 29 | N |
| | *Epigonus spp.* | | N |
| **Dory** | *Zenopsis nebulosa* | 37 | N |
| | *Cyttus novaezealandiae* | | N |
| **Frostfish** | *Lepidopus caudatus* | 9 | N |
| **Gemfish** | *Rexea solandri* | 24 | Y |
| **Hagfish** | *Eptatretus spp.* | 4 | N |
| **Hapuku** | *Polyprion oxygeneios* | 1 | Y |
| **Morid cods** | Moridae | 1 | Y |
| **Morwong** | *Nemadactylus macropterus* | 3 | Y |
| **Ocean perch** | *Helicolenus spp.* | 103 | Y |
| **Pink ling** | *Genypterus blacodes* | 25 | Y |
| **Ribaldo** | *Mora moro* | 3 | Y |
| **Silver Warehou** | *Seriolella punctata* | 703 | N |
| **Sunfish** | *Mola spp.* | 2 | N |
| **Trevalla** | *Hyperoglyphe antarctica* | 7 | Y |
| **Whiptails** | Macrouridae | 128 | N |
| **Chimaera** | Chimaeridae | 6 | Y |
| **Gummy shark** | *Mustelus antarcticus* | 2 | Y |
| **Lantern shark** | *Etmopterus spp.* | 3 | Y |
| **Longsnout dogfish** | *Deania quadrispinosa* | 1 | N |
| **Sawtail shark** | *Figaro boardmani* | 5 | Y |
| **School shark** | *Galeorhinus galeus* | 1 | Y |
| **Sharpnose sevengill** | *Heptranchias perlo* | 2 | Y |
| **Shark** | Hexanchidae | 1 | |
| **Spurdog** | *Squalus spp.* | 19 | (Y) |
| | *Squalus chloroculus* | | Y |
| | *Squalus megalops* | | Y |
| **Whitefin swellshark** | *Cephaloscyllium albipinnum* | 73 | Y |
| **Skate** | *Dipturus spp.* | 14 | (Y) |
| | *Dipturus gudgeri* | | Y |
| | *Dentiraja confusa/cerva* | | N |
| | *Narcinops spp.* | | N |
| | *Spiniraja whitleyi* | | N |
| | *Tetronarce nobiliana* | | N |
| **Fish** | Only identifiable as fish | 20 | |
| **Squid** | Teuthoidea | 1 | N |
| ***Grand Total*** | | **1346** | |

# 3 Results

## 3.1 Operations

Of the six conventional BRUVS units available, four were consistently operational and deployed daily in the Flinders Reference Area during the 2022 survey (Scoulding et al., 2022). BRUVS were deployed 22 times in the Flinders Reference Area. Five of these were unsuitable for analysis due to the unit moving along the seafloor (Table 2, Figure 4). All six units were operational during the 2023 surveys in the Hunter, Endeavour, Port MacDonnell and Murray Reference Areas. A total of 21 operations were conducted during the 2023 surveys in these reference areas, but operations were unsuccessful in Hunter (9), Endeavour (2) and Murray (4) because of strong currents which caused the units to bounce and move along the seafloor (Untiedt et al., 2023). All six operations conducted in the Port MacDonnell Reference Area were suitable for analysis (Table 2, Figure 5). To be considered valid for annotation, units had to remain in the landed location on the seafloor and record at least 1 hour of footage.

Two Deep BRUVS units were deployed in the Flinders Reference Area at a site where large gulper catches were reported in the 2022 survey (Figure 4c – Scoulding et al., 2022). During the deployment period (2$^{nd}$ July to 27$^{th}$ September 2023) Deep BRUV1 collected 43, 30-minute videos starting at 18:00 each day from 16$^{th}$ August to 26$^{th}$ September 2023. Deep BRUV2 collected 26, 1-hour videos starting at 18:00 each day from 16$^{th}$ Aug to 9$^{th}$ September 2023. An error in programming resulted in a 18:00 recording start time rather than the intended 06:00 timeslot. Of the 43 videos collected from Deep BRUV1, 19 were corrupted while two videos of the total 26 collected from Deep BRUV2 were corrupted, resulting in 24 recording periods suitable for analysis from each unit.

**Table 2 Summary details of BRUVS operations at 5 reference areas**

| SVY_OPS | Reference Area | Set Date Time (local) | Longitude (dec$^0$) | Latitude (dec$^0$) | Depth (m) | total soak time (Hrs) | Valid for analyses |
|---|---|---|---|---|---|---|---|
| **DI202201_201** | Flinders | 04/09/2022 04:35:48 | 148.8853 | -40.3486 | 270 | 8.37 | Yes |
| **DI202201_202** | Flinders | 04/09/2022 04:43:11 | 148.8862 | -40.3403 | 200 | 8.50 | Yes |
| **DI202201_203** | Flinders | 04/09/2022 05:02:49 | 148.8885 | -40.3237 | 325 | 8.51 | Yes |
| **DI202201_204** | Flinders | 04/09/2022 05:08:59 | 148.8907 | -40.3150 | 370 | 8.67 | No |
| **DI202201_205** | Flinders | 05/09/2022 05:05:17 | 148.8864 | -40.0047 | 445 | 7.41 | Yes |
| **DI202201_206** | Flinders | 05/09/2022 05:16:29 | 148.8763 | -40.0169 | 380 | 6.92 | Yes |
| **DI202201_207** | Flinders | 05/09/2022 05:25:24 | 148.8834 | -40.0282 | 364 | 6.38 | Yes |
| **DI202201_208** | Flinders | 05/09/2022 05:31:15 | 148.8897 | -40.0265 | 460 | 6.01 | Yes |
| **DI202201_209** | Flinders | 06/09/2022 05:13:39 | 148.8465 | -39.5881 | 490 | 6.60 | Yes |
| **DI202201_210** | Flinders | 06/09/2022 05:21:34 | 148.8469 | -39.5914 | 490 | 6.70 | Yes |
| **DI202201_211** | Flinders | 06/09/2022 05:32:35 | 148.8496 | -39.6044 | 490 | 6.71 | Yes |

| SVY_OPS | Reference Area | Set Date Time (local) | Longitude (dec$^0$) | Latitude (dec$^0$) | Depth (m) | total soak time (Hrs) | Valid for analyses |
|---|---|---|---|---|---|---|---|
| **DI202201_212** | Flinders | 06/09/2022 05:38:54 | 148.8515 | -39.6090 | 497 | 6.70 | Yes |
| **DI202201_213** | Flinders | 07/09/2022 04:53:51 | 148.8084 | -39.5081 | 490 | 6.02 | No |
| **DI202201_214** | Flinders | 07/09/2022 05:04:00 | 148.7936 | -39.5111 | 400 | 6.17 | Yes |
| **DI202201_215** | Flinders | 07/09/2022 05:24:25 | 148.8379 | -39.5345 | 494 | 6.77 | No |
| **DI202201_216** | Flinders | 07/09/2022 05:33:39 | 148.8176 | -39.5305 | 420 | 6.17 | Yes |
| **DI202201_217** | Flinders | 08/09/2022 04:59:02 | 148.8295 | -39.8228 | 425 | 6.32 | Yes |
| **DI202201_218** | Flinders | 08/09/2022 05:09:16 | 148.8214 | -39.8193 | 410 | 6.53 | Yes |
| **DI202201_219** | Flinders | 08/09/2022 05:17:17 | 148.8188 | -39.8133 | 427 | 6.76 | Yes |
| **DI202201_220** | Flinders | 08/09/2022 05:25:53 | 148.8151 | -39.8096 | 420 | 6.92 | No |
| **DI202201_221** | Flinders | 09/09/2022 05:03:45 | 148.8400 | -39.9135 | 400 | 7.44 | No |
| **DI202201_222** | Flinders | 09/09/2022 06:04:05 | 148.8324 | -39.8859 | 410 | 6.97 | Yes |
| **DI202301_004** | Hunter | 25/08/2023 04:33:03 | 152.9068 | -32.5092 | 417 | 6.22 | No |
| **DI202301_005** | Hunter | 25/08/2023 04:42:09 | 152.9111 | -32.5111 | 460 | 6.24 | No |
| **DI202301_006** | Hunter | 25/08/2023 04:54:08 | 152.9190 | -32.4887 | 425 | 6.52 | No |
| **DI202301_007** | Hunter | 25/08/2023 05:05:38 | 152.9238 | -32.4657 | 390 | 6.67 | No |
| **DI202301_008** | Hunter | 25/08/2023 05:20:22 | 152.9358 | -32.4389 | 380 | 6.83 | No |
| **DI202301_009** | Hunter | 25/08/2023 05:25:06 | 152.9406 | -32.4390 | 405 | 6.91 | No |
| **DI202301_013** | Hunter | 26/08/2023 04:39:41 | 152.9846 | -32.3464 | 390 | 7.17 | No |
| **DI202301_014** | Hunter | 26/08/2023 04:43:04 | 152.9882 | -32.3461 | 415 | 7.45 | No |
| **DI202301_015** | Hunter | 26/08/2023 04:48:40 | 152.9911 | -32.3452 | 440 | 7.56 | No |
| **DI202301_019** | Endeavour | 27/08/2023 04:55:37 | 151.9080 | -33.6630 | 400 | 6.87 | No |
| **DI202301_020** | Endeavour | 27/08/2023 04:59:30 | 151.9037 | -33.6638 | 385 | 7.12 | No |
| **DI202302_004** | Port MacDonnell | 02/09/2023 04:13:00 | 140.2056 | -38.1383 | 456 | 6.66 | Yes |
| **DI202302_005** | Port MacDonnell | 02/09/2023 04:17:46 | 140.2083 | -38.1350 | 425 | 6.76 | Yes |
| **DI202302_006** | Port MacDonnell | 02/09/2023 04:28:55 | 140.2297 | -38.1501 | 460 | 6.93 | Yes |
| **DI202302_007** | Port MacDonnell | 02/09/2023 04:38:32 | 140.2506 | -38.1655 | 450 | 7.18 | Yes |
| **DI202302_008** | Port MacDonnell | 02/09/2023 04:51:52 | 140.2715 | -38.1824 | 450 | 7.17 | Yes |
| **DI202302_009** | Port MacDonnell | 02/09/2023 04:56:07 | 140.2766 | -38.1812 | 415 | 7.40 | Yes |
| **DI202302_016** | Murray | 04/09/2023 04:57:59 | 138.2259 | -37.0952 | 390 | 6.51 | No |
| **DI202302_017** | Murray | 04/09/2023 05:03:32 | 138.2287 | -37.0973 | 380 | 6.15 | No |
| **DI202302_018** | Murray | 04/09/2023 05:22:32 | 138.1967 | -37.1011 | 380 | 6.50 | No |
| **DI202302_019** | Murray | 04/09/2023 05:32:07 | 138.1953 | -37.1037 | 410 | 4.36 | No |
| **IN2023_V05_025** | Flinders | 02/07/2023 09:11:00 | -39.7698 | 148.8441 | 462 | 87 days | Yes |
| **IN2023_V05_026** | Flinders | 02/07/2023 09:55:00 | -39.8242 | 148.8370 | 414 | 87 days | Yes |

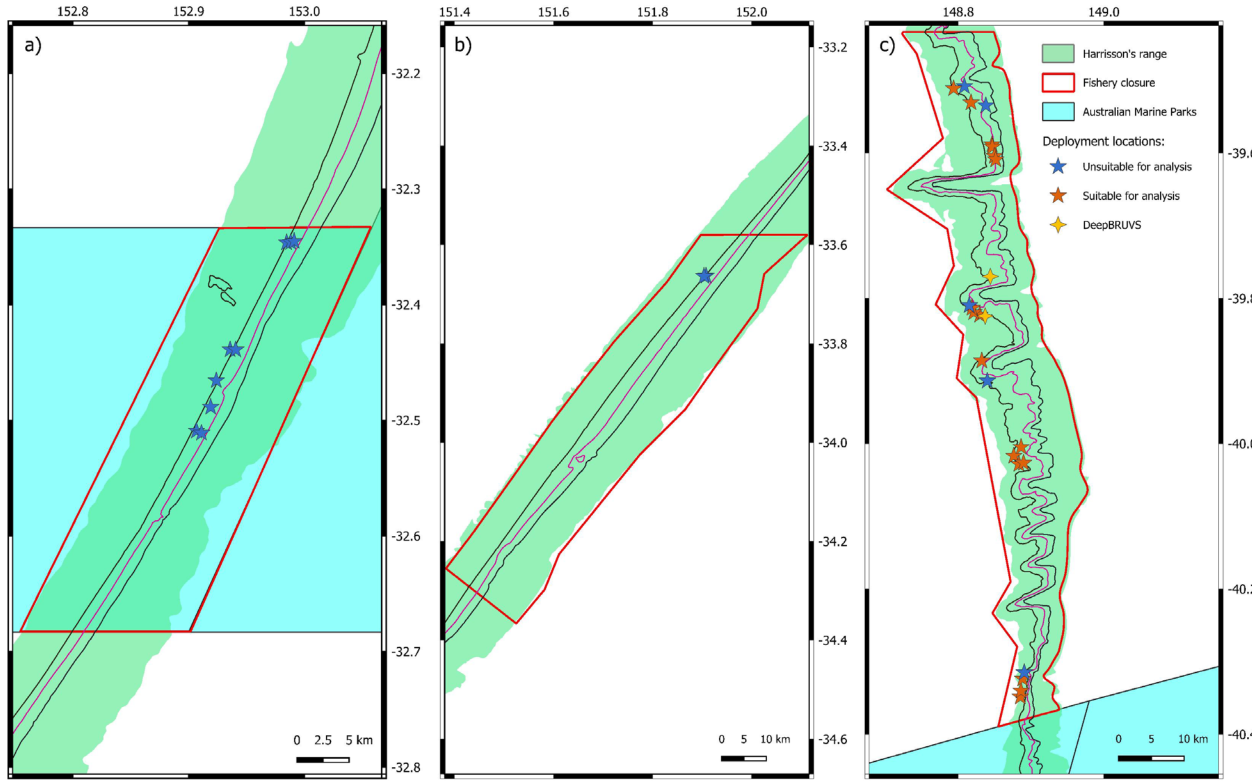


**Figure 4 Maps of the east coast reference areas showing the locations of the conventional BRUVS and Deep BRUVS operations, and their suitability for analysis at a) Hunter Reference Area, b) Endeavour Reference Area, and c) Flinders Reference Area.**

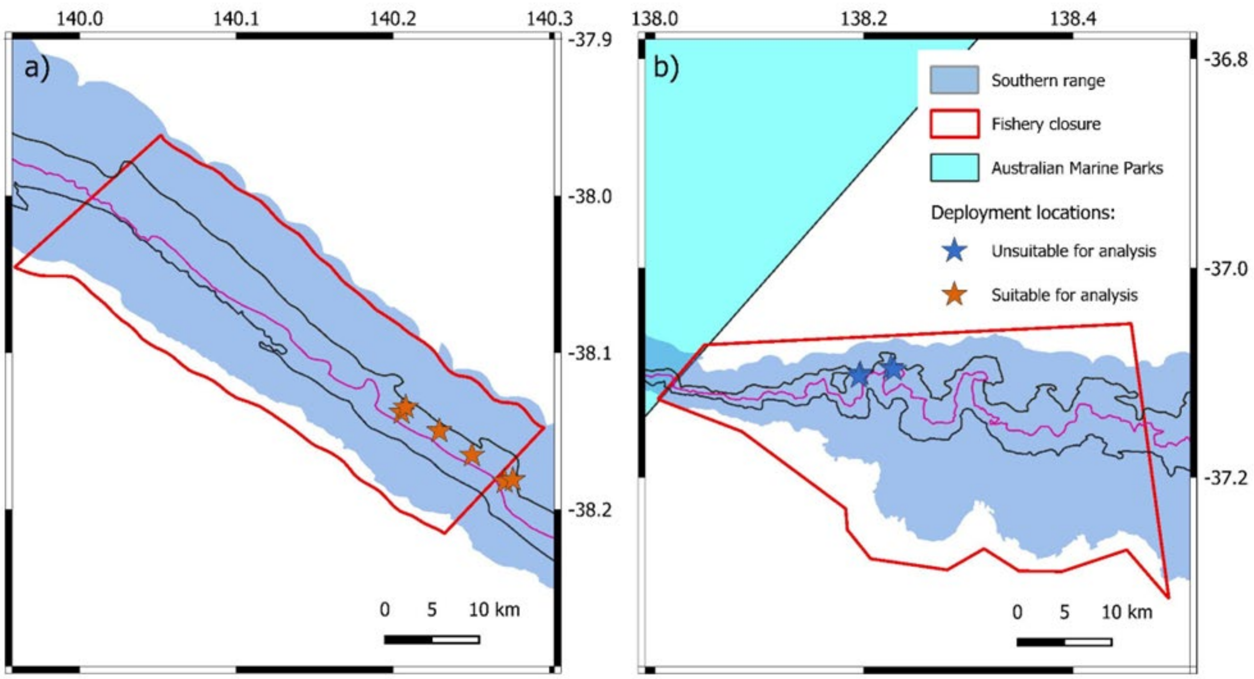


**Figure 5 Maps of the south coast reference areas showing the locations of the conventional BRUVS operations, and their suitability for analysis at a) Port MacDonnell Reference Area, and b) Murray Reference Area.**

## 3.2 Observations

### 3.2.1 Gulper shark observations

All observations of gulper sharks were counted, resulting in a total of 18 gulper sharks identified across both reference areas from the conventional and Deep BRUVS (Figure 6). Multiple individuals were observed in three of the conventional BRUVS operations at Flinders; however, the MaxN metric for this taxon never exceeded 1, and was reached within the 1st hour of deployment in 6 of 8 operations (see section 3.2.2 and Appendix Table 1 & Appendix Table 2).

At Flinders we observed 11 Harrisson's dogfish (*Centrophorus harrissoni*) (Figure 7) and one gulper shark (*Centrophorus*) only identifiable to genus level, from six of the 17 conventional BRUVS operations (Figure 6). In three of these (operations 211, 214 and 216; Table 2) multiple observations of gulpers meant there was uncertainty as to whether the same individual was counted twice. In operation 214 a total of four gulper sightings were recorded; the first two individuals sighted did had overlapping FL measurements, but the large difference in SP suggests that these observations were of two individuals (Figure 8). FL and SP length were both not overlapping between the third and fourth individuals recorded in this operation, suggesting that these were two different individuals. However, there might be a small overlap between the second and fourth gulpers (Figure 8); thus, there were at least three, possibly four individual gulpers observed in this operation. In operation 216 there was no overlap in SP length for the two individuals recorded, thus we are confident that two separate individuals were sighted, despite not having an FL measurement for individual six. The two observations from operation 211 had no overlap in DF length, confirming a count of two individuals (Figure 8). From the Deep BRUVS operations at Flinders, Harrisson's dogfish were observed in four separate recording periods on Deep BRUV1; none were seen in Deep BRUV2. Length measurements could not be obtained for Deep BRUVS due to synchronisation and frame rate errors which prevents calibration of stereo cameras.

Two observations of Southern dogfish (*Centrophorus uyato*) (Figure 9), one confirmed male, were made from two operations at Port MacDonnell from the conventional BRUVS footage (Figure 6). Length measurements were made; however, no comparison of length measurement was necessary as observations were in separate operations, therefore no uncertainty was associated with the abundance count.

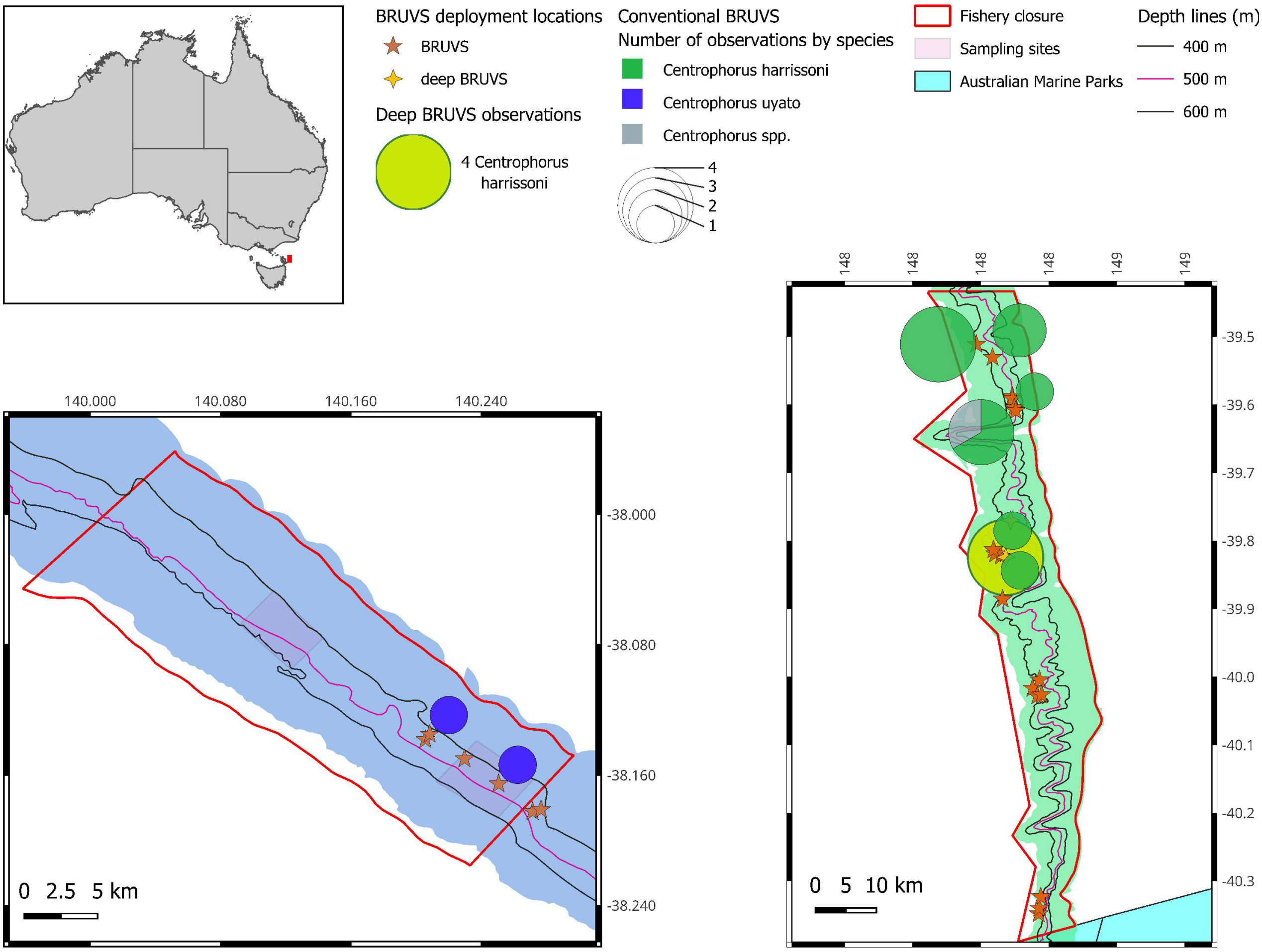


**Figure 6 Map of Port MacDonnell (left) and Flinders (right) Reference Areas, inset map of Australia displays survey locations. Gulper shark observations are depicted by circles and the number of observations by circle size, species and genus level depicted by colour.**

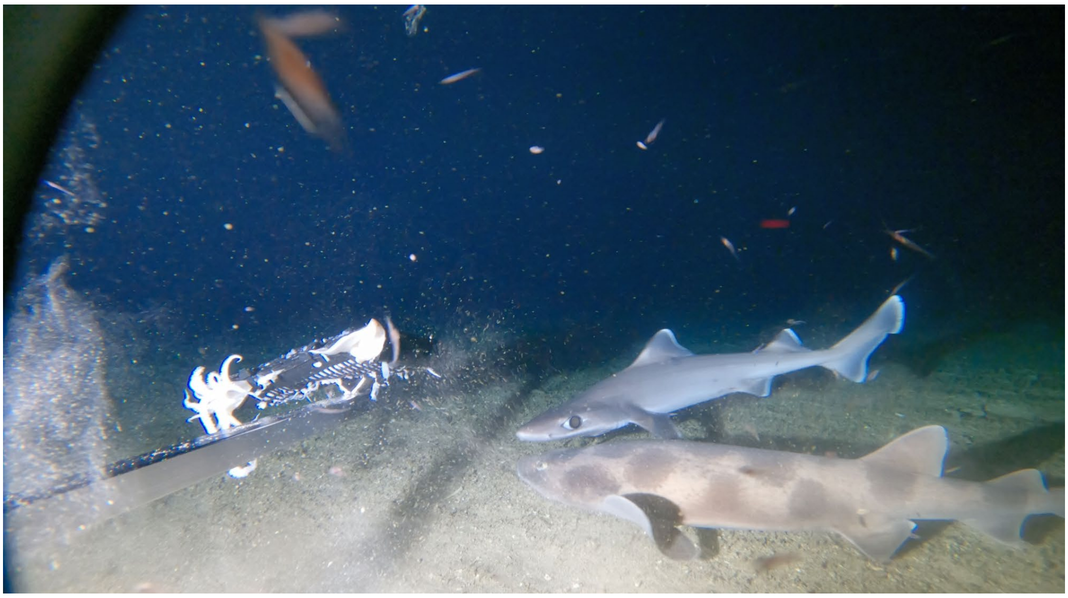

**Figure 7 example of a Harrisson's dogfish (top) observed with a whitefin swellshark (bottom) in BRUVS footage taken in the Flinders Reference Area during the survey.**

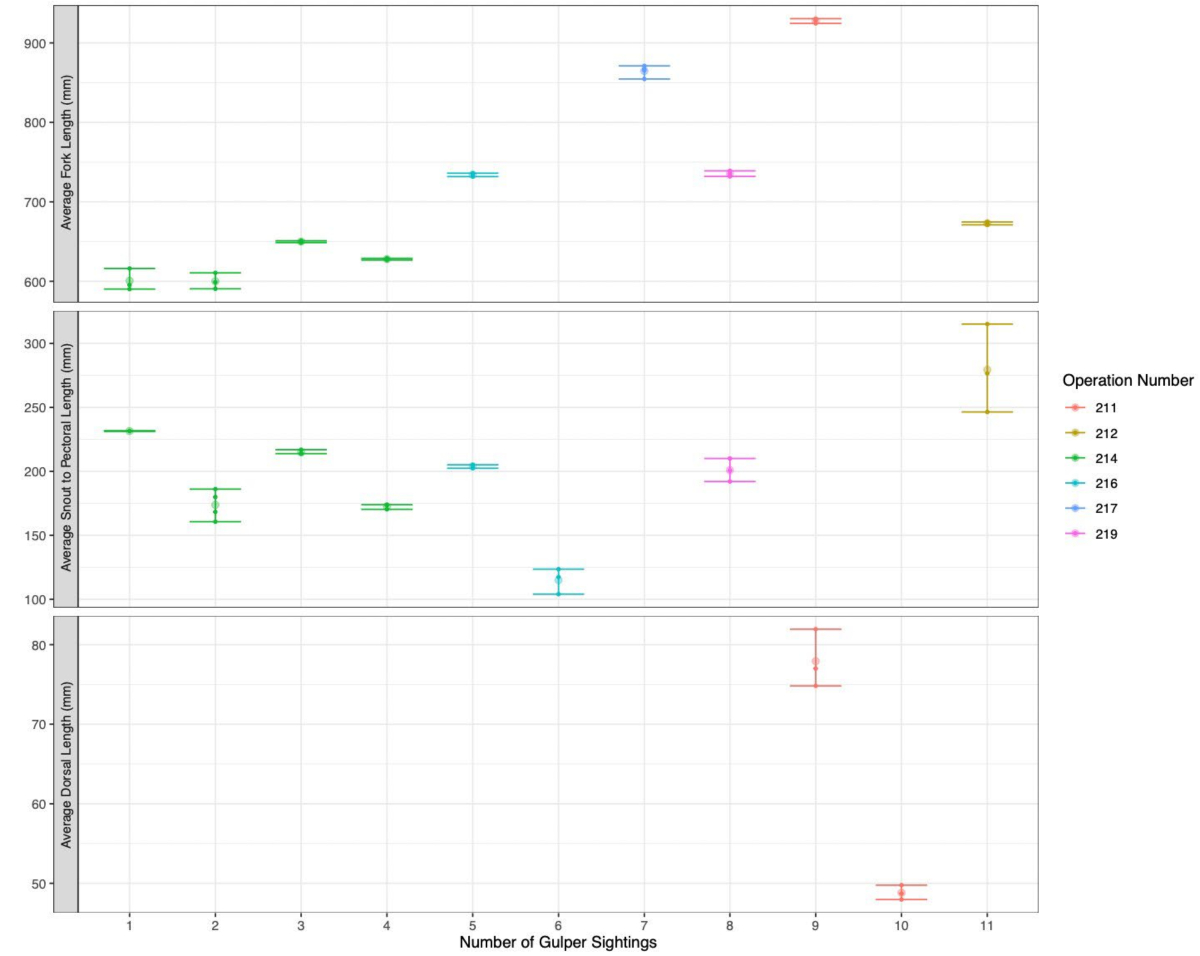


**Figure 8 Whisker plots of multiple fork, snout to pectoral and dorsal fin length (mm) measurements made of individual Harrisson's dogfish, coloured by the operation in which they were observed.**

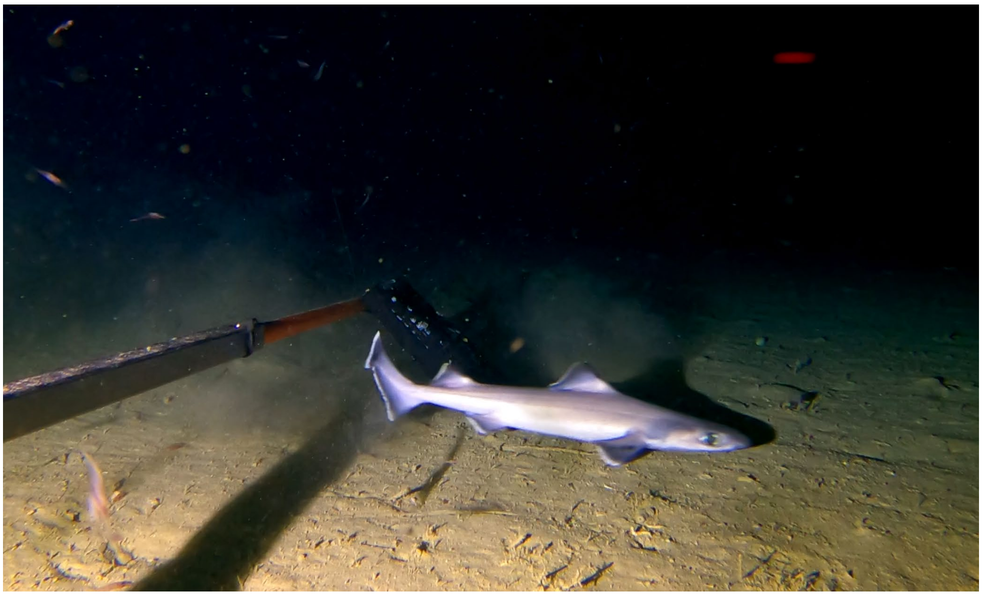

**Figure 9 Example of a Southern Dogfish observed in BRUVS footage taken in the Port MacDonnell Reference Area during the survey.**

### 3.2.2 Observations from conventional BRUVS

In total 31 taxa were observed in conventional BRUVS recordings, including 21 teleosts and 10 elasmobranchs across both reference areas; 10 of these taxa were not caught on longlines (Table 1; Figure 10). The raw annotations of MaxN by BRUVS operation are shown for the Flinders and Port MacDonnell Reference Areas in Appendix Table 1 and Appendix Table 2, respectively.

Species of interest to conservation and management that were observed from conventional BRUVS included, at Flinders: longsnout dogfish and lantern sharks (*Etmopterus* spp.) (Appendix Table 1); at Port MacDonnell: school shark (*Galeorhinus galeus*) and gummy shark (*Mustelus antarcticus*) (Appendix Table 2). Whitefin swellsharks were commonly observed at both reference areas (Appendix Table 1 & Appendix Table 2).

As mentioned in the methods, MaxN was recorded consistently for the first hour for all taxa, while for elasmobranchs (including gulpers) MaxN was recorded for both, the first hour and the entire duration of BRUVS operations. To report standardised results, we constrained the data below to occurrence and MaxN of taxa observed during first hour of BRUVS deployments.

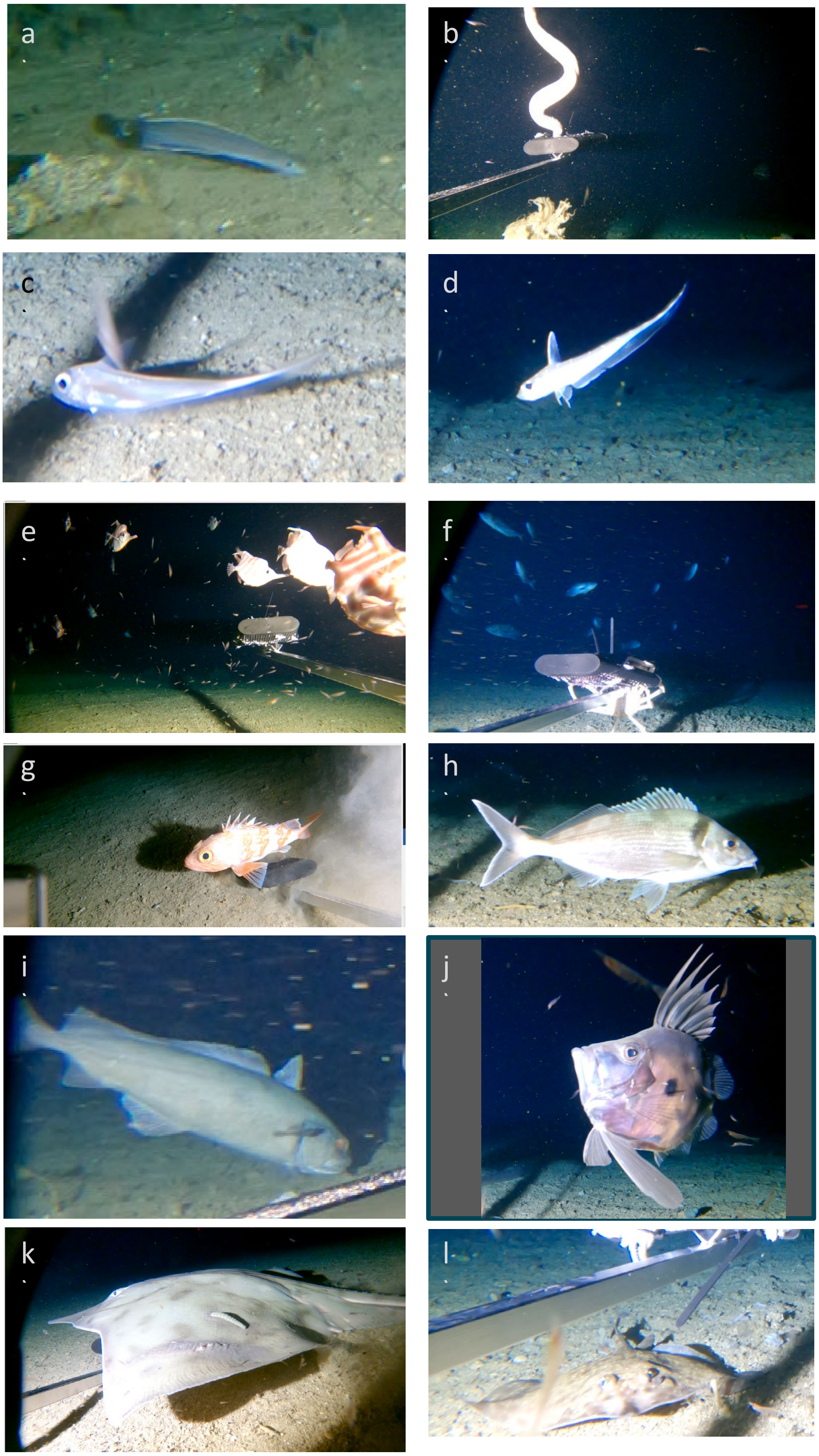


**Figure 10 Frame grabs showing a selection of the annotation taxa observed in conventional BRIUVS.** a) Eel (*Bassanago* spp), b) Hagfish (*Eptatretus* sp.), c) & d) Whiptails (Macrouridae), e) Bellows fish (*Centriscops humerosus ),* f) Silver warehou (*Seriolella punctata*), g) ocean perch (*Helicolenus* spp.), h) Morwong (*Nemadactylus macropterus*), i) Ribaldo (*Mora moro*), j) Dory (Zenopsis nebulosa), k) skate (*Dipturus* sp.), l) skate (*Dentiraja cerva*)

### Occurrences in the first hour of deployment

Within the first hour of the BRUVS deployments, gulper sharks were observed at both reference areas. They were present in five of 17 operations (29%) at Flinders and in one of six operations (16.5%) at Port MacDonnell (Figure 11).

Other taxa observed in the first hour of the conventional BRUVS recordings included 17 teleost and six elasmobranchs (Figure 11). A total of 23 taxa (16 teleosts and six elasmobranchs) were observed in Flinders, while 13 taxa (10 teleosts and three elasmobranchs) were recorded at Port MacDonnell. Berycidae were only recorded in the Port MacDonnell Reference Area. Of the 12 taxa that occurred across both reference areas, whiptails (*Macrouridae* spp.) were recorded in the first hour of every operation at both survey sites. The other most commonly occurring taxa in Flinders were bellows fish (*Centriscops humerosus* & *Macroramphosus scolopax*), ocean perch (*Helicolenus spp.*), and the whitefin swellshark (*Cephaloscyllium albipinnum*) which were present in 82%, 64% and 58% of operations, respectively. At Port MacDonnell spurdog sharks (*Squalus* spp.) were observed in 66% of all BRUVS operations, while bellows fish, pink ling (*Gentypterus blacodes*), and silver warehou (*Seriolella punctata*) were present in half of the operations (Figure 11). The taxa observed in a single operation at Flinders were eel-like fishes, gemfish (*Rexea solandri*), hagfish (*Eptatretus* spp.), morwong (*Nemadactylus macropterus)*, longsnout dogfish (*Deania quadrispinosa*), ribaldo (*Mora mora*) and spurdog sharks; at Port MacDonnell Berycidae, eels, ocean perch, whitefin swellsharks and trevalla (*Hyperoglyphe antarctica*) were the rarest taxa observed.

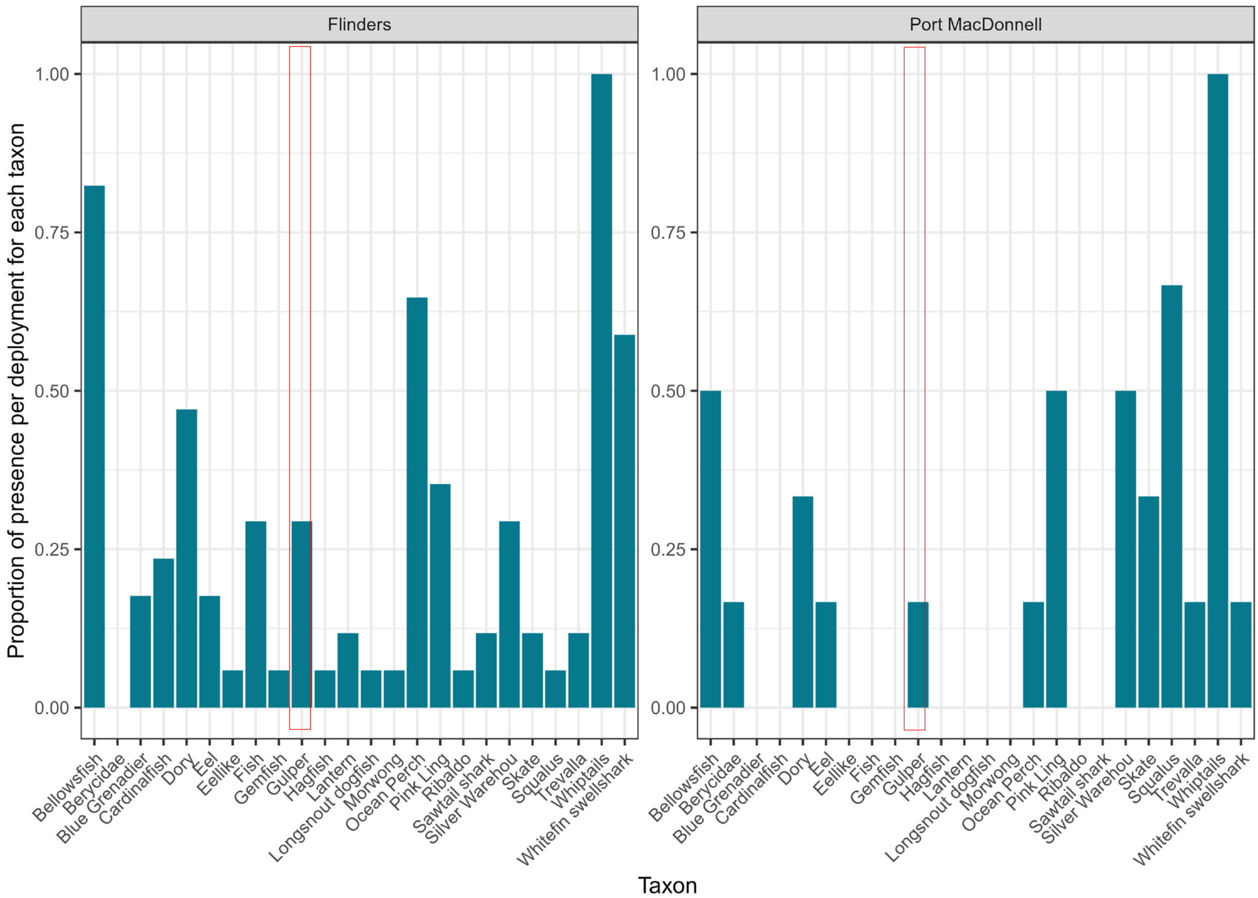


**Figure 11 Bar charts displaying the proportion of occurrence of annotation taxa over valid BRUVS operations, within the first hour of deployment, at Flinders and Port MacDonnell Reference Areas (n = 17 Flinders; n = 6 Port MacDonnell). Gulpers are highlighted with a red box.**

## Average MaxN

Gulper shark MaxN within an operation never exceeded 1; this resulted in an average MaxN across all successful operations of 0.29 at Flinders and 0.16 at Port MacDonnell (Figure 12).

MaxN for any taxon within an operation in our surveys was rarely greater than two. The exceptions to this are silver warehou that were observed in large schools (max 45), Bellows fish (18), whiptails (seven), ocean perch (six) and dory (seven). Whitefin swellshark was the only elasmobranch seen at MaxN >2 (with a maximum of five seen during the first hour).

Here we report the average MaxN over the number of successful operations in each reference area, to account for the uneven numbers of successful operations. In both reference areas silver warehou had the highest average MaxN and were more abundant at Flinders (avg. MaxN = 5.2) than Port MacDonnell (avg. MaxN = 3.1) (Figure 12). The whitefin swellshark was the most abundant elasmobranch at Flinders, with an average MaxN of 1.5, while spurdogs were the most abundant elasmobranch taxon at Port MacDonnell, with an average MaxN of 0.6 individuals (Figure 12).

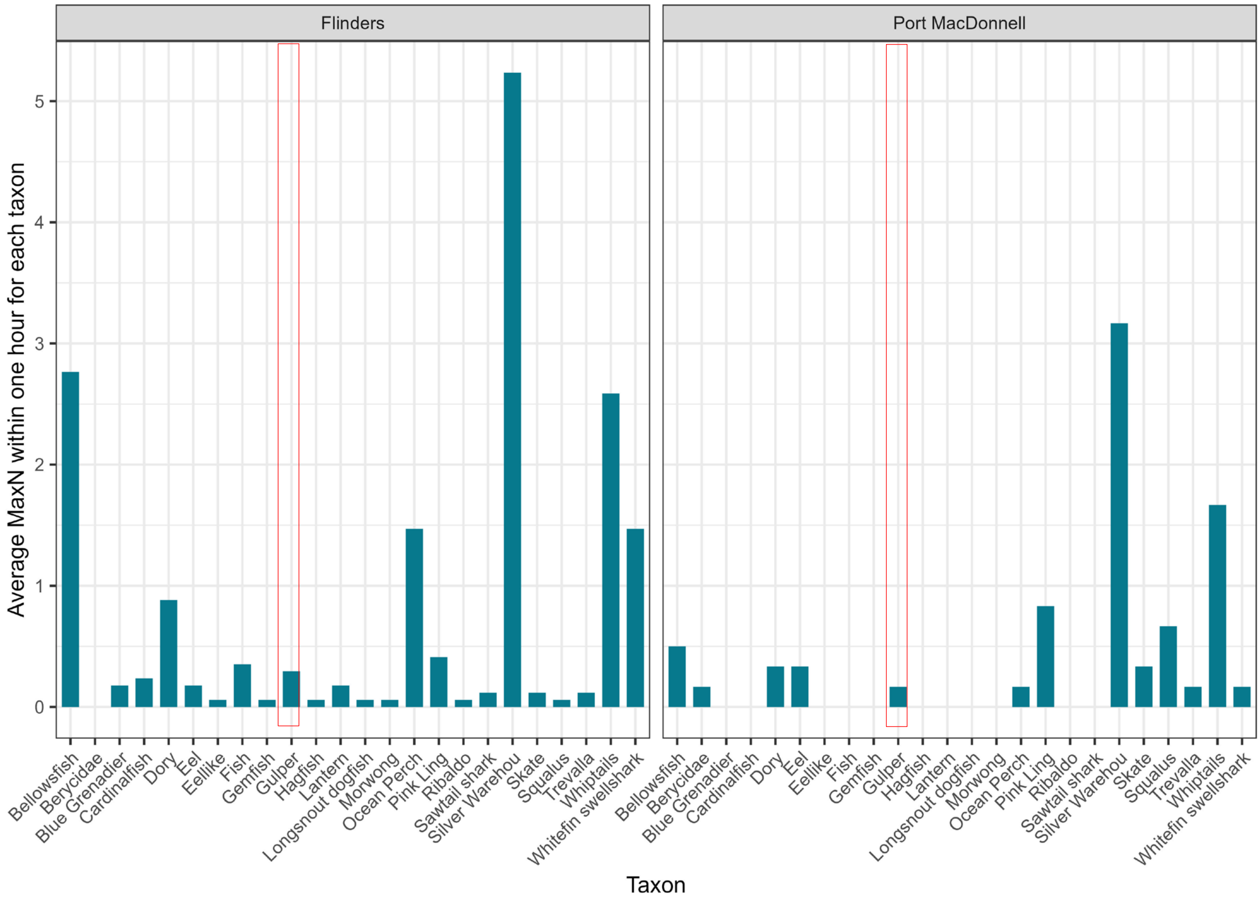


**Figure 12 Bar charts displaying the average MaxN for each taxon within the first hour of valid BRUVS operations at Flinders and Port MacDonnell Reference Areas (n = 17 Flinders; n = 6 Port MacDonnell). Gulpers are highlighted with a red box.**

## Additional observations beyond the 1st hour

Some taxa were only observed after the first hour of the operation; these were noted, but not included in the standardised data plots shown above. At the Flinders Reference Area, we observed three fish and two elasmobranch taxa: frostfish (*Lepidopus caudatus*), hapuku (*Polyprion oxygeneios*), sunfish (*Mola* spp.), sharpnose sevengill shark (*Heptranchias perlo*), and a shark identifiable only to the family Hexanchidae (Figure 13; Table 1). At Port MacDonnell, gemfish (*Rexea solandri*) and two shark species, gummy shark (*Mustelus antarcticus*) and school shark (*Galeorhinus galeus*) were observed only after the first hour (Figure 13; Table 1). All other species were identified within the first hour in at least one operation, however many elasmobranchs were noted at higher MaxN after the first hour had elapsed (the raw data is shown in Appendix Table 1 & Appendix Table 2).

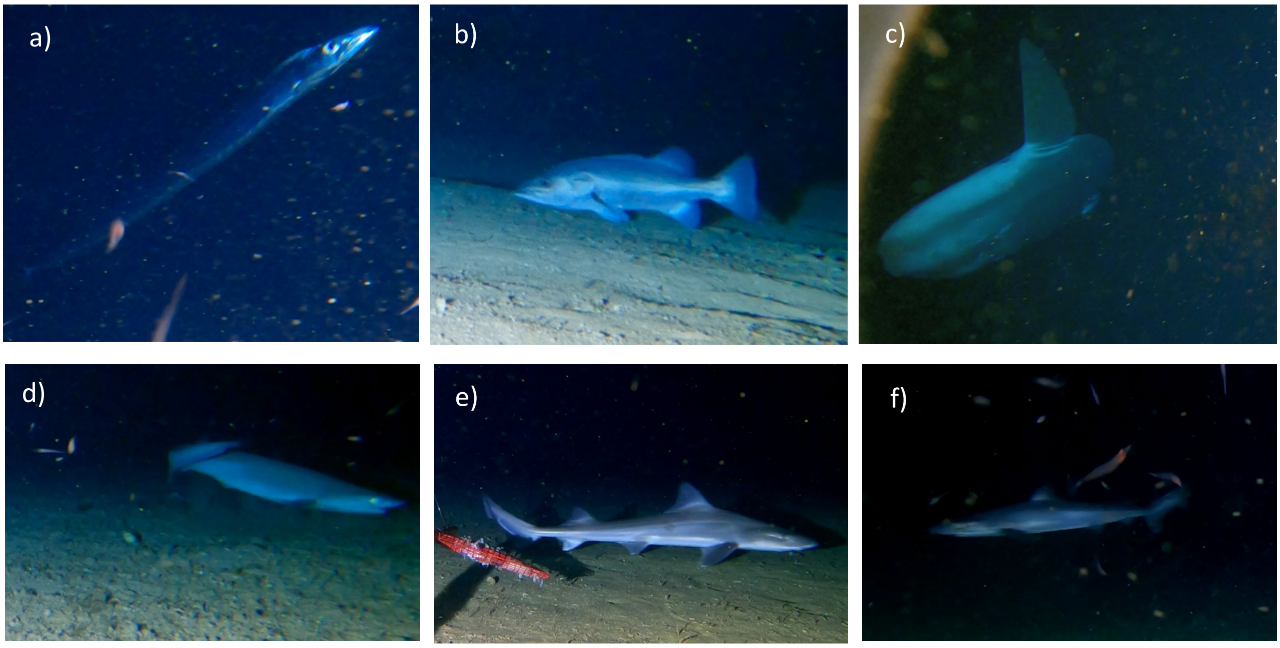


**Figure 13 Additional observations after the standard 1-hour MaxN annotation period (a) frostfish (*Lepidopus caudatus*), (b) hapuku (*Polyprion oxygeneios*), (c) sunfish (*Mola* spp.), (d) sharpnose sevengill (*Heptranchias perlo*), (e) gummy shark (*Mustelus antarcticus*), (f) school shark (Galeorhinus galeus).**

### 3.2.3 Observations from Deep BRUVS

Gulpers (*C. harrissoni*) were present in 17% of the 24 recording periods from Deep BRUV1 and no gulper sharks were observed from Deep BRUV2. Two of the gulpers that were observed were recorded within 10 seconds of the light turning on, and the other two were observed within 6.5 minutes and 2.5 minutes of the light turning on, in all instances the gulpers did not return to the frame within the same recording period.

Silver warehou were the most common taxa observed, being present in 91% of the 30 min recording periods from Deep BRUV1 followed by whiptails (87%) (Figure 14). This trend was reversed for Deep BRUV2, where whiptails were the most common taxa observed, being present in 91% of the 60 min recording periods, followed by silver warehou (83%). Chimaeras (*Chimaeridae* spp.; Figure 15) which were not recorded by the conventional BRUVS, were the most common elasmobranch seen in Deep BRUV1 recordings (20%; Figure 14). The whitefin swellshark was most common in the longer recording period of Deep BRUV2 (21%; Figure 14).

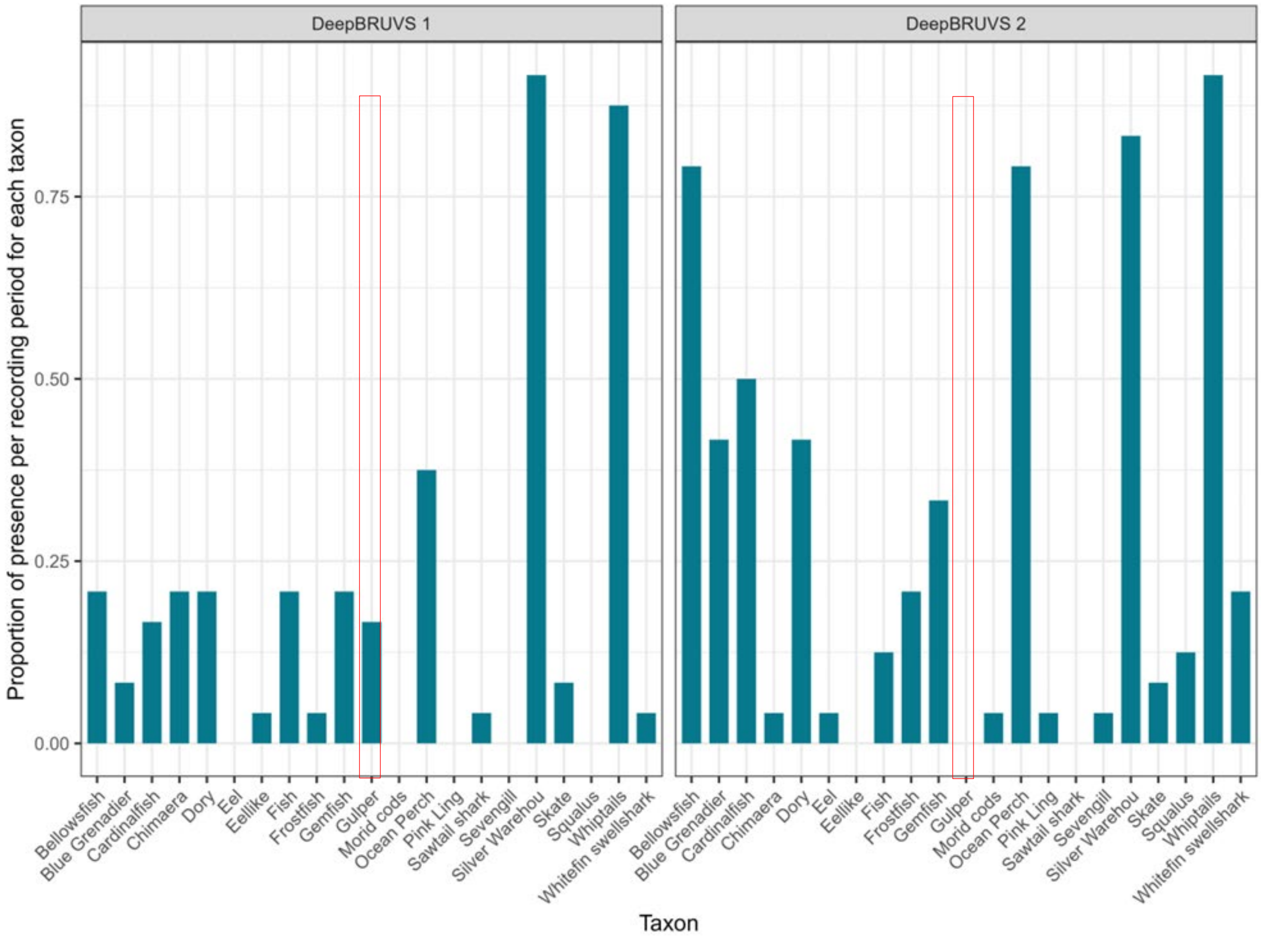


**Figure 14 Bar Charts displaying the proportion of presence per recording period (n=24) for each taxon imaged by Deep BRUV1 (30 min) and Deep BRUV2 (60 min). Gulpers are highlighted with a red box.**

**Figure 15 Example of a Chimaera observed in Deep BRUV1 footage taken in the Flinders Reference Area.**

### 3.2.4 Whitefin swell sharks – IUCN red list

The whitefin swellshark (*Cephaloscyllium albipinnum*) is listed on the IUCN Red List. In 2019 the listing for this species was changed from "near threatened" to "critically endangered" (Pardo et al., 2019). This listing evaluation is partially based on Graham et al. (2001) who documented the species decline in south-east Australia's trawl grounds; over the past three generations, it was estimated that the species population had undergone a reduction of greater than 80%. Pardo et al. (2019) acknowledge that the fishery closures intended for gulper sharks have the potential to benefit the population, although, this has not been assessed.

We consistently observed whitefin swellsharks in BRUVS footage from both reference areas, and they were the most abundant elasmobranch within the first hour at Flinders (Figure 12). Interestingly, this species was observed in higher numbers after the first hour had elapsed, in seven of the 11 operations where whitefin swellsharks were observed within the first hour, and in an additional seven operations (Flinders: 2, Port MacDonnell: 5) where they were absent in the first hour. When considering the entire deployment time (i.e. total time), whitefin swellshark was the most abundant elasmobranch observed. These sharks were recorded in 70% of operations in the Flinders Reference Area, with an average whole-operation MaxN of more than two individuals per operation (mean = 2.2, range = 1 to 7). At Port MacDonnell they were observed in all operations, with an average MaxN greater than three individuals per operation (mean = 3.6, range = 3 to 5). The largest MaxN, of seven, was the greatest for any elasmobranch recorded in our study (Figure 16). Our data show that this species is suited for observation using BRUVS and is abundant in the two AFMA Gulper Shark closures where we had successful BRUVS operations.

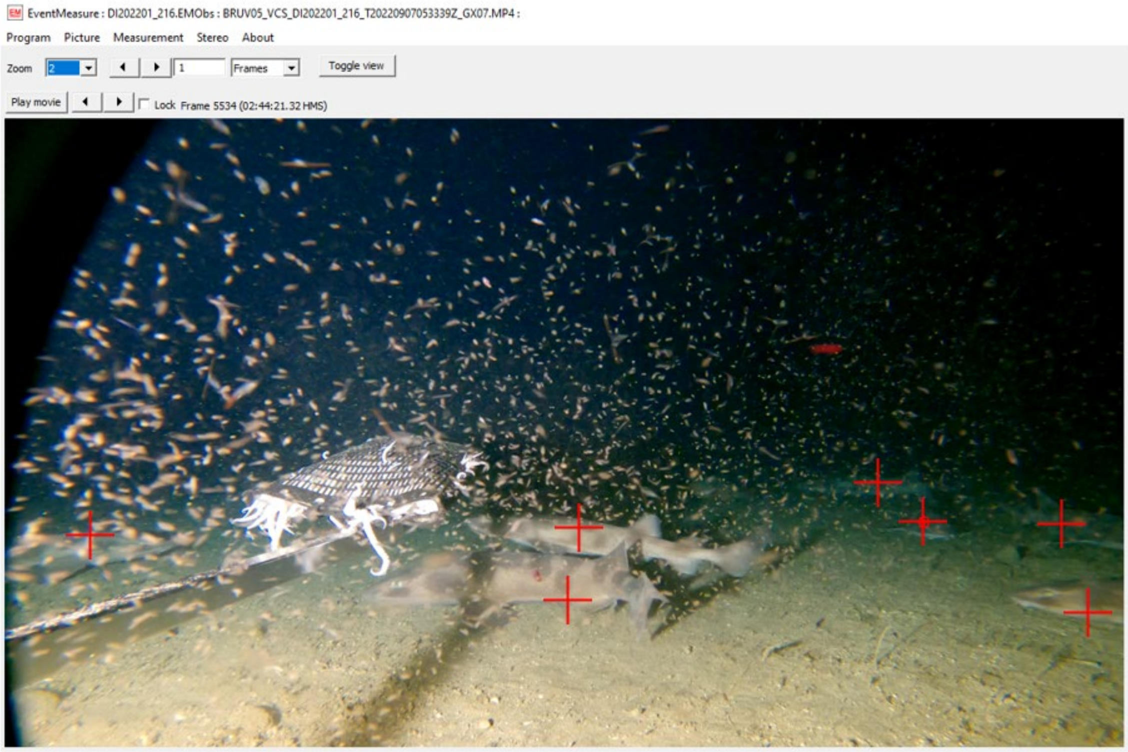


**Figure 16 Example of BRUVS footage showing a MaxN of seven whitefin swellshark in operation 216 at Flinders Reference Area. The individuals are marked with red crosses.**

# 4 BRUVS for gulper monitoring

The use of conventional BRUVS was identified as an integral part of the monitoring design implemented, based on the recommendations from two stakeholder workshops (Williams et al., 2018). They were to be used in parallel with hook-and-line fishing, to enable further study and refinement of this non-extractive technique.

Our field program demonstrated that there were significant operational challenges in using conventional BRUVS units in certain conditions (e.g. current and swell). BRUVS operations were successful in collecting data suitable for analysis from only two of the five surveyed reference areas – Flinders and Port MacDonnell, with between two and six operations per day. In the other reference areas the units tended to bounce on the seafloor in high wind and swell conditions, and strong winds, tides and currents caused the movement of BRUVS units (vertically and horizontally) along the seafloor. It is likely that engineering (e.g. the addition of platform legs which would anchor the unit), and operational refinements (e.g. a longer surface rope and more weight) would increase the likelihood of successful operations in the future.

Results from conventional and Deep BRUVS analysis show that while gulpers are observed in video (presence) from both baited and unbaited platforms, they are present in far lower numbers (greatest MaxN = 1) compared with longline catches. This means that many more BRUVS operations (100s) would be needed to collect the data necessary to assess the abundance of gulper sharks in future monitoring surveys.

The use of Deep BRUVS enables the collection of temporal data from a single sampling location. The lack of a surface tether (i.e. float and rope) meant that the Deep BRUVS were not affected by surface or current conditions and remained in place throughout the deployment period.

**Figure 17 Example of footage from the stereo cameras when the BRUVS unit is bouncing, stirring up sediments with the bait arm. (starboard camera image on the left, port camera image on the right)**

# Appendix

**Appendix Table 1 MaxN observation data at Flinders Reference Area showing MaxN recorded in the first hour of deployment and the MaxN over the whole duration of the operation**

| TaxGrp | Taxon | Operation | MaxN 1hr | MaxN (operation) |
|---|---|---|---|---|
| **Shark** | **Gulper** | **DI202201_211** | **1** | **1** |
| **Shark** | **Gulper** | **DI202201_212** | **1** | **1** |
| **Shark** | **Gulper** | **DI202201_214** | **1** | **1** |
| **Shark** | **Gulper** | **DI202201_216** | **1** | **1** |
| **Shark** | **Gulper** | **DI202201_219** | **1** | **1** |
| **Shark** | **Gulper** | **DI202201_217** | **0** | **1** |
| Eellike | Eel | DI202201_210 | 1 | 1 |
| Eellike | Eel | DI202201_211 | 1 | 1 |
| Eellike | Eel | DI202201_217 | 1 | 1 |
| Eellike | Eellike | DI202201_219 | 1 | 1 |
| Eellike | Eellike | DI202201_202 | 0 | 1 |
| Eellike | Hagfish | DI202201_212 | 1 | 1 |
| Eellike | Hagfish | DI202201_211 | 0 | 1 |
| Fish | Bellowsfish | DI202201_206 | 1 | 1 |
| Fish | Bellowsfish | DI202201_209 | 1 | 1 |
| Fish | Bellowsfish | DI202201_212 | 1 | 1 |
| Fish | Bellowsfish | DI202201_216 | 1 | 1 |
| Fish | Bellowsfish | DI202201_217 | 1 | 1 |
| Fish | Bellowsfish | DI202201_218 | 1 | 1 |
| Fish | Bellowsfish | DI202201_203 | 0 | 1 |
| Fish | Bellowsfish | DI202201_211 | 2 | 2 |
| Fish | Bellowsfish | DI202201_214 | 2 | 2 |
| Fish | Bellowsfish | DI202201_222 | 2 | 2 |
| Fish | Bellowsfish | DI202201_219 | 2 | 3 |
| Fish | Bellowsfish | DI202201_201 | 4 | 4 |
| Fish | Bellowsfish | DI202201_210 | 4 | 4 |
| Fish | Bellowsfish | DI202201_205 | 7 | 7 |
| Fish | Bellowsfish | DI202201_208 | 18 | 18 |
| Fish | Blue Grenadier | DI202201_202 | 1 | 1 |
| Fish | Blue Grenadier | DI202201_214 | 1 | 1 |
| Fish | Blue Grenadier | DI202201_216 | 1 | 1 |
| Fish | Cardinalfish | DI202201_205 | 1 | 1 |
| Fish | Cardinalfish | DI202201_206 | 1 | 1 |
| Fish | Cardinalfish | DI202201_208 | 1 | 1 |

| TaxGrp | Taxon | Operation | MaxN 1hr | MaxN (operation) |
|---|---|---|---|---|
| Fish | Cardinalfish | DI202201_217 | 1 | 1 |
| Fish | Cardinalfish | DI202201_203 | 0 | 1 |
| Fish | Cardinalfish | DI202201_216 | 0 | 1 |
| Fish | Cardinalfish | DI202201_218 | 0 | 1 |
| Fish | Cardinalfish | DI202201_201 | 0 | 2 |
| Fish | Dory | DI202201_201 | 1 | 1 |
| Fish | Dory | DI202201_202 | 1 | 1 |
| Fish | Dory | DI202201_205 | 1 | 1 |
| Fish | Dory | DI202201_206 | 1 | 1 |
| Fish | Dory | DI202201_214 | 1 | 1 |
| Fish | Dory | DI202201_222 | 1 | 1 |
| Fish | Dory | DI202201_216 | 0 | 1 |
| Fish | Dory | DI202201_218 | 0 | 1 |
| Fish | Dory | DI202201_207 | 2 | 2 |
| Fish | Dory | DI202201_203 | 7 | 7 |
| Fish | Fish | DI202201_201 | 1 | 1 |
| Fish | Fish | DI202201_202 | 1 | 1 |
| Fish | Fish | DI202201_206 | 1 | 1 |
| Fish | Fish | DI202201_218 | 1 | 1 |
| Fish | Fish | DI202201_207 | 0 | 1 |
| Fish | Fish | DI202201_211 | 0 | 1 |
| Fish | Fish | DI202201_208 | 2 | 2 |
| Fish | Frostfish | DI202201_214 | 0 | 1 |
| Fish | Frostfish | DI202201_216 | 0 | 1 |
| Fish | Gemfish | DI202201_208 | 1 | 1 |
| Fish | Gemfish | DI202201_210 | 0 | 1 |
| Fish | Gemfish | DI202201_214 | 0 | 1 |
| Fish | Gemfish | DI202201_216 | 0 | 1 |
| Fish | Gemfish | DI202201_217 | 0 | 1 |
| Fish | Gemfish | DI202201_219 | 0 | 1 |
| Fish | Hapuku | DI202201_218 | 0 | 1 |
| Fish | Mola | DI202201_218 | 0 | 1 |
| Fish | Morwong | DI202201_203 | 1 | 3 |
| Fish | Ocean Perch | DI202201_207 | 1 | 1 |
| Fish | Ocean Perch | DI202201_203 | 0 | 1 |
| Fish | Ocean Perch | DI202201_205 | 0 | 1 |
| Fish | Ocean Perch | DI202201_222 | 0 | 1 |
| Fish | Ocean Perch | DI202201_202 | 2 | 2 |
| Fish | Ocean Perch | DI202201_206 | 1 | 2 |
| Fish | Ocean Perch | DI202201_217 | 1 | 2 |

| TaxGrp | Taxon | Operation | MaxN 1hr | MaxN (operation) |
|---|---|---|---|---|
| Fish | Ocean Perch | DI202201_214 | 2 | 3 |
| Fish | Ocean Perch | DI202201_219 | 3 | 3 |
| Fish | Ocean Perch | DI202201_209 | 1 | 4 |
| Fish | Ocean Perch | DI202201_211 | 1 | 4 |
| Fish | Ocean Perch | DI202201_210 | 5 | 5 |
| Fish | Ocean Perch | DI202201_212 | 2 | 5 |
| Fish | Ocean Perch | DI202201_216 | 6 | 8 |
| Fish | Pink Ling | DI202201_206 | 1 | 1 |
| Fish | Pink Ling | DI202201_207 | 1 | 1 |
| Fish | Pink Ling | DI202201_214 | 1 | 1 |
| Fish | Pink Ling | DI202201_222 | 1 | 1 |
| Fish | Pink Ling | DI202201_203 | 0 | 1 |
| Fish | Pink Ling | DI202201_205 | 0 | 1 |
| Fish | Pink Ling | DI202201_210 | 0 | 1 |
| Fish | Pink Ling | DI202201_211 | 0 | 1 |
| Fish | Pink Ling | DI202201_216 | 0 | 1 |
| Fish | Pink Ling | DI202201_209 | 2 | 2 |
| Fish | Pink Ling | DI202201_212 | 1 | 2 |
| Fish | Ribaldo | DI202201_212 | 1 | 1 |
| Fish | Ribaldo | DI202201_209 | 0 | 1 |
| Fish | Ribaldo | DI202201_211 | 0 | 1 |
| Fish | Silver Warehou | DI202201_206 | 1 | 1 |
| Fish | Silver Warehou | DI202201_222 | 2 | 2 |
| Fish | Silver Warehou | DI202201_211 | 0 | 4 |
| Fish | Silver Warehou | DI202201_212 | 0 | 15 |
| Fish | Silver Warehou | DI202201_207 | 0 | 16 |
| Fish | Silver Warehou | DI202201_214 | 1 | 24 |
| Fish | Silver Warehou | DI202201_216 | 40 | 40 |
| Fish | Silver Warehou | DI202201_209 | 45 | 45 |
| Fish | Trevalla | DI202201_209 | 1 | 1 |
| Fish | Trevalla | DI202201_219 | 1 | 1 |
| Fish | Trevalla | DI202201_217 | 0 | 1 |
| Fish | Whiptails | DI202201_209 | 1 | 1 |
| Fish | Whiptails | DI202201_210 | 1 | 1 |
| Fish | Whiptails | DI202201_214 | 1 | 1 |
| Fish | Whiptails | DI202201_217 | 1 | 1 |
| Fish | Whiptails | DI202201_218 | 1 | 1 |
| Fish | Whiptails | DI202201_219 | 1 | 1 |
| Fish | Whiptails | DI202201_222 | 1 | 1 |
| Fish | Whiptails | DI202201_203 | 2 | 2 |

| TaxGrp | Taxon | Operation | MaxN 1hr | MaxN (operation) |
|---|---|---|---|---|
| Fish | Whiptails | DI202201_207 | 2 | 2 |
| Fish | Whiptails | DI202201_208 | 2 | 2 |
| Fish | Whiptails | DI202201_216 | 2 | 2 |
| Fish | Whiptails | DI202201_205 | 3 | 3 |
| Fish | Whiptails | DI202201_211 | 3 | 3 |
| Fish | Whiptails | DI202201_212 | 3 | 3 |
| Fish | Whiptails | DI202201_202 | 6 | 6 |
| Fish | Whiptails | DI202201_201 | 7 | 7 |
| Fish | Whiptails | DI202201_206 | 7 | 7 |
| Shark | Lantern | DI202201_218 | 1 | 1 |
| Shark | Lantern | DI202201_222 | 2 | 2 |
| Shark | Longsnout dogfish | DI202201_209 | 1 | 1 |
| Shark | Sawtail shark | DI202201_203 | 1 | 1 |
| Shark | Sawtail shark | DI202201_208 | 1 | 1 |
| Shark | Sawtail shark | DI202201_214 | 0 | 1 |
| Shark | Sawtail shark | DI202201_217 | 0 | 1 |
| Shark | Sevengill | DI202201_217 | 0 | 1 |
| Shark | Hexanchidae | DI202201_210 | 0 | 1 |
| Shark | Squalus | DI202201_203 | 1 | 1 |
| Shark | Squalus | DI202201_206 | 0 | 1 |
| Shark | Squalus | DI202201_207 | 0 | 1 |
| Shark | Squalus | DI202201_214 | 0 | 1 |
| Shark | Squalus | DI202201_222 | 0 | 1 |
| Shark | Whitefin swellshark | DI202201_208 | 1 | 1 |
| Shark | Whitefin swellshark | DI202201_212 | 1 | 1 |
| Shark | Whitefin swellshark | DI202201_222 | 2 | 2 |
| Shark | Whitefin swellshark | DI202201_205 | 0 | 2 |
| Shark | Whitefin swellshark | DI202201_211 | 0 | 2 |
| Shark | Whitefin swellshark | DI202201_209 | 2 | 3 |
| Shark | Whitefin swellshark | DI202201_210 | 3 | 3 |
| Shark | Whitefin swellshark | DI202201_217 | 1 | 4 |
| Shark | Whitefin swellshark | DI202201_218 | 3 | 4 |
| Shark | Whitefin swellshark | DI202201_214 | 4 | 5 |
| Shark | Whitefin swellshark | DI202201_219 | 3 | 5 |
| Shark | Whitefin swellshark | DI202201_216 | 5 | 7 |
| Skate | Skate | DI202201_203 | 1 | 1 |
| Skate | Skate | DI202201_205 | 1 | 1 |
| Skate | Skate | DI202201_207 | 0 | 1 |
| Skate | Skate | DI202201_214 | 0 | 1 |

**Appendix Table 2 MaxN observation data at Port MacDonnell Reference Area showing MaxN recorded in the first hour of deployment and the MaxN over the whole duration of the operation**

| TaxGrp | Taxon | Operation | MaxN1hr | MaxN (operation) |
|---|---|---|---|---|
| **Shark** | **Gulper** | **DI202302_007** | **1** | **1** |
| **Shark** | **Gulper** | **DI202302_005** | **0** | **1** |
| Eellike | Eel | DI202302_004 | 0 | 1 |
| Eellike | Eel | DI202302_008 | 0 | 1 |
| Eellike | Eel | DI202302_006 | 2 | 2 |
| Fish | Bellowsfish | DI202302_004 | 1 | 1 |
| Fish | Bellowsfish | DI202302_007 | 1 | 1 |
| Fish | Bellowsfish | DI202302_009 | 1 | 1 |
| Fish | Berycidae | DI202302_006 | 1 | 1 |
| Fish | Dory | DI202302_005 | 1 | 1 |
| Fish | Dory | DI202302_009 | 1 | 1 |
| Fish | Gemfish | DI202302_004 | 0 | 1 |
| Fish | Gemfish | DI202302_007 | 0 | 1 |
| Fish | Ocean Perch | DI202302_007 | 1 | 1 |
| Fish | Pink Ling | DI202302_006 | 1 | 1 |
| Fish | Pink Ling | DI202302_007 | 1 | 1 |
| Fish | Pink Ling | DI202302_004 | 0 | 1 |
| Fish | Pink Ling | DI202302_009 | 3 | 3 |
| Fish | Silver Warehou | DI202302_004 | 2 | 2 |
| Fish | Silver Warehou | DI202302_008 | 2 | 2 |
| Fish | Silver Warehou | DI202302_005 | 15 | 15 |
| Fish | Trevalla | DI202302_006 | 1 | 1 |
| Fish | Whiptails | DI202302_004 | 1 | 1 |
| Fish | Whiptails | DI202302_006 | 1 | 1 |
| Fish | Whiptails | DI202302_007 | 1 | 1 |
| Fish | Whiptails | DI202302_008 | 1 | 1 |
| Fish | Whiptails | DI202302_009 | 2 | 2 |
| Fish | Whiptails | DI202302_005 | 4 | 4 |
| Shark | Gummy | DI202302_005 | 0 | 1 |
| Shark | School | DI202302_007 | 0 | 1 |
| Shark | Squalus | DI202302_006 | 1 | 1 |
| Shark | Squalus | DI202302_007 | 1 | 1 |
| Shark | Squalus | DI202302_009 | 1 | 1 |
| Shark | Squalus | DI202302_004 | 0 | 2 |
| Shark | Squalus | DI202302_008 | 0 | 2 |
| Shark | Squalus | DI202302_005 | 1 | 4 |
| Shark | Whitefin swellshark | DI202302_004 | 0 | 2 |
| Shark | Whitefin swellshark | DI202302_006 | 0 | 3 |

| TaxGrp | Taxon | Operation | MaxN1hr | MaxN (operation) |
|---|---|---|---|---|
| Shark | Whitefin swellshark | DI202302_005 | 1 | 4 |
| Shark | Whitefin swellshark | DI202302_007 | 0 | 4 |
| Shark | Whitefin swellshark | DI202302_008 | 0 | 4 |
| Shark | Whitefin swellshark | DI202302_009 | 0 | 5 |
| Skate | Skate | DI202302_004 | 1 | 1 |
| Skate | Skate | DI202302_005 | 1 | 1 |
| Skate | Skate | DI202302_007 | 0 | 1 |
| Skate | Skate | DI202302_008 | 0 | 1 |
| Skate | Skate | DI202302_009 | 0 | 1 |

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## A.5 Handling of gulper sharks – SOP Guidelines

Untiedt, C., Scoulding, B., Althaus, F. and Green, M. (2022) Field Manual -- Project: Determining the Status and Recovery of Depleted or Declining Fish Species: A Case Study of Southern Dogfish and Harrisson's Dogfish in the Context of AFMA's Upper Slope Dogfish Management Strategy. Hobar, Australia: CSIRO Internal Document. (pg 1-34)

Australia's National Science Agency

# Field Manual

## PROJECT: Determining the status and recovery of depleted or declining fish species: a case study of Southern Dogfish and Harrisson's Dogfish in the context of AFMA's upper slope dogfish management strategy

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Oceans & Atmosphere -

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## Important disclaimer

# Foreword

This document details the data collection and field procedures to be followed during the 2022 field surveys conducted under the project: *Determining the status and recovery of depleted or declining fish species: a case study of Southern Dogfish and Harrisson's Dogfish in the context of AFMA's upper slope dogfish management strategy (USDMS)*.

# Contents

# Figures



# Tables

# Objectives

The main aim of this survey is to collect baseline data (e.g., abundance, biological), representing the time zero sample of a long-term program (~10-year intervals between sampling) to monitor the relative abundance and recovery of Harrisson's and Southern Dogfish. A secondary aim of the project is to gauge the relative effectiveness and comparability between the established method of auto-longline catch and release, and the non-extractive (image-based) technique using Baited Remote Video Systems (BRUVS) – both conventional BRUVS (McLean et al. 2015), which are tired and tested as well as trialling the use of 'DeepBRUVS' systems (Marouchos et al, 2011).

# 2022 Surveys

Survey 1 will be conducted in the Flinders site, aboard the *FV Diana* from the 2nd to 11th September. Survey 2 will be conducted in the Murray and Port Mac sites, aboard the *FV Candice K* form the 16th to the 22nd of September (Figure 1). The rational for selecting of these two surveys is that the areas are expected to show moderate to large change in the population of Southern and Harrisson's Gulper at PortMac and Flinders, respectively (Williams et al. 2018). In addition, Murray had no previous records of gulper shark catches (Williams et al. 2018), thus this represents an important area to sample for a baseline.

Fishing shots will be distributed as evenly as possible over each defined survey zone at each of the three reference sites, with a general rule of no less than 2 km (just over 1 nautical mile) between fishing lines (see Figure 2 for indicative positions). The exact positioning of fishing shots will have to be dynamically decided during operations, taking account of multiple factors, including weather and currents.

Four fishing shots (1500 hooks) and six BRIV operations will be conducted per day (Table 1). Lines will be set along slope (400-600 m) in the early hours of the morning, followed by BRUV deployments. The longlines will then be hauled following an approximate 4 hour soak time and the BRUVS will be retrieved after all long line operations have been completed.

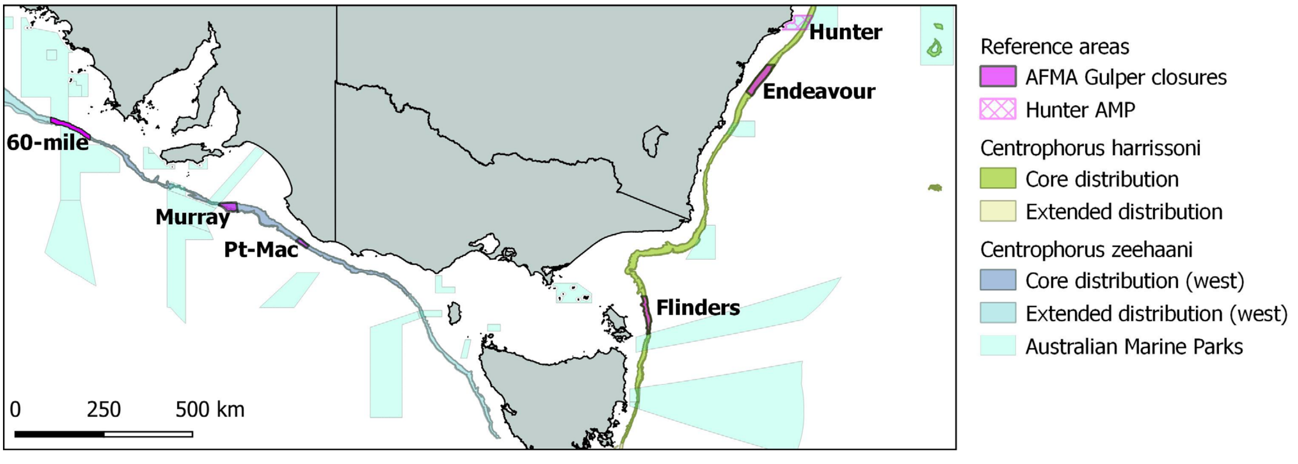



**Figure 1 Location of the six reference areas**

**Table 1 Monitoring Option 1a: six reference areas, medium effort, four separate charter trips to be implemented. The number of fishing line shots is based on 1000 hooks per shot. The number in brackets is a modified number of fishing line shots needed if 1500 hooks is used. [approved by AFMA following a review of the monitoring options paper (Williams et al, 2018)]**

| Trip | Area | Transit days Per trip | Trips needed | No. Line shots | BRUVS deployments (6 units per sample day) | Sample Days | Total charter days |
|---|---|---|---|---|---|---|---|
| 2 | Murray | 2 | 1 | 12 (8) | 12 | 2 + | 6 |
| | Pt-Mac | | | 12 (8) | 12 | 2 | |
| 3 | Flinders | 2 | 1 | 40 (27) | 42 | 7 | 9 |

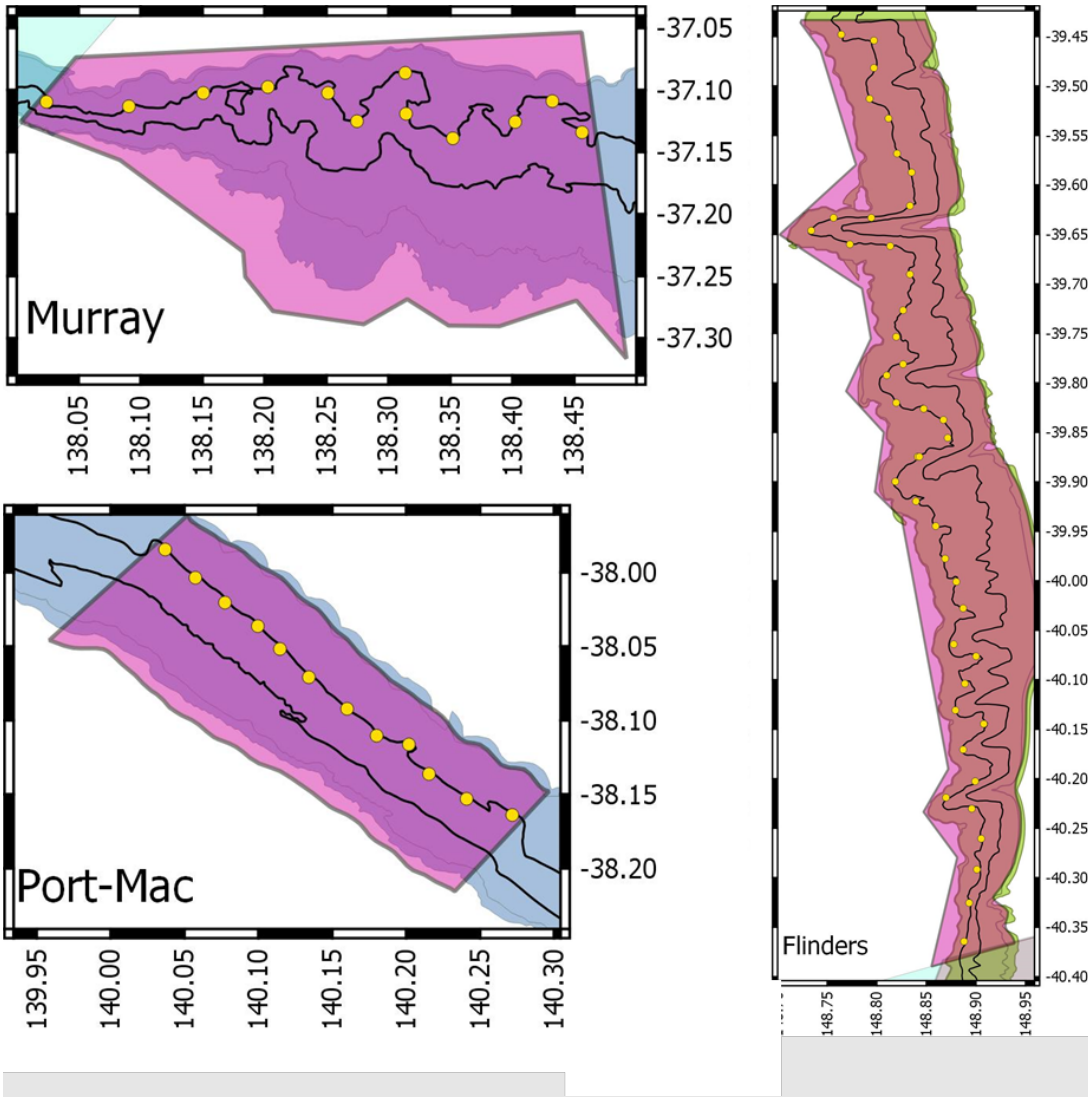



**Figure 2 Individual maps of the three survey sites with indicative distribution of sampling locations for LL shot and/or BRUVS; LL target lines between 400-600m depth; BUVS target at 500m depth down-slope from indicated position (the max. number of shots per area from Table 1 are used)**

# Fieldwork

## 1.1 Auto-Longline (ALL) catches - field procedures

### 1.1.1 Fishing operations (Fishing Crew)

- **Setting the longlines will be completed pre-dawn and recovery will commence shortly after dawn.** The objective is to keep soak times to 2—4 hours to minimise the time animals spend on the hook, but still maintain sufficient soak time for animals to locate the baits. The actual set and recover times will depend on both the fishing latitude and the time of year. The recovery of the lines will be in the order set with a recognition that the last line set will have the longest soak time, and by the time it is completely hauled more than 4 hours may have elapsed.
- **Longline sets are either 4 lines 1500 hooks per day, or 6 lines of 1000 hooks per day, depending on the site and terrain.** The length of lines and thus number of shots per day will be pre-determined in the survey design, but might be site dependent. A **maximum** of 6000 hooks is deployed per day.
- **Longlines are set across the depth gradient, commencing at a depth of 400 metres, out to 600 metres.**

### 1.1.2 Data collection – fishing operations

**Fishing operation recording**

- operation number,
- set longitude/latitude,
- set date/time (UTC),
- haul longitude/latitude,
- haul date/time (UTC),
- number of hooks set/retrieved,
- depth (start and end set),
- catch by species (specimen) data (full catch composition: see below)

**Operation information for Longline shots and BRUVS sets will be recorded in the Fishwell software system**

### 1.1.3 Catch - handling and data collection

There are only two target species for scientific research. These are the Harrisson's gulper shark (*Centrophorus harrissoni*) and the southern gulper shark (*Centrophorus zeehaani*). These small sharks have a maximum length of 110 cm and maximum weight of 10 kg, thus they can safely be handled. All other fish captured are part of the commercial catch, which are the responsibility of the commercial fishing crew. The commercial bony fishes are retained for sale under research quota, weight data is collected at point of sale. Surviving sharks and rays, are to be released before reaching the de-hooker.

#### Full catch composition data

**One member of the scientific crew will be responsible for recording fishing operations data and for recording the total catch composition as catch numbers by species and fate of each line set using the Fishwell software system**. (or recorded on data sheets (Apx Figure 3).

This data will be reported to the Animal Ethics Committee and AFMA. A separate data sheet will be used to recorded biological and tagging data (see below), which are only collected for the two targeted Gulper species.

### 1.1.4 Gulper specimens - processing and data collection

#### General

- Animal handling (post capture) is important to maximise the survival of research specimens. For this reason, there will be a minimum of three scientists on each voyage to process the sharks as soon as practical after they are landed.
- Appropriate preparations should be made between processing individual specimens including: disinfection of tag applicator, pre-loading of tag-applicator, disinfection of punch and any tools and trays in contact with DNA samples.
- Typically, sharks should be processed within 2 minutes of capture; if sharks cannot be processed immediately, because of a large catch of the target species, they will have the hook removed and be placed into a covered holding tank of flowing or aerated seawater to keep dark and cool.
- Animals which are found moribund or are critically injured in the capture process will be humanely killed by blunt force trauma to the head by sharp blows with a club central on the dorsal surface of the head between the spiracles near the base of the eyes (Figure 3). The dead specimens should be bagged and labelled with the relevant fishing shot (operation) details and retained in the freezer as biological specimens (subject to AFMA permission).

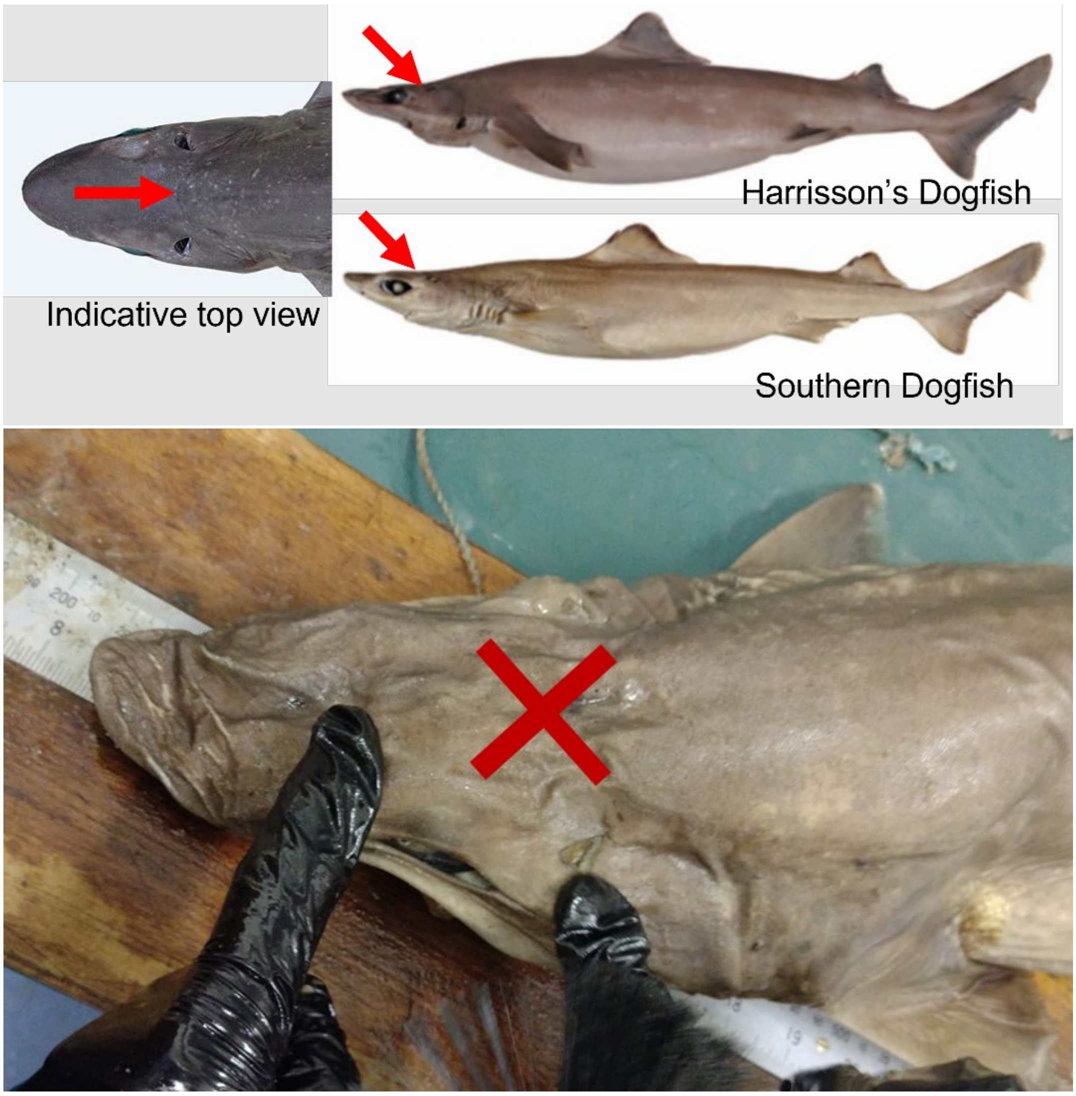



**Figure 3 Indictive location of where to strike moribund or critically injured sharks a sharp blow with a hammer to humanely kill them (re. AEC Research Authority 2022-02).**

- All data sheets will be retained, and data digitised as soon as practicable. Data sheets will be scanned, and these pdf files retained with the entire data set from each voyage. – An example data sheet for recording are shown in Appendix xxx; an electronic template for entering data at sea will be provided.
- Cleaning of any equipment is important to avoid cross contamination of genetic material and to prevent infection.

The cleaning protocol is to:

(1) wipe any obvious adhering material off all tools with a clean tissue,

(2) vigorously rinse tools under freshwater,

(3) soak them in an antiseptic Chlorhexidine solution between samples.

Tools are cleaned between sampling days by soaking them in a mild bleach solution (alcohol is unsuitable because it does not destroy DNA) and then vigorous rinsing in freshwater before use the next day. Tags are soaked in Chlorhexidine solution to disinfect them prior to application.

### Specimen processing and data collection procedures

**Two members of the scientific crew will be responsible for collecting images, species ID, biological data, DNA samples and tagging of gulper shark specimens. This data will be recorded on pre-printed waterproof datasheets (**Apx Figure 4**) and digitised daily.**

- The gulper shark should be handed to science crew members by the fishing vessel crew by holding the animal with one arm positioned under the animal and supporting most of its weight and the other hand placed on the dorsal part of the animal just in front of the second dorsal fin.

  *Sharks must not be held only by the tail as this causes damage to their muscles.

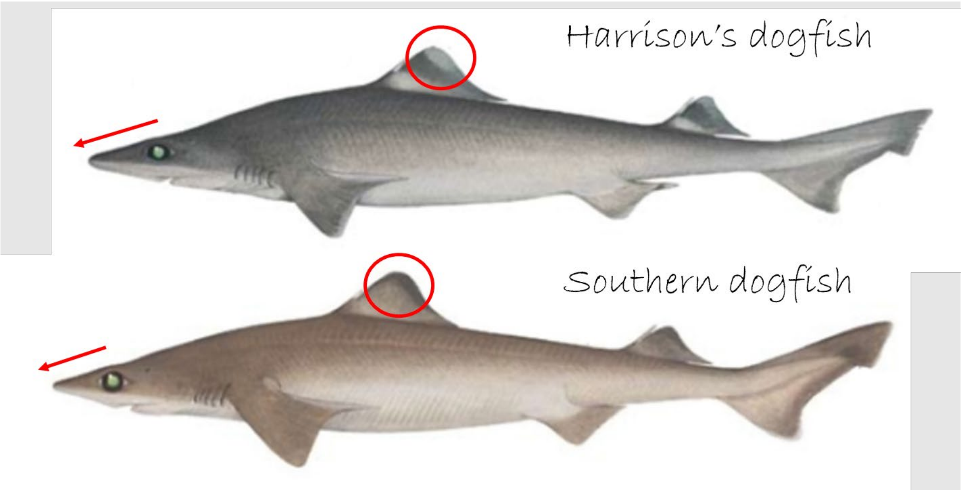
  

  *Be careful to avoid the spines on the dorsal fins – they are not poisonous but will likely hurt if they jab you!

- The animal should be laid onto a suitable work bench with a measuring board and the animals' head is shaded to protect the eyes from bright light (*for the purposes of training the shading was not used and therefore the images in this manual do not have this present).

- The hook should be carefully removed by hand, cutting the barbed end away with a set of mini bolt cutters or other suitable stout wire cutter to minimise any damage to the animals' jaw structure and tissues. *Any existing jaw damage should be noted in the Gulper data sheet. In the image below we can see that there is some prior damage to this shark, likely caused from a previous capture event.

- Record the unique specimen ID # and species ID




- Sex the animal.

Females do not have claspers (L) males do (R)

In the case of males – maturity needs to be determined and recorded using a clasper rigidity scale, where 1 = soft (able to bend); 2 = semi-rigid; 3 = rigid (not able to bend)

- Measure Total length (cm)

    1. Position the animal on its ventral surface and make sure the tip of the nose is against the measuring board (at the 0 cm measurement mark).

    2. Using the apposing hand, stretch out and compress the tail reading the Total length to the nearest 0.5 cm (in this case 110 cm)

- Apply a tag and record the tag number on the datasheet.

  Fin tags are preferred in sharks because they are more easily seen by the fisher and require only a small hole punched in the dorsal fin, considered better for animal welfare. The dart tags are more easily shed, are less easily observed by fishers and require a more intrusive method of attachment by inserting a needle into the flesh on the animals back.

  ✓ *Sharks > 90 cm shall have a Jumbo Roto tag fitted to the dorsal fin.*

  ✓ *Sharks 70-90 cm will have a smaller Roto tag fitted.*

- ✓ *Sharks < 70 cm will have a dart tag fitted.*

**A. To apply a Roto tag:**

1. Punch a 4 mm hole in the animal's dorsal fin using the leather punch. *THe small piece of tissue removed by the leather punch while fitting a fin tag is the source of tissue for genetic study.
    - The positioning of the hole should be in between the spine and the rest of the fin and about about 1/3 of the way from the dorsal surface of the animal to accommodate future growth.

    - When depressed – rotate the punch from side to side a number of times to ensure that a clean section of fin is removed.

    - Release the punch, remove it from the shark and inspect it to make sure that the sample has been retained

- Place the punch in the tray and proceed with the tagging

2. Use the tag applicator to apply the preloaded Roto tag – using the hole you just made as a guide and squeezing the applicator when the tag is in the correct position. You should hear a click, signifying that the two sections of the tag have been joined and correctly applied to the animal (the tag pin is going through the hole).

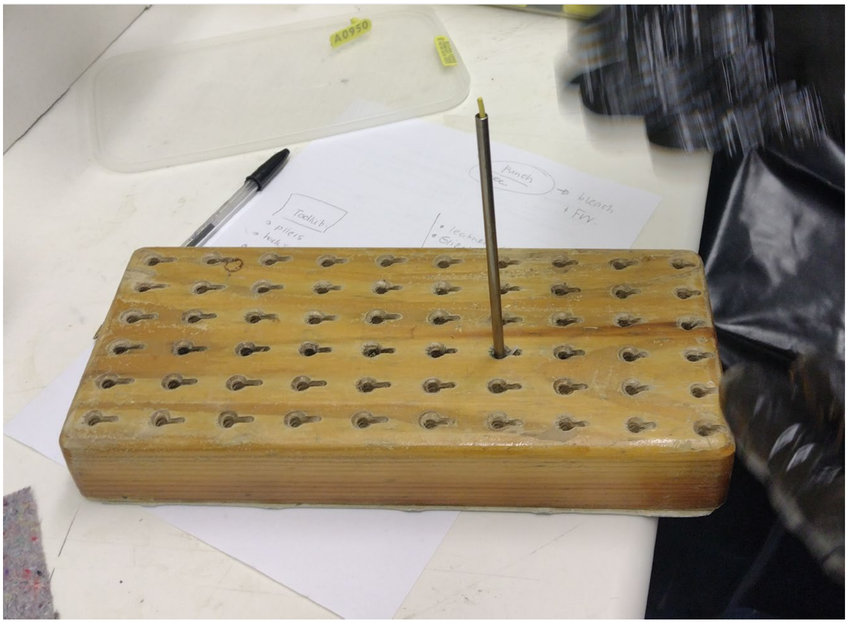
- Make sure when you remove the applicator you move it up and away from you

**B. To apply a dart tag:**

1. Dart tags are fitted using an applicator needle to insert the tag into muscle tissue at the base of the dorsal fin

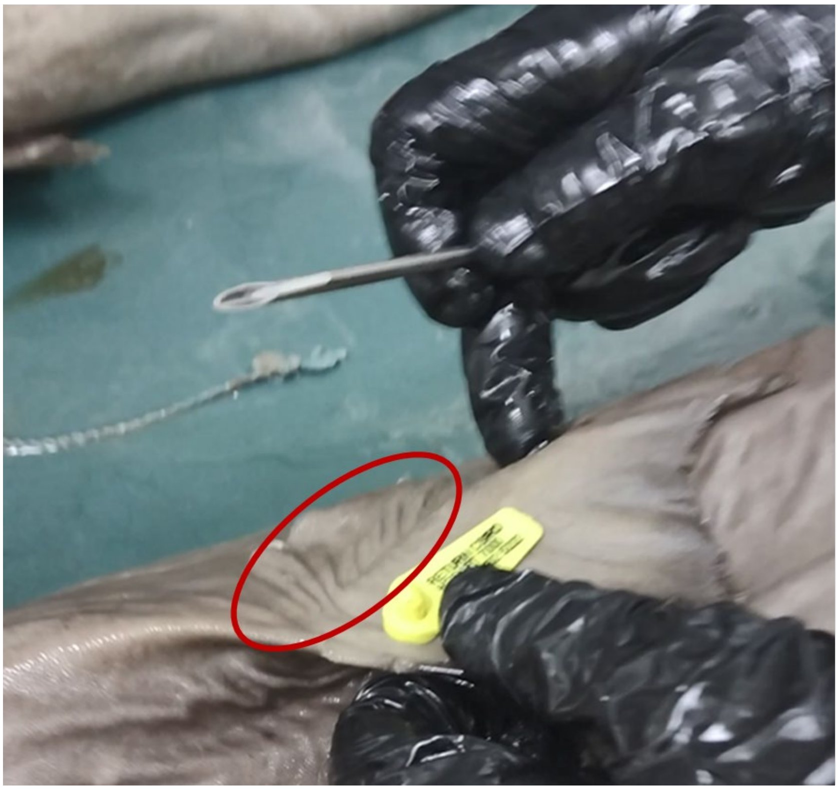
- The tag should be inserted into the applicator with the “barbed” end positioned and slotted (locked) into the grooved side

- Load the applicators (with tags) into the wooden holder. *Applicator needles should be preloaded with tags and slots in the wooden holder filled before processing starts for each shot.



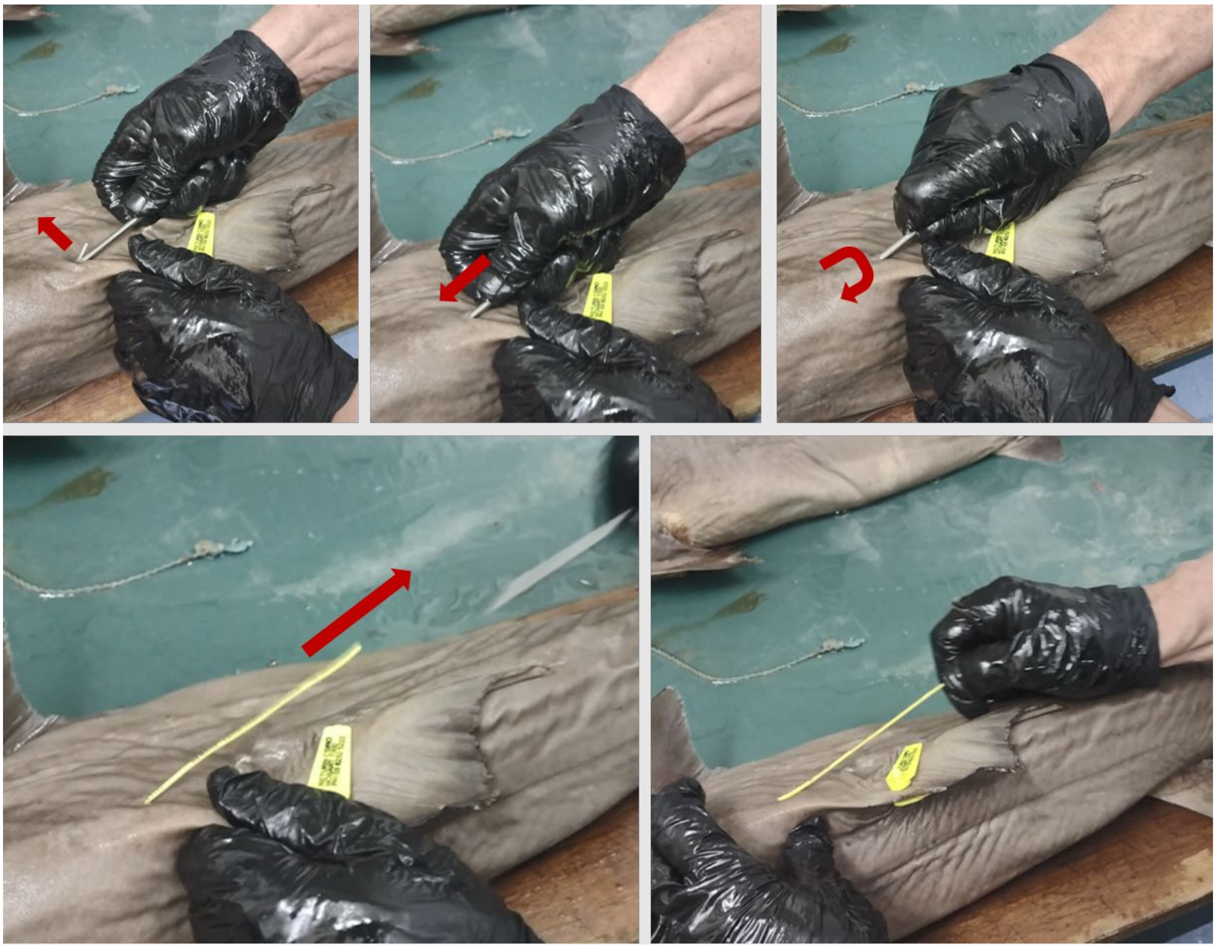
2. Applying a dart tag

- Holding and moving the dorsal fin to one side with one hand, use the other hand to feel for the pterygiophores – the bony cartilage that supports the base of the dorsal fin



- Position the applicator just below the insertion of the dorsal fin, and facing the barb (grooved end of the applicator cylinder) towards the head of the animal. We want the tag to be placed into the tissues surrounding the pterygiophores so that it is locked into the cartilage and less likely to fall out over time.


- Push the tag applicator with the barb facing away from the animal into the tissue at an angle and by applying enough force to get through the tough flesh; once the applicator cylinder is inserted and pushed into the tissue twist the applicator to lock the tag bard in place in the tissue; remove the applicator cylinder; tug on the dart tag to make sure it is correctly inserted



- Take photographs of the tagged specimen to provide visual data and confirm species ID, **in the following order**:

*Specimen images should be downloaded daily, stored in survey_operation folders (DI202201_XX) and labelled with the appropriate survey_operation and specimen number

- At least one photograph of the whole specimen – ensuring the tag is visible

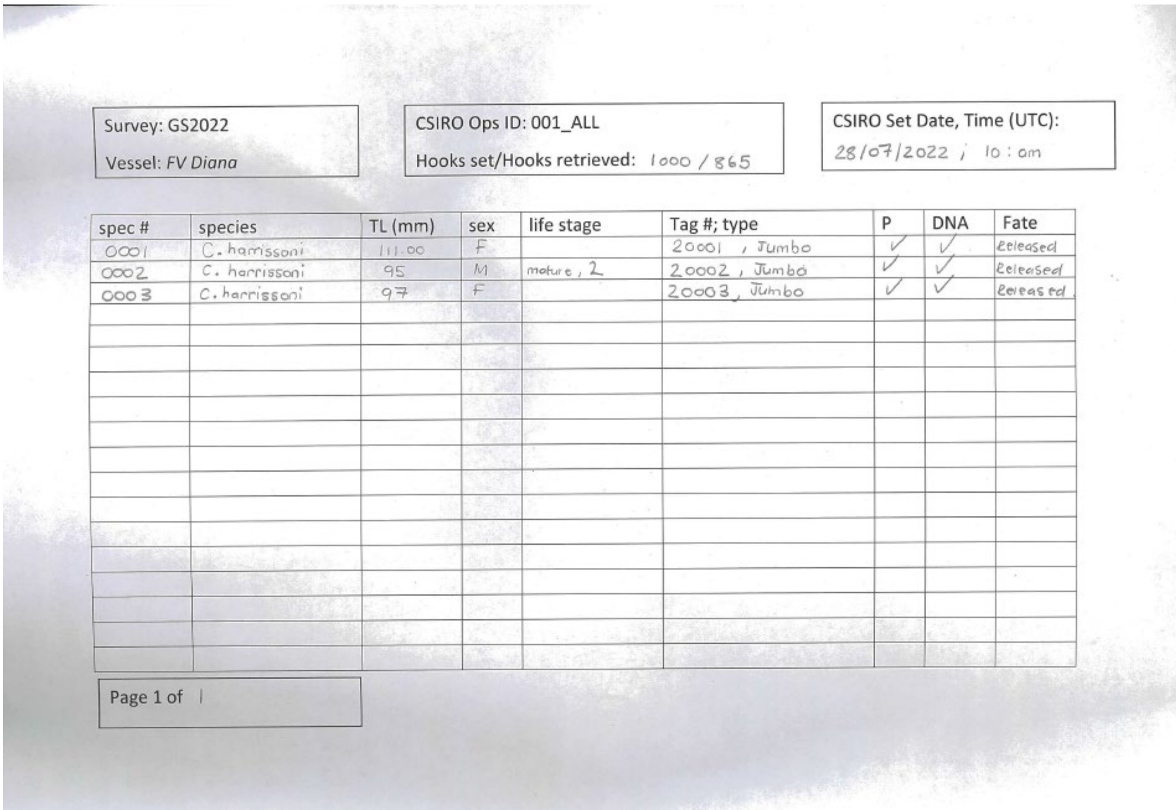

- Close up photographs of areas with important, diagnostic features needed to confirm species ID determinations made in the field

- Release the shark back into the sea by carrying it to the side of the vessel, one hand under the belly adjacent to the pectoral fins (where most of the animal mass is), and another positioned near the rear dorsal fin, and lowering it into the water head first, the angle of least resistance. * Sharks must not be held only by the tail as this damages their muscles.

- Complete the DNA sample collection
    - For fin tags carefully remove the tissue sample in the leather punch – using a small plastic rod to poke out the tissue dropping it directly into the cryovial (preloaded with tag #) or onto a piece of alfoil. Fill the cryovial with EtOH and place in small plastic bag or cryovial holder. DNA samples should be placed in EtOH as soon as possible and DNA samples should be stored in the fridge on board the vessel.

- For animals fitted with a dart tag, a small piece of tissue from the tip of a pectoral fin can be removed using sharp, clean scissors. Tissue samples are placed into (correspondingly numbered) cryovials, covered with preserved in a suitable medium such a 95% de-natured alcohol or RNAlater then placed into the vessel freezer when convenient.

- Make sure all the data fields are filled in appropriately before moving onto the next specimen



Survey: GS2022
Vessel: *FV Diana*

CSIRO Ops ID: 001_ALL
Hooks set/Hooks retrieved: 1000 / 865

CSIRO Set Date, Time (UTC):
28/07/2022 ; 10 : am

| spec # | species | TL (mm) | sex | life stage | Tag #; type | P | DNA | Fate |
|---|---|---|---|---|---|---|---|---|
| 0001 | C. harrissoni | 111.00 | F | | 20001 , Jumbo | ✓ | ✓ | Released |
| 0002 | C. harrissoni | 95 | M | mature , 2 | 20002 , Jumbo | ✓ | ✓ | Released |
| 0003 | C. harrissoni | 97 | F | | 20003 , Jumbo | ✓ | ✓ | Released |

Page 1 of 1

### Staff training

All staff who will be involved with handling the animals have attended a training session on the 28th July 2022 conducted by Mark Green which covered all aspects of processing including: how to handle, measure and tag Gulper sharks, disinfect tools etc. (using specimens collected on the 2009/2010 FV Diana Survey). Staff demonstrated competence in these practices during the training session.

## 1.2 BRUVS – sampling procedures

Baited Remote Video Systems (BRUVS) are landers fitted with video cameras (stereo vision), lights and a bait bag in clear view of the cameras. Conventional BRUVS have a surface float for retrieval and are usually deployed for a few hours, with recording times typically set between 1-2 hours.

The sampling plan detailed in Williams et al. (2018) entails six deployments of conventional BRUVS on each sampling day, equating to one BRUVS deployment for each 1000 hooks.

### 1.2.1 Deployment / Retrieval

The BRUVS will be set in depths of 400 to 500 metres (McLean et al, 2015). They should be deployed immediately following the longline sets and, ideally, they should be positioned such that they do not interfere with the fishing lines. The accepted rule of thumb is to keep individual BRUVS at least 500 metres from each other, and a similar distance from any fishing line. The bait used will be the same as deployed on the longlines.

The video will be downloaded to a computer or external hard drive, and archived on the CSIRO network on return from the field. be viewed and annotated for all fishes using established BRUVS annotation methods.

#### BRUV operation recording

All BRUV operations will be documented using the xx Fishwell software system including:

- an operation number,
- set start/end date/time,
- set start/end latitude/longitude,
- set depth,
- video time

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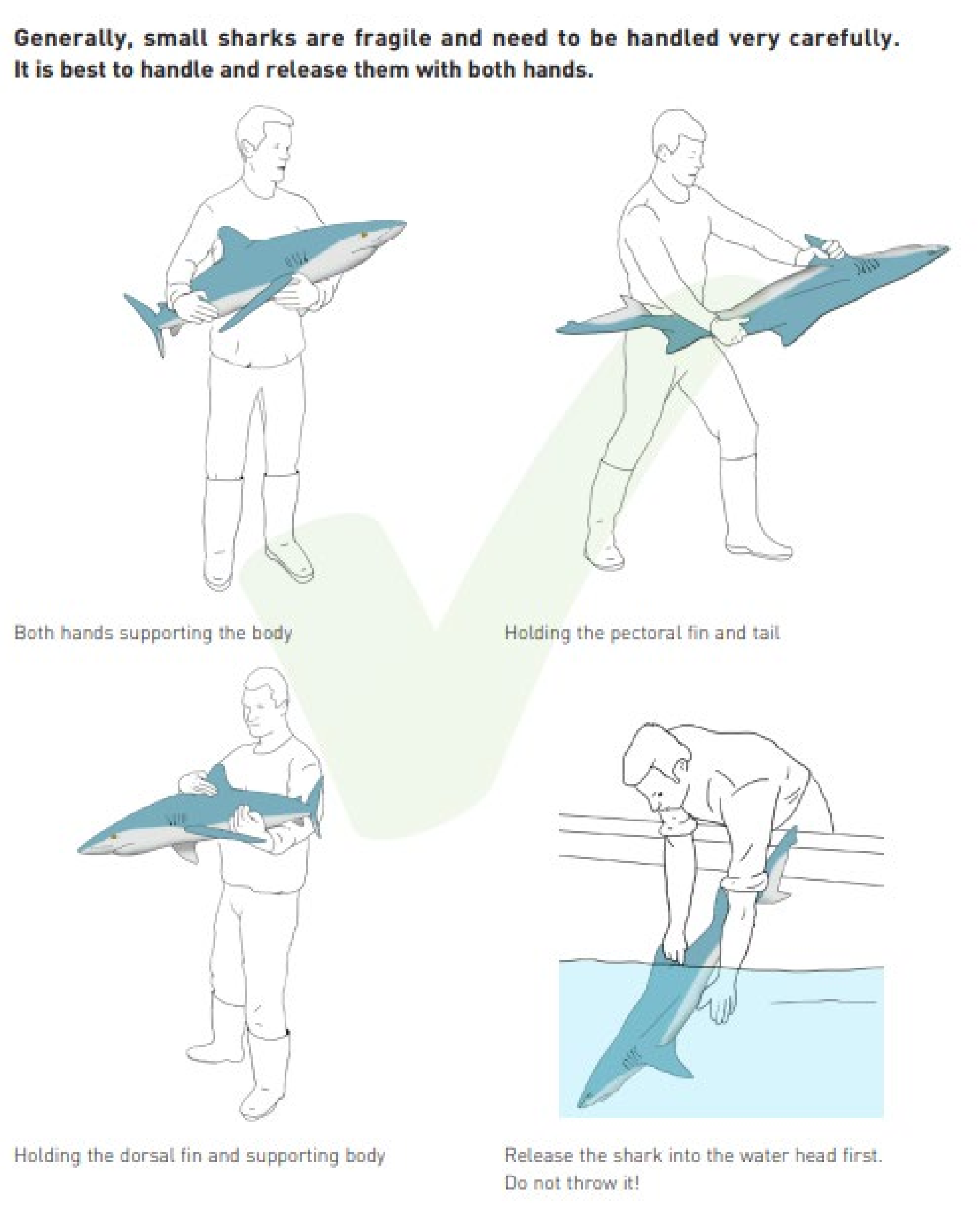
- Williams, A., Althaus, F., Smith, A.D.M., Daley, R., Barker, B.A. and Fuller, M. 2013. Developing and applying a spatially-based seascape analysis (the “habitat proxy” method) to inform management of gulper sharks: Compendium of CSIRO Discussion Papers, CSIRO Marine and Atmospheric Research, Hobart, Tasmania. 188pp.
- Williams, A., M. A. Green, F. Althaus, I. Knuckey, D. McLean, and M. Koopman. 2018. Research to support the upper slope dogfish management strategy: options for monitoring the recovery of Southern Dogfish and Harrisson’s Dogfish. Report to AFMA. CSIRO, Hobart, Australia.

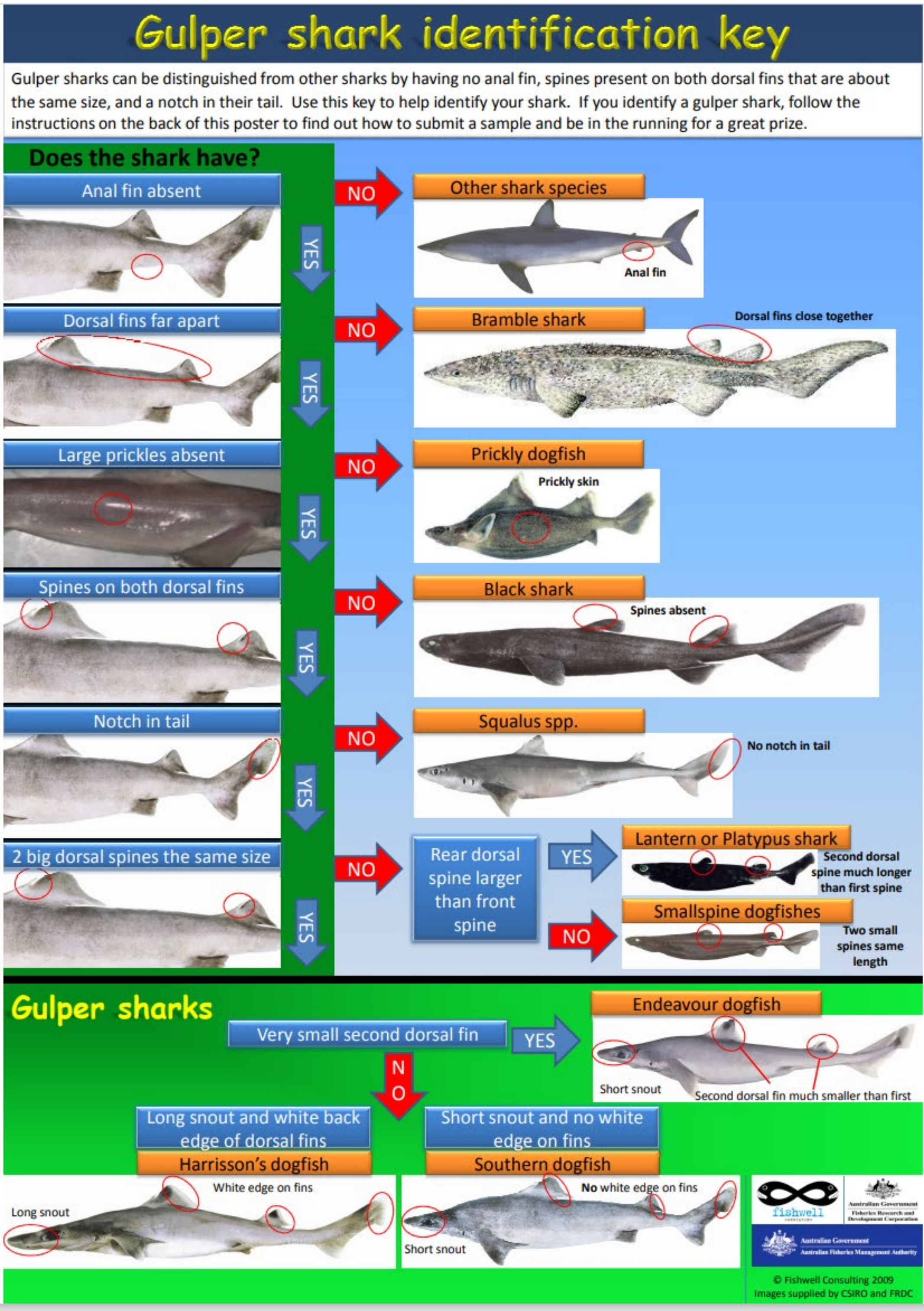
# Appendix

## Handling practices




**Apx Figure 1 Correct gulper shark handling practices (taken from AFMA, 2016).**

# Target species identification guide




**Apx Figure 2 Gulper shark identification key, poster made for industry aging program.**

## Example of Field data sheets

Survey: GS2022

Vessel: *FV Diana*

CSIRO Ops ID: 001_ALL

Hooks set/Hooks retrieved:

CSIRO Set Date, Time (UTC):

Page 1 of

| species | CAAB | Count | Fate |
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**Apx Figure 3 Example of the ALL Catch composition data sheet**

Survey: GS2022

Vessel: *FV Diana*

CSIRO Ops ID: 001_ALL

Hooks set/Hooks retrieved:

CSIRO Set Date, Time (UTC):

| spec # | species | TL (mm) | sex | life stage | Tag #; type | P | DNA | Fate |
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**Apx Figure 4 Example of Gulper shark data sheet**

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