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Stock survey of sea cucumbers in East Torres Strait

Final report

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Acronyms

AFMA	Australian Fisheries Management Authority
BDM	Bêche-de-mer
B0	Unfished Biomass
BLIM	Biomass Limit Reference Point
BMEY	‘target reference point’ biomass necessary to produce MEY
BMSY	‘target reference point’ biomass necessary to produce MSY
CDR	Catch Disposal Record
CITES	Convention on International Trade in Endangered Species
CPUE	Catch per Unit Effort
CSIRO	Commonwealth Scientific Industrial Research Organisation
GBR	Great Barrier Reef
GPS	Global Positioning System
HS	Harvest Strategy
O&A	Oceans and Atmospheric
MEY	Maximum Economic Yield
MSE	Management Strategy Evaluation
MLS	Minimum Legal Size
MSY	Maximum Sustainable Yield
PBC	Prescribed Body Corporate
RNTBC	Registered Native Title Body Corporate
ROV	Remotely Operated Vehicle
TAC	Total Allowable Catch
TSBDMF	Torres Strait Bêche-de-mer Fishery
TSBDMHS	Torres Strait Bêche-de-mer Harvest Strategy
TSHCWG	Torres Strait Hand Collectable Working Group

Summary

The sea cucumber fishery in Torres Strait, referred to as the Torres Strait Bêche-de-mer Fishery, is an important source of income for Torres Strait Islanders. The last fishery independent survey of these populations was carried out in 2009 and stock surveys are currently considered the only viable method for determining the size and status of fished sea cucumber populations in Torres Strait. This report includes the results and outcomes of sea cucumber surveys of East Torres Strait conducted in November 2019 and January 2020.

The 2019/20 survey was conducted using methods that were previously applied in 1995-96, 2002, 2005 and 2009, with the addition of a new method to survey deep-reef species. The sea cucumber survey (re-visiting sites surveyed in previous years) was conducted in November 2019, and a second survey with a focus on deep-reef sites, detailed mapping of Ugar reef and additional repeated sites (where possible) was carried out in January 2020.

The analyses include an assessment of stock status from site counts and size frequency data, a technique that has been shown to be viable from previous surveys. Estimates of environmental parameters including seagrass and algae species and cover, live coral cover and other biota and substrate (sand, rubble, etc.), were calculated for monitoring of the environment in general.

The data gathered during the survey showed that Black teatfish, a previously depleted high value species closed to fishing in 2003, has continued to recover. High densities observed in preferred Black teatfish habitats and observations shared by Traditional Owners with long-term fishing experience, indicate the population is likely near virgin biomass levels. This is a significant example of the successful recovery of a depleted sea cucumber population in response to effective implementation of active management measures that were supported and acted on by fishers and one of the few documented recoveries world-wide.

Medium value species of Curryfish and Prickly redfish that are currently important targeted species, indicate a possible fishing decline compared to the previous survey in 2009, however survey estimates suggest that current catch limits are sustainable. High value species of Surf redfish were found in higher numbers relative to previous surveys, which supports species recovery, being currently closed to fishing after mis-identification with Deepwater redfish.

Hairy blackfish densities were relatively lower than in previous surveys. This may be due to their natural patchy distribution, or may indicate a possible decline. Targeted survey sampling may need to be factored into future fishery surveys. Deepwater blackfish were only properly identified in surveys and catch in 2019, after concerted review of taxonomy and working with Torres Strait Islander fishers (Murphy et al., 2019). A small number of Deepwater blackfish were found, however due to limited survey data for the species, future fishing should be very pre-cautionary. This is also the case for Burrowing blackfish which were not recorded during the survey.

Uniquely, we also surveyed the deep-reef (>20 m) habitat to investigate deep water sea cucumber populations, using a modified Remotely Operated Vehicle. Of interest for the recent survey was investigating the full extent of the distribution of White teatfish, in order to fully quantify total stock biomass and evaluate the potential for further sustainable development of this fishery. The underwater camera system proved very successful at observing sea cucumbers. Although we surveyed habitat down to 50 m, we did not observe White teatfish deeper than 37 m. Given the extent of the deep-reef habitat in East Torres Strait, the White teatfish in this deep (>20m) habitat accounted for 72 % of the entire

White teatfish population in the area. We are confident we have now delimited and quantified the deep-reef White teatfish population of East Torres Strait.

Environmental monitoring allowed for comparison to previous survey years, which enabled trend estimates to be identified for important fishery biota and habitat. Results from the 2019/20 survey showed hard and soft coral cover have declined since 2002, which was also the same for sponges, with giant clams down from 2009 (but higher than previous survey years). Seagrass cover was in comparison found to have increased, compared to lower levels in previous years. Crown of thorn starfish numbers were low with no suggestion of an outbreak, and Trochus numbers were lower from 2002, but considered stable as trochus specific habitat was not surveyed. The decline of live coral cover and other biota (sponges) is of concern as they provide key ecosystem functions and habitat, and may indicate wider and ongoing environmental and physical changes occurring in Torres Strait.

Overall, survey data show a healthy fishery with the potential to provide moderate long-term income to local Islander communities. Estimates of sea cucumber population size and status will support management decisions and are assisting in the implementation of the new Torres Strait Bêche-de-mer Harvest Strategy. This is particularly important for meeting recent listings of teatfish species on CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora) Appendix II - Teatfish species can only be exported under a CITES export permit.

Outcomes of the 2019/20 survey have supported the current CITES *Non-Detriment* Finding for the Torres Strait Bêche-de-mer Fishery.

Non-technical summary

Community summary

The sea cucumber fishery in Torres Strait - known as the Torres Strait Bêche-de-mer Fishery is found in East Torres Strait, and is only fished by Traditional Owners.

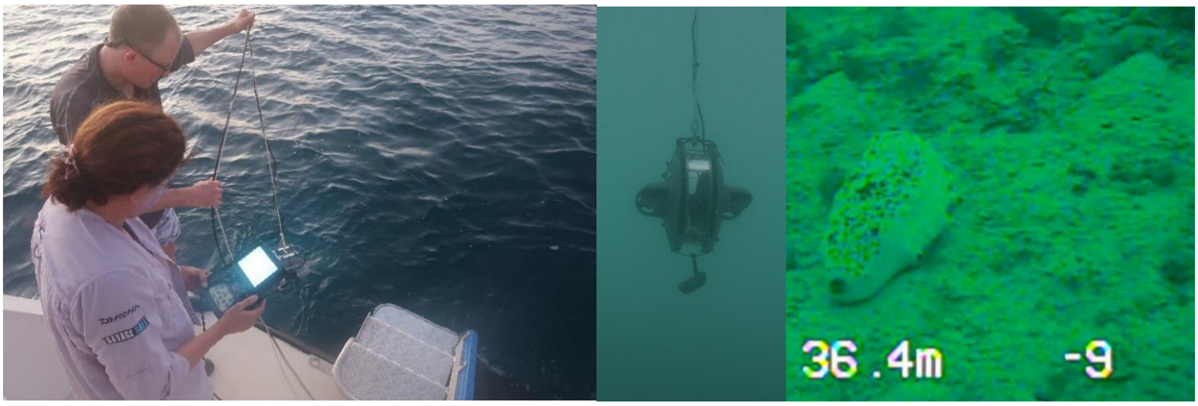
Sea cucumbers can be easy to over-fish as they are easily collected by hand and can be slow growing. This has happened before in Torres Strait before, which has meant some species like Sandfish and Black teatfish were banned (closed) to fishing. The fishing bans were done to give these sea cucumbers a chance to breed and for their numbers to go up to an amount that can handle fishing in the future.

In order to work out the number of sea cucumbers that can be safely fished, we need to know how many sea cucumbers for each species there are at the moment, in East Torres Strait. This has been done a few times before by carrying out a scientific (diving) survey to count them. You also need to know for sure which sea cucumbers species and how many are being taken during fishing. This is why the ‘Fish Receiver’ catch records were made compulsory in 2017.

A scientific survey is still the best way to work out sea cucumber numbers for East Torres Strait, especially because the catch records have only been compulsory since 2017 and the last scientific diving survey was done in 2009. Knowing these numbers is important for management, so sea cucumbers like Black teatfish can be opened to fishing again.

A sea cucumber scientific survey of East Torres Strait was carried out in November 2019 and January 2020. The survey was run in the same way as the surveys carried out before in 1995-96, 2002, 2005 and 2009, and even had some of the same people. That way, we can compare the numbers seen during this survey with past surveys to understand how healthy the sea cucumber populations are in this year, compared to previous years.

One new activity that we undertook this time was to look for sea cucumber species in waters deeper than 20 metres. We used underwater video cameras to look for sea cucumbers like White teatfish, which live at these depths.



Using the underwater video camera and a picture of a White teatfish found in the deep-reef habitats.

During the scientific surveys, sea cucumber numbers were counted along transects. They were also collected and their size and weight measured, before we returned all of them back to the water. We also recorded information about where the sea cucumbers live (scientists call these places ‘the habitat’). We looked at the amount of sea grass and seaweed, as well as coral, sand and rock because sea cucumbers like to live in places where these things are. All this knowledge allows us to understand where different sea cucumber species live and this helps to better manage the fishery.

One of the major results of the scientific survey was that Black teatfish numbers have continued to rise – which is also what Traditional Owners have been seeing. Numbers are now high enough that Black teatfish can be re-opened to fishing. This is a very important outcome for Traditional Owners, because their effort to close the fishing of Black teatfish for a while can now be demonstrated to have worked, to the benefit of fishers. There are only few examples of sea cucumber species elsewhere in the world recovering from being over-fished.

The underwater video camera worked very well for finding and counting deep-reef sea cucumbers, particularly White teatfish. The deepest we saw White teatfish was 37 m and the deepest we had the camera down to was 50 m - and there was only sand at this depth! This is important to know as now we are confident about how many White teatfish are in East Torres Strait, so catch limits can be set with more certainty.

We also looked at numbers of other important sea cucumbers such as Prickly redfish and Curryfish. We found that while there has been increased fishing for these sea cucumbers, catch levels are considered acceptable for the moment.

All the sea cucumber numbers and habitat information from the recent scientific surveys are now being used in the new Torres Strait Bêche-de-mer Harvest Strategy. This helps management to make decisions about the Torres Strait sea cucumber fishery and helps to ensure that sea cucumbers are fished sustainably now and in the future, to the benefit of communities.

This is particularly important as Teatfish species (White teatfish and Black teatfish) have just been added to an international list of species on the CITES list - the Convention on International Trade in Endangered Species of Wild Fauna and Flora. Species that are on this list can only be commercially exported by being awarded a Non-Detriment Finding. These are given out based on an examination of the fishery and being able to demonstrate that it is managed and fished sustainably.

The recent Torres Strait scientific sea cucumber surveys and the introduction of the new Torres Strait Bêche-de-mer Harvest Strategy are very important because they supported the Torres Strait Bêche-de-mer Fishery being given a ‘Non-Detriment’ finding and can be commercially exported safely. This is a significant outcome for Torres Strait, as it is one of the first Australian sea cucumber fisheries that has been awarded a Non-Detriment finding.

1 Background

Sea cucumber fisheries in Australia and the South Pacific have been subject to increased fishing pressure in recent years due to relatively high prices for bêche-de-mer (the dried product) in Asia and the easiness to catch them. Research has shown that some Australian (see references to reports on closure of Sandfish and Black teatfish fisheries: Skewes et al., 1998 Skewes et al., 2004) and many South Pacific sea cucumber fisheries have been over-exploited, with recovery being slow and sporadic (Purcell, 2013).

The sea cucumber fishery in Torres Strait (referred to as the Torres Strait Bêche-de-mer Fishery (TSBDMF) in the remainder of the report) (Figure 1-1), is an important source of income for Torres Strait Islanders since it was re-established in the early 1990's. Sandfish (*Holothuria scabra*) on Warrior Reef provided the bulk of the early catches, however, after its closure in 1998 from over-harvesting (Skewes et al., 1998), the fishery targeted several other species in East Torres Strait (Figure 1-1), including Black teatfish. In response to declining populations, closure or catch limits were subsequently implemented for several high value fishery species such as Black teatfish (*H. whitmaei*) and Surf redfish (*Actinopyga mauritiana*) in 2003 (Skewes et al., 2004). Currently, fishing is mainly focused on Prickly redfish (*Thelenota ananas*), White teatfish (*H. fuscogilva*), Deep-water blackfish (mostly *A. palauensis*), Deep-water redfish (*A. echinites*) and of late, Curryfish (*Stichopus herrmanni* and *S. vastus*).

Recently, there has been some evidence of localised depletion for Prickly redfish and Curryfish i.e. fishermen reporting decreased catch rates. Therefore, quantifying the sea cucumber populations and assessing the status of important fishery species, is a high priority to support adequate management decisions, in the interest of the long-term sustainability of the TSBDMF.

There is also a strong desire from some Torres Strait fishers to reopen the Black teatfish fishery and contemporary estimates of population size and status would also support management decisions for this species and assist in the implementation of the new Torres Strait Bêche-de-mer Harvest Strategy. Based on results from this survey inputted to the TSBDM Harvest Strategy, an opening trial for Black teatfish was agreed by stakeholders and set in place starting 30th April 2021 for 20 t - closed 3rd May 2021; 17.26 t caught as at 15:00 on 5th May 2021 (https://www.pzja.gov.au/2021-black-teatfish-trial-opening).

Additionally, the full extent of the distribution of White teatfish in deeper (>20 m) habitats is currently of interest, in terms of quantifying total stock biomass and evaluating the potential for further development of this fishery. See Appendix A.2. for a compilation of sea cucumber species issues.

Fishery-dependent data (Catch Disposal Records; known as the Torres Strait Fish Receiver System a requirement for all commercial fishers to unload their catch to licensed fish receivers) were introduced to the TSBDMF in December 2017. There is still however, limited information available to assess the status of fishery populations, with incomplete catch and effort time series data available prior to 2017. The last fishery independent survey of these populations was carried out in 2009 (Skewes et al., 2010), therefore a stock survey is presently the only viable method for determining the size and status of fished sea cucumber populations for Torres Strait.

This project summarises the findings for two recent sea cucumber surveys (December 2019 and January 2020) of East Torres Strait. The analyses include an assessment of stock status for the most economically important fishery species, from site counts and size frequency data, a technique that has been shown to be viable from previous surveys. Estimates of environmental parameters including seagrass and algae species, live coral cover and other biota and substrate (sand, rubble, etc.) collected during the survey, were calculated and used to characterise, map and monitor the environment in which sea cucumbers grow in Torres Strait.

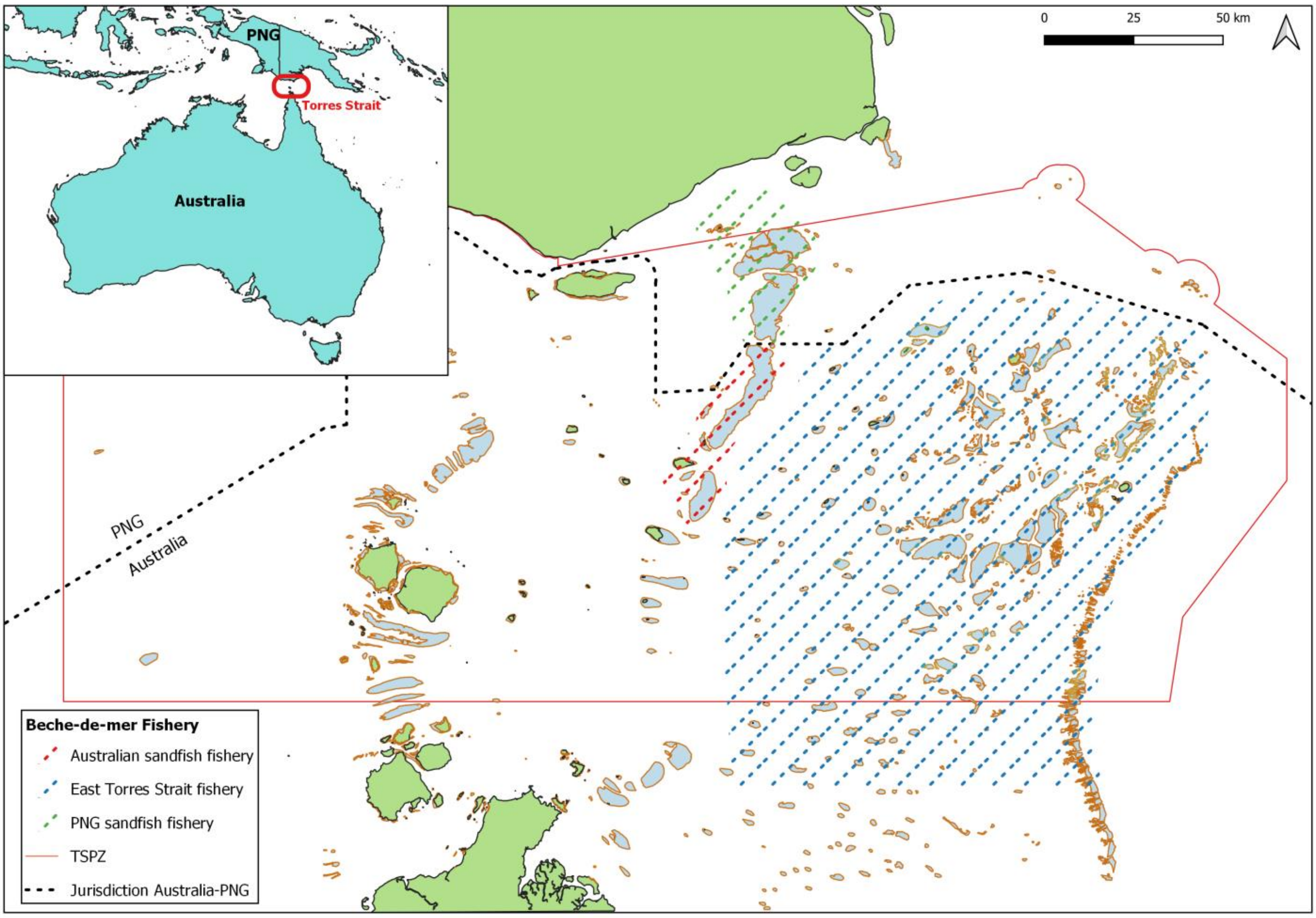


Figure 1-1. Map of Torres Strait showing the approximate location of the three sea cucumber fisheries in Torres Strait.

1.1 Project objectives

1. Survey of the East Torres Strait Bêche-de-mer Fishery with the focus on Prickly redfish, Curryfish species, Black teat fish and Surf redfish.
2. Carry out a preliminary exploration of deeper-water habitats for White teatfish.
3. Carry out survey of Sandfish on Warrior Reef: this was not possible to undertake due to unforeseen circumstances and a variation for the January 2020 survey was approved by AFMA and TSRA. Additional effort was spent on:
    - Further deep-water surveys and additional activities to include targeting of surf redfish and extra BDM sampling sites.

- Map reef and quantify habitats of Ugar home reef for possible sea cucumber re-seeding project.

1.2 Deliverables

1. Produce stock size estimates and distribution data, and assess the fishery status for each population of sea cucumber in East Torres Strait.
2. Use survey data to comment on potential for fishery expansion (e.g. TAC's) and reopening of closed fisheries.
3. Map important habitat variables, especially those relevant to fishery production.
4. Survey results will be made available in a form suitable for use in the new Bêche-de-mer Harvest Strategy for Torres Strait.
5. Information from the project will be provided to AFMA, TSRA and Torres Strait Island stakeholders in the form of formal final reports and a plain English summary document. Special consideration will be taken with Traditional Knowledge.

2 Methods

2.1 Review of existing data

The collation of existing data is important to understand historical trends about the fishery and key deliverable of the project. In what follows we present all data available relevant to the fishery, including survey and seabed data.

2.2 Survey data

A range of biological (e.g. sea cucumber, algae and seagrass species, habitats (live and bleached coral and seagrass cover) and physical (e.g. depth, temperature, sediments) data were collected in previous surveys (Table 2-1). These data have been collated and used to determine habitat ranges for sea cucumber species of interest, with bio-physical data gathered providing insights into physical correlates. Together, this information provided guidance for macro and micro scale spatial envelopes for species occurrence.

Table 2-1. Eastern Torres Strait sea cucumber surveys.

Year	Date	Days	Survey type	Sites
1995; 1996	Feb 95, Nov 95, Feb 96	-	Full scale, including western, central & eastern Torres Strait	1519 15m depth
2002	End March/April	14	Full scale, eastern Torres Strait	424 (*two dive teams/2 dinghies) 20m depth
2005	End Jan/Feb	9	Relative, eastern Torres Strait	122 sites, 75 planned (extra assistance from crew) 20m depth
2009	March	10	Relative, eastern Torres Strait (combined Trochus; 5 from 6 zones)	113 15m depth

2.3 Historical CSIRO seabed (inter-reefal) surveys

Mapping and characterisation of key biotic and physical attributes of the Torres Strait ecosystem was undertaken in 2007, where samples of plants, invertebrates and fishes were collected (Pitcher et al., 2007). The database from this survey was interrogated to collate all sea cucumber records, and subsequent images and site descriptions were extracted to support species identification (where not recorded) and species counts.

A total of 352 sea cucumber records were collated from towed video, digital cameras, epibenthic sleds and trawls, with the more abundant species distribution mapped. Thirteen sea cucumber species were described to species level, mapped and quantified, three of these were current commercial species – *Stichopus herrmanni, Holothuria atra*, and *H. lessoni* (Table 2-2). The two most abundant species, in terms of estimated biomass, were *Pseudocolochirus violaceus* and *S. horrens* (Table 2-2). The most widespread species were *H. ocellata* and *Cercoderma anceps* (Table 2-2).

Table 2-2. List of identified species from seabed (inter-reefal) surveys carried out in 2007, the number of sites they were observed, and the estimated biomass for modelled species (Pitcher et al., 2007)

Species	Sites observed	Biomass (kg)
Actinopyga lecanora	1	-
Cercoderma anceps	37	19,376
Cladolabes perspicillum	2	-
Cladolabes schmeltzi	2	-
Holothuria edulis	1	-
Pentacta australis	17	-
Pseudocolochirus violaceus	17	929,828
Stichopus horrens	21	314,098
Holothuria ocellata	50	69,811
Stichopus herrmanni	2	-
Holothuria atra	1	-
Holothuria lessoni	7	-
Stichopus ocellatus	1	-

The review of the inter-reefal seabed data does not indicate a significant population of high value commercial species in the inter-reefal seabed areas of Torres Strait (apart from *S. horrens*, a commercial but not currently targeted species), such as White teatfish and Prickly redfish. Nor does it indicate the existence of significant populations of Burrowing blackfish (*Actinopyga spinea*) that now forms the largest single species on the Qld East coast (GBR) sea cucumber fishery.

2.4 Community consultation

Feedback was sought on the aims of the survey and its design at targeted pre-consultation and consultation phases for the project. This involved contacting Islander representatives, including Community Fisher Groups, Prescribed Body Corporates and Island Councillors, where information about the survey was provided and it was requested that flyers detailing project information and a request for feedback, be posted on community notice boards (see Appendix A.1). Permission and support for the survey work from communities was sought and answers to questions raised by communities and feedback were incorporated into survey planning.

As part of the development of the recently endorsed TSBDM Harvest Strategy, the history, status and previous research carried out on the TSBDMF has been communicated to Torres Strait Islanders through Torres Strait Hand Collectable Working Group (TSHCWG) meetings and dedicated community workshops in 2019 and several years before. Our understanding is that there is a high level of awareness of the specifics of the fishery e.g. locations, species distribution, seasonal abundance and fishery operations among Traditional Owners, who also have good knowledge of the various levels of stock status. This is evidenced by feedback received from AFMA, in relation to the Fish Receiver community information sessions that were undertaken on a number of Islands. The project’s overall design was ratified by the TSHCWG.

2.5 Study area

The TSBDMF area covers 16,844 km^2 of Torres Strait, situated at its Eastern extreme which includes the Australian side of the Torres Strait Protected Zone East of Warrior Reef (Figure 1-1). It contains about 1,388 km^2 of shallow reefs, which accounts for about 64 % of all the reefs in Torres Strait (Table 2-3) (Skewes et al., 2004).

2.5.1 Deep reef habitat area estimation

The habitat was delineated as the area of reef inside the outline of the AIMS-NESP reef map (Lawrey and Stewart, 2016), and outside the shallow reef outlined from the 1:100,000 Topographic map series (Royal Australian Survey Corps; Taranto et al., 1997). The deep-reef strata also includes (where not contained in above) the deep outer reef edge (>20 m) to the bottom of the reef slope (Skewes et al., 2004) and deep-reef lagoon.

This delineation is likely to include a reasonable representation of the deep-reef area, as the AIMS-NESP dataset included the “boundaries of all features raised off the sea floor” (Lawrey and Stewart, 2016), and the CSIRO 1:100,000 Topographic map based reef outlines usually correspond to the outline of the shallow (emergent or near emergent) reef. In practice, this deep-reef map did include the deeper reef lagoon area that is a common feature of many larger reefs in East Torres Strait (Figure 2-1).

The area of the deep-reef strata was calculated as the area of the AIMS-NESP reef map (Level 1=Reef), minus CSIRO’s 1:100,000 Topographic based reef map (emergent reef – reef top and reef top buffer strata) and also minus the calculated area of the shallow reef edge (0-20 m) (Table 2-3). The new total calculated area of the fishery, including the deep-water strata is 16,980 km^2 (Table 2-3), where the deep reef strata covers an area of 622km^2.

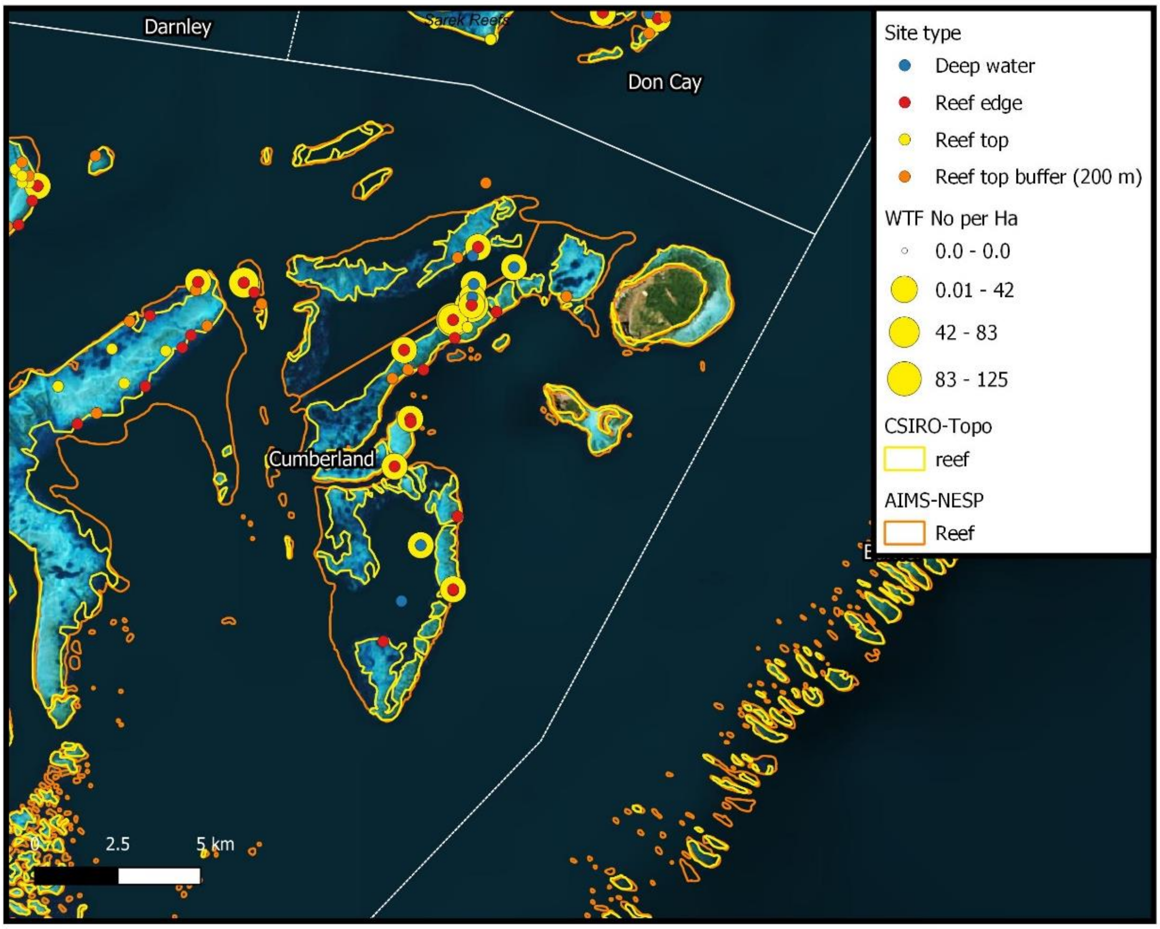


Figure 2-1. Map of reefs in vicinity of Mer (Murray Island) in East Torres Strait. Overlays are LandSat image of reefs and islands, CSIRO's Topographic reef map outline, AIMS-NESP reef outline, sample sites (designated by strata) from the 2019/20 survey, and the density of White teatfish (*H. fuscogilva*) observed in 2019/20.

Table 2-3. Area (km^2) of reef strata in East Torres Strait zones (GNE = Great North East) (Refer to Figure 2-2 for location of zones (strata) in East Torres Strait).

Zone\Strata (Km^2)	Reef top	Reef top buffer	Reef edge	Deep reef	Total reef	Non-Reef	Total area
Barrier	26.0	93.4	42.6	77.9	239.9	3,584.8	3824.8
Cumberland	309.4	133.7	46.8	140.8	630.6	1,318.5	1,949.1
Darnley	161.7	107.0	39.7	207.7	516.1	2,729.1	3,245.1
Don Cay	52.1	69.4	24.5	47.9	193.9	1,672.7	1,866.6
GNE Channel	77.0	50.6	17.2	4.9	149.6	4,369.7	4,519.3
Seven Reefs	73.8	49.8	13.7	143.0	280.4	1,294.7	1,575.1
East Torres Strait	700.1	503.9	184.5	622.0	2,010.5	14,969.5	16,980.0

2.6 Sample design

Seven zones (Barrier, Great North East Channel, Cumberland, Darnley, Don Cay, Seven Reefs and South East) were established in the TSBDMF area to incorporate the large extent of shallow reefs distributed over the fishery area (Figure 2-2). These zones have been used since 2002, as the basis for the collection of fishery catch data (logbook areas) (Skewes et al., 2004). The zones were established based on available catch information, likely Holothurian abundance and physiographic characteristics of the fishery habitats (Figure 2-2), and formed the basis for the sample design and stratified analysis.

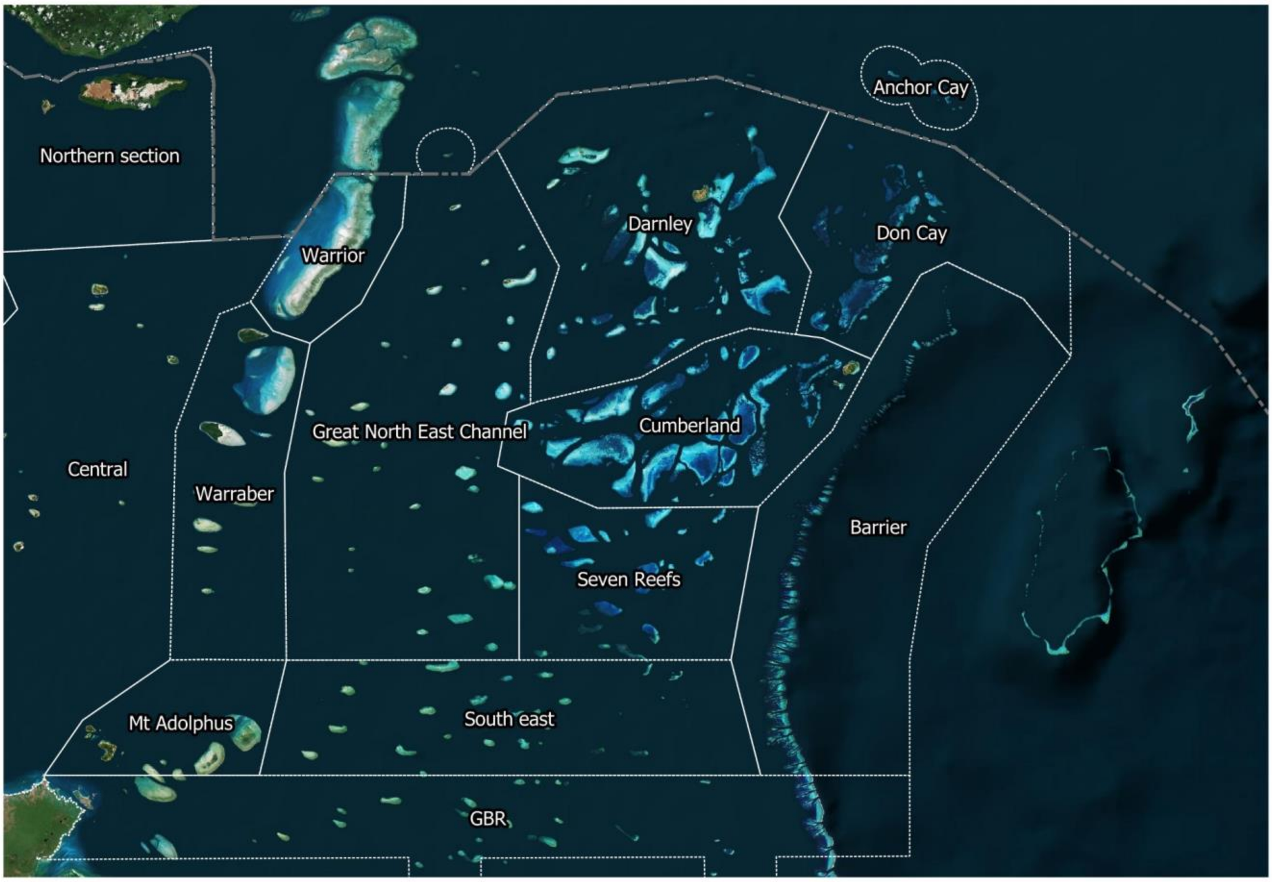


Figure 2-2. Location of fishery catch area zones for the Torres Strait Bêche-de-mer Fishery (source = LandSat).

A marine habitat map that delineated shallow reefs was superimposed on the fishery zones and used as the basis for the survey. Each zone was further divided into four habitat strata (Table 2-3):

- the reef top
- the reef top buffer (a 200 m wide buffer around the inside of the reef margin)
- the reef edge (<20 m), and
- deep-reef (>20 m) stratum

During previous surveys, the reef top buffer was identified as an area likely to contain higher abundance of targeted species, especially Surf redfish and Black teatfish (Skewes et al., 2010).

Past sea cucumber surveys of East Torres Strait have been undertaken in 1995-96 (full scale), 2002 (full scale), 2005 (relative – subset of sites from full scale survey) and 2009 (relative) (Long et al., 1996; Skewes et al., 2004; Skewes et al., 2010) (see Appendix A.2). The current survey was conducted using similar methods applied to previous surveys, with the addition of a new method to survey deep-reef species - modified drop down camera (Murphy et al., 2021). Two of the survey staff - Nicole Murphy and Tim Skewes, have led or participated on all of these previous sea cucumber surveys.

The timing of the current survey was planned to coincide with the seasonal timing of previous surveys. This was to reduce differences in survey observer rates resulting from changes in sea cucumber burrowing behaviour, caused by seasonal and tidal factors. Based on previous survey dates, project scope and logistics, a sea cucumber survey (visiting sites surveyed in previous years) was conducted in November 2019, and a second survey with a focus on deep-reef sites, mapping of Ugar reef and additional repeated sites (where possible) was carried out in January 2020. The time between the two surveys allowed for additional planning necessary for trialling the use of drop video cameras, where tides, currents and depths needed to be managed for targeted sampling of White teatfish.

2.7 Field survey

2.7.1 East Torres Strait survey

The survey team carried out 2 x 2 week surveys during November 2019 and January 2020. Across the two surveys, 298 sites were visited in East Torres Strait (Table 2-4, Figure 2-3). Repeated measures were undertaken for most of the reef sites previously surveyed in 2002, 2005 and 2009. Uniquely in 2019/20, we also successfully surveyed 53 deep-reef sites to investigate sea cucumber deep-reef species, such as White teatfish.

Table 2-4. Number of survey sites by year, zone and stratum.

Year	Zones	Reef top	Reef top buffer	Reef edge	Deep reef	Total
1995/96	14	1089	164	365	0	1618
2002	6	136	139	159	0	434
2005	5	35	52	40	0	127
2009	5	33	25	45	0	103
2019/20	6	88	86	71	53	298

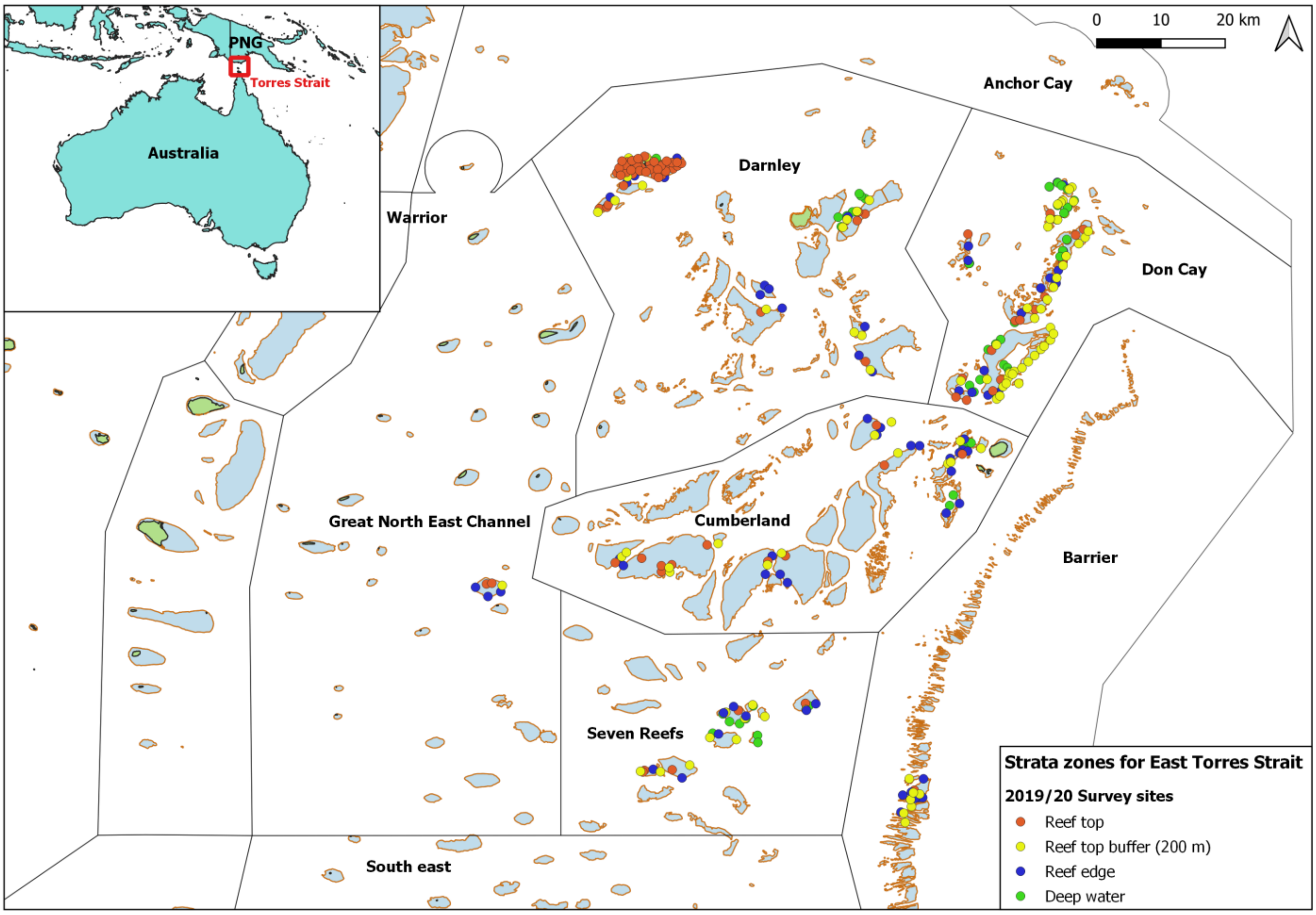


Figure 2-3. Sites visited in 2019/20, by zone and stratum.

2.7.2 Field sampling

Field work was undertaken by a team of divers operating from the CSIRO 5.0 m inflatable Naiad. Sampling sites were located using a portable GPS. Resource and habitat information were recorded 2 m either side of a set transect length:

Reef top and Reef top buffer

Divers swam along a 40 m transect line. Holothurians and other benthic fauna of commercial or ecological interest were counted. Where possible these species were measured (total length) and weighed using a hand-held scale in the dinghy and returned back to the water after measurements.

At each site, the substrate was described in terms of the percentage of sand, rubble, consolidated rubble, pavement and live coral. The growth forms and dominant taxa of the live coral component and the percentage cover of all other conspicuous biota such as coral, seagrass and algae were estimated and recorded.

Reef edge

Divers swam adjacent transects perpendicular to the reef edge from the reef crest to a depth of 20 m or a distance of 100 m, whichever came first. Divers counted species of interest and recorded habitat information using the same protocol as described for the reef top (and reef top buffer), as well as collecting sea cucumbers for length and weight measurements.

Deep-reef:

The TSRA kindly offered for the research team a number of their Remotely Operated Vehicle (ROV) units to trial for surveying deep-reef habitats. The DTG3 model proved the most adequate for deployment from the CSIRO 5.0 m inflatable Naiad, as well as for handling in conditions of swell, wind and inclement weather. The DTG3 was used as a modified ‘drop camera’ with a cabled tether and towed to collect data in drift transects undertaken from the Naiad. Of note for the DTG3 was the 270 degree of view, and capability to record high quality video (Figure 2-4).

Figure 2-4. Deep Trekker DTG3 Remotely Operated Vehicle.

For the deep-reef transects (>20 m), observations were made in real time e.g. sea cucumbers seen and significant habitat, with depth and time noted and a sampling data sheet completed afterwards. Transects undertaken during 10-minute drifts and were 20 m to 50 m deep, over lengths of 40 m to 675 m.

All recorded video was reviewed to verify sea cucumber identification and total number, and habitat information was also updated on site data sheets.

Time was also spent quantifying the DTG3 field of view to determine area estimates needed for subsequent analyses. This was undertaken by placing an object of known length on transect and video captured, with a diver also taking measurements. Photos were used (after review) for comparison and assessment.

The White teatfish survey was exploratory and highly targeted. Data records from previous Torres Strait surveys - including the planned CSIRO seabed mapping review (see section 2.2), as well as advice from fishers and other stakeholders was used to choose sites. Deep-reef sites included sites off the shallow reef edge continuing down the reef slope and in the deeper lagoons of the sunken North Easterly reefs.

Notes

We were assisted by TSRA cadet, Ms Madeina David, for part of the cruise. This was very helpful for conducting the survey, particularly in terms of assistance with operation of the DTG3 camera system. The camera system was very successful at observing and quantifying sea cucumbers, particularly White teatfish (Figure 2-5). Although we surveyed habitat down to 50 m deep, we did not observe White teatfish deeper than 37 m. We are confident we have delimited and quantified the deep-reef White teatfish population.

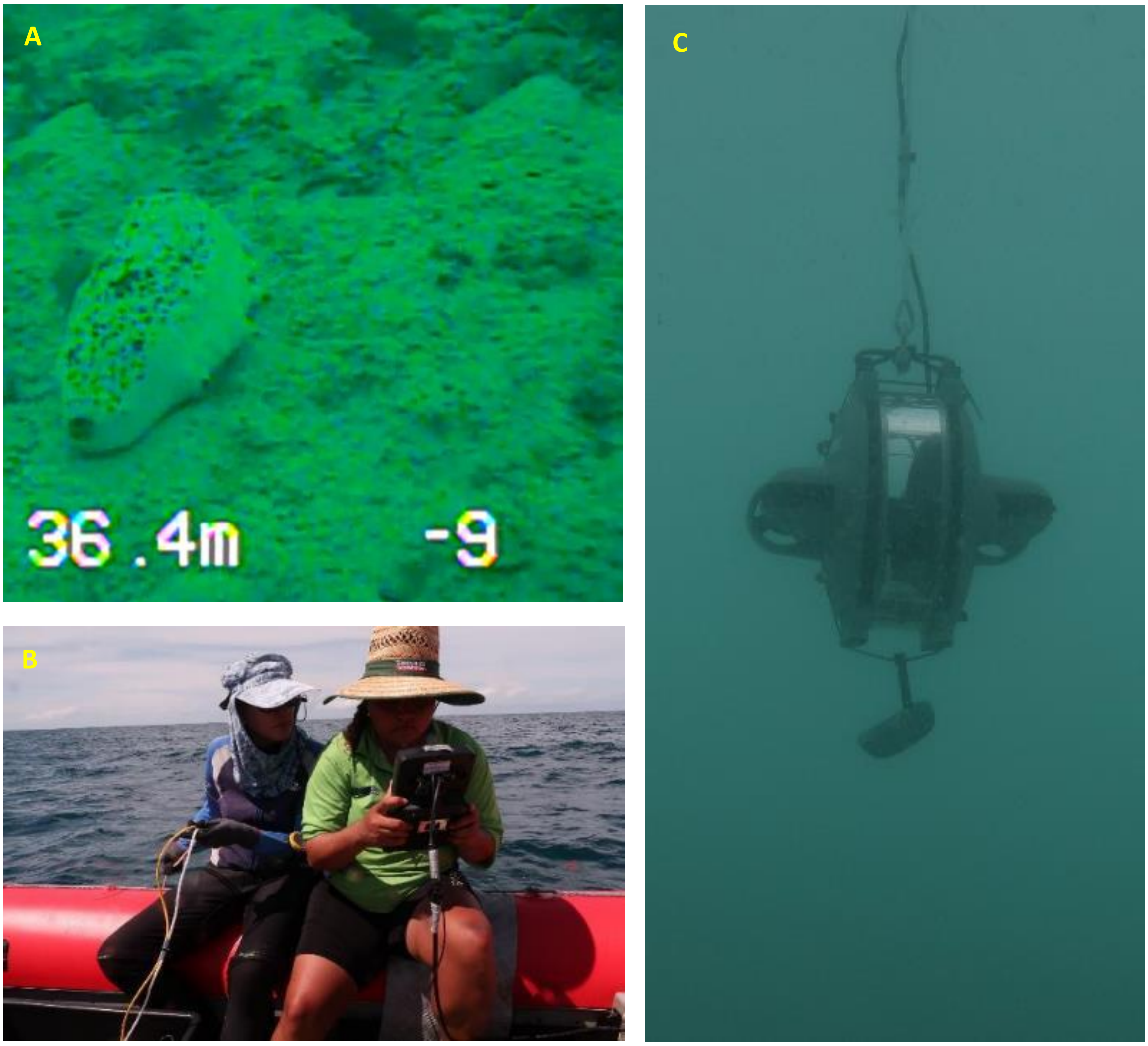


Figure 2-5. Deep-reef habitat survey A) White teatfish (*H. fuscogilva*) on video transect B) Undertaking video transect - N. Murphy and M. David C) Deep Trekker DGT3 Remotely Operated Vehicle (underwater view).

2.7.3 Survey highlights

This was the fifth survey of East Torres Strait. The number of sites in 2019/20 was the highest since 2002. The survey also included deep-reef (>20 m) sites for the first time. We managed to sample all zones in East Torres Strait. Sites were mostly repeated sites that have been visited in previous surveys. For the first time, we were able to investigate deep-reef populations, particularly for White teatfish (see section 2.7.2). The study also included intensive sampling of Ugar reef to investigate the fine scale habitats and sea cucumber populations (Murphy et al., 2020) (see section 2.8).

2.8 Ugar Island survey

Surveys of Ugar Island and Campbell Reef to map habitats and quantify populations of sea cucumbers and giant clams were undertaken in order to provide information to the community, and for support of a sea cucumber re-seeding proposal currently being developed by Mr Rocky Stephens and CSIRO researcher Dr Leo Dutra. This work will help to improve sea cucumber stocks for the benefit of local communities in Torres Strait.

This survey received approval from Mr Sereako Stephen, Chair of the Ugar RNTBC and Councillor, Mr Rocky Stephen upon survey consultation (see Appendix A.1).

Sixty snorkel and dive transects were undertaken as part of the December 2019 and January 2020 survey. Of the sites sampled, 38 were surveyed in previous years (repeated measures), with 22 new reef top, reef top buffer and representative reef edge sites were added to inform on sea cucumber species, distribution and habitat (Figure 2-6).

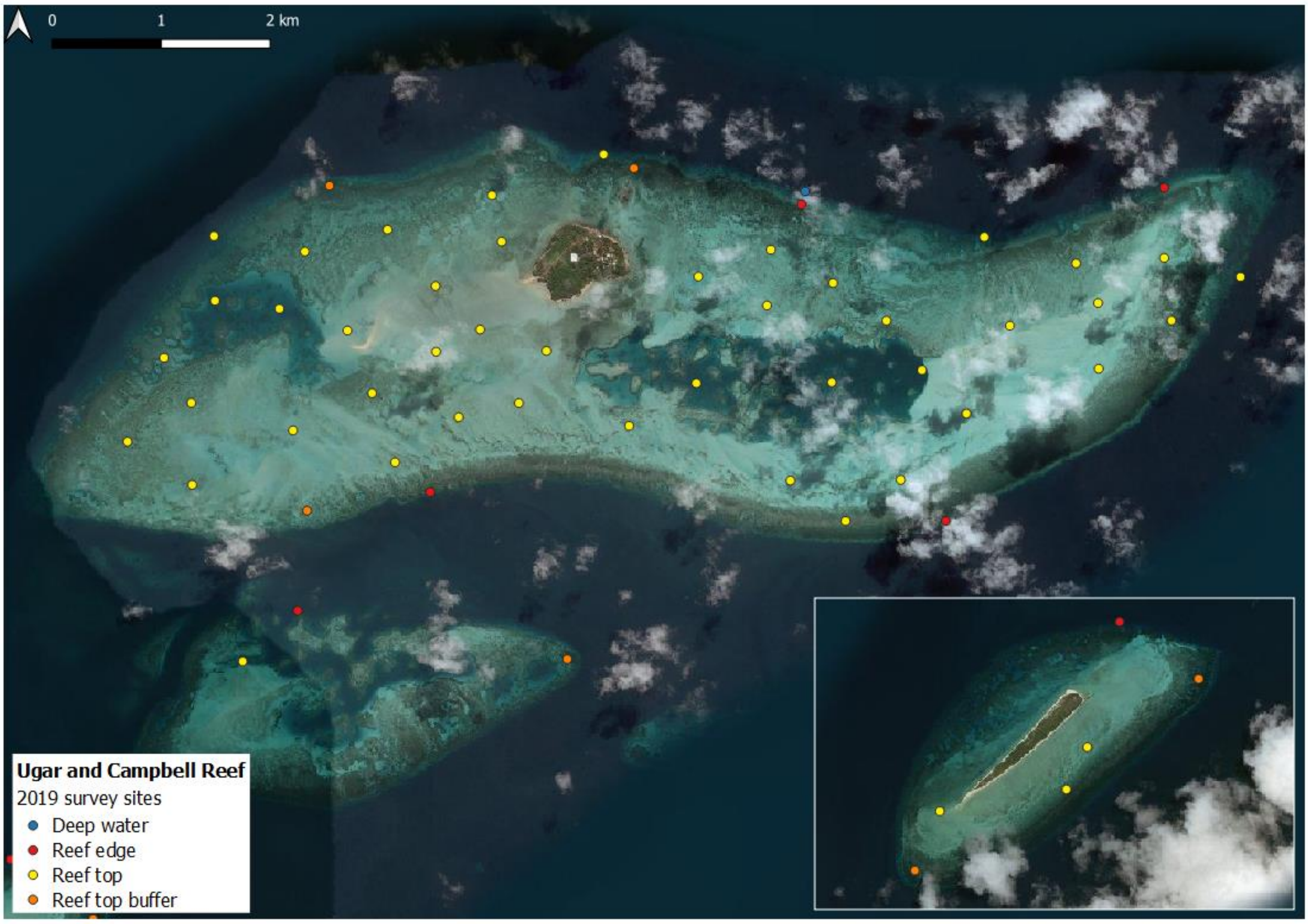


Figure 2-6. Survey sites sampled at Ugar Island and Campbell Reef during 2019/20 survey, Torres Strait.

2.8.1 Ugar survey report

A separate report for the Ugar field survey was produced for provision of results to the community, as part of project consultation and support for the re-seeding proposal (Murphy et al., 2020).

2.9 Data analysis

2.9.1 Stratified density

Estimates of mean density (count per hectare) were derived using a stratified analysis of transect counts based on zones (logbook areas) and reef strata. This takes into account the heterogeneity in the variance of observed counts and is representative of the physical size differences of the varying habitats in the surveys.

Note: Zone by Strata combinations – Great North East Channel + Deep-reef, and Barrier + Deep-reef were not sampled.

Density trends

For investigating trends in species density, we compared survey sites within zones and strata that were sampled in previous years. For all surveys since 1995, four zones were sampled consistently: Cumberland, Darnley, Seven Reefs and Don Cay zones.

Standing stock

Estimates of standing stock were calculated as the product of estimates of density, reef area and average weight from size frequency data collected during the survey. These data are suitable for calculating standing stock estimates for the surveyed areas, but not for direct comparison between years.

As the fishery catch in Torres Strait is recorded as (mostly) landed (gutted) weight (AFMA, 2019), we converted this estimate to landed (gutted) weight (referred to as fishery stock estimate) for comparison with catch data using updated fishery conversion factors (updated since the 2009 survey; Murphy et al. 2020). The 90th percentile of the mean estimate for distribution (assumes that the real estimate would be 90% certain of being greater than this value), were also used as a conservative stock estimate (where possible).

Note: the population estimates in this report are updated from those provided in the Milestone Report (Murphy et al., 2020) using the latest estimates of deep-reef habitat where applicable.

2.9.2 Mirror-match bootstrapping

Mirror-match bootstrapping was also used to construct sampling distribution for the difference in stratified means for estimates of standing stock. The combination of some small within-stratum sample sizes; zero-inflation of counts (high proportion of sites with zero counts); and the skew and nonconformity of the distribution of observed densities renders many standard parametric analyses inappropriate.

To obtain comparable measures of uncertainty in density estimates across surveys, bootstrap confidence intervals were derived via the mirror-match bootstrapping technique developed by Sitter (1992). Mirror-match bootstrapping extends standard resampling methodology to stratified, multistage sample designs by emulating the original within-stratum sampling procedure.

Confidence intervals were set as the quantile corresponding to the desired percentile of the distribution. The use of an increasing number of runs was tested to ensure that bootstrap summary statistics converged satisfactorily, with results provided in the report corresponding to using 1000 bootstrap runs.

We calculated the bottom 90th percentile of the bootstrapped mean estimate of the distribution (this assumes that the real estimate would be 90% certain of being greater than this value), as a conservative stock estimate.

B = Fishery biomass as Biomass (tonne) of L90th Landed (wet gutted) weight

Stock Estimate = B (accounts for uncertainties for the stock)

This approach is consistent with the new Harvest Strategy specification that the “Trial opening TAC needs to be set at a demonstrably conservative level” (AFMA, 2019).

2.9.3 Morphometrics

Length and weight measurements were used to produce frequency distributions and regression analyses for Black teatfish. Fishery size statistics were also calculated for sea cucumber species where applicable.

2.9.4 Catch

Catch data from 2017 to 2020 recorded as part of the Fish Receiver System were analysed to view total catch for species across years fished and Catch per Unit Effort (CPUE) for species for catch, recorded in standard weight (application of conversion ratio). Processing methods used for sea cucumber species were also considered and used to convert to standardised biomass estimates. As there are limited data, these analyses are still developing.

3 Results

3.1 Black teatfish (*H. whitmaei*)

3.1.1 Density

The Barrier zone had the highest "whole of reef" density of Black teatfish (*H. whitmaei*), followed by Don Cay. Darnley and Great North East Channel zones had a very low density. Cumberland and Seven Reef zones were intermediate. This follows the common pattern in Torres Strait (Skewes et al., 2010; Murphy et al., 2020) and the GBR (Benzie and Uthicke, 2003; Knuckey and Koopman, 2016), with Black teatfish more common in the barrier and outer shelf reefs (Table 3-1).

The highest densities of Black teatfish in 2019/20 were found for the reef top buffer strata of the Barrier (27 per Ha) and Don Cay (21 per Ha) zones, and overall, the reef top buffer strata had the highest density of all reef strata (Table 3-1; Figure 3-1). Reef edge had the next highest density, followed by the reef top strata. No Black teatfish were observed in the deep-reef habitats (>20 m) strata. This distribution pattern is consistent with previous surveys in Torres Strait (Skewes et al., 2010) and also on the adjacent Great Barrier Reef (Benzie and Uthicke, 2003; Knuckey and Koopman, 2016).

Table 3-1. Density (No. per ha) for Black teatfish (*H. whitmaei*) in each zone and stratum in 2019/20 (GNE = Great North East) Note: Includes sites that are not Black teatfish specific habitat.

Zone	Reef top	Reef top buffer	Reef edge	Deep reef	Zone Ave
Barrier	0	26.8	7.8	-	17.5
Cumberland	7.6	8.9	12.5	0	6.5
Darnley	0	0	4.2	0	0.3
Don Cay	19.8	21.3	12.9	0	14.6
GNE Channel	0	0	0	-	0
Seven Reefs	4.7	14.1	11.1	0	4.3
All	5.3	11.7	8.7	0	5.8

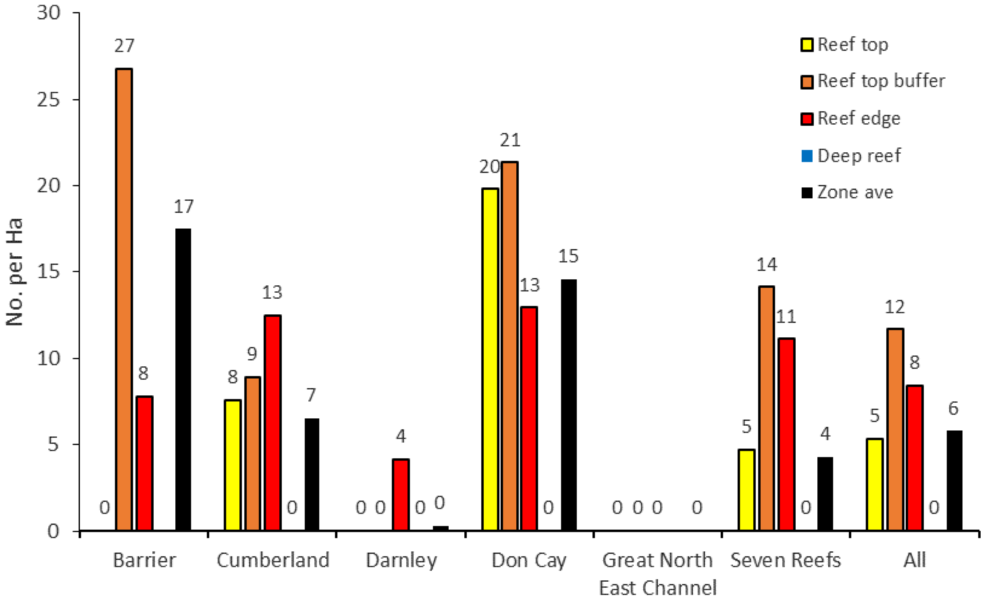


Figure 3-1. Zone and stratum average density (No. per Ha) for Black teatfish (*H. whitmaei*) in 2019/20.

3.1.2 Stock estimate

The landed (wet gutted) weight of Black teatfish in East Torres Strait in 2019/20 was 1,233 t and the bootstrapped lower 90th percentile (landed (wet gutted) weight) of the stock estimate (B) was 787 t (Table 3-2). Of that estimate, the available stock above fishery size limit (> Minimum Legal Size = 250 mm) for Black teatfish was 172.3 t (Table 3-3).

Table 3-2. Stock estimate for Black teatfish (*H. whitmaei*). For each Zone and for East Torres Strait (ETS), the number of sites, total area of fishery habitat, stratified mean density, stratified variance, population stock estimate in numbers (n), live weight (wt) and landed (wet gutted) weight (wt); and for all ETS, the bootstrapped lower 90th percentile of the landed (wet gutted) weight (B) (GNE = Great North East, ETS = East Torres Strait; MLS = Minimum Legal Size).

Zone	Sites	Mean density	Var (st)	Stock (n)	Live wt (t)	Landed wt (t)	B (t)	B >MLS (t)
Barrier	16	17.5	117.5	283,515	462.7	313.3	-	-
Cumberland	50	6.5	17.7	412,235	672.8	455.5	-	-
Darnley	89	0.3	0.1	16,534	27.0	18.3	-	-
Don Cay	104	14.6	16.2	282,963	461.8	312.7	-	-
GNE Channel	6	0	0	0	0	0	-	-
Seven Reefs	33	4.3	3.4	120,489	196.7	133.1	-	-
ETS	298	5.8	3.0	1,115,735	1821.0	1232.8	787.0	172.3

*Weight statistics calculated using average weight data for species for survey year, or across survey years.

3.1.3 Size and weight

Length-frequency

Survey length measurements for Black teatfish for 2019/20 were represented across a wide size range (100 mm to 325 mm). The size classes measured represented a wider range of sizes than previously observed (Table 3-3, Figure 3-2), with some of the largest Black teatfish also recorded, indicating a healthy population. However, the average size was slightly smaller than in 2009, with a slightly lower proportion of legal-size animals (>250 mm) (Table 3-3; Figure 3-2).

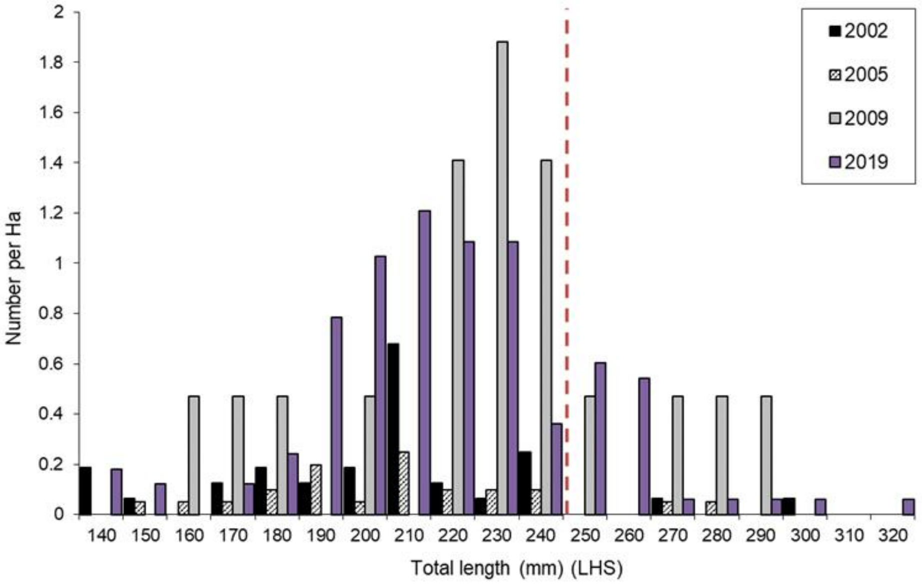


Figure 3-2. Length frequency for Black teatfish (*H. whitmaei*) collected during population surveys in East Torres Strait in 2002, 2005, 2009 and 2019. Minimum Legal Size (MLS) of 250 mm indicated; LHS = minimum size of bin range.

Statistics

Size and weight measurements for Black teatfish collected during surveys in 1995/96, 2002, 2005, 2009 and 2019/20 were used to calculate fishery size statistics and their application to Minimum Legal Size (MLS = 250 mm) (Table 3-3).The proportion of legal-size Black teatfish stock (MLS >250 mm) for the 2019/20 survey was 18.9 % (Table 3-3).

Table 3-3. Size statistics for measured Black teatfish (*H. whitmaei*) during 5 surveys between 1995 and 2019.

Length and weight	1995/96	2002	2005	2009	2019/20
Count	7	35	23	18	127
Mean Length (mm)	203.9	209.3	209.3	228.1	219.0
Standard Deviation (mm)	58.8	44.5	31.9	34.5	31.5
% Legal size (250 mm)	14.3	8.6	8.7	22.2	18.9
Mean Weight (g)	1542.9	1666.5	1704.3	1701.0	1632.1
Standard Deviation (g)	383.4	387.8	251.8	216.6	344.1
Mean Wt (g) >MLS (250 mm)	1900.0	2051.9	1900.0	1976.4	1891.2
Standard Deviation (g)	-	127.6	318.2	103.7	399.8
Min length (mm)	106.3	120.5	156.7	160.0	100.0
Max length (mm)	259.9	300	280.0	290.0	325.0

Size

For Torres Strait, the maximum size for Black teatfish is around 300 mm, with individuals commonly measuring 150 mm (Murphy et al., 2019). The maximum size recorded for the 2019/20 survey was 325 mm and the average size was 219 mm, which was lower than the 2009 survey but larger than historical surveys. This indicates that full size adults are present in the population, with average size Black teatfish above common size and almost at size at maturity - determined as 220-260 mm (Murphy et al., 2019) (Table 3-3).

Weight

The average (live) weight for Black teatfish for the 2019/20 survey was 1,632 g, with the weight range recorded as 580-2,980 g for 91 individuals. The mean weight of Black teatfish >MLS (250 mm) for Torres Strait was 1,891 g (Table 3-3).

Measurements of Black teatfish from the Great Barrier Reef (GBR) during a survey in 2015, recorded an average (live) weight of 1,820 g and a weight range of 500-2900 g for 207 individuals (Knuckey and Koopman, 2016). The average weight of Black teatfish for Torres Strait was lower than the GBR, which may be due to more, smaller sized individuals being sampled during the 2019/20 survey, or smaller sized individuals present in the population. The weight range for the GBR was comparable to Torres Strait.

3.1.4 Length-weight relationships

Length and weight measurements for Black teatfish collected during Torres Strait surveys were analysed by fitting a power function according to Pauly (1996), to formulate a relationship between the two measures (Table 3-4): $W = aL^b$ (where)

W = weight in grams
L = length in mm
a, b = constants that determine the shape of the relationship

Analyses were undertaken for all measurements from combined survey years and for the 2019/20 survey (Table 3-4).

Table 3-4. Number of Black teatfish (*H. whitmaei*) measured, length-weight relationship and regression parameters for combined survey years (All = 1995/96, 2002, 2005, 2019/20) and for the 2019/20 survey.

Survey	n	Length-Weight relationship	r	a	b
All	131	$W=18.248\ L^{0.835}$	0.276	18.248	0.835
2019	91	$W=9.918\ L^{0.943}$	0.135	9.918	0.943

The results suggest a weak power relationship only between length and weight for Black teatfish in the size range measured in Torres Strait (though still statistically significant; $p<0.001$ - the fits to the data are significant, but suggest that the relationship is not strongly described by a power function), indicating there was considerable variation in weight for animals for the length range of 150 - 300 mm (Figure 3-3).

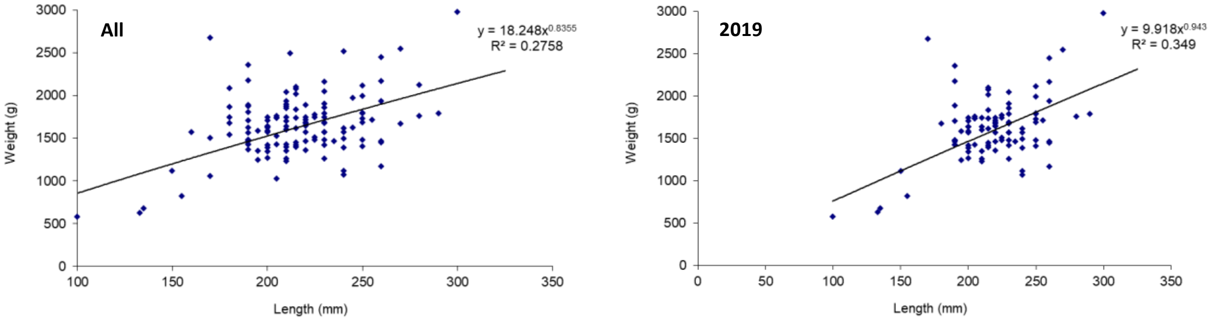


Figure 3-3. Length-weight relationship for Black teatfish (*H. whitmaei*) for combined survey years (All n = 131) and for the 2019/20 survey (n = 91).

3.1.5 Stock status

Stock status is usually assessed as the populations density or biomass relative to its virgin (before fishing) density/biomass (often referred to as B0), which is related to the ecological system carrying capacity for that species. This can be a difficult process when dealing with species that may have variable recruitment and/or population density over time, or have a patchy distribution between or even within fishery habitat areas.

Additionally, fisheries depend on increases in productivity as populations are reduced by fishing, with the maximum productivity (maximum sustainable yield – MSY) at BMSY, and the maximum economic yield (MEY) at BMEY. Population depletion to levels lower than this will reduce productivity and can eventually lead to levels where recruitment is impaired, resulting in a very slow recovery or even local extinction. Understanding these levels is important for maintaining populations in a healthy state. Unfortunately, for sea cucumbers, these “reference” levels (often expressed as the target biomass reference level – BTARG – where we want the population to be based on BMEY; and the limit reference biomass level – BLIM – where the danger of recruitment failure is unacceptably high) are not well understood.

While default values of BTARG and BLIM in the Commonwealth Harvest Strategy Guidelines (DAF, 2007) are 48% B0 for BTARG and 20% B0 for BLIM, there is wide recognition that these reference levels may be too low for sea cucumbers, due in part to the “Allee” affect where there is disproportionately low fertilisation success in the water column at low densities.

The TSBDMF Harvest Strategy acknowledges this uncertainty by specifying a conservative proxy value of BLIM of 40% B0. It is envisaged that values of BTARG will be developed as more data become available.

The current status of the Black teatfish fishery population can be assessed by comparison of current density, with density estimates from previous surveys and with surveys in neighbouring fisheries and regional surveys.

Note

Unbiased comparisons of animal densities over time and between locations is dependent on a clear delineation of the surveyed habitats, and the application of objective and repeatable sampling approaches. Sea cucumbers, particularly Black teatfish, are found at variable densities across reef morphometric habitats and in relation to distance from terrigenous influence (across shelf)—and likely several other lesser known gradients.

Fortunately, historical surveys in Torres Strait have been carried out using the same sample design and survey approach, therefore comparisons of density over time likely indicate actual population status (within the bounds of statistical confidence). While the Torres Strait surveys sample all reef habitats and the majority of the geographical range of Black teatfish in Torres Strait (at least at the level of Zones), other surveys on the GBR have only surveyed “suitable habitat” (usually defined as the weather edge reef buffer (200 m) zone) (Benzie and Uthicke, 2003; Knuckey and Koopman, 2016), making comparisons difficult. Other reference values from the South Pacific are even more poorly defined.

3.1.6 Comparison to previous surveys in Torres Strait

The overall average density for Black teatfish in 2019/20 was slightly lower than 2009, which in turn, were the highest ever observed in Torres Strait since surveys began (though with low statistical confidence) (Table 3-5; Figure 3-4).

The zone with highest average densities were found in the Barrier and Don Cay zones (Table 3-5, Figure 3-4, Figure 3-5), which is consistent with earlier surveys, and is consistent with surveys in other regions (e.g. GBR has highest population density in outer shelf and barrier reefs—Benzie and Uthicke, 2003; Knuckey and Koopman, 2016). Cumberland zone density in 2019/20 was lower than in 2009 but still higher than historic surveys, and Seven reefs had the highest density since surveys have been undertaken. Darnley has the lowest density ever observed (though never a high-density zone in any year) and no Black teatfish were observed at the Great North East Channel zone.

The highest density reef habitats for Black teatfish were the reef top buffer (outer 200 m) strata of the Don Cay and Barrier zones (Figure 3-1; Table 3-1) at 21.3 and 26.8 per Ha respectively, which was consistent with previous surveys (and studies elsewhere; see section 3.1.7).

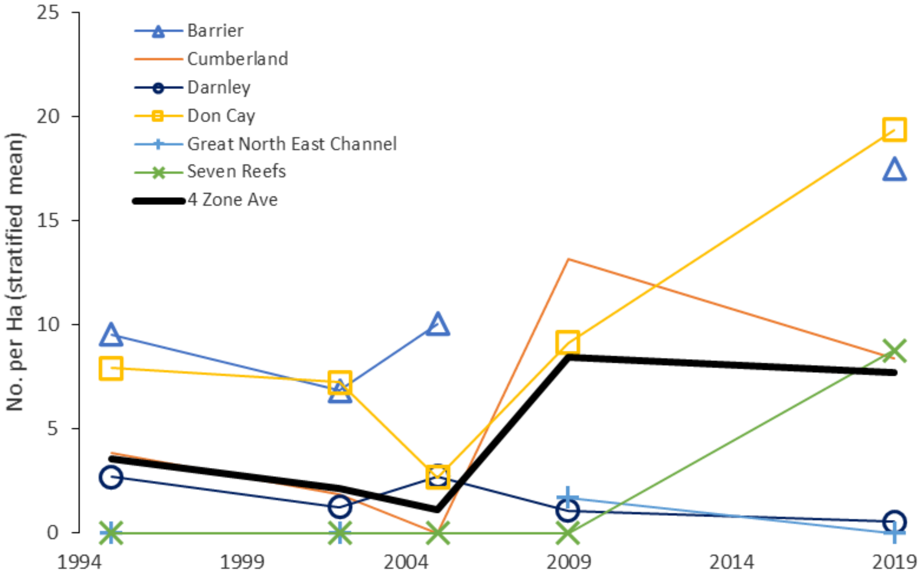
Given the low levels of exploitation since the fishery was closed in 2003 (~40 t) relative to current estimates of fishery biomass, and current density relative to previous surveys, we can say with some confidence that the population is likely to be above the limit refence point (B_{LIM}) of 40% B_0. Furthermore, high densities observed in the preferred Black teatfish habitats (reef-top buffer strata) of Don Cay and Barrier, and observations of long-term Traditional Owner fishers (reported anecdotally at HCWG meetings), indicate the population is likely near virgin biomass levels (B_0).

However, there are still some uncertainties in the assessment, particularly with regard to the lower density values in the Darnley and Cumberland zones (Figure 3-4; Figure 3-5) - two zones that would likely be subject to the highest fishing pressure in the reopened fishery.

Table 3-5. Zones and East Torres Strait (4 zone = Cumberland, Darnley, Seven Reefs and Don Cay) average (Ave) (stratified) density (No. per ha) for reef stratum for Black teatfish (*H. whitmaei*) for five surveys (does not include deep-reef strata) (GNE = Great North East). Note: Includes sites that are not Black teatfish specific habitat.

Year	Barrier	Cumberland	Darnley	Don Cay	GNE Channel	Seven Reefs	4 Zone Ave
1995/96	9.5	3.9	2.7	7.9	0	0	3.6
2002	6.8	1.8	1.2	7.2	0	0	2.2
2005	10.0	0	2.7	2.7	-	0	1.1
2009	-	13.2	1.1	9.1	1.7	0	8.5
2019	17.5	8.4	0.5	19.4	0	8.8	7.7

A)



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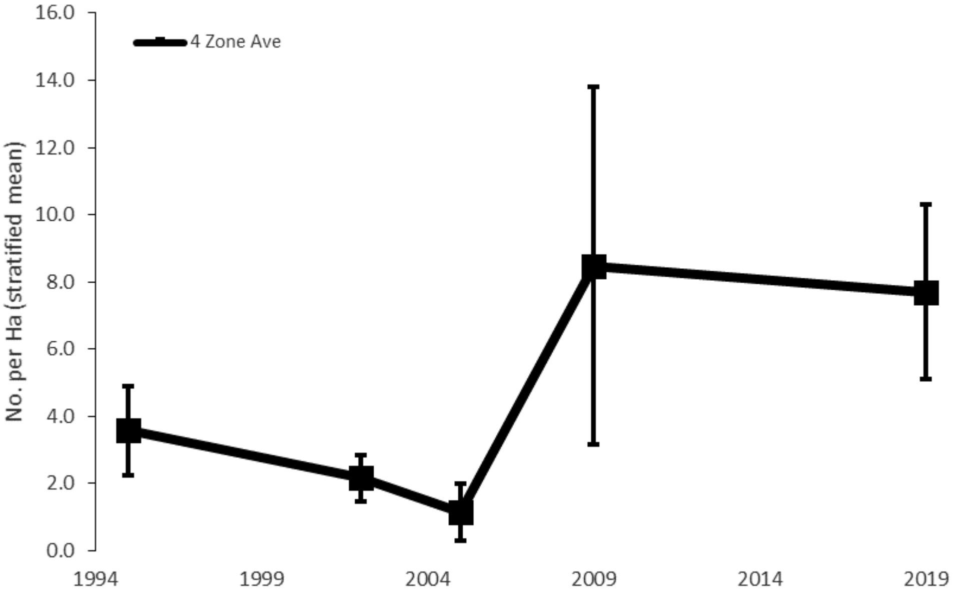


Figure 3-4. Zones (A) and East Torres Strait (4 zone = Cumberland, Darnley, Seven Reefs and Don Cay) (B) average (stratified) density (No. per Ha) for all reef stratum for Black teatfish (*H. whitmaei*) from five surveys (does not include deep-reef strata) (error bars = 1 s.e.). Note: Includes sites that are not Black teatfish specific habitat.

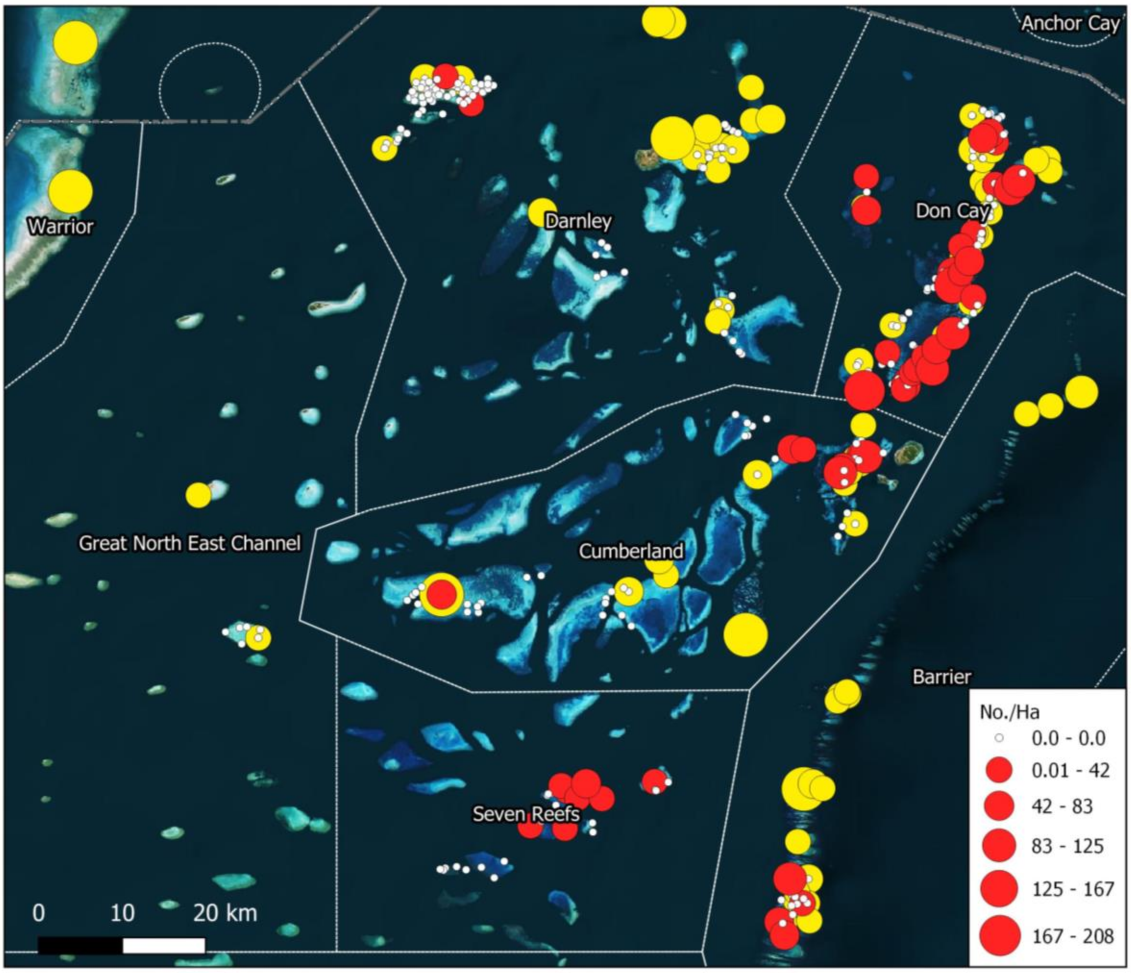


Figure 3-5. Density of Black teatfish (*H. whitmaei*) at individual survey sites during surveys in East Torres Strait from 1995 to 2009 (yellow) and 2019 (red).

3.1.7 Comparisons to other Black teatfish populations

Great Barrier Reef (East Coast Fishery)

A survey on the Great Barrier Reef (GBR) was carried out in 1999 (Benzie and Uthicke, 2003). Density estimates varied throughout the GBR, and although Black teatfish were found throughout the GBR, there was a gradient in density from high in the north to lower in the south. Black teatfish were also found in higher density on outer shelf and barrier reefs.

Stock status was assessed using density estimates of the mid and outer shelf reefs in the “area of the fishery” (12-19° S—Princess Charlotte Bay to Lucinda) (Benzie and Uthicke, 2003; Uthicke and Benzie, 2000). The habitat for the survey was described as the “shallow reef flat, though “areas with > 60% sand cover were avoided” (Benzie and Uthicke, 2003) and “we excluded areas from the reef flat that are unlikely habitat” (Uthicke and Benzie, 2000). Other than that, it is not clear how reefs were sampled, or the transect start locations (Knuckey and Koopman, 2016). Density estimates from the “fishery area” (Princess Charlotte Bay to Lucinda) were:

- Black teatfish in the “main habitat” on the shallow reef flat on ‘closed reefs’ were 20.97 individuals/Ha (n=6, 95% confidence interval [CI] = 16.3–25.73) (Uthicke and Benzie, 2000).

- Density of Black teatfish on the same habitat on ‘open reefs’ was 5.01 individuals/Ha (indicating a severe depletion caused by the fishery, and the fishery was closed in 1999) (Uthicke and Benzie, 2000).
- The virgin biomass estimate for the “fishery area” (Princess Charlotte Bay to Lucinda) was 5,585 t, and the depleted biomass was 2,518 t (Uthicke et al., 2004).

A recent survey in the northern zone of the GBR (Knuckey and Koopman, 2016) was carried out in 2015. Again, it was focused on the same fishery area as the 1999 survey but delineated the survey habitat area as the 200 m reef edge buffer on the weather (SE facing) side of reefs >1km^2. This survey found:

- Densities of Black teatfish of 13.5 (closed reefs) and 12.5 (open reefs) individuals/Ha in exposed mid-shelf reefs, and;
- Densities of 27.0 (closed reefs) and 23.6 (open reefs) individual/Ha for outer barrier reefs, in the exposed reef buffer (200 m) habitat.
- Overall, total gutted biomass estimated as 379 t. Note that this was only from reef buffer strata of reefs >1km^2 for only two bioregional strata in the Great Barrier Reef (18,365 Ha) (out of 636,500 Ha of dry reef area in GBR—2.9%). (Note that the habitat area for the 2019/20 East Torres Strait survey was 138,849 Ha.)

Based on the results of the 2015 survey, the Black teatfish population in the GBR “area of the fishery” was determined to have recovered to >70% of virgin biomass, therefore the fishery was opened in 2019 with a 30 t TAC.

Both studies indicate that densities in the reef buffer zone of midshelf and outer barrier reefs had a carrying capacity in the order of 12.5 to 27 individuals per Ha. This compares well with the density observed in the reef top buffer strata for the current Torres Strait survey, with densities of 21 to 27 per Ha recorded.

Natural Densities

A review of survey data from throughout the West Pacific concluded (Kinch et al., 2008):

- Densities above 12.5 per Ha represent a “natural density” in “suitable habitat”.
- Noting *“*the range of densities found at “closed” sites it seems a conservative assumption that densities above 12.5 ind. ha^{-1} represent a “natural” density for this species on suitable habitat.”

Densities higher than this are also possible. Guidance from the Secretariat Pacific Community provides “rule of thumb” regional reference densities of 50 individuals per Ha for Black teatfish — estimated from the upper 25% of densities across 91 sites assessed in 17 countries over the period 2002–2012 (Pakoa et al., 2014).

The highest site density observed during the 2019/20 survey of Torres Strait was 167 per Ha, and the mean of the upper 25% of densities in the reef top buffer strata for all reefs was 62.6 per Ha, and 82.3 per Ha for the Don Cay and Barrier zones combined.

Other estimates of "natural" density for Black teatfish in Western Australia include: 11.4 to 17.1 individuals/Ha in "habitats occupied by Black teatfish" and likely represents minimum natural population densities for Ningaloo Reef (Shiell and Knott, 2010).

Conclusion

Comparisons with regional density data from the GBR and West Pacific indicate that the Black teatfish populations in Torres Strait observed during the survey undertaken in 2019/20, are at near natural (unfished) densities (Figure 3-6) and this finding further corroborates Traditional Owners observations (of high densities) reported to HCWG meetings.

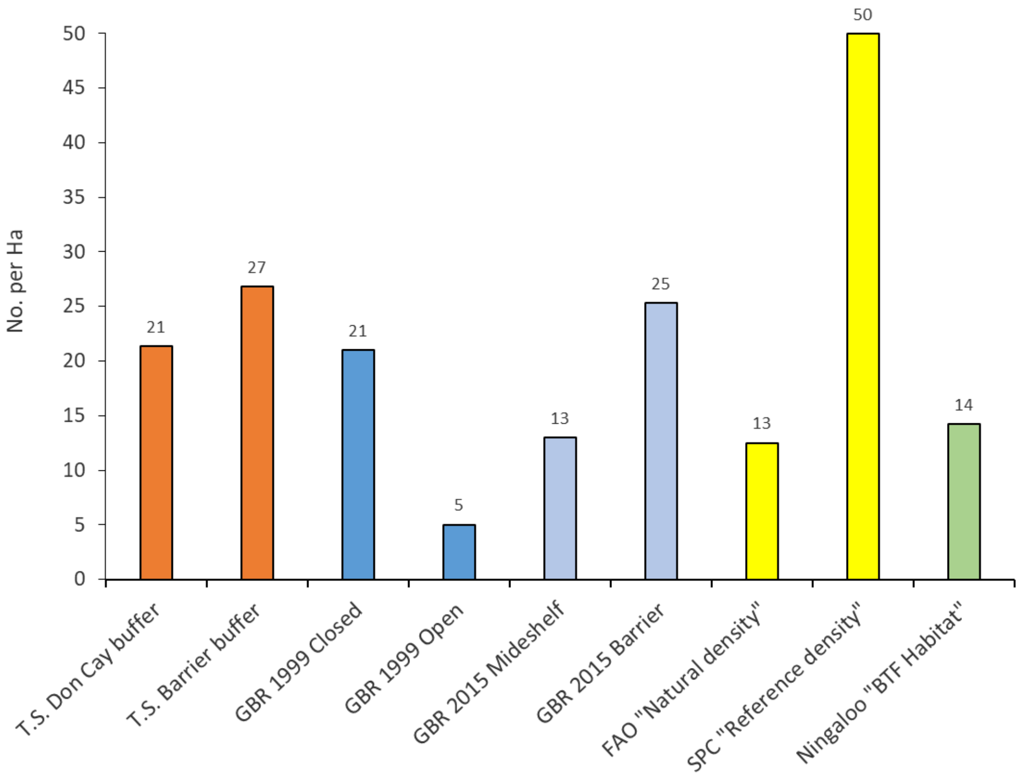


Figure 3-6. Comparison of density estimates for Black teatfish (*H. whitmaei*) in preferred habitat from various studies/regions (see text for source references).

3.1.8 Preliminary Population Modelling

Summary

A simple Pella-Tomlinson biomass dynamics population model was applied to the Torres Strait Black teatfish population as a whole, and was fitted to all available survey indices of abundance. The model is a preliminary simple model, only used for illustrative purposes and recommendations are provided for improved modelling that could be done in future. The modelling exercise acknowledges that there are limited data and large uncertainties. Nonetheless, when considering a range of uncertainties and across a number of model sensitivities, the modelling results suggest that 15 t is likely a sustainable annual TAC whereas a sustained 30 t TAC may result in the stock declining in future years. As more data become available, it will be possible to refine and substantially improve modelling results and adjust recommended TAC accordingly.

Introduction

To complement recent survey estimates and associated analyses for Black teatfish (BTF) in Torres Strait, some simple population modelling of BTF was done. There are a large number of uncertainties and limited data available to inform a population model. However, as a time series of survey estimates have become available, the purpose of the preliminary modelling was to assist in informing whether an increased initial reopening TAC might be possible for this species, considering some key uncertainties. We note that it would be better to use the spatial age-structured operating model used in previous Management Strategy Evaluation (MSE) analyses (Plagányi et al. 2013, 2015) but there was insufficient time and resources to provide updated modelling results for current purposes. Hence as an additional method for investigating what level of fishing might be sustainable, a simple aggregated modelling approach was applied here.

Methods

Population Model

One of the simplest population models that assumes logistic growth is the Schaefer model, for which Maximum Sustainable Yield (MSY) is achieved at half the carrying capacity (or pre-exploitation biomass) *K*. A more generalised form which allows a different shape of the production curve is the Pella-Tomlinson model. The following discrete Pella-Tomlinson equation with annual time-step was thus applied to the BTF population as a whole, with start year 1994:

$$N_{t+1} = N_t + r\,N_t\left(1 - \left(\frac{N_t}{K}\right)^{\mu}\right) - C_t \qquad (1)$$

where

N_t is biomass of BTF at start of year t;

K is the carrying capacity of BTF, which is assumed to be the total population biomass in 1994 when the fishery in TS started in earnest;

μ controls the shape of the production curve, with default value 1 (Schaefer model)

r is the net growth rate (encompassing somatic and population growth rate and including all non-anthropogenic sources of mortality);

C_t is the total annual catch (in tons live weight) of BTF in year t.

Fitting to Data

The model was fitted to the 5 available survey indices of abundance, together with their associated standard errors. The contributions by each of these to the negative of the log-likelihood (-*ln L*) are calculated assuming that the observed abundance index is log-normally distributed about its expected value:

$$I_t^s = \hat{I}_t^s e^{\varepsilon_t^s} \qquad \text{or} \qquad \varepsilon_t^s = \ln(I_t^s) - \ln(\hat{I}_t^s) \qquad (2)$$

where I_t^s is the survey *s* abundance index for year *t*,

$\hat{I}_t^s = q\ N_t$ is the corresponding model estimated value, where N_t is the model value for resource biomass, which uses the average of the four-zone estimates for each of the survey years (Table 3-6);

q is the constant of proportionality, and

ε_t^s from $N\left(0,\left(\sigma_t^{sp}\right)^2\right)$.

The contribution of the abundance data to the negative of the log-likelihood function (after removal of constants) is given then by:

$$-\ln L = \sum_t \ln \sigma_t^{sp} + \left(\varepsilon_t^s\right)^2 / 2\left(\sigma_t^{sp}\right)^2 \qquad (3)$$

The survey catchability coefficient *q* is estimated by its maximum likelihood value which, for the case of a log-normal error distribution, is given by:

$$\ln \hat{q} = \frac{\sum_t 1\big/\left(\sigma_t^{sp}\right)^2 \left(\ln I_t^s - \ln \hat{N}_t\right)}{\sum_t 1\big/\left(\sigma_t^{sp}\right)^2} \qquad (4)$$

where $\left(\sigma_t^{sp}\right)^2 = \ln\left(1+\left(CV_t\right)^2\right)$ and the coefficient of variation (CV_t) of the resource abundance estimate for year *t* is input.

A similar approach is used in a model version that fits to the absolute abundance estimate for 2019.

Model Alternative Versions and Parameter Estimates

The two key parameters estimated by the model were *r* and *K.* Alternative model versions were also attempted with these parameters fixed one at a time at plausible values, but these simulations didn’t yield any more insights than the preliminary results presented here. The default setting of parameter μ which controls the shape of the production curve, was 1 such that it corresponds to a Schaefer model. This parameter was also estimated by the model. The base-case model fitted only to the survey relative abundance indices. An alternative model was also run which included also fitting to the absolute estimate of abundance from the 2019 survey.

Base-case Model

The base-case model used was a Schaefer model that was fitted to the survey relative indices of abundance (4-zone averages; Cumberland, Darnley, Don Cay, Seven Reefs). As it is likely that the 1994 survey may have under-estimated stock size given it was an initial exploratory survey, the 1994 survey estimate is doubled in the base-case model. It is also recognised that there is uncertainty regarding historical catches (under-reporting and wastage), as in the early years in particular it was not compulsory to record catches. For this reason, the historical annual catch estimates have been multiplied by a factor of 1.5 (i.e. assumed 50% larger). Conversion rate for Total weight estimate to convert to landed (gutted) weight (to be equivalent to catch data) is 0.677.

Sensitivity Tests

A number of sensitivity tests were conducted and the results of a few key tests are presented here. These include different assumptions regarding the 1994 survey estimate, catches are double the base-case estimates and estimating the production shape parameter.

Results

A summary of the model results is given in Table 3-6.

Table 3-6. Summary of model results when fitting to 4-zone survey averages. Model variants shown are either S=Schaefer model or P=Pella-Tomlinson form (with associated parameter mu) and dbl represents doubling the 1995 survey estimate. The hessian-based standard deviations are shown in square brackets where appropriate. Models 3 and 8 are in italics because they resulted in a significantly poorer fit and hence there is substantially less confidence in these model versions.

	Description	No.pars	r & [STDEV]	K (t) & [STDEV]	q	-lnL	AIC	MSY (t)	BMSY (t)	B(2019) (t)	B2019/BMSY
Model 1	S; fix r	1	0.15	490.7 [67]	0.014	-2.336	-2.672	18.5	245.4	336.9	1.37
Model 2	double surv(95)	1	0.15	450.0 [257]	0.0233	-3.552	-5.104	16.9	225	242.3	1.08
Model 3	*S; fix r*	*1*	*0.1*	*600.9 [172]*	*0.01*	*-1.605*	*-1.21*	*15*	*300.5*	*385.7*	*1.28*
Model 4	S; fix r; dbl	1	0.2	416.6 [150]	0.025	-4.442	**-6.884**	20.8	208.3	274.7	1.31
Model 5	S; est r,K	2	0.29 [0.13]	391.8 [60]	0.017	-3.173	-2.346	28.5	195.8	344.3	1.75
Model 6	S; est r,K; dbl	2	0.25 [0.08]	396 [35]	0.025	-4.665	-5.33	24.6	197.8	308.2	1.56
Model 7	P; est r,K,mu; dbl; mu=3.5	3	0.25 (0.08]	396 [35]	0.025	-4.665	-3.33	49.7	257.4	308.2	1.19
Model 8	*Fix K, est r*	*1*	*0.097 [0.08]*	*820.6*	*0.0068*	*-1.23*	*-0.46*	*19.9*	*410.2*	*647.8*	*1.57*

The model was fitted for a range of fixed r values from lower to higher values, but the model failed to converge for very low *r* values and yielded a poor fit for the more conservative value of 0.1. When *r* was estimated together with *K*, the model estimate was 0.25, but the estimation of an additional parameter using the Akaike information criterion (AIC) means that it was not considered the best model. The model version with *r*=0.2 was therefore selected as the base-case model based on it having the lowest AIC score (noting that model selection criteria cannot be used to compare models with and without the 1995 survey estimate doubled, but the version with the 1995 survey estimate doubled was used as the base-case and sensitivities presented to support that this did not substantially affect model results). The fit of the base-case model is shown in (Figure 3-7).

The base-case model estimate of MSY was 20.8 t with 90% Hessian-based confidence interval 19.6-22.1 t (Table 3-6). Across all model versions and sensitivity tests, a TAC of 20 t was found to be sustainable whereas there were indications from most models that 30 t per year may be unsustainable in the longer term (Figure 3-8). Model 3 uses a more conservative *r* value which suggests a lower sustainable TAC of 15 t, but the model does not adequately fit the data. The Pella-Tomlinson MSY estimate is much higher but the model could not satisfactorily estimate the shape parameter μ(parameter could not be reliably estimated (C.V. >1) and hence the associated MSY estimate is highly uncertain. The model version (Model 8) that fixed *K* at higher values (821 t used in Model 8) resulted (as expected) in lower associated estimates of *r* (0.1 in Model 8) but did not satisfactorily fit the data (see AIC in Table 3-6) and hence is not considered further here, but this aspect will be investigated further in future work and as more data become available.

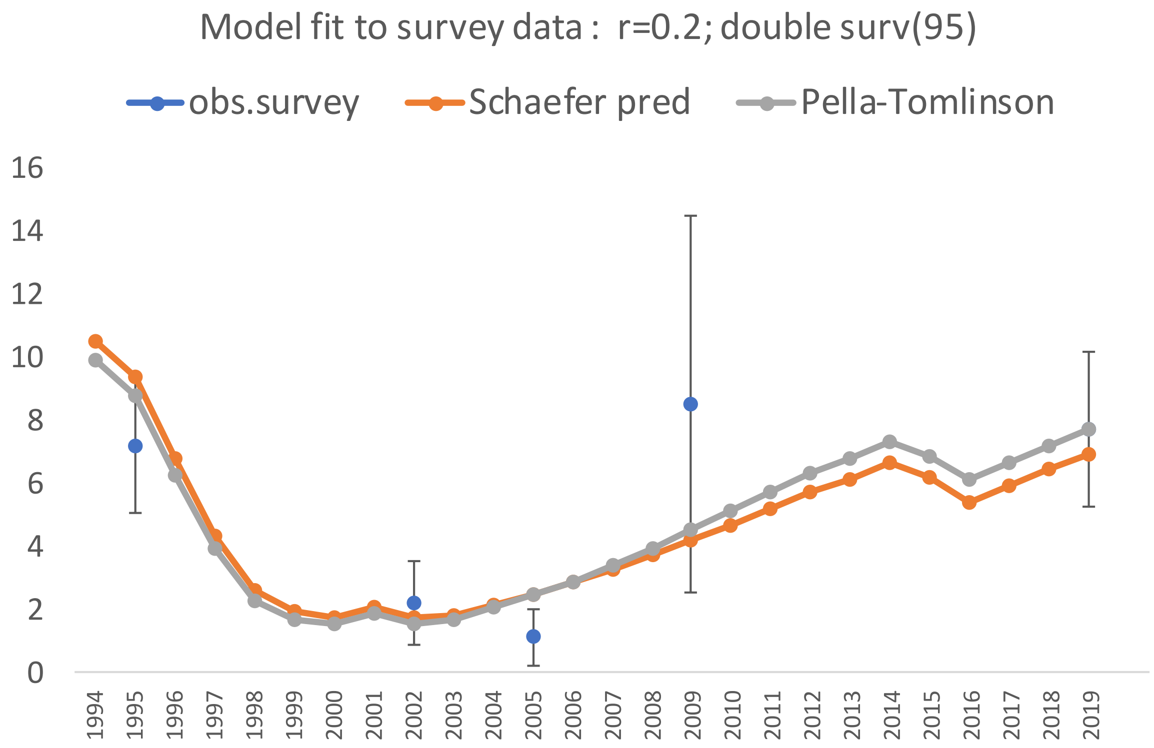
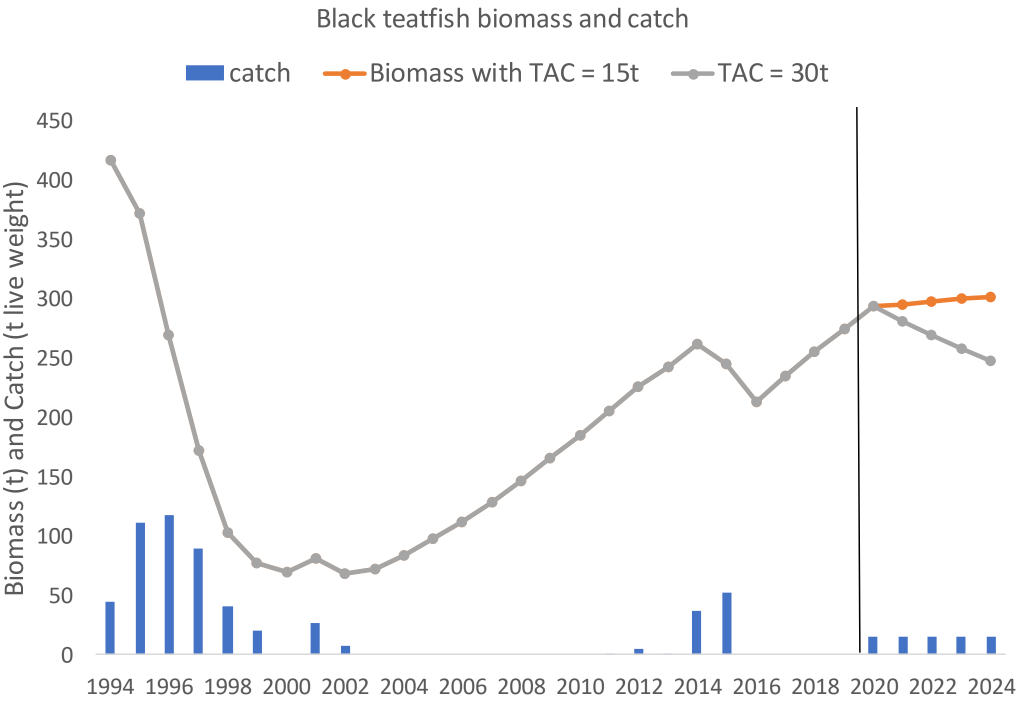


Figure 3-7. Base-case Schaefer model fit to observed survey data using observed standard error estimates (S.E.), and compared with model trajectory estimated using Pella-Tomlinson model version. Note: 1995 estimate doubled.



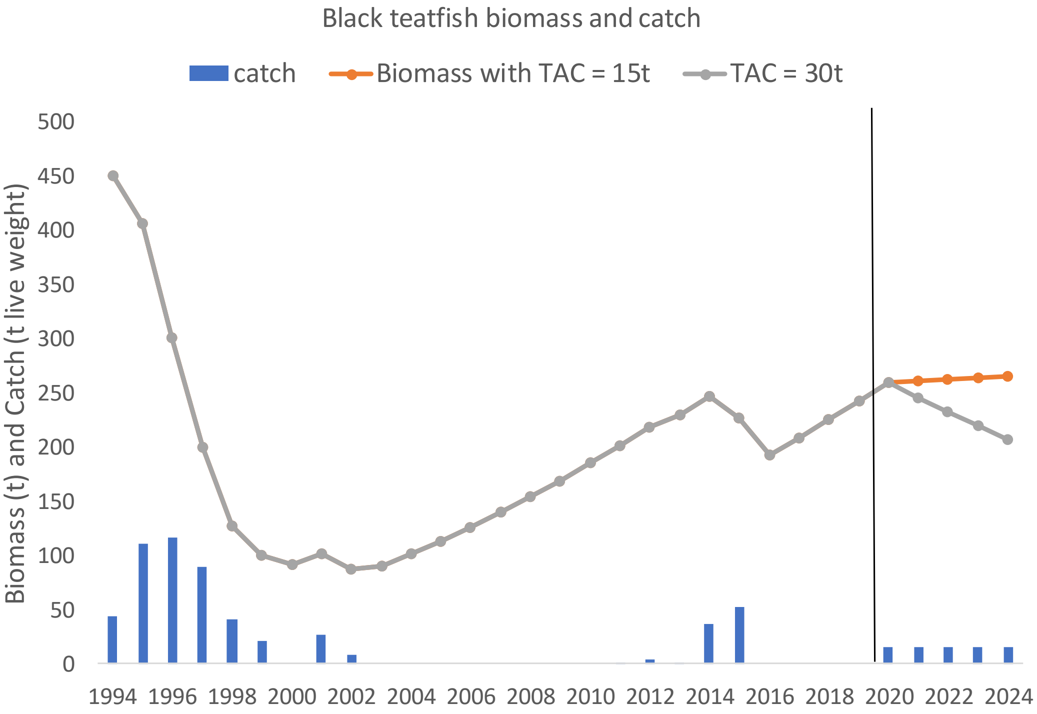


Figure 3-8. Base-case (Model 4) model-estimated (top) and model with lower r value (Model 2) (lower figure) total BTF biomass historical trajectory and showing 5-year forward projections when assuming an annual TAC of 15 t compared with 30 t.

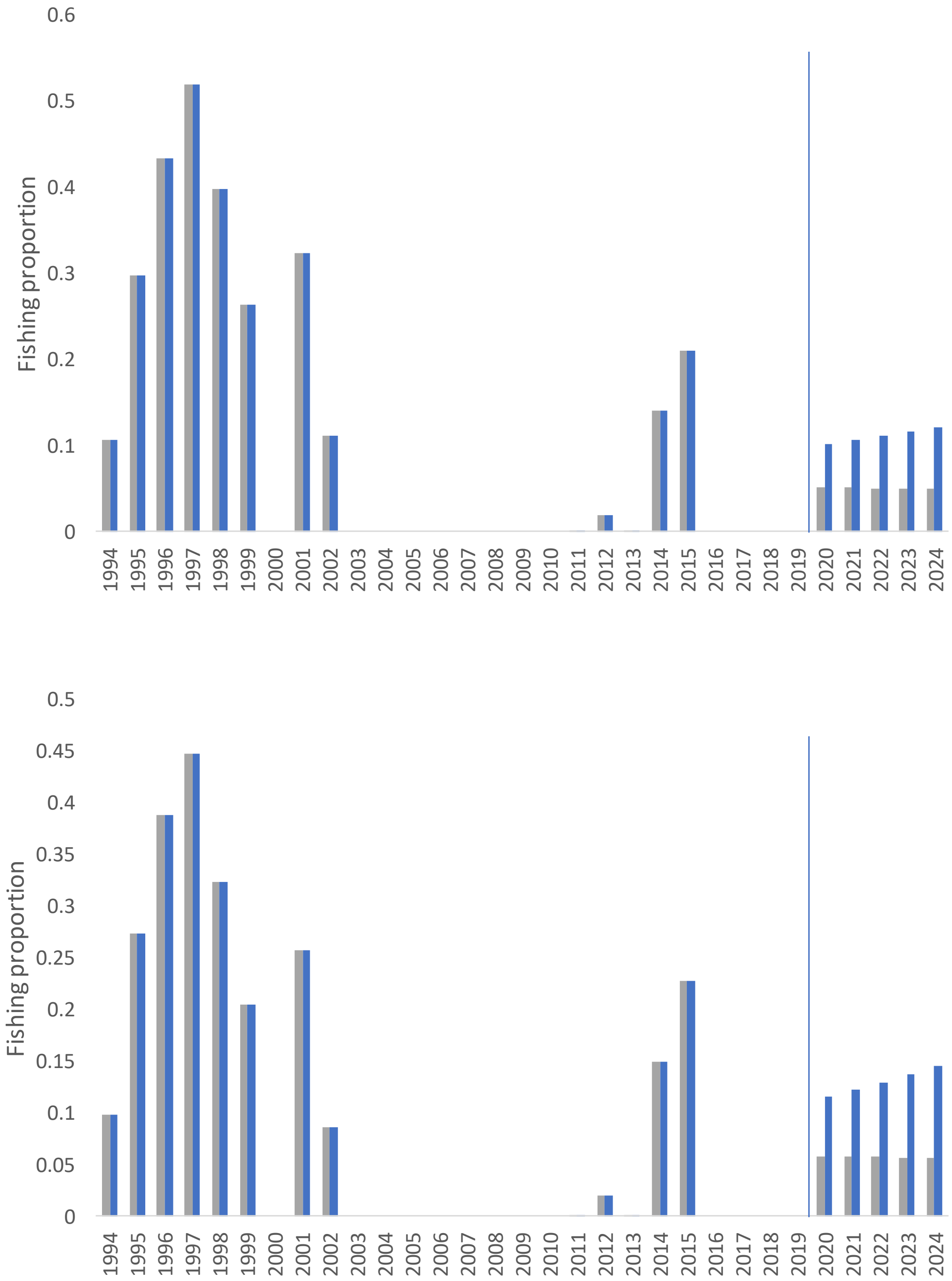


Figure 3-9. Base-case (Model 4) model-estimated fishing proportions (top) and Model 2 (bottom), computed simply as the total annual catch as a proportion of the total biomass. The vertical line separates the future projected illustrative catch proportions, where the grey bars correspond to a 15 t TAC and the blue bars a 30 t TAC.

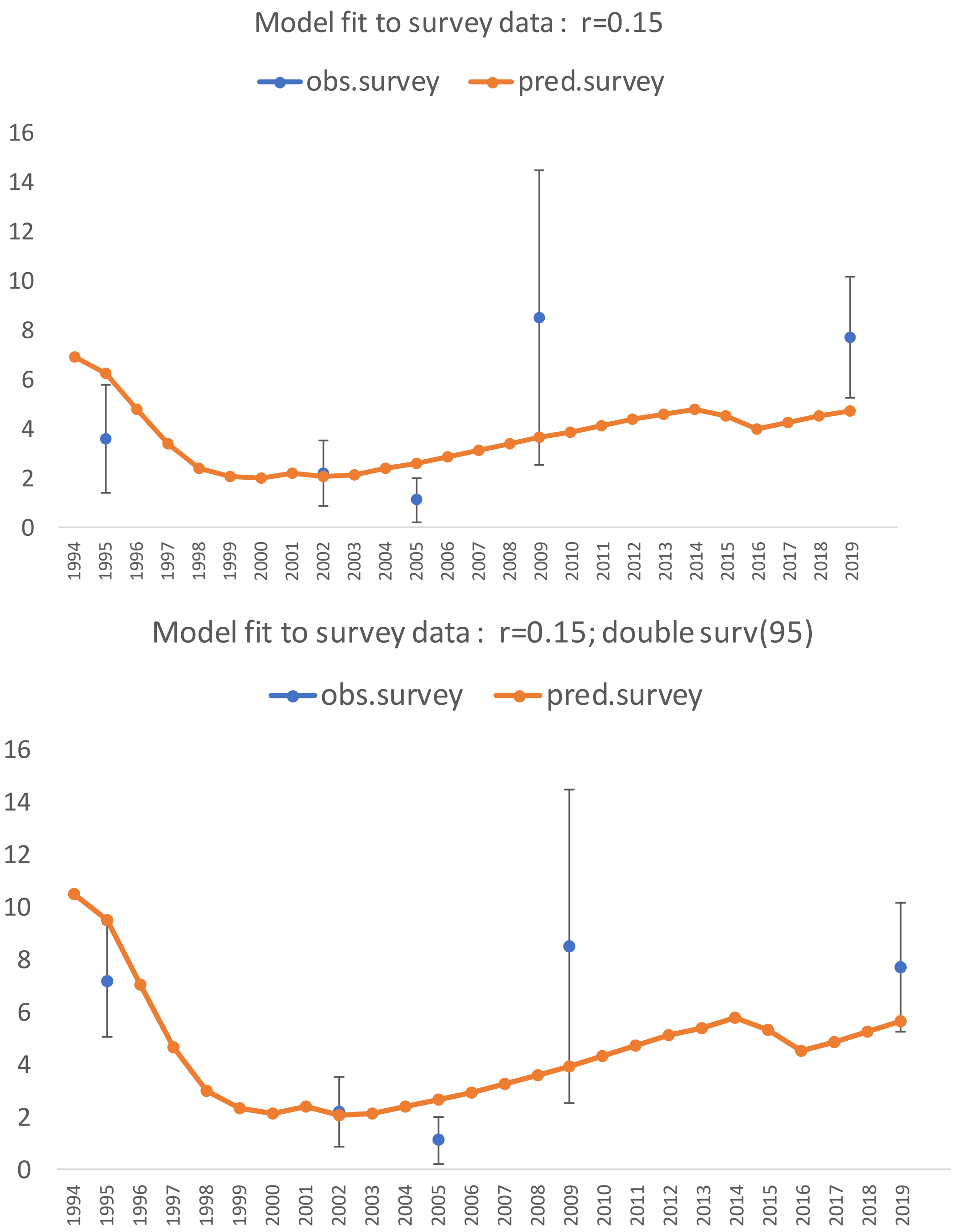


Figure 3-10. Alternative models fit to survey data: (A) Model 1 and (B) Model 2.

Discussion

These model results are preliminary only, acknowledging that there are limited data to inform a model and that the preferred modelling approach is that used in previous MSE testing, but that that approach requires more time to implement. Nonetheless, the modelling results may be useful to quantify likely sustainable catch limits when considering some key uncertainties. It wasn't possible with this simple model to match the absolute estimate of abundance of 2019 as the corresponding estimate of *r* was too low and the historical catches much smaller than the biomass so that the survey data could not be satisfactorily fitted. However, it is well known for surplus production models that the replacement yield is a much more robust estimate than the *r* and *K* parameters on their own, i.e. estimates of what level of future catch is likely to be sustainable.

The base-case model estimate of *r* had fairly large associated uncertainty but across all the model versions, *r* was estimated to be roughly 0.2 which is a relatively low turnover rate as expected. In the MSE model, a number of more detailed slow growth sensitivities are explored. A useful diagnostic used here was to consider the model-estimated fishing proportions as shown in Figure 3-9. This suggests that the base-case model is not unrealistic as the maximum annual fishing proportions were approximately in the range 0.1-0.5.

Across most model versions, projections suggested that a constant annual TAC of 30t may not be sustainable, whereas a TAC of 20 t (and hence 15 t) was sustainable across all model versions run. The base-case model estimate of MSY was 21 t, which is slightly higher than the 15 t precautionary TAC that is currently recommended by the Harvest Strategy.

As more data become available, it will be possible to refine and substantially improve modelling results.

3.2 White teatfish (*H. fuscogilva*)

3.2.1 Density

The highest density for White teatfish (*H. fuscogilva*) was for the deep-reef stratum, for Cumberland zone (17.1 ind./Ha), with Don Cay having the highest overall average zone density (10.9 ind./Ha) (Table 3-7; Figure 3-11).

Table 3-7. Density (No. per Ha) for White teatfish (*H. fuscogilva*) in each zone and stratum in 2019/20 (GNE = Great North East).

Zone	Reef top	Reef top buffer	Reef edge	Deep reef	Zone Ave
Barrier	0	0	5.7	-	1.5
Cumberland	0	0	3.9	17.1	4.1
Darnley	0.7	0	6.9	13.9	6.3
Don Cay	13.2	8.9	2.9	15.4	10.9
GNE Channel	0	0	0	-	0
Seven Reefs	0	0	2.8	10.4	5.4
All	1.1	1.2	4.4	13.9	5.0

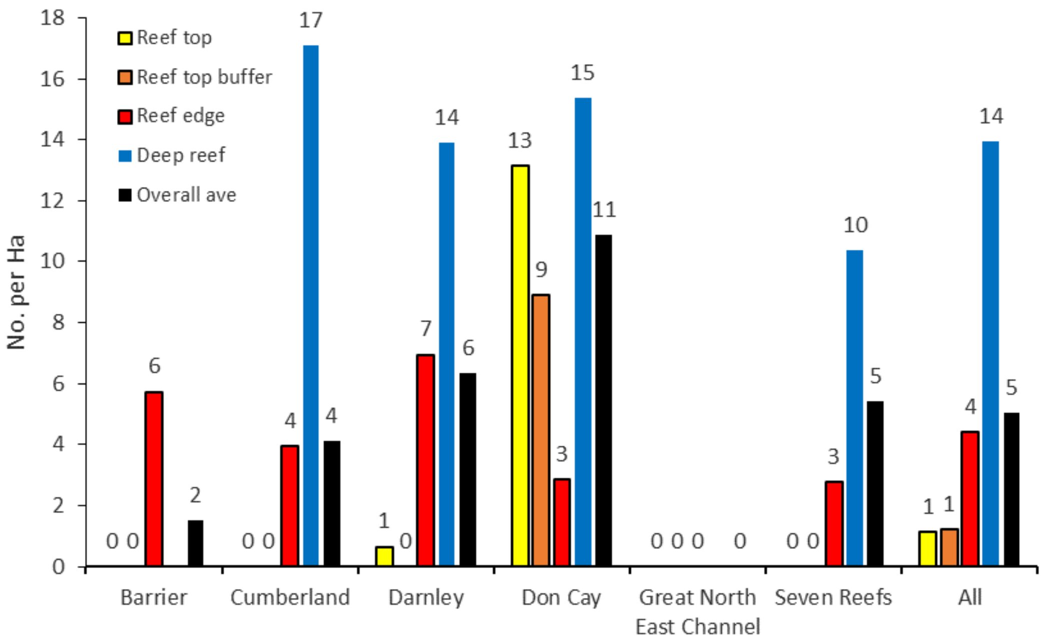


Figure 3-11. Zone and stratum average density (No. per Ha) for White teatfish (*H. fuscogilva*) in 2019/20.

3.2.2 Density trends

The highest survey density for White teatfish was found in the Don Cay zone (9.4 ind./Ha). The overall zone average was similar to 2005 (1.8 ind./Ha) (Table 3-8; Figure 3-12).

The 2009 survey data included sites only from the southern end of the Don Cay zone. Known White teatfish areas for the northern Don Cay zone were not surveyed, therefore this data point is not considered representative (Skewes et al. 2010).

Table 3-8. Zone and East Torres Strait (4 zone = Cumberland, Darnley, Seven Reefs and Don Cay) average (stratified) density (No. per ha) for reef stratum for White teatfish (*H. fuscogilva*) for five surveys (does not include deep-reef strata) (GNE = Great North East).

Year	Barrier	Cumberland	Darnley	Don Cay	GNE Channel	Seven Reefs	4 Zone Ave
1995/96	0.2	0	0.2	8.2	0	0	1.2
2002	0	0.4	0.6	13.4	0	2.6	2.5
2005	0	0.2	0.3	9.6	-	0.6	1.6
2009	-	1.3	0	0.8	0	0	0.8
2019	1.5	0.4	1.2	9.4	0	0.3	1.8

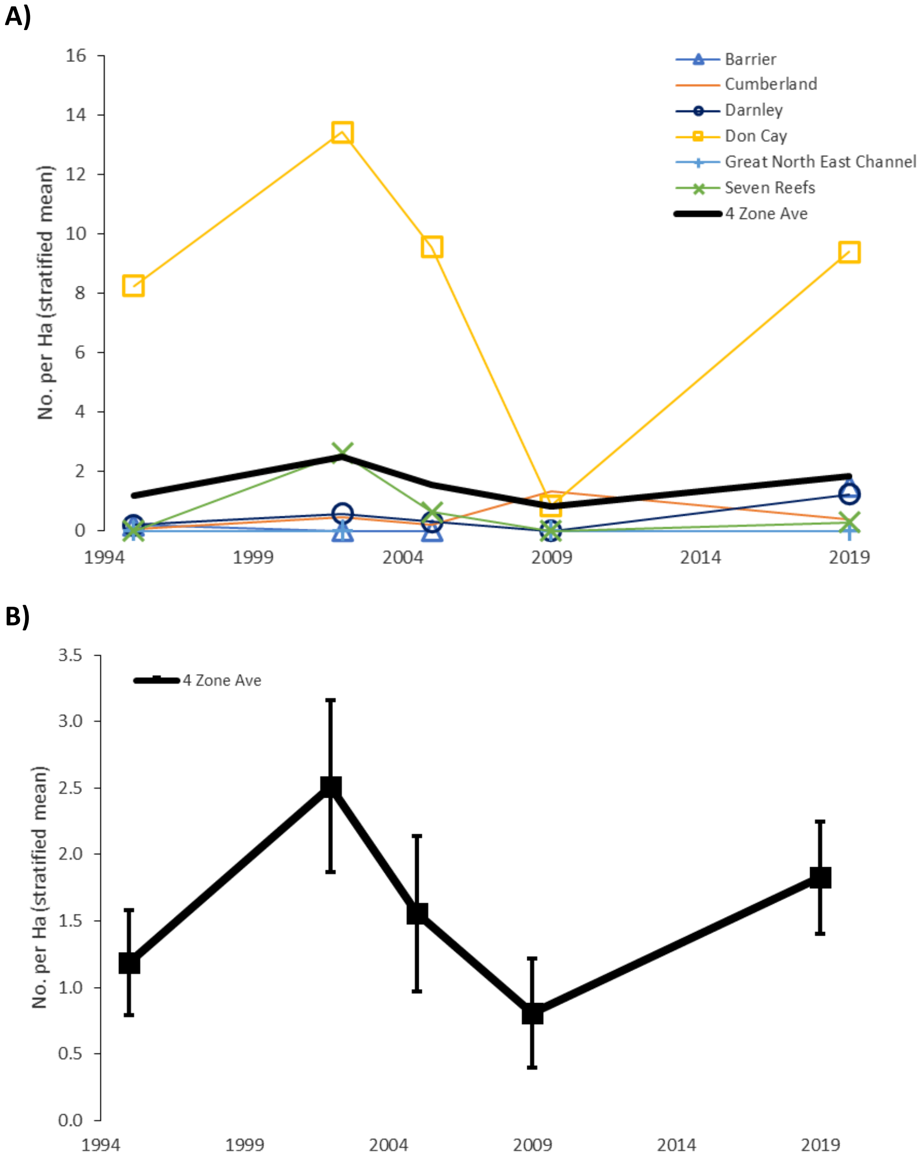


Figure 3-12. Zone (A) and East Torres Strait (4 zone = Cumberland, Darnley, Seven Reefs and Don Cay) (B) average (stratified) density (No. per Ha) for reef stratum for White teatfish (*H. fuscogilva*) from five surveys (error bars = 1 s.e.) (does not include deep-reef strata).

Population estimates

The landed (wet gutted) weight of White teatfish in East Torres Strait in 2019/20 was 1,493 t and the bootstrapped lower 90th percentile (landed (wet gutted) weight) of the stock estimate (B) was 880 t (Table 3-9). Of that estimate, the available stock above fishery size limit (> Minimum Legal Size = 320 mm) for White teatfish was 142.9 t (Table 3-9).

Table 3-9. Stock estimate for White teatfish (*H. fuscogilva*). For each Zone and for East Torres Strait (ETS), the number of sites, total area of fishery habitat, stratified mean density, stratified variance, population stock estimate in numbers (n), live weight (wt) and landed (wet gutted) weight (wt); and for all ETS, the bootstrapped lower 90th percentile of the landed (wet gutted) weight (B) (GNE = Great North East, ETS = East Torres Strait; MLS = Minimum Legal Size).

Zone	Sites	Mean density	Var (st)	Stock (n)	Live wt (t)	Landed wt (t)	B (t)	B >MLS (t)
Barrier	16	1.5	1.2	24,426	59.8	37.5	-	-
Cumberland	50	4.1	1.6	258,989	633.7	397.3	-	-
Darnley	89	6.3	31.4	326,497	798.9	500.9	-	-
Don Cay	104	10.9	8.6	210,747	515.7	323.3	-	-
GNE Channel	6	0	0	0	0	0	-	-
Seven Reefs	33	5.4	16.1	152,258	372.5	233.6	-	-
ETS	298	5.0	2.9	972,917	2,380.5	1,492.6	879.5	142.9

*Weight statistics calculated using average weight data for species for survey year, or across survey years.

3.2.3 Length frequency

Length frequency for White teatfish were comparable to 2009, with larger sizes recorded for 2019/20 (Figure 3-13).

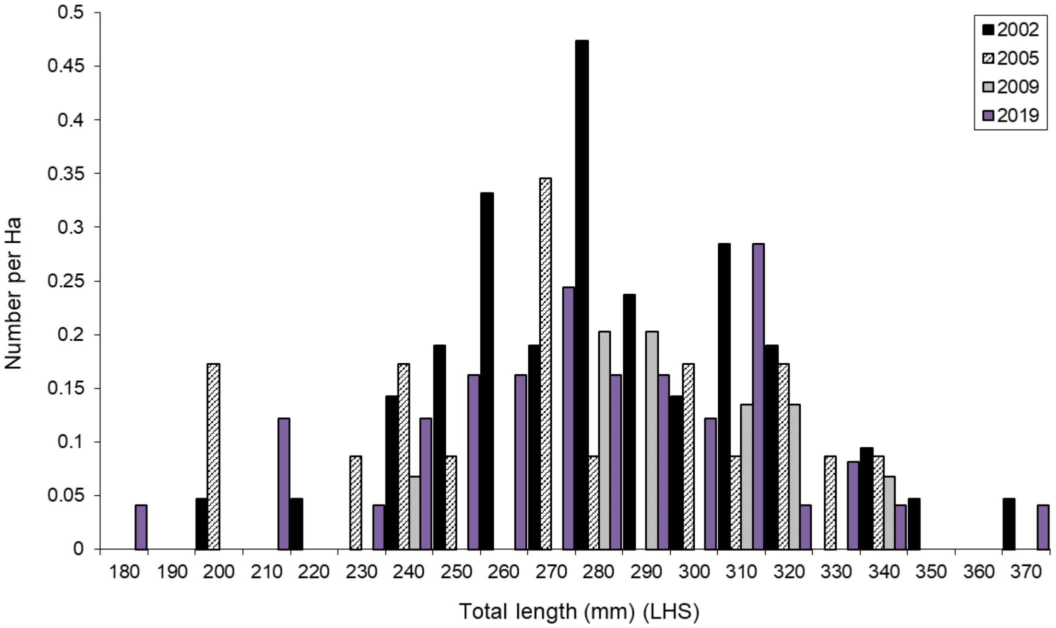


Figure 3-13. Length frequency for White teatfish (*H. fuscogilva*) collected during population surveys in east Torres Strait in 2002, 2005, 2009 and 2019. LHS = minimum size of bin range.

3.2.4 Depth profile

The number White teatfish and the depths they were found for all survey sampling sites for East Torres Strait was plotted to display the distribution profile. The majority of White teatfish were found between 5 m and 30 m depth, with typically one White teatfish found on survey transect, which varied in length from 40 m to 693 m. Consistent counts (3-5 counts) were recorded at around 15m deep (Figure 3-14).

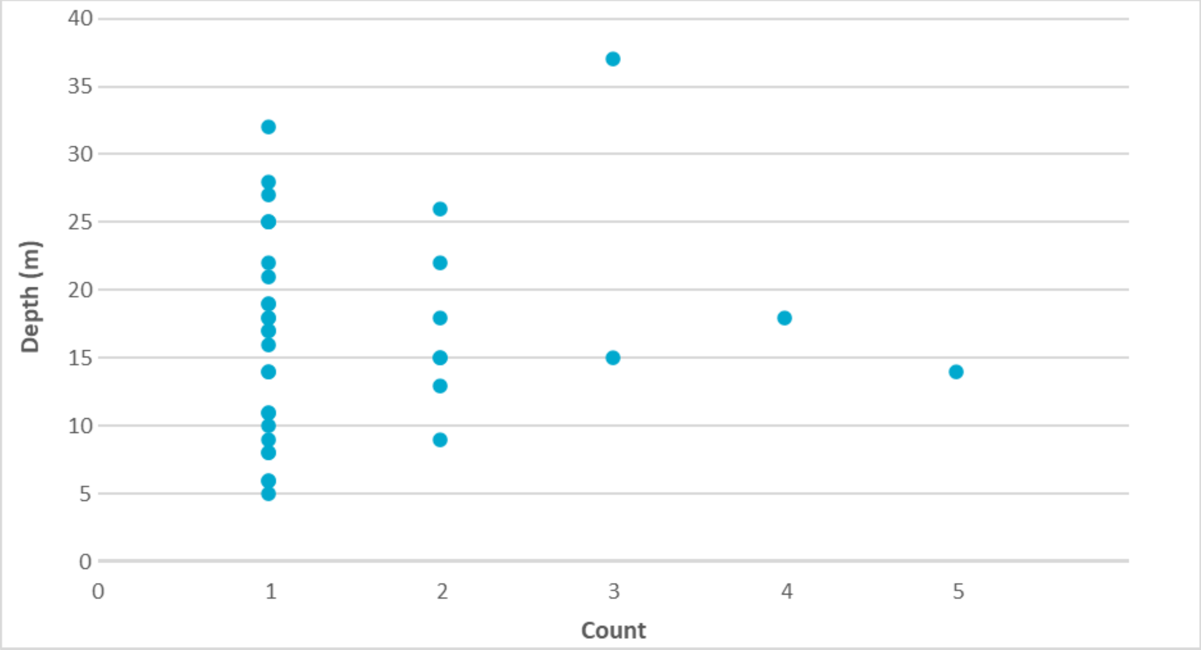


Figure 3-14. Number of White teatfish (*H. fuscogilva*) at depths for all survey sampling sites for East Torres Strait.

3.3 Prickly redfish (*T. ananas*)

3.3.1 Density

The highest Prickly redfish (*T. ananas*) density (16.4 ind/Ha) was recorded at the reef edge stratum, for the Barrier zone (55.2 ind./Ha), which also had the highest overall average zone density (14.5 ind./Ha) (Table 3-10; Figure 3-15).

Table 3-10. Density (No. per Ha) for Prickly redfish (*T. ananas*) in each zone and stratum in 2019/20 (GNE = Great North East).

Zone	Reef top	Reef top buffer	Reef edge	Deep reef	Zone Ave
Barrier	0	0	55.2	-	14.5
Cumberland	0	0	6.6	0	0.5
Darnley	0	0	1.4	0	0.1
Don Cay	14.8	3.2	6.1	1.1	6.2
GNE Channel	0	0	0	-	0
Seven Reefs	0	4.2	11.1	2.7	2.6
All	1.1	0.9	16.4	0.8	2.4

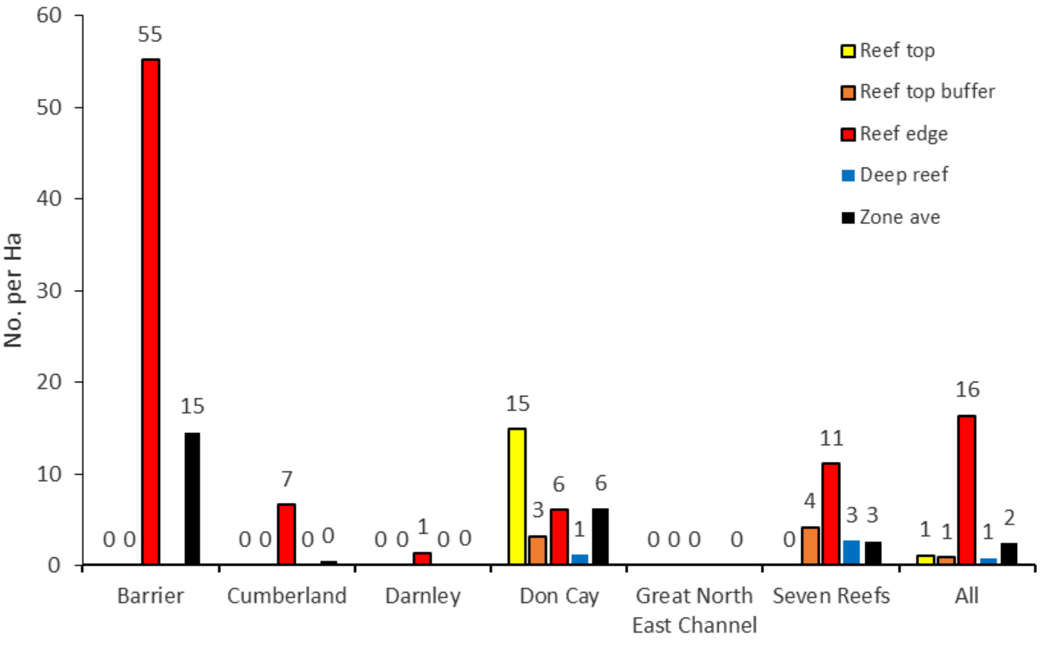


Figure 3-15. Zone and stratum average density (No. per Ha) for Prickly redfish (*T. ananas*) in 2019/20.

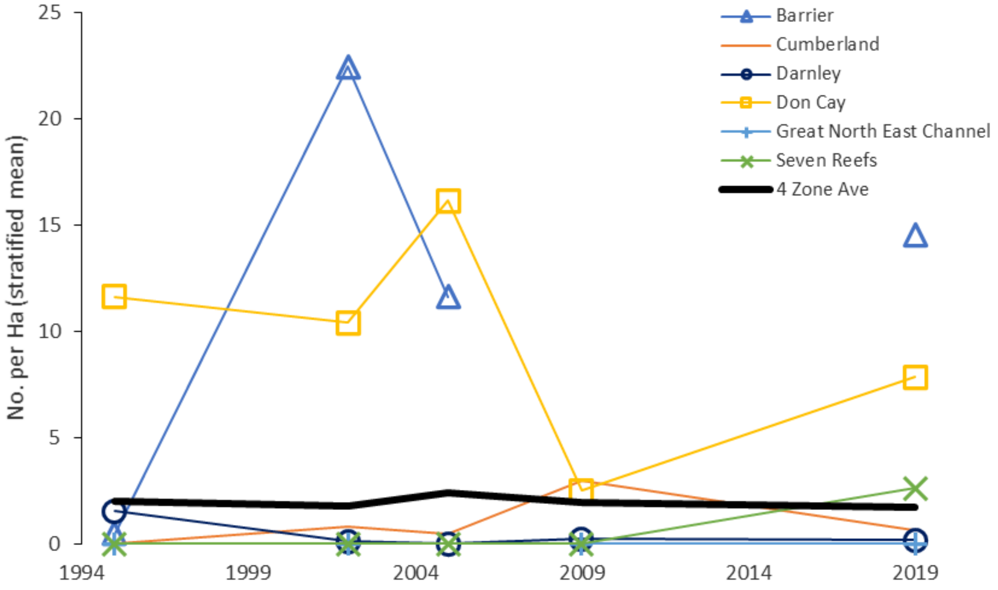
3.3.2 Density trends

The Barrier zone showed the highest density for Prickly redfish (14.5 ind./Ha). The overall average zone density for 2019 (1.73 ind./Ha) was the lowest observed across survey years (Table 3-11, Figure 3-16).

Table 3-11. Zone and East Torres Strait (4 zone = Cumberland, Darnley, Seven Reefs and Don Cay) average (stratified) density (No. per Ha) for reef stratum for Prickly redfish (*T. ananas*) for five surveys (does not include deep-reef strata) (GNE = Great North East).

Year	Barrier	Cumberland	Darnley	Don Cay	GNE Channel	Seven Reefs	4 Zone Ave
1995/96	0.5	0	1.5	11.6	0	0	2.01
2002	22.5	0.8	0.1	10.4	0	0	1.81
2005	11.6	0.5	0	16.1	-	0	2.41
2009	-	3.0	0.2	2.5	0	0	1.98
2019	14.5	0.6	0.2	7.8	0	2.6	1.73

A)



B)

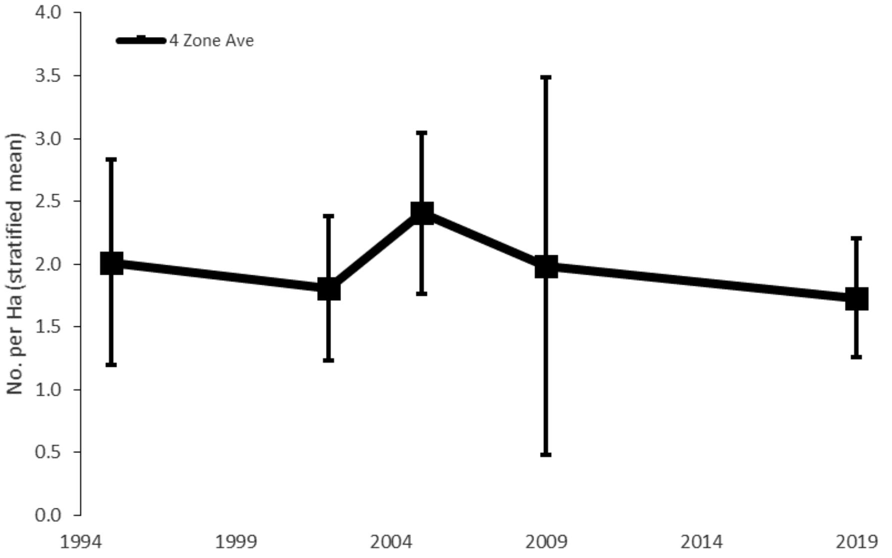


Figure 3-16. All Zones (A) and East Torres Strait (4 zone = Cumberland, Darnley, Seven Reefs and Don Cay) (B) average (stratified) density (No. per Ha) for reef stratum for Prickly redfish (*T. ananas*) from five surveys (error bars = 1 s.e.) (does not include deep-reef strata).

3.3.3 Population estimates

The landed (wet gutted) weight of Prickly redfish in East Torres Strait in 2019/20 was 918 t and the bootstrapped lower 90th percentile (landed (wet gutted) weight) of the stock estimate was 461 t (Table 3-12). Of that estimate, the available stock above fishery size limit (> Minimum Legal Size = 300 mm) for Prickly redfish was 253.3 t (Table 3-12).

Table 3-12. Stock estimate for Prickly redfish (*T. ananas*). For each Zone and for East Torres Strait (ETS), the number of sites, total area of fishery habitat, stratified mean density, stratified variance, population stock estimate in numbers (n), live weight (wt) and landed (wet gutted) weight (wt); and for all ETS, the bootstrapped lower 90th percentile of the landed (wet gutted) weight (B) (GNE = Great North East, ETS = East Torres Strait; MLS = Minimum Legal Size).

Zone	Sites	Mean density	Var (st)	Stock (n)	Live wt (t)	Landed wt (t)	B (t)	B >MLS (t)
Barrier	16	14.5	125.5	235374	695.2	463.7	-	-
Cumberland	50	0.5	0.2	30785	90.9	60.6	-	-
Darnley	89	0.1	0.0	5511	16.3	10.9	-	-
Don Cay	104	6.2	3.8	120072	354.6	236.5	-	-
GNE Channel	6	0	0	0	0	0	-	-
Seven Reefs	33	2.6	2.2	74276	219.4	146.3	-	-
ETS	298	2.4	1.0	466018	1376.4	918.0	461.3	253.3

*Weight statistics calculated using average weight data for species for survey year, or across survey years.

3.3.4 Length frequency

The length frequency for Prickly redfish showed a reduction in terms of both number and sizes for the 2019/20 survey (Figure 3-17).

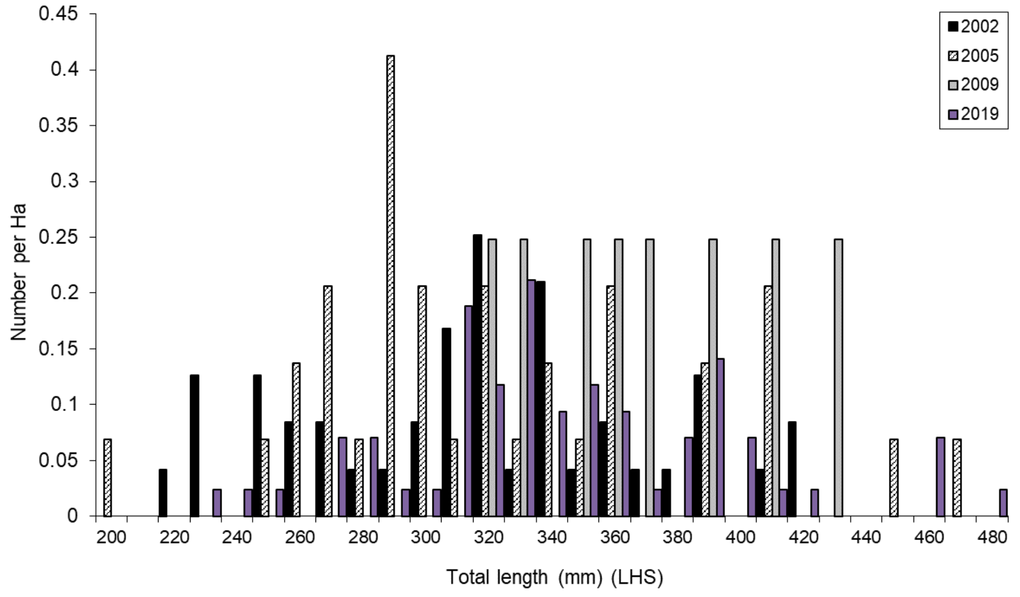


Figure 3-17. Length frequency for Prickly redfish (*T. ananas*) collected during population surveys in East Torres Strait in 2002, 2005, 2009 and 2019.

3.4 Curryfish (*S. herrmanni*)

3.4.1 Density

The highest density for Curryfish (*S. herrmanni*) was found at the reef top buffer stratum (10.6 ind./ha), for the Darnley zone (38.4 ind./Ha), which also had the highest overall average zone density (11.1 ind./Ha) (Table 3-13; Figure 3-18).

Table 3-13. Density (No. per Ha) for Curryfish (*S. herrmanni*) in each zone and stratum in 2019/20 (GNE = Great North East).

Zone	Reef top	Reef top buffer	Reef edge	Deep reef	Zone Ave
Barrier	0	0	0	-	0
Cumberland	2.8	8.9	9.9	3.5	4.8
Darnley	6.5	38.4	14.6	0	11.1
Don Cay	6.8	0.9	10.7	0	3.5
GNE Channel	0	0	4.2	-	0.5
Seven Reefs	0	0	2.8	0	0.1
All	3.3	10.6	7.7	0.9	5.0

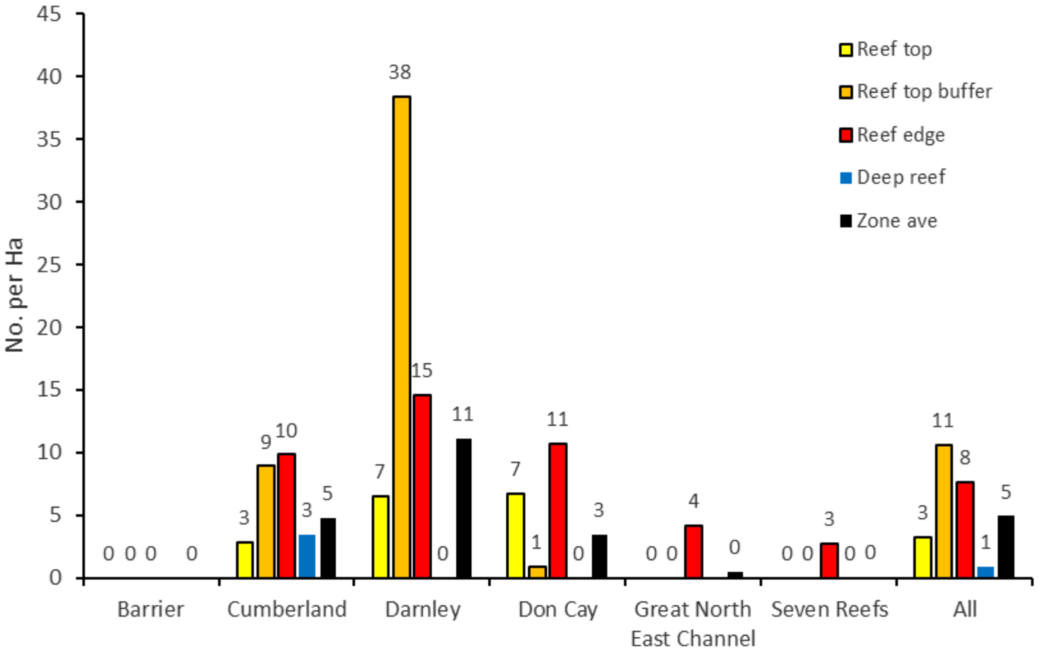


Figure 3-18. Zone and stratum average density (No. per Ha) for Curryfish (*S. herrmanni*) in 2019/20.

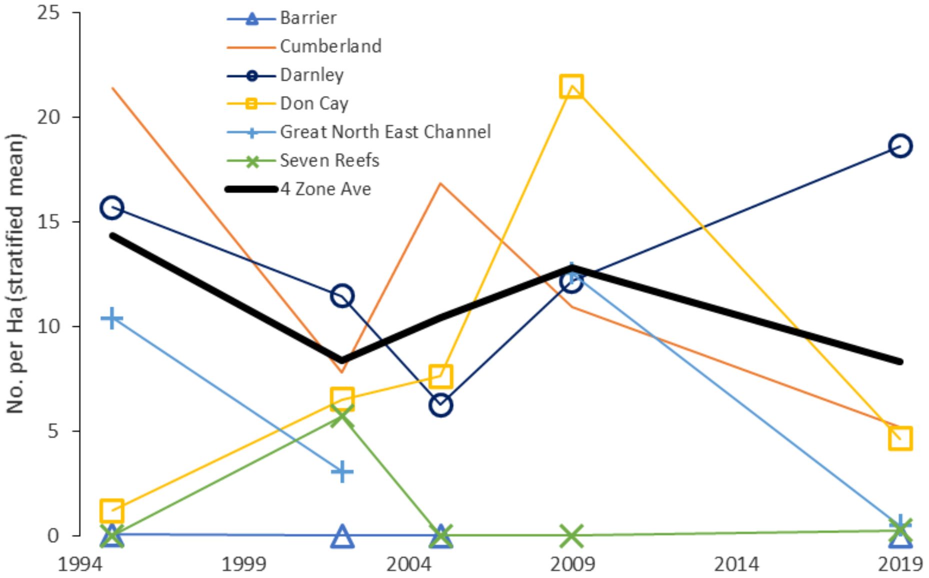
3.4.2 Density trends

The highest zone density for Curryfish recorded at Darnley was also the highest density recorded across survey years (18.6 ind./Ha). However, the overall average (four) zone density (8.3 ind./Ha) was similar to the lowest found in 2002 (Table 3-14, Figure 3-19).

Table 3-14. Zone and East Torres Strait (4 zone = Cumberland, Darnley, Seven Reefs and Don Cay) average (stratified) density (No. per Ha) for reef stratum for Curryfish (*S. herrmanni*) for five surveys (does not include deep-reef strata) (GNE = Great North East).

Year	Barrier	Cumberland	Darnley	Don Cay	GNE Channel	Seven Reefs	4 Zone Ave
1995/96	0.1	21.4	15.7	1.2	10.4	0	14.32
2002	0	7.8	11.4	6.5	3.1	5.7	8.40
2005	0	16.9	6.3	7.6	-	0	10.44
2009	-	10.9	12.2	21.5	12.5	0	12.78
2019	0	5.2	18.6	4.6	0.5	0.3	8.31

A)



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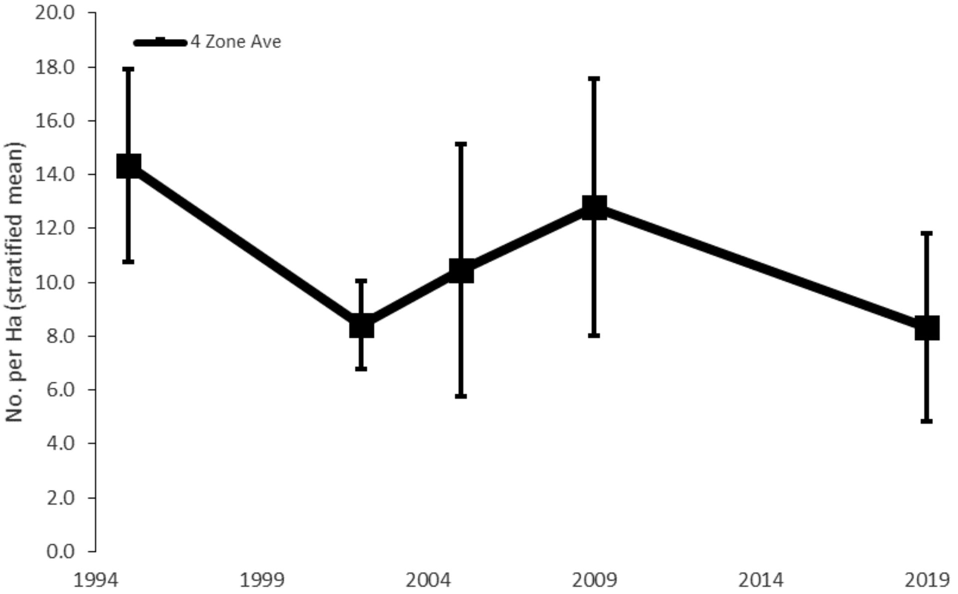


Figure 3-19. Zones (A) and East Torres Strait (4 zone = Cumberland, Darnley, Seven Reefs and Don Cay) (B) average (stratified) density (No. per Ha) for reef stratum for Curryfish (*S. herrmanni*) from five surveys (error bars = 1 s.e.) (does not include deep-reef strata).

3.4.3 Population estimates

The landed (wet gutted) weight of Curryfish in East Torres Strait in 2019/20 was 1,362 t and the bootstrapped lower 90th percentile (landed (wet gutted) weight) of the stock estimate (B) was 667 t (Table 3-15). Of that estimate, the available stock above fishery size limit (> Minimum Legal Size = 310 mm) for Curryfish was 632.4 t (Table 3-15).

Table 3-15. Stock estimate for Curryfish (*S. herrmanni*). For each Zone and for East Torres Strait (ETS), the number of sites, total area of fishery habitat, stratified mean density, stratified variance, population stock estimate in numbers (n), live weight (wt) and landed (wet gutted) weight (wt); and for all ETS, the bootstrapped lower 90th percentile of the landed (wet gutted) weight (B) (GNE = Great North East, ETS = East Torres Strait; MLS = Minimum Legal Size).

Zone	Sites	Mean density	Var (st)	Stock (n)	Live wt (t)	Landed wt (t)	B (t)	B >MLS (t)
Barrier	16	0	0	0	0	0	-	-
Cumberland	50	4.8	6.2	302,306	662.3	431.2	-	-
Darnley	89	11.1	44.5	574,050	1257.6	818.7	-	-
Don Cay	104	3.5	2.5	67,856	148.7	96.8	-	-
GNE Channel	6	0.5	0.2	7,149	15.7	10.2	-	-
Seven Reefs	33	0.1	0	3,817	8.4	5.4	-	-
ETS	298	5.0	3.9	955,178	2092.6	1362.3	667.2	632.4

*Weight statistics calculated using average weight data for species for survey year, or across survey years.

3.4.4 Length frequency

Length frequency for Curryfish in 2019 was similar to 2002, with fewer smaller to medium size (180 – 310 mm) seen and a higher number of larger animals recorded (Figure 3-20).

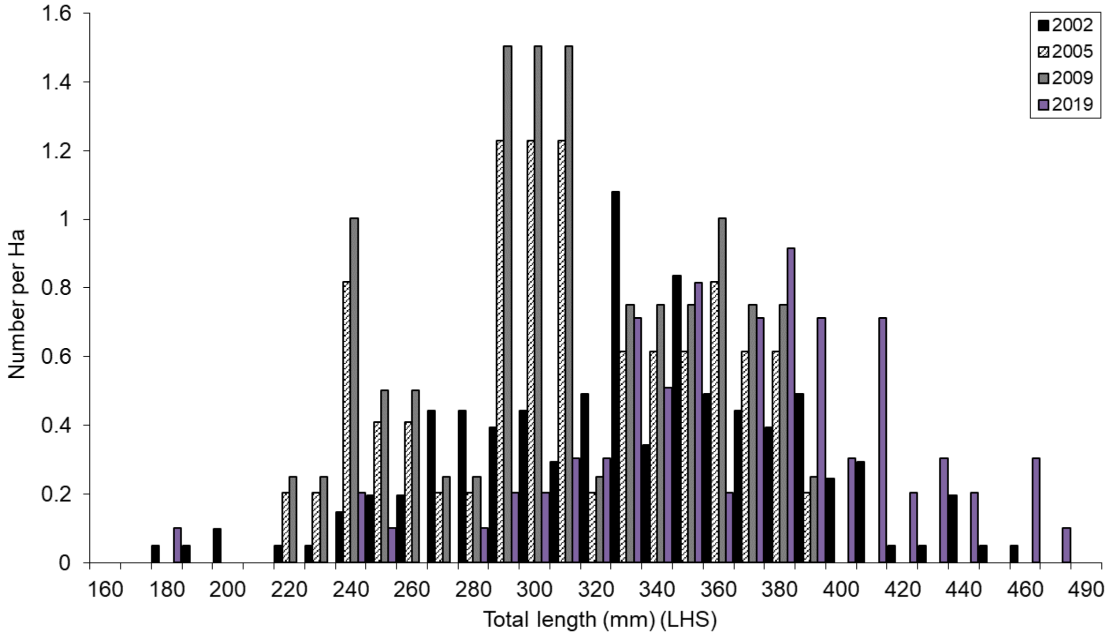


Figure 3-20. Length frequency for Curryfish (*S. herrmanni*) collected during population surveys in east Torres Strait in 2002, 2005, 2009 and 2019. LHS = minimum size of bin range.

3.5 Curryfish (vastus) (*S. vastus*)

3.5.1 Density

The highest density for Curryfish (vastus) (*S. vastus*) was found at the reef top stratum (17.1 ind./Ha), for the Cumberland zone (34.1 ind./Ha), which also had the highest overall average density (16.9 ind./Ha) (Table 3-16; Figure 3-21).

Table 3-16. Density (No. per Ha) for Curryfish (vastus) (*S. vastus*) in each zone and stratum in 2019/20 (GNE = Great North East).

Zone	Reef top	Reef top buffer	Reef edge	Deep reef	Zone Ave
Barrier	0	0	0	-	0
Cumberland	34.1	0	2.0	0	16.9
Darnley	8.7	0	14.6	5.8	6.2
Don Cay	0	0	0	0	0
GNE Channel	0	0	0	-	0
Seven Reefs	0	0	0	0	0
All	17.1	0	3.6	2.2	7.2

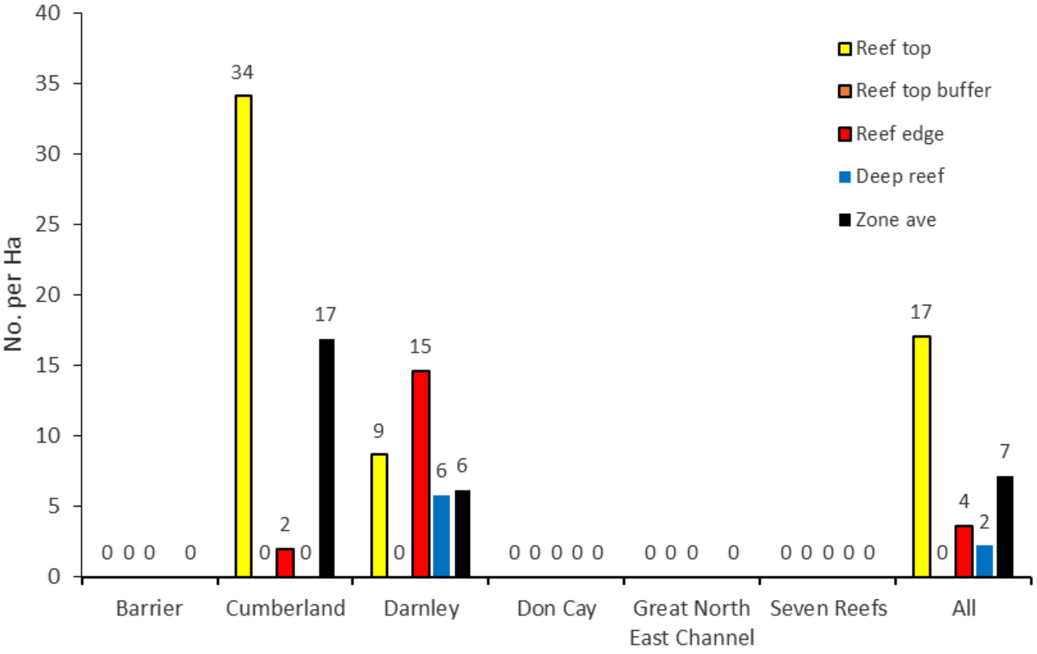


Figure 3-21. Zones and stratum average density (No. per ha) for Curryfish (vastus) (*S. vastus*) in 2019/20.

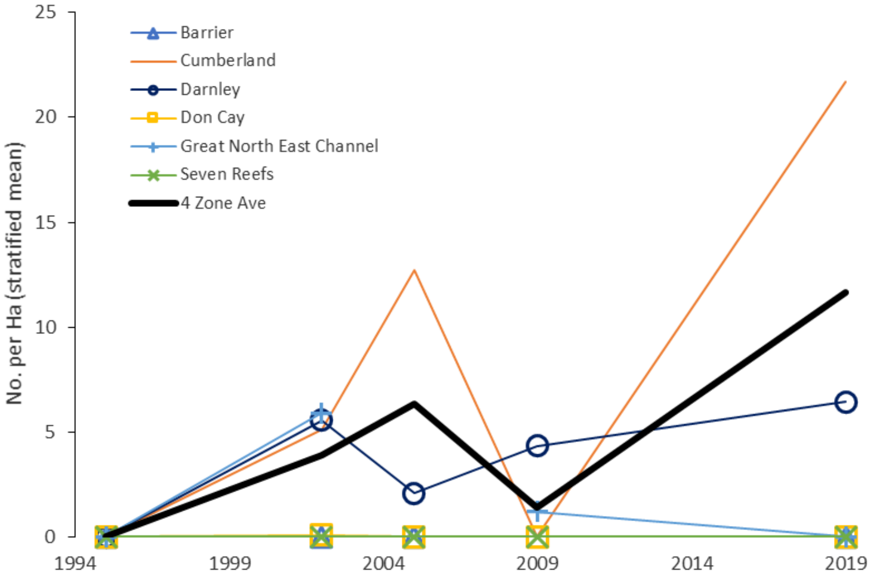
3.5.2 Density trends

The highest zone density for Curryfish (vastus) was found at Cumberland (21.7 ind./Ha), which also showed the highest density recorded across all survey years. The highest overall average zone density across survey years was recorded for the 2019 survey (11.7 ind./Ha) (Table 3-17; Figure 3-22).

Table 3-17. Zone and East Torres Strait (4 zone = Cumberland, Darnley, Seven Reefs and Don Cay) average (stratified) density (No. per Ha) for reef stratum for Curryfish (vastus) (*S. vastus*) for five surveys (does not include deep-reef strata) (GNE = Great North East).

Year	Barrier	Cumberland	Darnley	Don Cay	GNE Channel	Seven Reefs	4 Zone Ave
1995/96	0	0	0	0	0	0	0
2002	0	5.1	5.6	0.1	5.9	0	3.91
2005	0	12.7	2.1	0	-	0	6.35
2009	-	0	4.3	0	1.2	0	1.39
2019	0.0	21.7	6.4	0	0	0	11.67

A)



B)

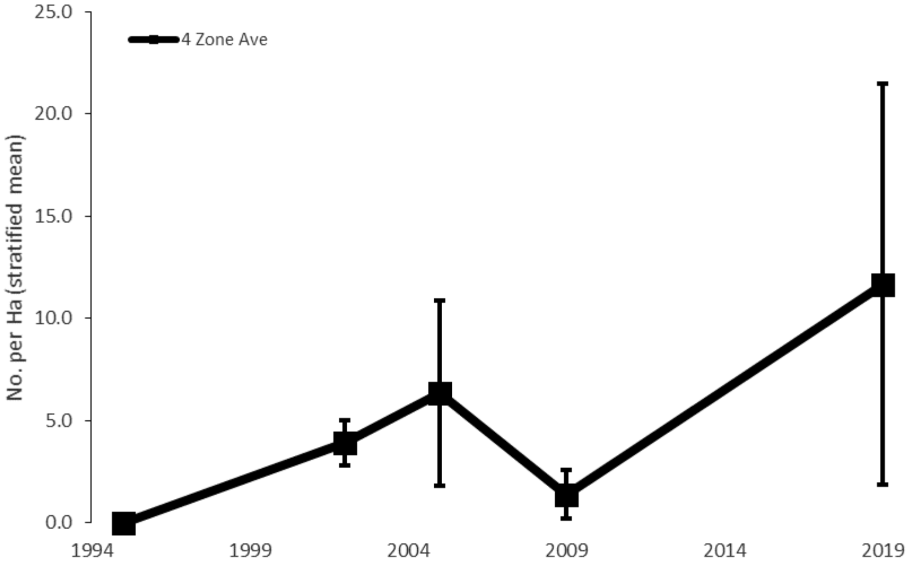


Figure 3-22. Zones (A) and East Torres Strait (4 zone = Cumberland, Darnley, Seven Reefs and Don Cay) (B) average (stratified) density (No. per Ha) for reef stratum for Curryfish (vastus) (*S. vastus*) from five surveys (error bars = 1 s.e.) (does not include deep-reef strata) .

3.5.3 Population estimates

The landed (wet gutted) weight of Curryfish (vastus) in East Torres Strait in 2019/20 was 1,189 t and the bootstrapped lower 90th percentile (landed (wet gutted) weight) of the stock estimate (B) was 168 t (Table 3-18). Of that estimate, the available stock above fishery size limit (> Minimum Legal Size = 150 mm) for Curryfish (vastus) was 168 t (i.e. all individuals sampled were >MLS) (Table 3-18).

Table 3-18. Stock estimate for Curryfish (vastus) (*S. vastus*). For each Zone and for East Torres Strait (ETS), the number of sites, total area of fishery habitat, stratified mean density, stratified variance, population stock estimate in numbers (n), live weight (wt) and landed (wet gutted) weight (wt); and for all ETS, the bootstrapped lower 90th percentile of the landed (wet gutted) weight (B) (GNE = Great North East, ETS = East Torres Strait; MLS = Minimum Legal Size).

Zone	Sites	Mean density	Var (st)	Stock (n)	Live wt (t)	Landed wt (t)	B (t)	B >MLS (t)
Barrier	16	0	0	0	0	0	-	-
Cumberland	50	16.9	279.7	1,063,966	1405.1	914.7	-	-
Darnley	89	6.2	9.6	318,399	420.5	273.7	-	-
Don Cay	104	0	0	0	0	0	-	-
GNE Channel	6	0	0	0	0	0	-	-
Seven Reefs	33	0	0	0	0	0	-	-
ETS	298	7.2	30.6	1,382,365	1825.6	1188.5	168.0	168.0

*Weight statistics calculated using average weight data for species for survey year, or across survey years.

3.5.4 Length frequency

The size frequency for Curryfish (vastus) shows a higher number of larger animals in 2019 compared to previous surveys and had also some of the largest animals observed in all surveys (Figure 3-23).

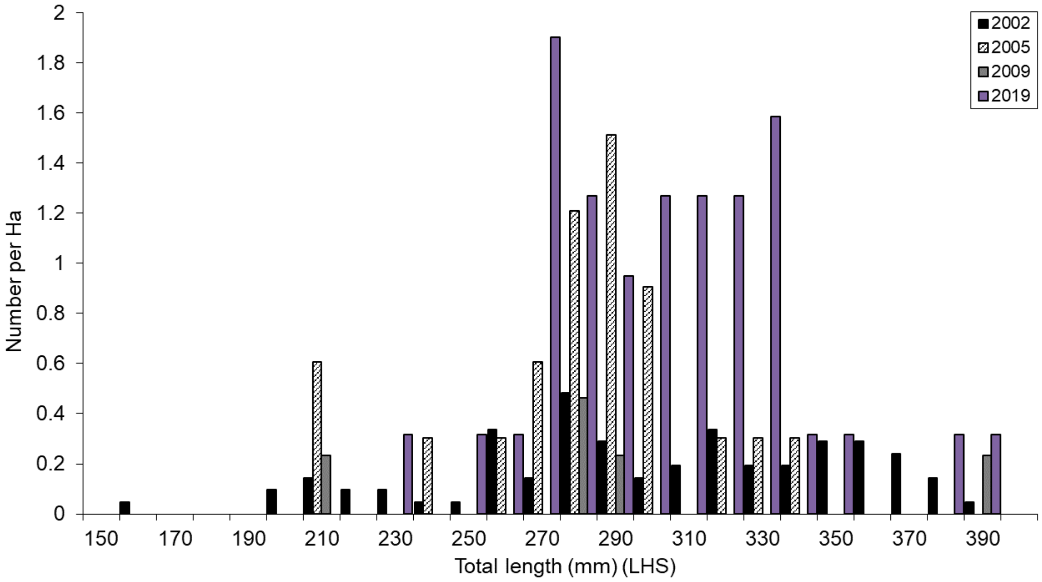


Figure 3-23. Length frequency for Curryfish (vastus) (*S. vastus*) collected during population surveys in east Torres Strait in 2002, 2005, 2009 and 2019. LHS = minimum size of bin range.

3.6 Surf redfish (*A. mauritiana*)

3.6.1 Density

The highest density for Surf redfish (*A. mauritiana*) was recorded on the reef top buffer stratum (0.6 ind./ha), for the Don Cay zone (4.1 ind./Ha), which also had the highest overall average zone density (1.7 ind./Ha) (Table 3-19; Figure 3-24).

Table 3-19. Density (No. per Ha) for Surf redfish (*A. mauritiana*) in each zone and stratum in 2019/20 (GNE = Great North East).

Zone	Reef top	Reef top buffer	Reef edge	Deep reef	Zone Ave
Barrier	0	0	0	-	0
Cumberland	0	0	0	0	0
Darnley	0	0	0	0	0
Don Cay	0.8	4.1	0	0	1.7
GNE Channel	0	0	0	-	0
Seven Reefs	0	0	0	0	0
All	0.1	0.6	0	0	0.2

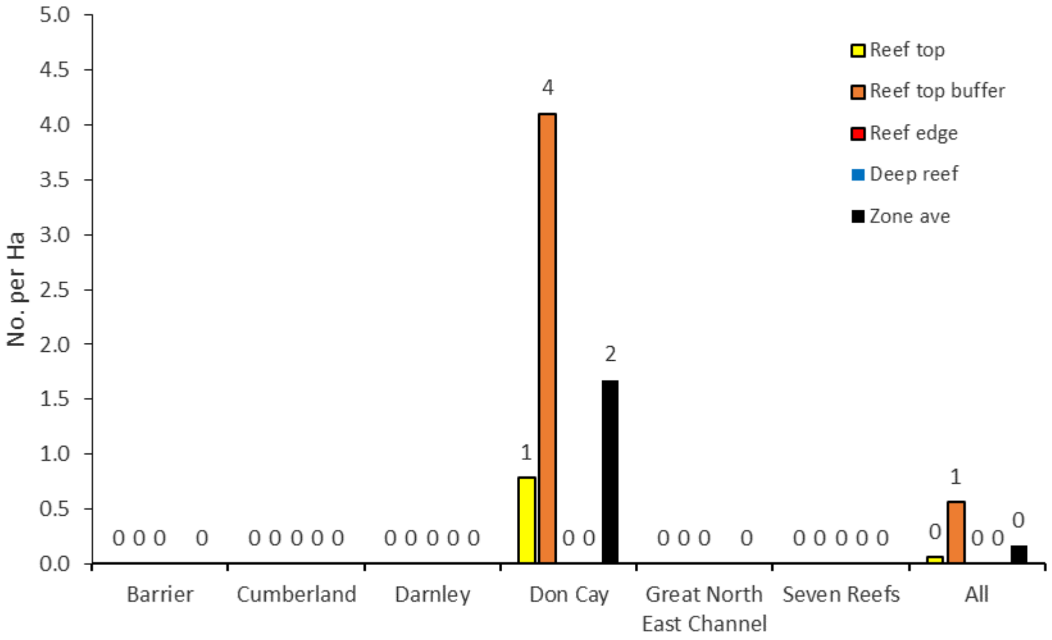


Figure 3-24. Zone and stratum average density (No. per Ha) for Surf redfish (*A. mauritiana*) in 2019/20.

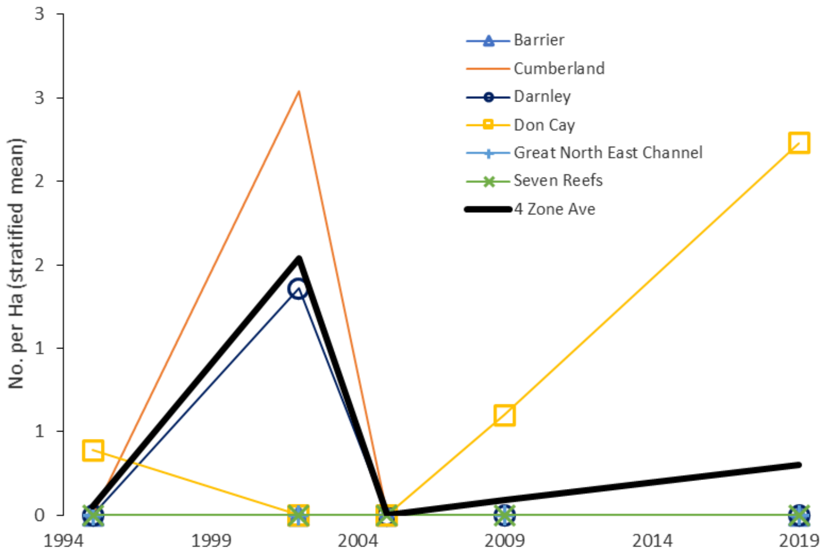
3.6.2 Density trends

The highest zone density for Surf redfish (was found at Don Cay (2.2 ind./Ha). The overall 4 Zone average density slightly higher in 2019 compared to the lowest values for 1995/96 and 2009 (Table 3-20; Figure 3-25).

Table 3-20. Zone and East Torres Strait (4 zone = Cumberland, Darnley, Seven Reefs and Don Cay) average (stratified) density (No. per Ha) for reef stratum for Surf redfish (*A. mauritiana*) for five surveys (does not include deep-reef strata) (GNE = Great North East).

Year	Barrier	Cumberland	Darnley	Don Cay	GNE Channel	Seven Reefs	4 Zone Ave
1995/96	0	0	0	0.4	0	0	0.05
2002	0	2.5	1.4	0	0	0	1.54
2005	0	0	0	0	-	0	0
2009	-	0	0	0.6	0	0	0.09
2019	0	0	0	2.2	0	0	0.30

A)



B)

Figure 3-25. Zones (A) and East Torres Strait (4 zone = Cumberland, Darnley, Seven Reefs and Don Cay) (B) average (stratified) density (No. per Ha) for reef stratum for Surf redfish (*A. mauritiana*) from five surveys (error bars = 1 s.e.) (does not include deep-reef strata).

3.6.3 Population estimates

The landed (wet gutted) weight of Surf redfish in East Torres Strait in 2019/20 was 24 t and the bootstrapped lower 90th percentile (landed (wet gutted) weight) of the stock estimate (B) was 20 t (Table 3-21). Of that estimate, the available stock above fishery size limit (> Minimum Legal Size = 220 mm) for Surf redfish was 6.7 t (Table 3-21).

Table 3-21. Stock estimate for Surf redfish (*A. mauritiana*). For each Zone and for East Torres Strait (ETS), the number of sites, total area of fishery habitat, stratified mean density, stratified variance, population stock estimate in numbers (n), live weight (wt) and landed (wet gutted) weight (wt); and for all ETS, the bootstrapped lower 90th percentile of the landed (wet gutted) weight (B) (GNE = Great North East, ETS = East Torres Strait; MLS = Minimum Legal Size).

Zone	Sites	Mean density	Var (st)	Stock (n)	Live wt (t)	Landed wt (t)	B (t)	B (>MLS) (t)
Barrier	16	0	0	0	0	0	-	-
Cumberland	50	0	0	0	0	0	-	-
Darnley	89	0	0	0	0	0	-	-
Don Cay	104	1.9	0.5	32,542	35.4	24.2	-	-
GNE Channel	6	0	0	0	0	0	-	-
Seven Reefs	33	0	0	0	0	0	-	-
ETS	298	0.2	0	32,542	35.4	24.2	20.4	6.7

*Weight statistics calculated using average weight data for species for survey year, or across survey years.

3.6.4 Length frequency

Length frequency for Surf redfish shows there were less individuals recorded in 2019 compared to 2002, but there were larger animals recorded in the 2019 survey compared to previous years (2002 and 2009) (Figure 3-26).

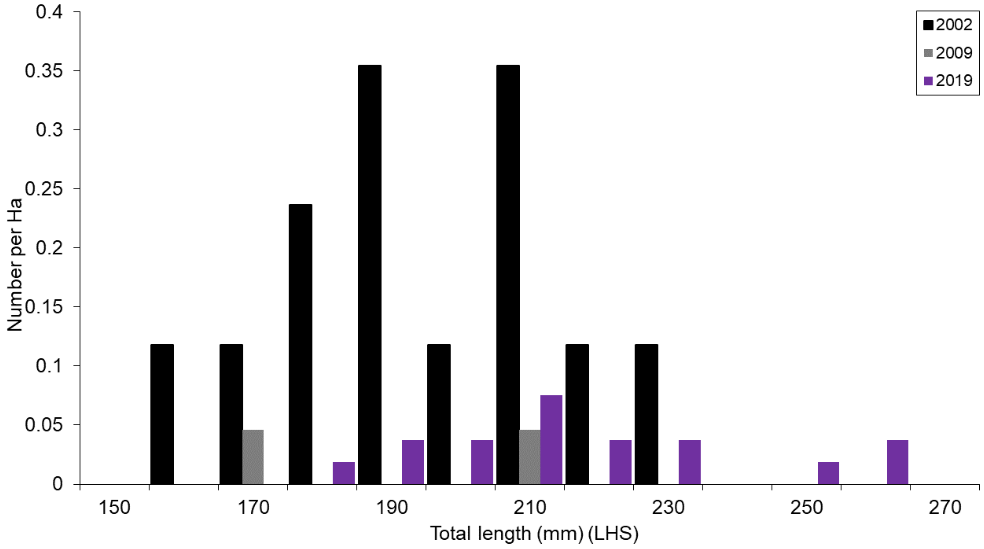


Figure 3-26. Length frequency for Surf redfish (*A. mauritiana*) collected during population surveys in east Torres Strait in 2002, 2005, 2009 and 2019. LHS = minimum size of bin range.

3.7 Deepwater redfish (*A. echinites*)

3.7.1 Density

The highest density for Deepwater redfish (*A. echinites*) was registered at the reef top buffer stratum (3.5 ind./Ha), for the Darnley zone (16.4 ind./Ha), which also had the highest overall average zone density (4.6 ind./Ha) (Table 3-22; Figure 3-27).

Table 3-22. Density (No. per ha) for Deepwater redfish (*A. echinites*) in each zone and stratum in 2019/20 (GNE = Great North East).

Zone	Reef top	Reef top buffer	Reef edge	Deep reef	Zone Ave
Barrier	0	0	0	-	0
Cumberland	0	0	0	0	0
Darnley	3.9	16.4	0	0	4.6
Don Cay	3.9	0.3	0	0	1.2
GNE Channel	0	0	0	-	0
Seven Reefs	0	0	0	0	0
All	1.2	3.5	0	0	1.4

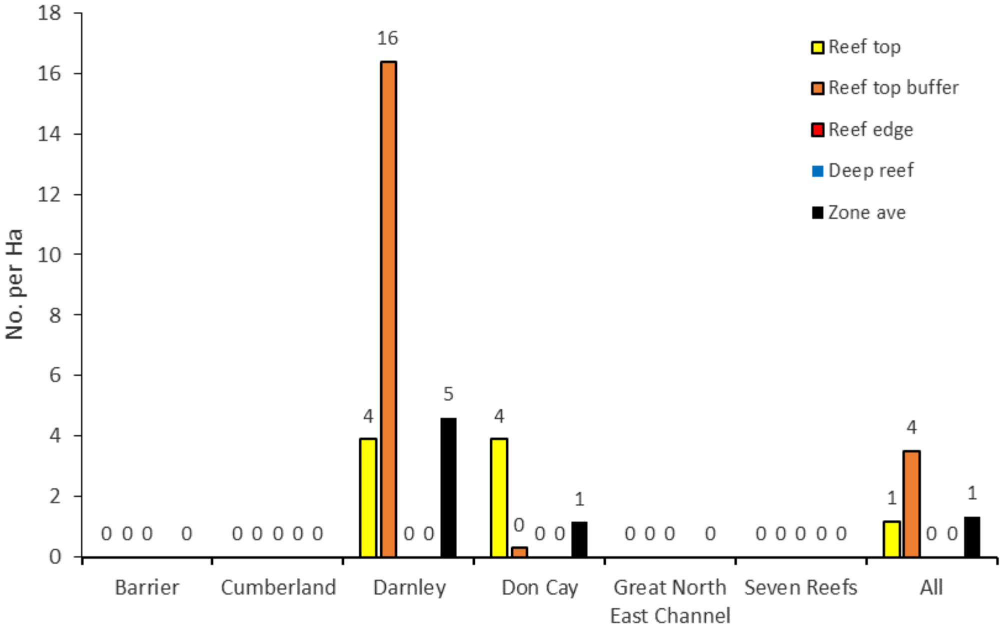


Figure 3-27. Zone and stratum average density (No. per ha) for Deepwater redfish (*A. echinites*) in 2019/20.

3.7.2 Density trends

The highest zone density for Deepwater redfish was for Darnley (7.7 ind./Ha). Of concern in 2019 was zero individuals found for Great North East Channel compared to the high density observed in 2009. Density in the GNE channel is highly variable across the survey years, with very low numbers recorded in 1995/6 and 2002 (zone not surveyed in 2005). The overall average zone density was similar to 2002 to 2009 (Table 3-23; Figure 3-28).

Table 3-23. Zone and East Torres Strait (4 zone = Cumberland, Darnley, Seven Reefs and Don Cay) average (stratified) density (No. per Ha) for reef stratum for Deepwater redfish (*A. echinites*) for five surveys (does not include deep-reef strata) (GNE = Great North East).

Year	Barrier	Cumberland	Darnley	Don Cay	GNE Channel	Seven Reefs	4 Zone Ave
1995/96	0.1	0	6.2	3.1	1.5	0	2.2
2002	0.3	1.2	0	0.3	0	0	0.6
2005	0	1.4	0	0	-	0	0.6
2009	-	0	1.9	9.9	20.8	0	2.1
2019	0	0	7.7	1.5	0	0	2.4

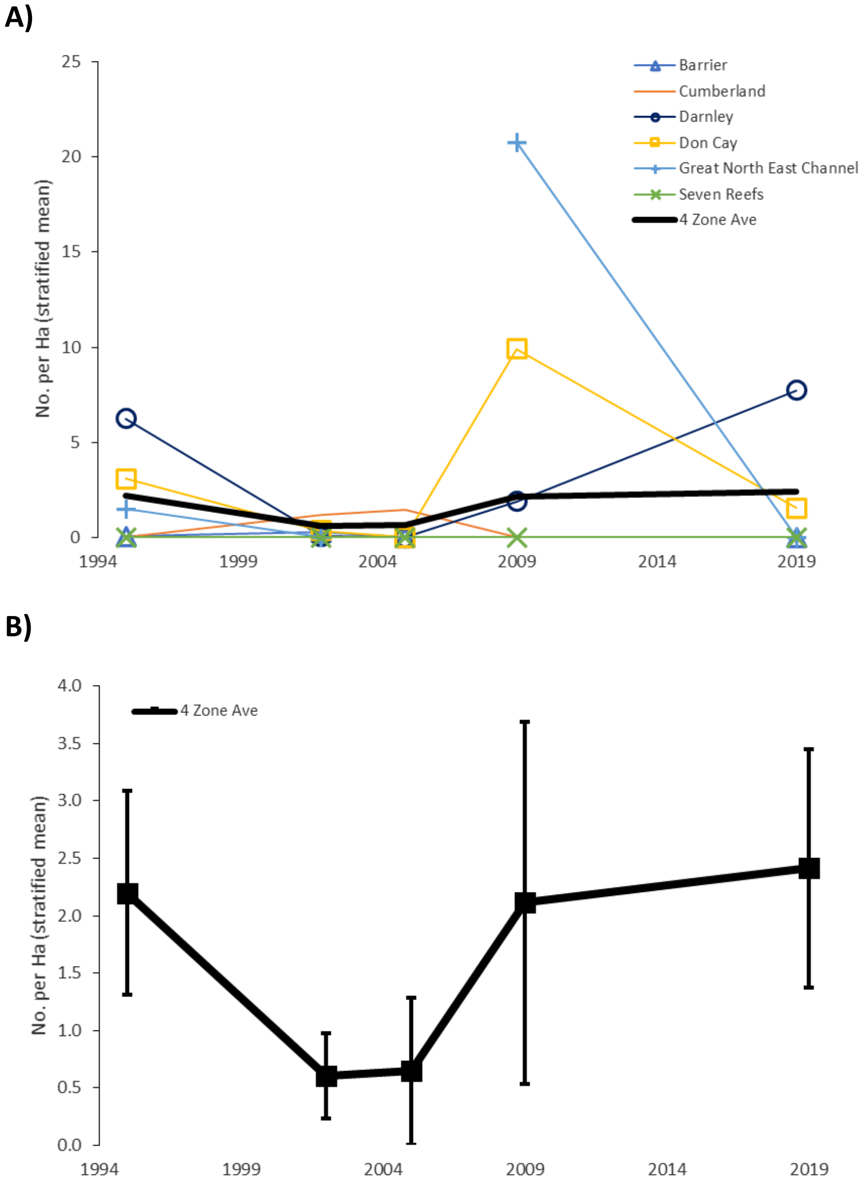


Figure 3-28. Zones (A) and East Torres Strait (bottom) (4 zone = Cumberland, Darnley, Seven Reefs and Don Cay) (B) average (stratified) density (No. per Ha) for reef strata for Deepwater redfish (*A. echinites*) from five surveys (error bars = 1 s.e.) (does not include deep-reef strata).

3.7.3 Population estimates

The landed (wet gutted) weight of Deepwater redfish in East Torres Strait in 2019/20 was 156 t and the bootstrapped lower 90th percentile (landed (wet gutted) weight) of the stock estimate (B) was 66 t (Table 3-24). Of that estimate, the available stock above fishery size limit (> Minimum Legal Size = 200 mm) for Surf redfish was 55 t (Table 3-24Table 3-21).

Table 3-24. Stock estimate for Deepwater redfish (*A. echinites*). For each Zone and for East Torres Strait (ETS), the number of sites, total area of fishery habitat, stratified mean density, stratified variance, population stock estimate in numbers (n), live weight (wt) and landed (wet gutted) weight (wt); and for all ETS, the bootstrapped lower 90th percentile of the landed (wet gutted) weight (B) (GNE = Great North East, ETS = East Torres Strait; MLS = Minimum Legal Size).

Zone	Sites	Mean density	Var (st)	Stock (n)	Live wt (t)	Landed wt (t)	B (t)	B (>MLS) (t)
Barrier	16	0	0	0	0	0	-	
Cumberland	50	0	0	0	0	0	-	-
Darnley	89	4.6	4.6	238,356	205.3	142.1	-	-
Don Cay	104	1.2	1.1	22,481	19.4	13.4	-	-
GNE Channel	6	0	0	0	0	0	-	-
Seven Reefs	33	0	0	0	0	0	-	-
ETS	298	1.4	0.3	260,837	224.7	155.5	66.1	55.0

*Weight statistics calculated using average weight data for species for survey year, or across survey years.

3.7.4 Length frequency

Size frequency for Deepwater redfish were similar in numbers to the 2009 survey, with larger sea cucumbers recorded for 2019/20 (Figure 3-29).

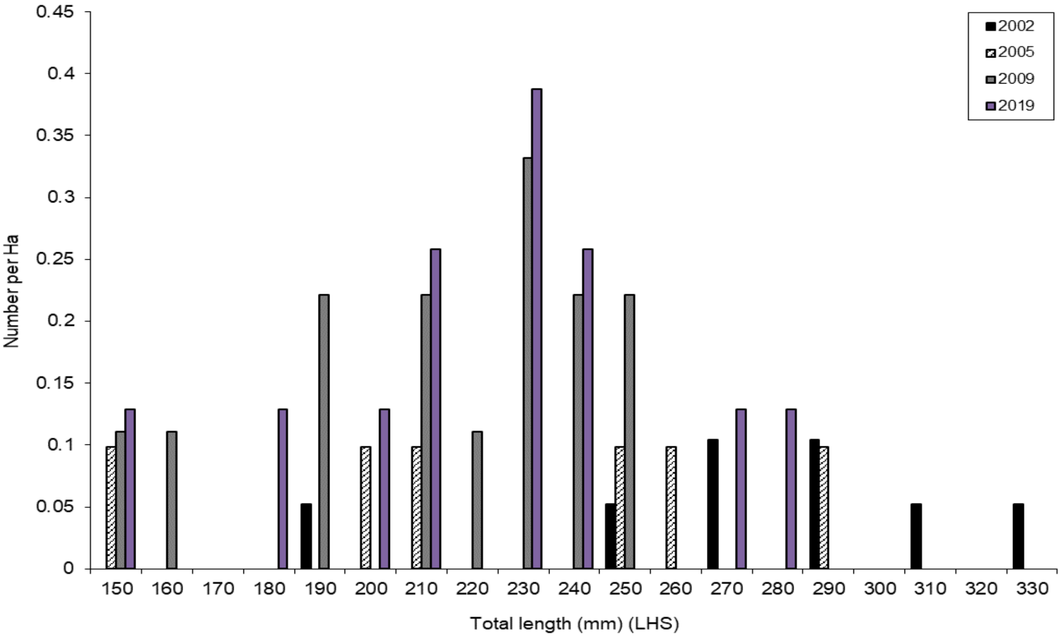


Figure 3-29. Length frequency for Deepwater redfish (*A. echinites*) collected during population surveys in east Torres Strait in 2002, 2005, 2009 and 2019. LHS = minimum size of bin range.

3.8 Hairy blackfish (*A. miliaris*)

3.8.1 Density

The highest density for Hairy blackfish (*A. miliaris*) was registered at the reef edge stratum (1.2 ind./Ha), for the Darnley zone (5.6 ind./Ha), which also had the highest overall zone average (0.4 ind./Ha) (Table 3-25; Figure 3-30).

Table 3-25. Density (No. per ha) for Hairy blackfish (*A. miliaris*) in each zone and stratum in 2019/20 (GNE = Great North East).

Zone	Reef top	Reef top buffer	Reef edge	Deep reef	Zone Ave
Barrier	0	0	0	-	0
Cumberland	0	0	0	0	0
Darnley	0	0	5.6	0	0.4
Don Cay	0	0	0	0	0
GNE Channel	0	0	0	-	0
Seven Reefs	0	0	0	0	0
All	0	0	1.2	0	0.1

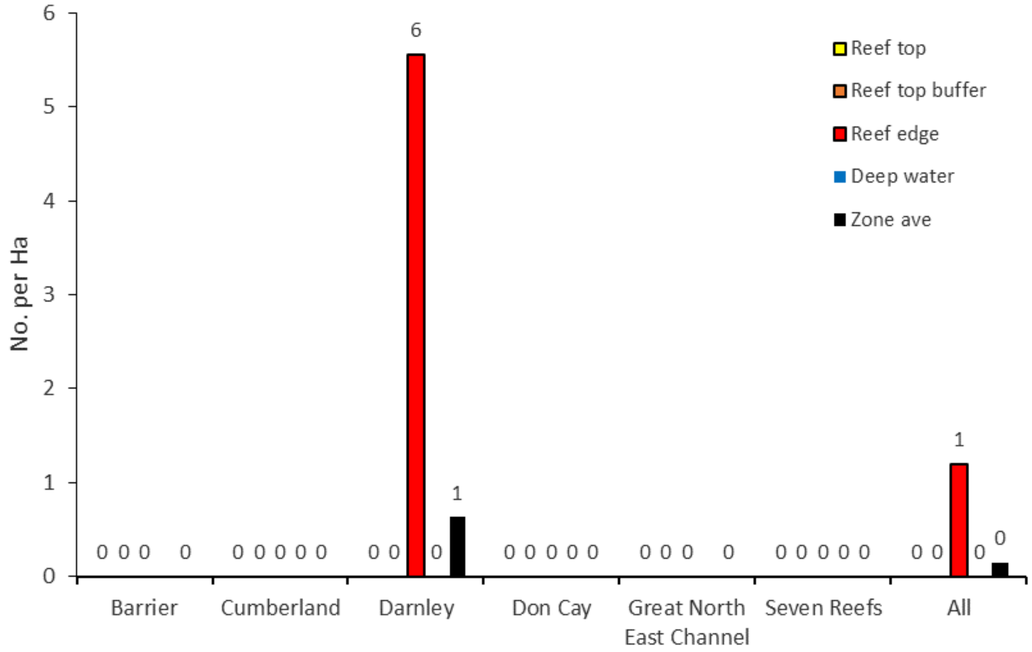


Figure 3-30. Zones and stratum average density (No. per ha) for Hairy blackfish (*A. miliaris*) in 2019/20.

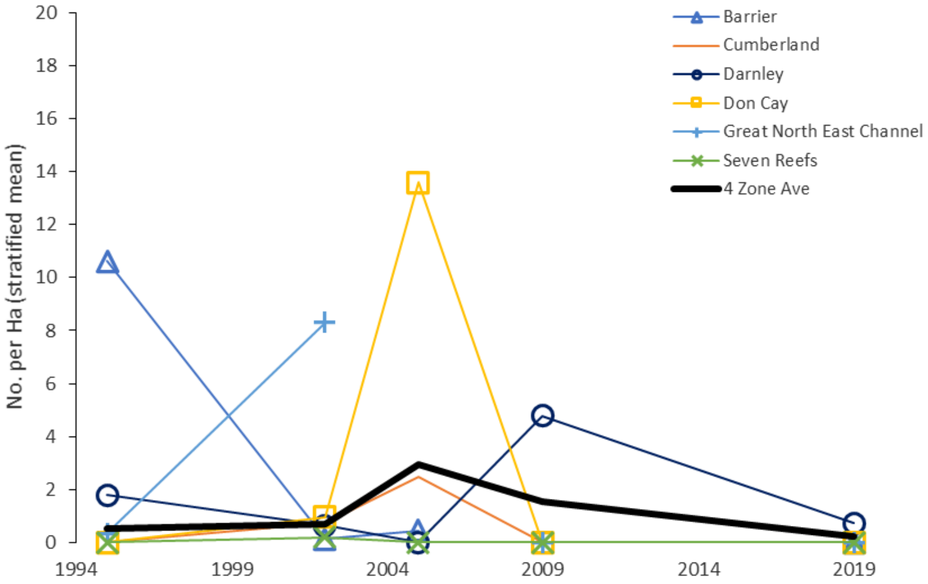
3.8.2 Density trends

The highest zone density for Hairy blackfish was recorded at Darnley. The overall average zone density was the lowest in 2019 (0.2 ind./Ha) compared to previous survey years (Table 3-26; Figure 3-31).

Table 3-26. Zone and East Torres Strait (4 zone = Cumberland, Darnley, Seven Reefs and Don Cay) average (stratified) density (No. per Ha) for reef stratum for Hairy blackfish (*A. miliaris*) for five surveys (does not include deep-reef strata) (GNE = Great North East).

Year	Barrier	Cumberland	Darnley	Don Cay	GNE Channel	Seven Reefs	4 Zone Ave
1995/96	10.6	0	1.8	0	0.3	0	0.5
2002	0.1	0.7	0.6	1.0	8.3	0.2	0.7
2005	0.4	2.5	0	13.6	-	0	3.0
2009	-	0	4.8	0	0	0	1.5
2019	0	0	0.7	0	0	0	0.2

A)



B)

Figure 3-31. Zones (A) and East Torres Strait (4 zone = Cumberland, Darnley, Seven Reefs and Don Cay) (B) average (stratified) density (No. per Ha) for reef stratum for Hairy blackfish (*A. miliaris*) from five surveys (error bars = 1 s.e.) (does not include deep-reef strata).

3.8.3 Population estimate

The landed (wet gutted) weight of Hairy blackfish in East Torres Strait in 2019/20 was 15 t (Table 3-27).

Table 3-27. Stock estimate for Hairy blackfish (*A. miliaris*). For each Zone and for East Torres Strait (ETS), the number of sites, total area of fishery habitat, stratified mean density, stratified variance, population stock estimate in numbers (n), live weight (wt) and landed (wet gutted) weight (wt); and for all ETS, the bootstrapped lower 90th percentile of the landed (wet gutted) weight (B) (GNE = Great North East, ETS = East Torres Strait; MLS = Minimum Legal Size).

Zone	Sites	Mean density	Var (st)	Stock (n)	Live wt (t)	Landed wt (t)	B (t)	B (>MLS) (t)
Barrier	16	0	0	0	0	0		-
Cumberland	50	0	0	0	0	0	-	-
Darnley	89	0.4	0.2	22,045	30.9	14.8	-	-
Don Cay	104	0	0	0	0	0	-	-
GNE Channel	6	0	0	0	0	0	-	-
Seven Reefs	33	0	0	0	0	0	-	-
ETS	298	0.1	0	22,045	30.9	14.8	-	-

*Weight statistics calculated using average weight data for species for survey year, or across survey years.

3.8.4 Length frequency

Length frequency numbers for both smaller and large-sized Hairy blackfish (*A. miliaris*) were lower in 2019 compared to previous survey years. Overall counts were also low compared to the 2009 survey (Figure 3-32).

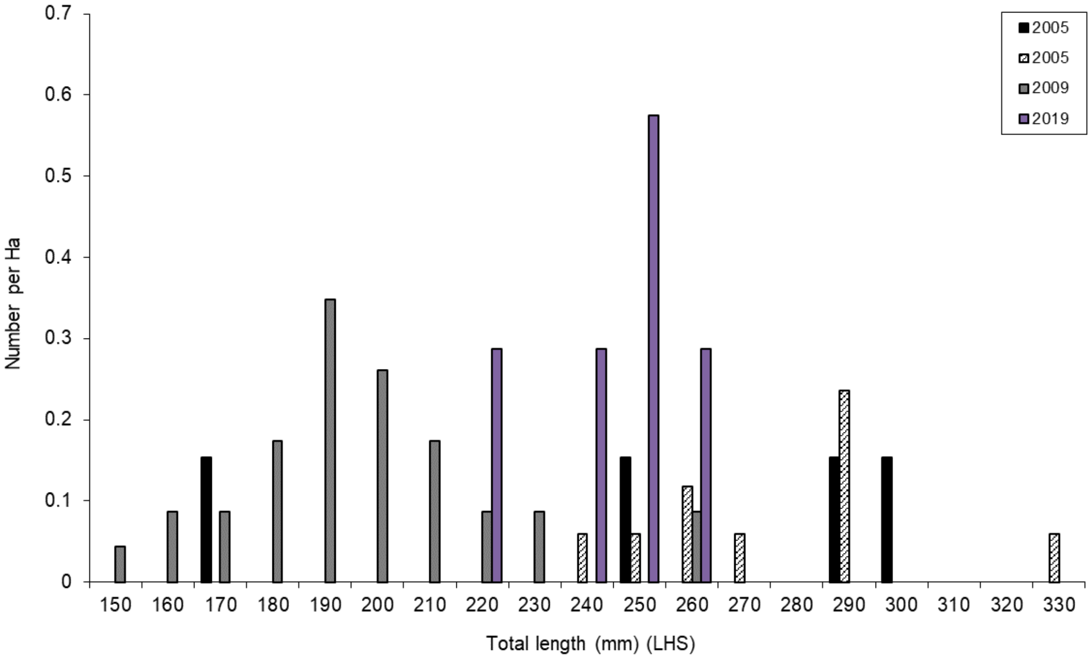


Figure 3-32. Length frequency for Hairy blackfish (*A. miliaris*) collected during population surveys in East Torres Strait in 2002, 2005, 2009 and 2019. LHS = minimum size of bin range.

3.9 Elephant trunkfish (*H. fuscopunctata*)

3.9.1 Density

The highest density for Elephant trunkfish (*H. fuscopunctata*) was for the reef edge stratum (5.5 ind./Ha), and for the reef top buffer stratum for the Don Cay zone (22 ind./Ha), which also showed the highest overall average zone density (14.6 ind./Ha) (Table 3-28; Figure 3-33).

Table 3-28. Density (No. per ha) for Elephant trunkfish (*H. fuscopunctata*) in each zone and stratum in 2019/20 (GNE = Great North East).

Zone	Reef top	Reef top buffer	Reef edge	Deep reef	Zone Ave
Barrier	0	0	2.1	-	0.5
Cumberland	0	0	7.2	3.9	1.4
Darnley	0	2.2	3.5	0.0	0.7
Don Cay	12.5	22.0	12.0	7.6	14.6
GNE Channel	0	0	0	-	0
Seven Reefs	4.0	11.1	11.1	0	3.6
All	1.4	4.6	5.5	1.7	2.7

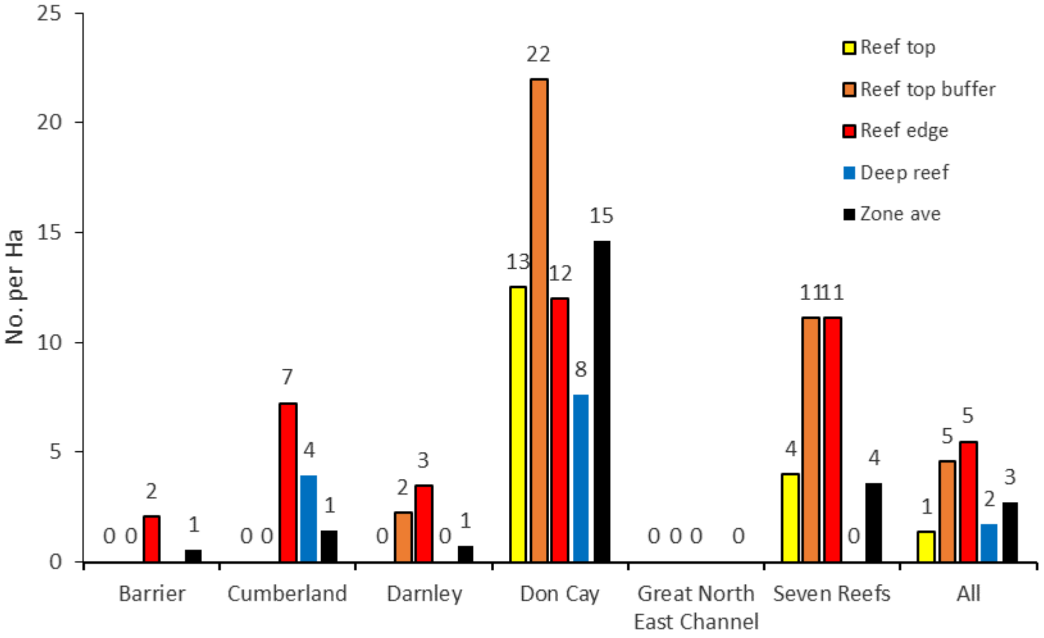


Figure 3-33. Zones and stratum average density (No. per ha) for Elephant trunkfish (*H. fuscopunctata*) in 2019/20.

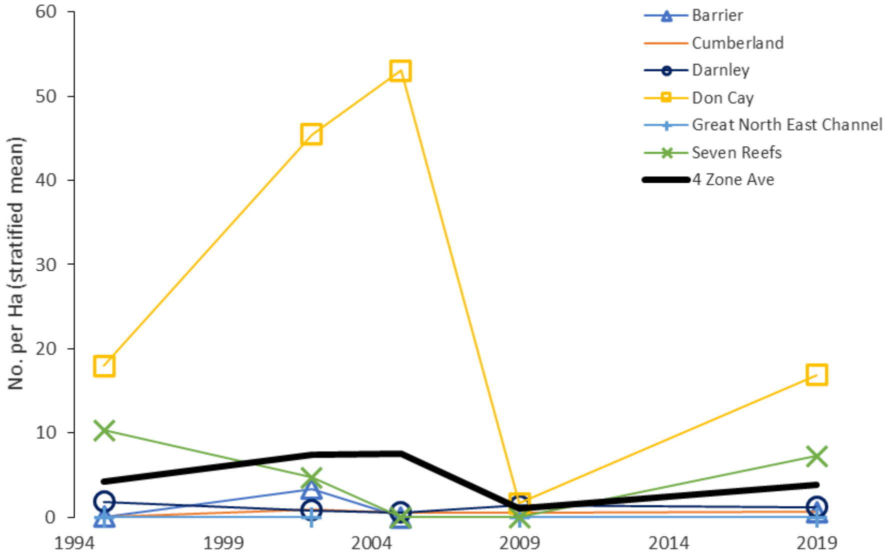
3.9.2 Density trends

The highest zone density for Elephant trunkfish Elephant trunkfish was for Don Cay (16.9 ind./Ha). The overall average zone density was higher in 2019 than the 2009 survey, but less than previous survey years (Table 3-29; Figure 3-34).

Table 3-29. Zones and East Torres Strait (4 zone = Cumberland, Darnley, Seven Reefs and Don Cay) average (stratified) density (No. per Ha) for reef stratum for Elephant trunkfish (*H. fuscopunctata*) for five surveys (does not include deep-reef strata) (GNE = Great North East).

Year	Barrier	Cumberland	Darnley	Don Cay	GNE Channel	Seven Reefs	4 Zone Ave
1995/96	0.1	0	1.8	18.0	0	10.3	4.3
2002	3.4	0.9	0.8	45.5	0	4.7	7.4
2005	0	0.5	0.5	53.1	-	0	7.6
2009	-	0.6	1.4	1.7	0	0	1.0
2019	0.5	0.7	1.2	16.9	0	7.3	3.9

A)



B)

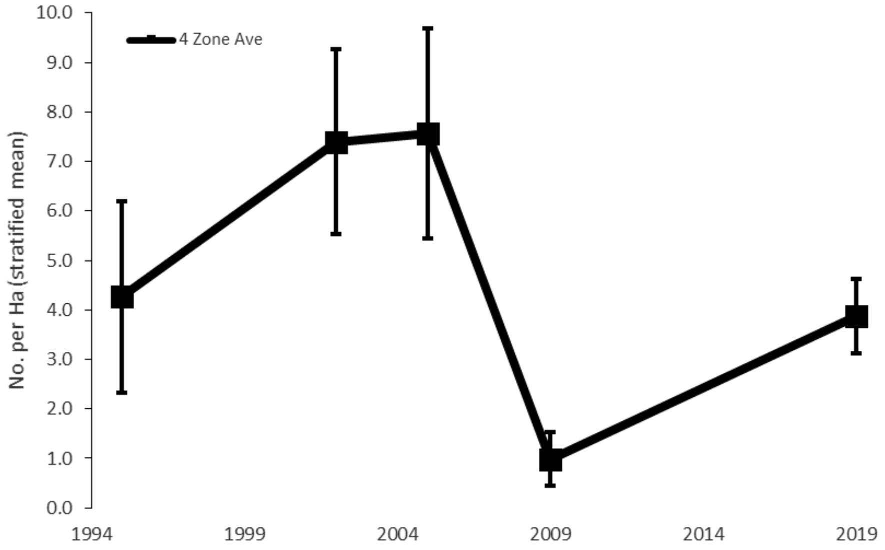


Figure 3-34. Zones (A) and East Torres Strait (4 zone = Cumberland, Darnley, Seven Reefs and Don Cay) (B) average (stratified) density (No. per Ha) for reef stratum for Elephant trunkfish (*H. fuscopunctata*) from five surveys (error bars = 1 s.e.) (does not include deep-reef strata).

3.9.3 Population estimate

The landed (wet gutted) weight of Elephant trunkfish in East Torres Strait in 2019/20 was 591 t and the bootstrapped lower 90th percentile (landed (wet gutted) weight) of the stock estimate (B) was 451 t (Table 3-30).

Table 3-30. Stock estimate for Elephant trunkfish (*H. fuscopunctata*). For each Zone and for East Torres Strait (ETS), the number of sites, total area of fishery habitat, stratified mean density, stratified variance, population stock estimate in numbers (n), live weight (wt) and landed (wet gutted) weight (wt); and for all ETS, the bootstrapped lower 90th percentile of the landed (wet gutted) weight (B) (GNE = Great North East, ETS = East Torres Strait; MLS = Minimum Legal Size).

Zone	Sites	Mean density	Var (st)	Stock (n)	Live wt (t)	Landed wt (t)	B (t)	B (>MLS) (t)
Barrier	16	0.55	0.30	8,882	19.5	10.1	-	-
Cumberland	50	1.41	0.87	89,065	195.4	101.4	-	-
Darnley	89	0.73	0.24	37,669	82.7	42.9	-	-
Don Cay	104	14.62	11.14	283,454	622.0	322.8	-	-
GNE Channel	6	0	0	0	0	0	-	-
Seven Reefs	33	3.57	2.85	100,191	219.8	114.1	-	-
ETS	298	2.69	0.29	519,261	1139.4	591.4	450.6	-

*Weight statistics calculated using average weight data for species for survey year, or across survey years.

3.9.4 Length frequency

Length frequency for Elephant trunkfish were comparable to previous survey years. A lower number of larger size individuals was recorded in 2019 compared to previous years (Figure 3-35).

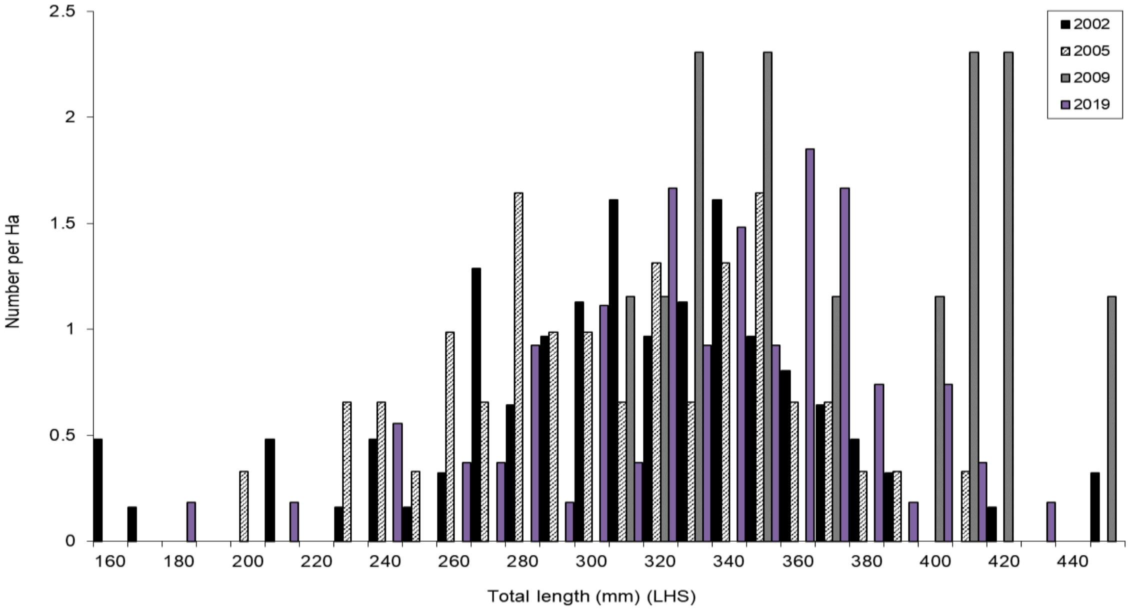


Figure 3-35. Length frequency for Elephant trunkfish (*H. fuscopunctata*) collected during population surveys in East Torres Strait in 2002, 2005, 2009 and 2019. LHS = minimum size of bin range.

3.10 Lollyfish (*H. atra*)

3.10.1 Density

The highest density for Lollyfish (*H. atra*) was recorded at the reef top stratum (161.2 ind./Ha), for the Great North East Channel zone (1,062.5 ind./Ha), which also had the highest overall average zone density (653.1 ind./Ha) (Table 3-31; Figure 3-36).

Table 3-31. Density (No. per Ha) for Lollyfish (*H. atra*) in each zone and stratum in 2019/20 (GNE = Great North East).

Zone	Reef top	Reef top buffer	Reef edge	Deep reef	Zone Ave
Barrier	0	53.6	21.9	-	36.6
Cumberland	51.1	39.4	11.2	0	34.3
Darnley	51.4	55.1	6.3	0	28.0
Don Cay	59.4	65.4	8.9	5.0	41.7
GNE Channel	1,062.5	250.0	4.2	-	653.1
Seven Reefs	51.7	82.4	87.5	2.7	33.9
All	161.2	74.3	17.3	1.2	80.0

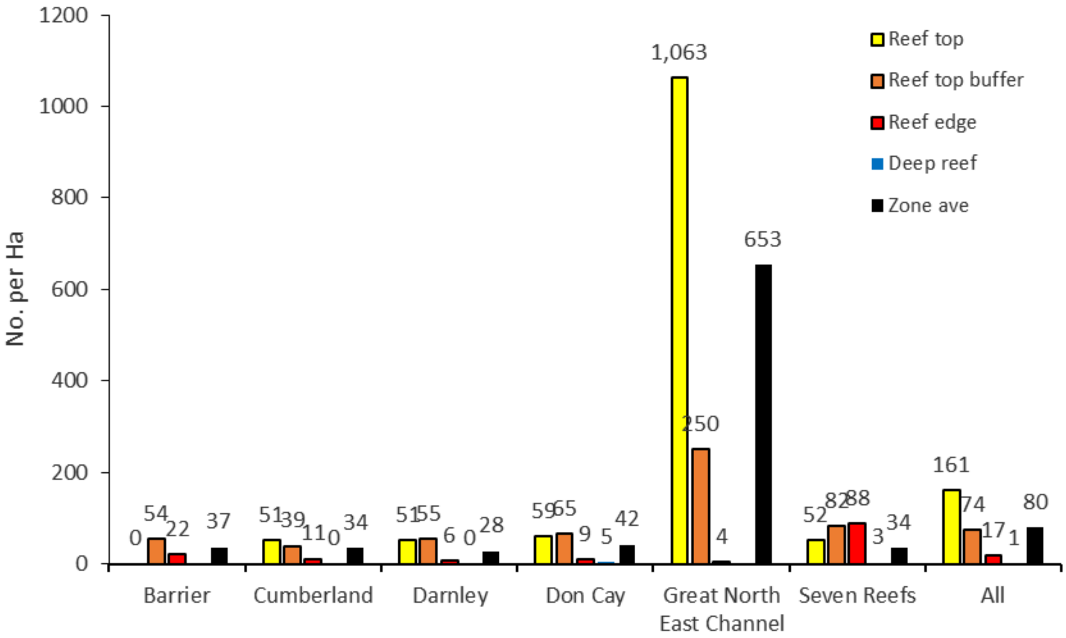


Figure 3-36. Zone and stratum average density (No. per ha) for Lollyfish (*H. atra*) in 2019/20.

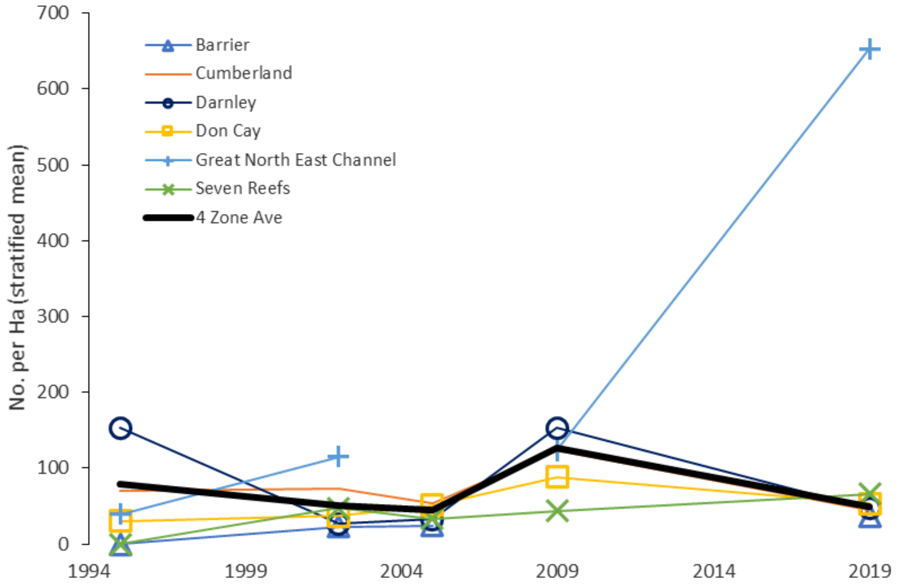
3.10.2 Density trends

The highest zone density for Lollyfish was recorded at the Great North East Channel (653.1 ind./Ha). The overall 4 zone average density was lower in 2019 compared to the 2009 survey and similar to previous survey years (Table 3-32; Figure 3-37).

Table 3-32. Zone and East Torres Strait (4 zone = Cumberland, Darnley, Seven Reefs and Don Cay) average (stratified) density (No. per ha) for reef stratum for Lollyfish (*H. atra*) for five surveys (does not include deep-reef strata) (GNE = Great North East).

Year	Barrier	Cumberland	Darnley	Don Cay	GNE Channel	Seven Reefs	4 Zone Ave
1995/96	0	70.6	153.0	30.7	39.1	0	79.75
2002	22.7	72.5	26.3	37.0	114.9	47.6	51.35
2005	24.3	53.2	32.6	51.4	-	33.6	44.59
2009	-	123.1	153.0	88.3	123.5	43.8	126.26
2019	36.6	44.1	46.9	53.8	653.1	66.4	49.04

A)



B)

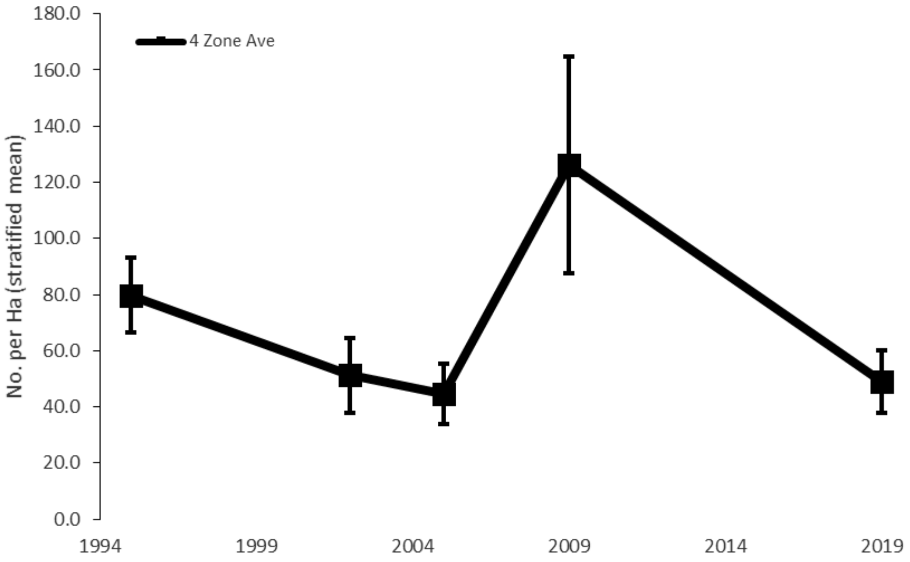


Figure 3-37. Zones (A) and East Torres Strait (4 zone = Cumberland, Darnley, Seven Reefs and Don Cay) (B) average (stratified) density (No. per ha) for reef stratum for Lollyfish (*H. atra*) from five surveys (error bars = 1 s.e.) (does not include deep-reef strata) .

3.10.3 Population estimate

The landed (wet gutted) weight of Lollyfish in East Torres Strait in 2019/20 was 3,449 t and the bootstrapped lower 90th percentile (landed (wet gutted) weight) of the stock estimate (B) was 2,857 t (Table 3-33).

Table 3-33. Stock estimate for Lollyfish (*H. atra*). For each Zone and for East Torres Strait (ETS), the number of sites, total area of fishery habitat, stratified mean density, stratified variance, population stock estimate in numbers (n), live weight (wt) and landed (wet gutted) weight (wt); and for all ETS, the bootstrapped lower 90th percentile of the landed (wet gutted) weight (B) (GNE = Great North East, ETS = East Torres Strait; MLS = Minimum Legal Size).

Zone	Sites	Mean density	Var (st)	Stock (n)	Live wt (t)	Landed wt (t)	B (t)	B (>MLS) (t)
Barrier	16	36.64	281.38	593,675	304.7	132.8	-	-
Cumberland	50	34.28	282.48	2,161,597	1,109.4	483.7	-	-
Darnley	89	28.01	72.43	1,445,716	742.0	323.5	-	-
Don Cay	104	41.72	67.08	808,917	415.1	181.0	-	-
GNE Channel	6	653.13	1,105.91	9,452,392	4,851.1	2,115.1	-	-
Seven Reefs	33	33.90	150.47	950,672	487.9	212.7	-	-
ETS	298	79.95	47.50	15,412,969	7,910.2	3,448.8	2,857.1	-

*Weight statistics calculated using average weight data for species for survey year, or across survey years.

3.10.4 Length frequency

Length frequency for Lollyfish was comparable to previous survey years (Figure 3-38).

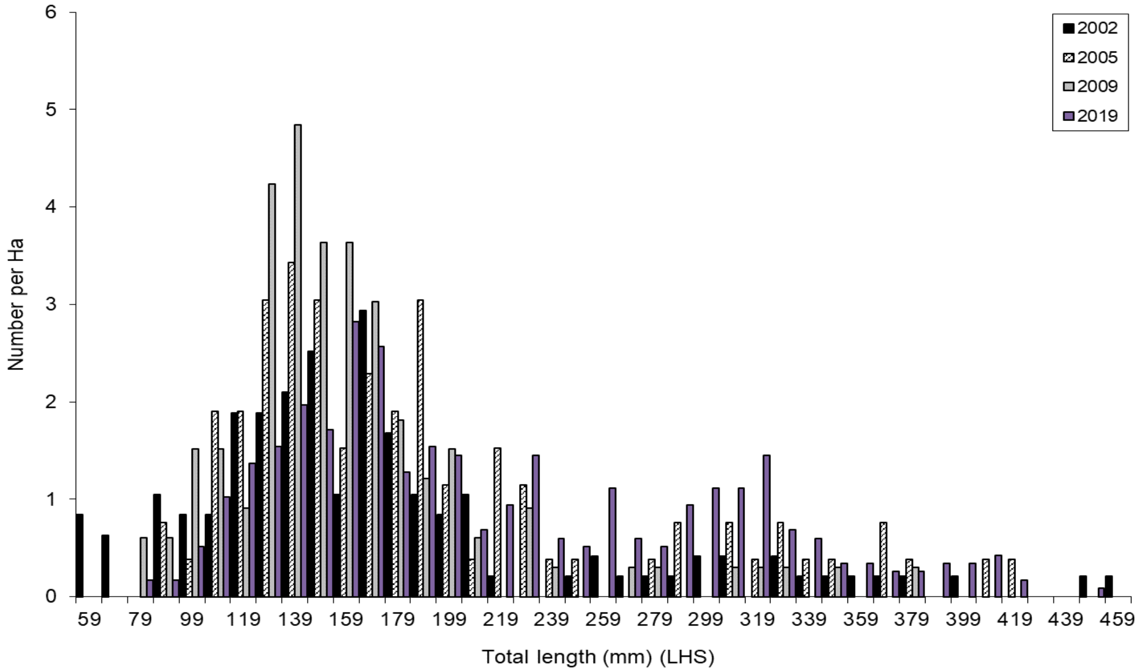


Figure 3-38. Length frequency for Lollyfish (*H. atra)* collected during population surveys in East Torres Strait in 2002, 2005, 2009 and 2019. LHS = minimum size of bin range.

3.11 Amberfish (*T. anax*)

3.11.1 Density

The highest density for Amberfish (*T. anax*) was for the reef edge stratum (6.1 ind./Ha), and the deep reef stratum for the Don Cay zone (10.3 ind./Ha), which also had the highest average zone density (5 ind./Ha) (Table 3-34; Figure 3-39).

Table 3-34. Density (No. per Ha) for Amberfish (*T. anax*) in each zone and stratum in 2019/20 (GNE = Great North East).

Zone	Reef top	Reef top buffer	Reef edge	Deep reef	Zone Ave
Barrier	0	0	1.8	-	0.4
Cumberland	0	0	9.9	7.4	2.4
Darnley	0	0	5.6	0	0.4
Don Cay	7.2	0	3.9	10.3	5.0
GNE Channel	0	0	0	-	0
Seven Reefs	0	0	19.4	4.1	3.1
All	0.5	0	6.1	3.9	1.9

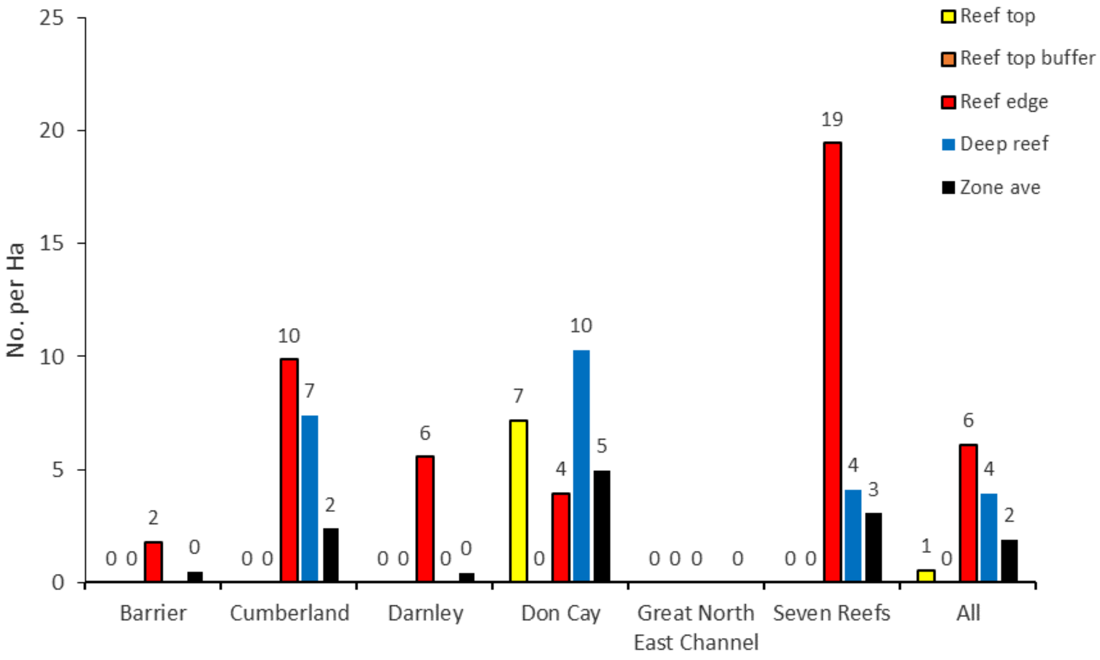


Figure 3-39. Zone and stratum average density (No. per ha) for Amberfish (*T. anax*) in 2019/20.

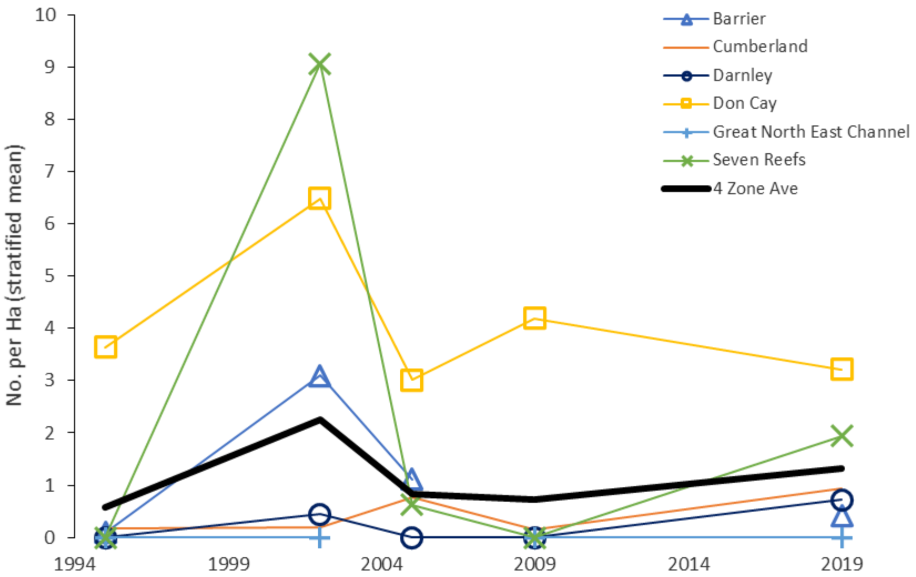
3.11.2 Density trends

The highest zone density for Amberfish in 2019 was for Don Cay (3.2 ind./Ha). The overall 4 zone density average in 2019 was the second higher compared to previous survey years (Table 3-35; Figure 3-40)

Table 3-35. Zone and East Torres Strait (4 zone = Cumberland, Darnley, Seven Reefs and Don Cay) average (stratified) density (No. per ha) for reef stratum for Amberfish (*T. anax)* for five surveys (does not include deep-reef strata) (GNE = Great North East).

Year	Barrier	Cumberland	Darnley	Don Cay	GNE Channel	Seven Reefs	4 Zone Ave
1995/96	0.1	0.2	0	3.6	0	0	0.57
2002	3.1	0.2	0.4	6.5	0	9.1	2.25
2005	1.1	0.8	0	3.0	-	0.6	0.83
2009	-	0.2	0	4.2	0	0	0.72
2019	0.4	0.9	0.7	3.2	0	1.9	1.31

A)



B)

Figure 3-40. Zones (A) and East Torres Strait (4 zone = Cumberland, Darnley, Seven Reefs and Don Cay) (B) average (stratified) density (No. per ha) for reef stratum for Amberfish (*T. anax*) from five surveys (error bars = 1 s.e.) (does not include deep-reef strata) .

3.11.3 Population estimate

The landed (wet gutted) weight of Amberfish in East Torres Strait in 2019/20 was 735 t and the bootstrapped lower 90th percentile (landed (wet gutted) weight) of the stock estimate (B) was 478 t (Table 3-36).

Table 3-36. Stock estimate for Amberfish (*T. anax*). For each Zone and for East Torres Strait (ETS), the number of sites, total area of fishery habitat, stratified mean density, stratified variance, population stock estimate in numbers (n), live weight (wt) and landed (wet gutted) weight (wt); and for all ETS, the bootstrapped lower 90th percentile of the landed (wet gutted) weight (B) (GNE = Great North East, ETS = East Torres Strait; MLS = Minimum Legal Size).

Zone	Sites	Mean density	Var (st)	Stock (n)	Live wt (t)	Landed wt (t)	B (t)	B (>MLS) (t)
Barrier	16	0.41	0.17	6662	20.4	13.6	-	-
Cumberland	50	2.38	1.33	150255	459.0	306.2	-	-
Darnley	89	0.43	0.18	22045	67.3	44.9	-	-
Don Cay	104	4.97	3.77	96324	294.3	196.3	-	-
GNE Channel	6	0.00	0.00	0	0.0	0.0	-	-
Seven Reefs	33	3.05	4.60	85548	261.3	174.3	-	-
ETS	298	1.87	0.29	360834	1102.3	735.3	477.8	-

*Weight statistics calculated using average weight data for species for survey year, or across survey years.

3.11.4 Length frequency

Length frequency for Amberfish (in 2019 was comparable to 2005 with fewer larger measurements recorded (Figure 3-41).

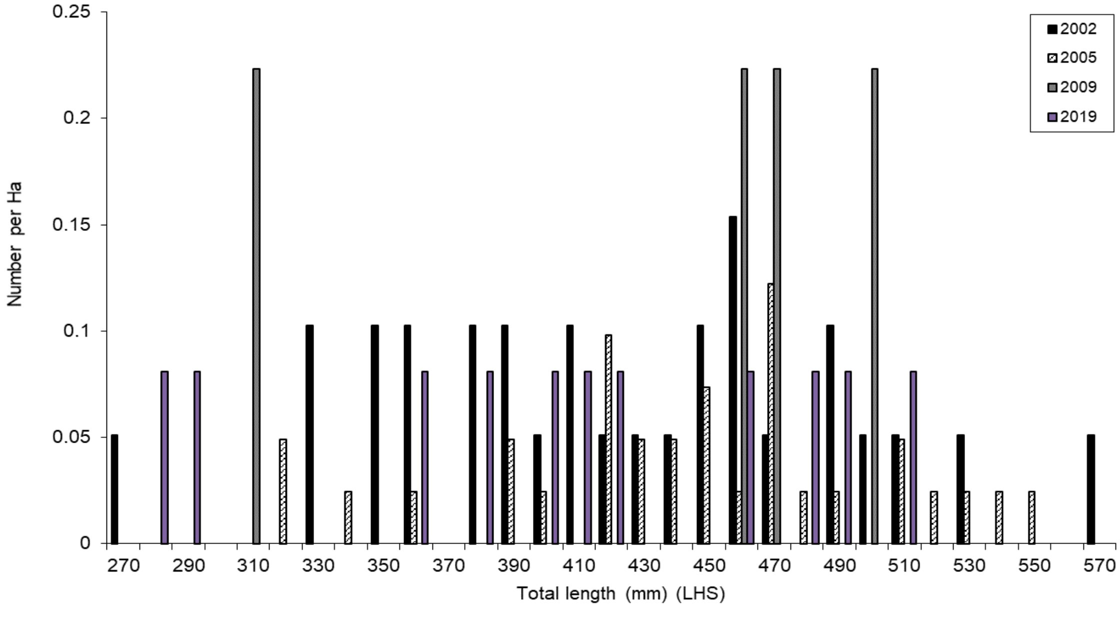


Figure 3-41. Length frequency for Amberfish (*T. anax*) collected during population surveys in east Torres Strait in 2002, 2005, 2009 and 2019. LHS = minimum size of bin range.

3.12 Greenfish (*S. chloronotus*)

3.12.1 Density

The highest density for Greenfish (*S. chloronotus*) was for the reef top buffer stratum (61.4 ind./Ha), for the Barrier zone (160.7 ind./Ha), which also had the highest overall zone average (92.6 ind./Ha) (Table 3-37; Figure 3-42).

Table 3-37. Density (No. per ha) for Greenfish (*S. chloronotus*) in each zone and stratum in 2019/20 (GNE = Great North East).

Zone	Reef top	Reef top buffer	Reef edge	Deep reef	Zone Ave
Barrier	0	160.7	0	-	92.6
Cumberland	21.8	69.4	0	0	25.4
Darnley	6.1	22.3	0	0	6.5
Don Cay	12.5	28.2	5.5	0	14.1
GNE Channel	62.5	0	8.3	-	34.2
Seven Reefs	0	46.3	5.6	0	8.5
All	18.8	61.4	1.9	0	23.1

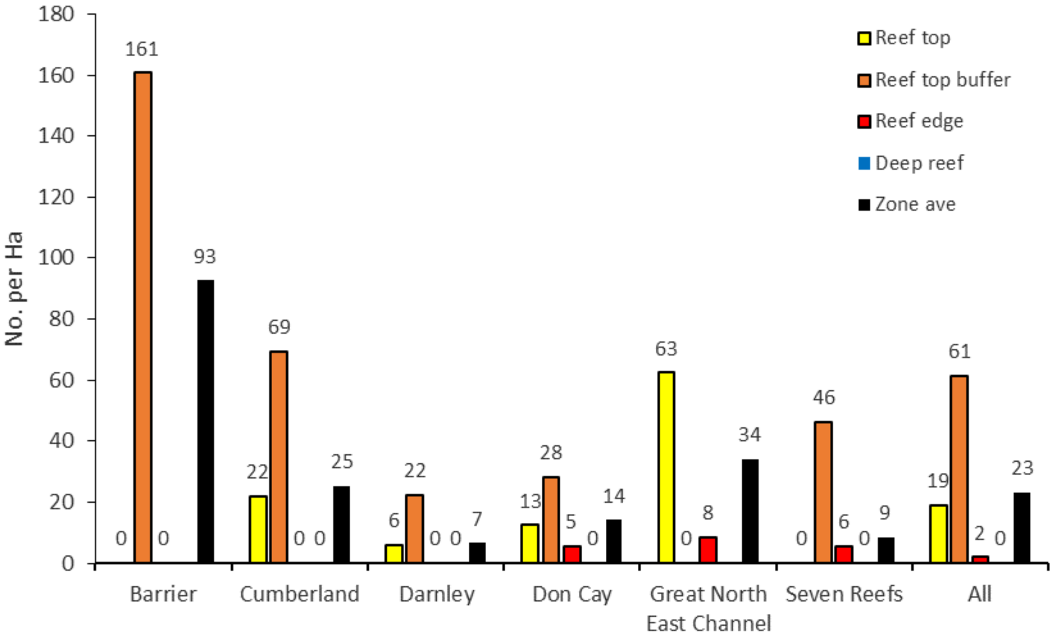


Figure 3-42. Zones and stratum average density (No. per ha) for Greenfish (*S. chloronotus*) in 2019/20.

3.12.2 Density trends

The highest survey density for Greenfish was found at the Barrier zone (92.6 ind./Ha). The overall zone average was the lowest compared to other survey years and notably different to 2009 (Table 3-38; Figure 3-43).

Table 3-38. Zone and East Torres Strait (4 zone = Cumberland, Darnley, Seven Reefs and Don Cay) average (stratified) density (No. per Ha) for reef stratum for Greenfish (*S. chloronotus*) for five surveys (does not include deep-reef strata) (GNE = Great North East).

Year	Barrier	Cumberland	Darnley	Don Cay	GNE Channel	Seven Reefs	4 Zone Ave
1995/96	25.7	38.4	29.3	3.0	51.5	0	26.13
2002	0.4	45.3	18.4	20.5	71.3	0	28.51
2005	14.4	34.7	59.7	27.5	-	0	36.45
2009	-	168.9	98.7	143.1	139.6	0	139.93
2019	92.6	32.7	10.9	18.8	34.2	17.3	22.67

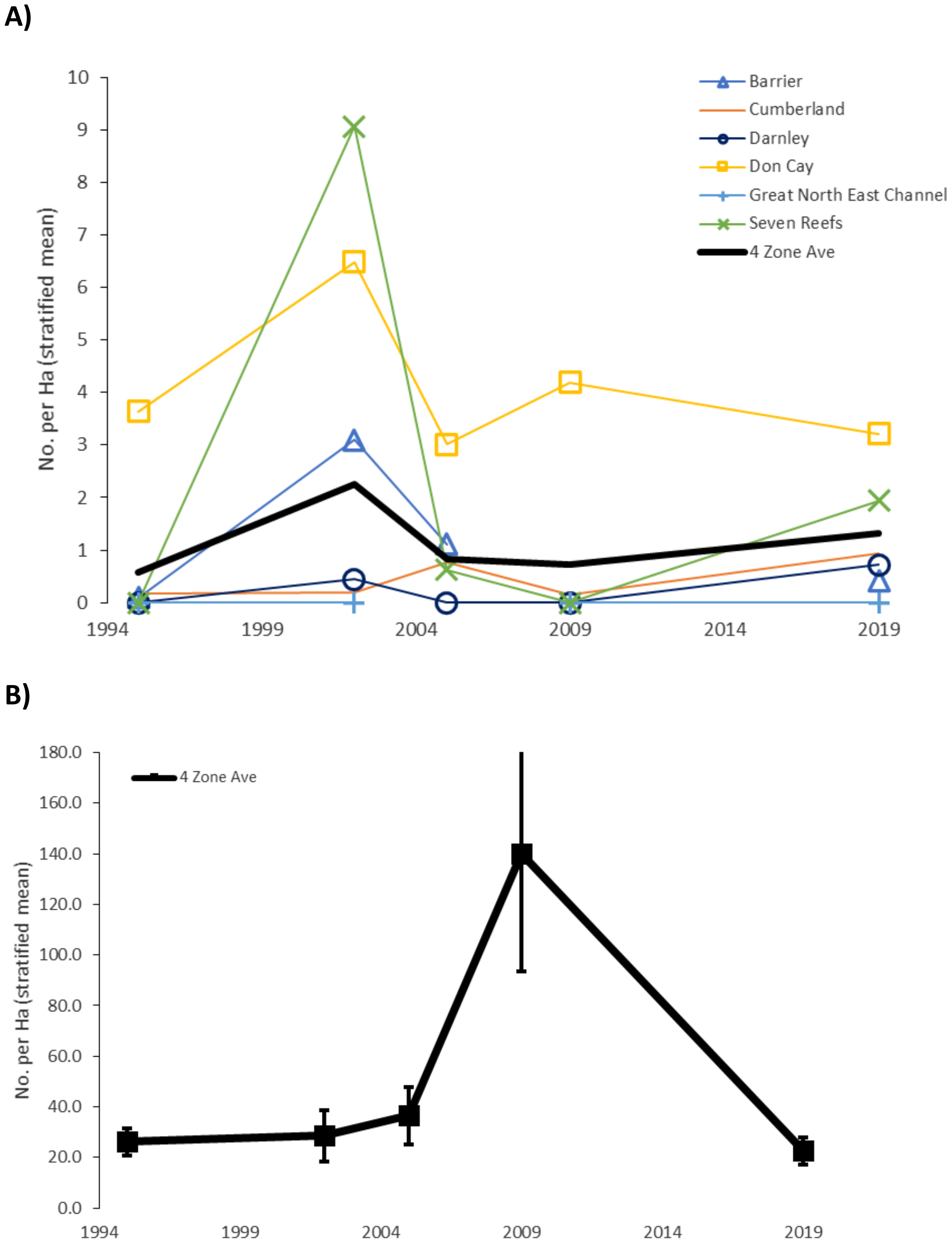


Figure 3-43. Zones (A) and East Torres Strait (4 zone = Cumberland, Darnley, Seven Reefs and Don Cay) (B) average (stratified) density (No. per Ha) for reef strata for Greenfish (*S. chloronotus*) from five surveys (error bars = 1 s.e.) (does not include deep-reef strata).

3.12.3 Population estimate

The landed (wet gutted) weight of Greenfish in East Torres Strait in 2019/20 was 1,304 t and the bootstrapped lower 90th percentile (landed (wet gutted) weight) of the stock estimate (B) was 906 t (Table 3-39).

Table 3-39. Stock estimate for Greenfish (*S. chloronotus*). For each Zone and for East Torres Strait (ETS), the number of sites, total area of fishery habitat, stratified mean density, stratified variance, population stock estimate in numbers (n), live weight (wt) and landed (wet gutted) weight (wt); and for all ETS, the bootstrapped lower 90th percentile of the landed (wet gutted) weight (B) (GNE = Great North East, ETS = East Torres Strait; MLS = Minimum Legal Size).

Zone	Sites	Mean density	Var (st)	Stock (n)	Live wt (t)	Landed wt (t)	B (t)	B (>MLS) (t)
Barrier	16	92.65	2,587.35	1,501,241	676.2	440.2	-	-
Cumberland	50	25.41	65.07	1,602,201	721.6	469.8	-	-
Darnley	89	6.53	7.53	337,153	151.9	98.9	-	-
Don Cay	104	14.15	13.60	274,246	123.5	80.4	-	-
GNE Channel	6	34.24	1,106.64	495,532	223.2	145.3	-	-
Seven Reefs	33	8.50	67.79	238,402	107.4	69.9	-	-
ETS	298	23.08	33.59	4,448,775	2003.7	1304.4	905.67	-

*Weight statistics calculated using average weight data for species for survey year, or across survey years.

3.12.4 Length frequency

Length frequency for Greenfish was comparable to previous survey years (Figure 3-44).

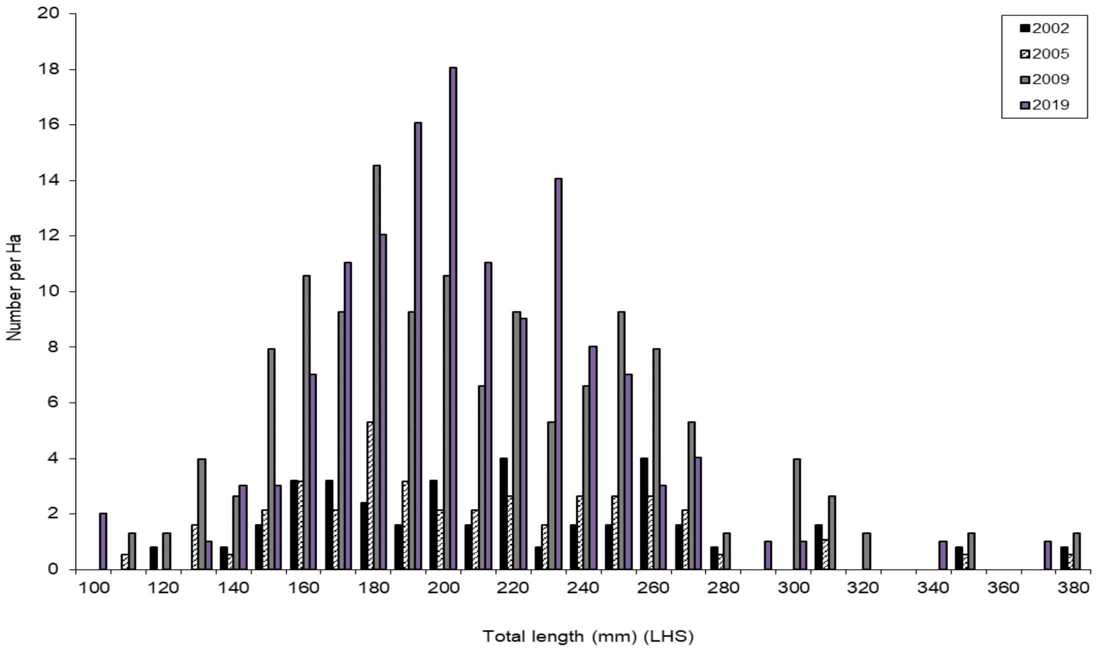


Figure 3-44. Length frequency for Greenfish (*S. chloronotus*) collected during population surveys in east Torres Strait in 2002, 2005, 2009 and 2019. LHS = minimum size of bin range.

3.13 Leopardfish (*B. argus*)

3.13.1 Density

The highest density for Leopardfish (*B. argus*) was recorded at the reef edge stratum (16.4 ind./Ha), and for the reef top of Don Cay zone (58.6 ind./Ha), which also had the highest overall zone average (24.8 ind./Ha) (Table 3-40; Figure 3-45).

Table 3-40. Density (No. per Ha) for Leopardfish (*B. argus*) in each zone and stratum in 2019/20 (GNE = Great North East).

Zone	Reef top	Reef top buffer	Reef edge	Deep reef	Zone Ave
Barrier	0	0	24.0	-	6.3
Cumberland	2.8	4.5	8.6	0	3.0
Darnley	0.7	4.5	17.4	0	2.5
Don Cay	58.6	21.5	10.3	0	24.8
GNE Channel	0	0	33.3	-	4.0
Seven Reefs	0	1.4	6.9	0	0.6
All	5.8	5.2	16.4	0	5.0

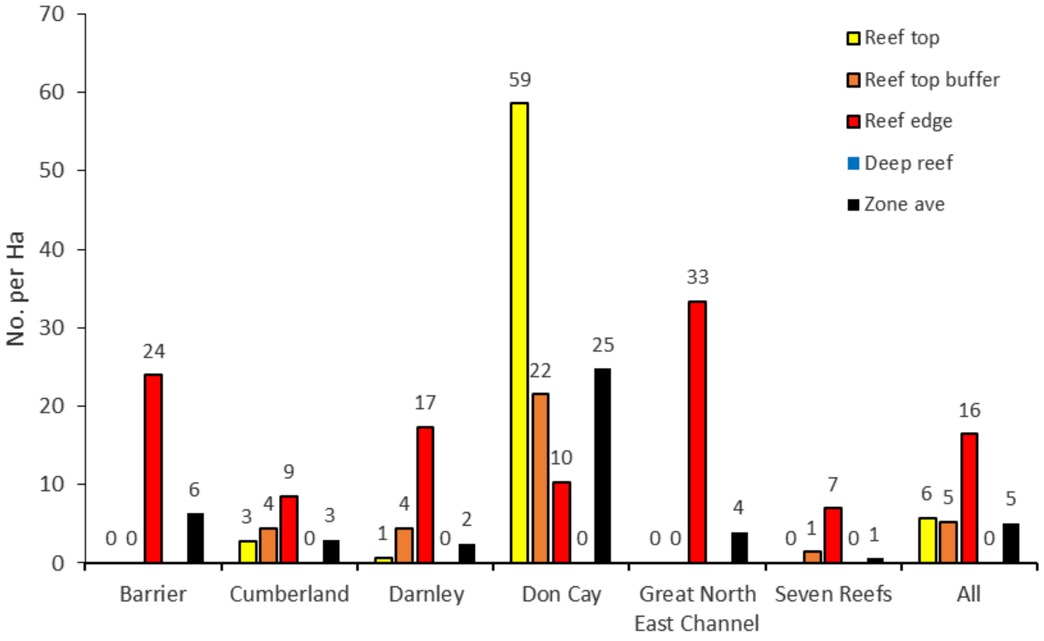


Figure 3-45. Zone and stratum average density (No. per Ha) for Leopardfish (*B. argus*) in 2019/20.

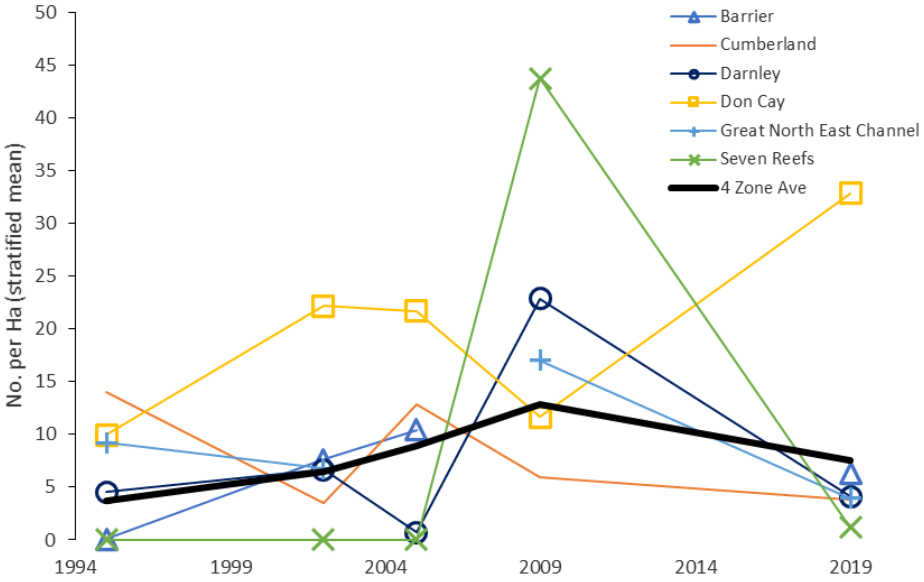
3.13.2 Density trends

The highest zone density for Leopardfish in 2019 was recorded at Don Cay (32.9 ind./Ha). The overall 4 zone density average was lower in 2019 compared to the 2009 survey, and similar to 2005 (Table 3-41; Figure 3-46).

Table 3-41. Zone and East Torres Strait (4 zone = Cumberland, Darnley, Seven Reefs and Don Cay) average (stratified) density (No. per ha) for reef stratum for Leopardfish (*B. argus*) for five surveys (does not include deep-reef strata) (GNE = Great North East).

Year	Barrier	Cumberland	Darnley	Don Cay	GNE Channel	Seven Reefs	4 Zone Ave
1995/96	0.1	14.0	4.6	10.0	9.2	0	3.67
2002	7.6	3.5	6.7	22.2	6.8	0	6.47
2005	10.4	12.8	0.7	21.7	-	0	8.93
2009	-	6.0	22.9	11.7	17.0	43.8	12.82
2019	6.3	3.8	4.1	32.9	4.0	1.2	7.50

A)



B)

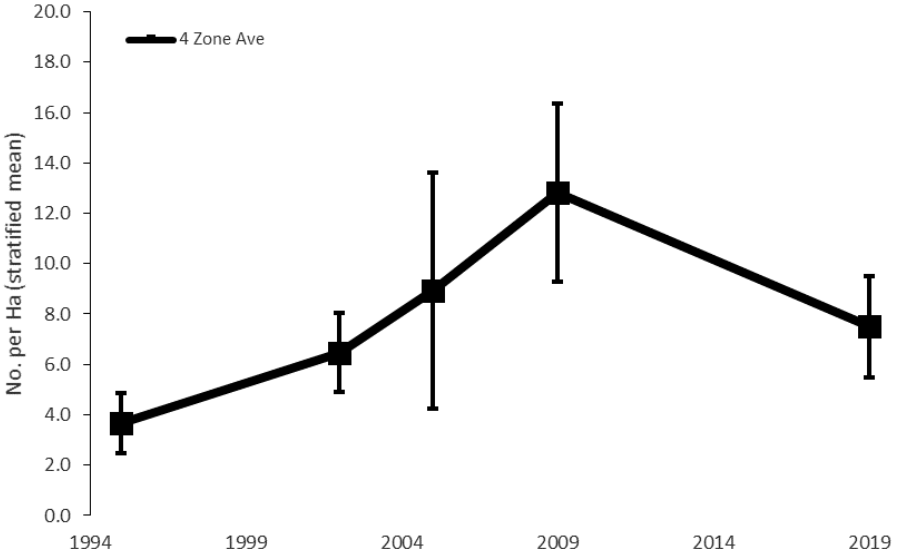


Figure 3-46. Zone (A) and East Torres Strait (4 zone = Cumberland, Darnley, Seven Reefs and Don Cay) (B) average (bottom) (stratified) density (No. per ha) for reef stratum for Leopardfish (*B. argus*) from five surveys (error bars = 1 s.e.) (does not include deep-reef strata).

3.13.3 Population estimate

The landed (wet gutted) weight of Leopardfish in East Torres Strait in 2019/20 was 717 t and the bootstrapped lower 90th percentile (landed (wet gutted) weight) of the stock estimate (B) was 508 t (Table 3-42).

Table 3-42. Stock estimate for Leopardfish (*B. argus*). For each Zone and for East Torres Strait (ETS), the number of sites, total area of fishery habitat, stratified mean density, stratified variance, population stock estimate in numbers (n), live weight (wt) and landed (wet gutted) weight (wt); and for all ETS, the bootstrapped lower 90th percentile of the landed (wet gutted) weight (B) (GNE = Great North East, ETS = East Torres Strait; MLS = Minimum Legal Size).

Zone	Sites	Mean density	Var (st)	Stock (n)	Live wt (t)	Landed wt (t)	B (t)	B (>MLS) (t)
Barrier	16	6.30	8.19	102,144	113.4	75.4	-	-
Cumberland	50	2.97	3.03	187,594	208.2	138.5	-	-
Darnley	89	2.46	1.28	127,199	141.2	93.9	-	-
Don Cay	104	24.76	83.92	480,009	532.8	354.3	-	-
GNE Channel	6	3.95	10.49	57,192	63.5	42.2	-	-
Seven Reefs	33	0.59	0.14	16,466	18.3	12.2	-	-
ETS	298	5.03	1.39	970,604	1077.4	716.5	508.0	-

*Weight statistics calculated using average weight data for species for survey year, or across survey years.

3.13.4 Length frequency

The length frequency for Leopardfish was comparable to the 2009 survey year, with lower numbers of larger individuals recorded (Figure 3-47).

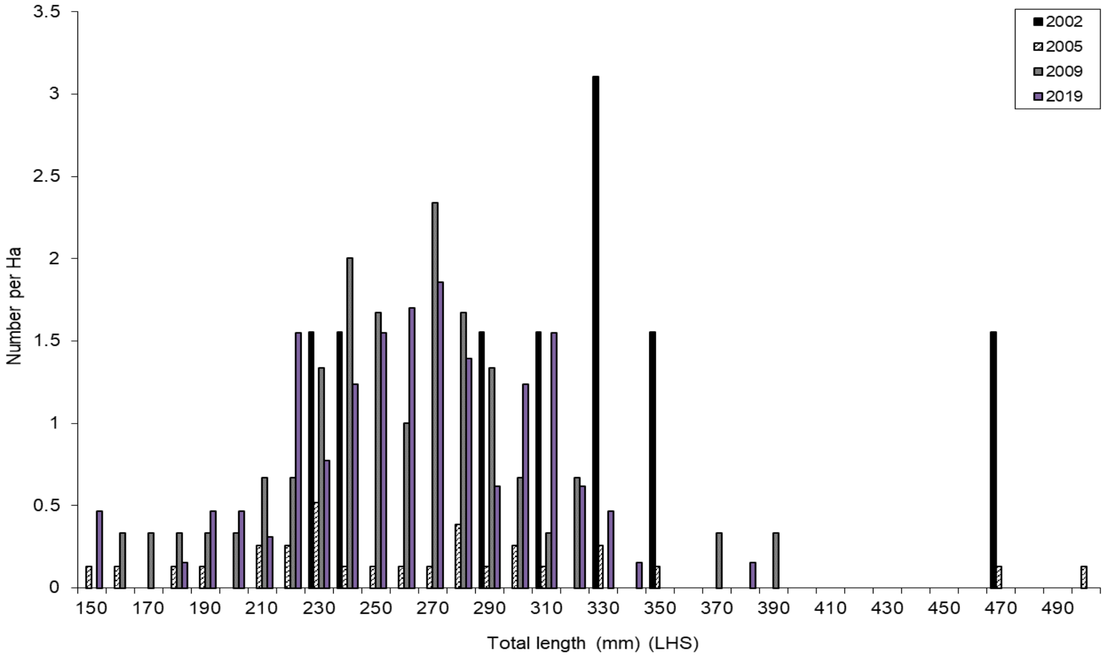


Figure 3-47. Length frequency for Leopardfish (*B. argus*) collected during population surveys in east Torres Strait in 2002, 2005, 2009 and 2019. LHS = minimum size of bin range.

3.14 Pinkfish (*H. edulis*)

3.14.1 Density

The highest density for Pinkfish (*H. edulis*) was recorded at the reef edge stratum (29.7 ind./Ha), for the Great North East Channel zone (54.2 ind./Ha). Don Cay had the highest overall zone average (13.8 ind./Ha) (Table 3-43; Figure 3-48).

Table 3-43. Density (No. per Ha) for Pinkfish (*H. edulis*) in each zone and stratum in 2019/20 (GNE = Great North East).

Zone	Reef top	Reef top buffer	Reef edge	Deep reef	Zone Ave
Barrier	0	0.0	5.7	-	1.5
Cumberland	0	24.3	37.5	0	7.9
Darnley	1.3	6.7	40.3	0	4.9
Don Cay	25.3	8.4	26.5	2.6	13.8
GNE Channel	0	0.0	54.2	-	6.4
Seven Reefs	8.2	0.0	22.2	0	3.2
All	3.0	9.0	29.7	0.2	6.4

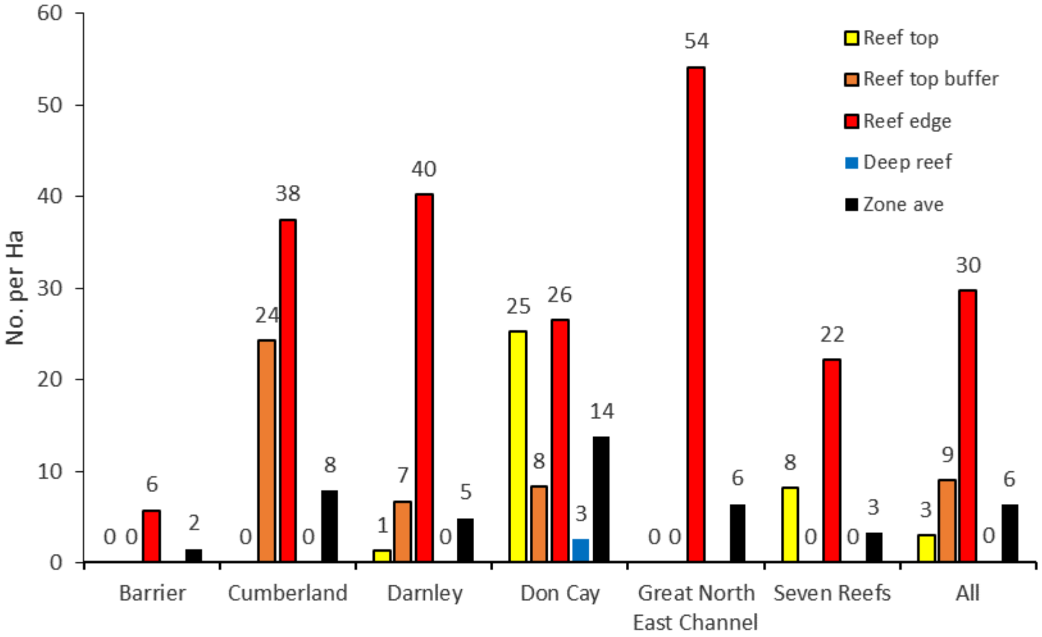


Figure 3-48. Zone and stratum average density (No. per Ha) for Pinkfish (*H. edulis*) in 2019/20.

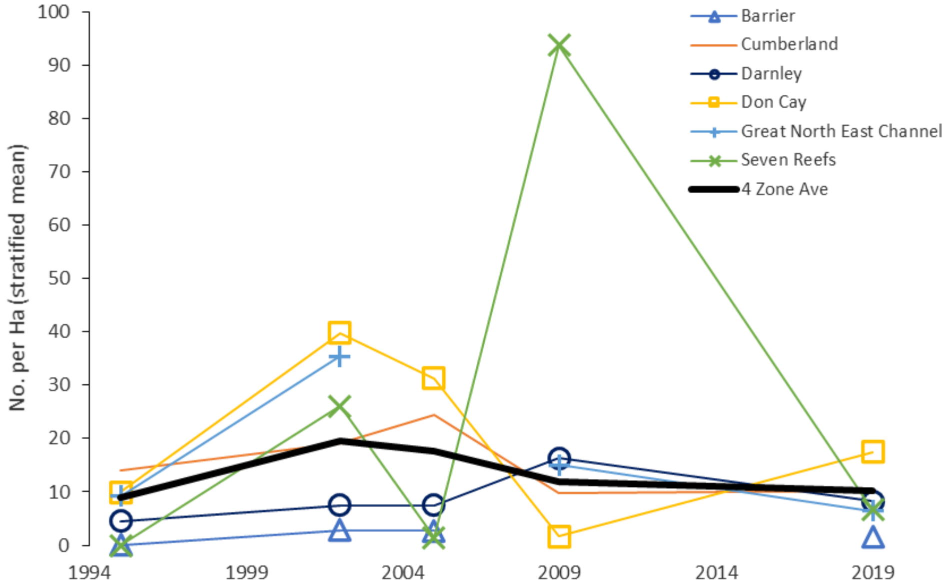
3.14.2 Density trends

The highest survey density for Pinkfish was recorded at Don Cay (17.4 ind./Ha), with Seven Reefs showing a notable decrease compared to the last two surveys. The overall 4 zone average density (10.2 ind./ha) was similar to 2009 (Table 3-44; Figure 3-49).

Table 3-44. Zone and East Torres Strait (4 zone = Cumberland, Darnley, Seven Reefs and Don Cay) average (stratified) density (No. per ha) for reef stratum for Pinkfish (*H. edulis*) for five surveys (does not include deep-reef strata) (GNE = Great North East).

Year	Barrier	Cumberland	Darnley	Don Cay	GNE Channel	Seven Reefs	4 Zone Ave
1995/96	0.1	14.0	4.6	10.0	9.2	0	9.00
2002	2.8	19.1	7.5	39.8	35.5	26.1	19.48
2005	2.7	24.4	7.5	31.3	-	1.4	17.61
2009	-	9.8	16.3	1.7	15.0	93.8	11.84
2019	1.5	10.2	8.2	17.4	6.4	6.6	10.15

A)



B)

Figure 3-49. Zone (A) and East Torres Strait (4 zone = Cumberland, Darnley, Seven Reefs and Don Cay) (B) average (stratified) density (No. per ha) for reef stratum for Pinkfish (*H. edulis)* from five surveys (error bars = 1 s.e.) (does not include deep-reef strata).

3.14.3 Population estimate

The landed (wet gutted) weight of Pinkfish in East Torres Strait in 2019/20 was 108 t and the bootstrapped lower 90th percentile (landed (wet gutted) weight) of the stock estimate (B) was 85 t (Table 3-45).

Table 3-45. Stock estimate for Pinkfish (*H. edulis*). For each Zone and for East Torres Strait, the number of sites, total area of fishery habitat, stratified mean density, stratified variance, population stock estimate in numbers (n), live weight and landed (wet gutted) wt (B); and for all ETS, the bootstrapped lower 90th percentile of the live weight and landed (wet gutted) weight (B) (GNE = Great North East, ETS = East Torres Strait).

Zone	Sites	Mean density	Var (st)	Stock (n)	Live wt (t)	Landed wt (t)	B (t)	B (>MLS) (t)
Barrier	16	1.51	1.24	24426	4.9	2.2	-	-
Cumberland	50	7.93	6.95	500395	101.2	44.1	-	-
Darnley	89	4.89	2.75	252553	51.1	22.3	-	-
Don Cay	104	13.77	15.66	266971	54.0	23.5	-	-
GNE Channel	6	6.42	25.13	92937	18.8	8.2	-	-
Seven Reefs	33	3.24	5.00	90738	18.3	8.0	-	-
ETS	298	6.37	1.36	1228019	248.3	108.2	85.1	-

*Weight statistics calculated using average weight data for species for survey year, or across survey years.

3.14.4 Length frequency

The length frequency for Pinkfish was comparable to previous survey years with a higher number of larger sizes recorded. Overall counts of Pinkfish were lower in 2019 compared to previous surveys (Figure 3-50).

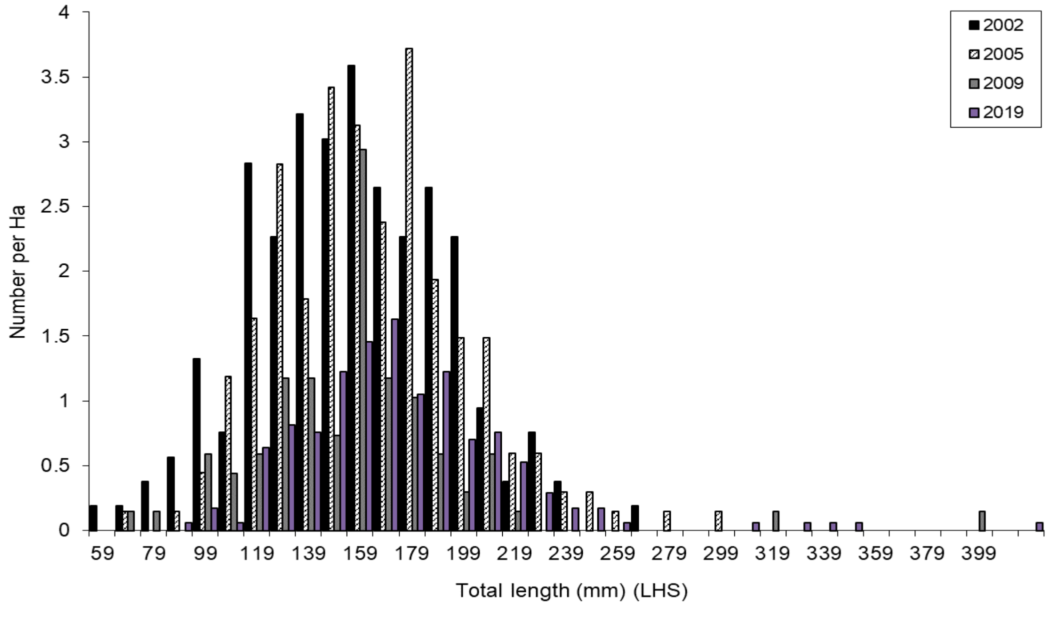


Figure 3-50. Length frequency for Pinkfish (*H. edulis)* collected during population surveys in east Torres Strait in 2002, 2005, 2009 and 2019. LHS = minimum size of bin range.

3.15 Deepwater blackfish (*A. palauensis*)

3.15.1 Density

The highest density for Deepwater blackfish (*A. palauensis*) was recorded at the reef edge stratum (2.8 ind./Ha), and reef top buffer of the Barrier zone (8.9 ind./Ha), which also had the highest overall average zone density (6.4 ind./Ha) (Table 3-46; Figure 3-51)

Table 3-46. Density (No. per ha) for Deepwater blackfish (*A. palauensis*) in each zone and stratum in 2019/20 (GNE = Great North East).

Zone	Reef top	Reef top buffer	Reef edge	Deep reef	Zone Ave
Barrier	0	8.9	4.7	-	6.4
Cumberland	0	0	0	0	0
Darnley	0	0	0.7	0	0.1
Don Cay	0.8	1.5	7.2	0	1.7
GNE Channel	0	0	0	-	0
Seven Reefs	0	0	8.3	0	0.4
All	0.1	1.9	2.8	0	0.8

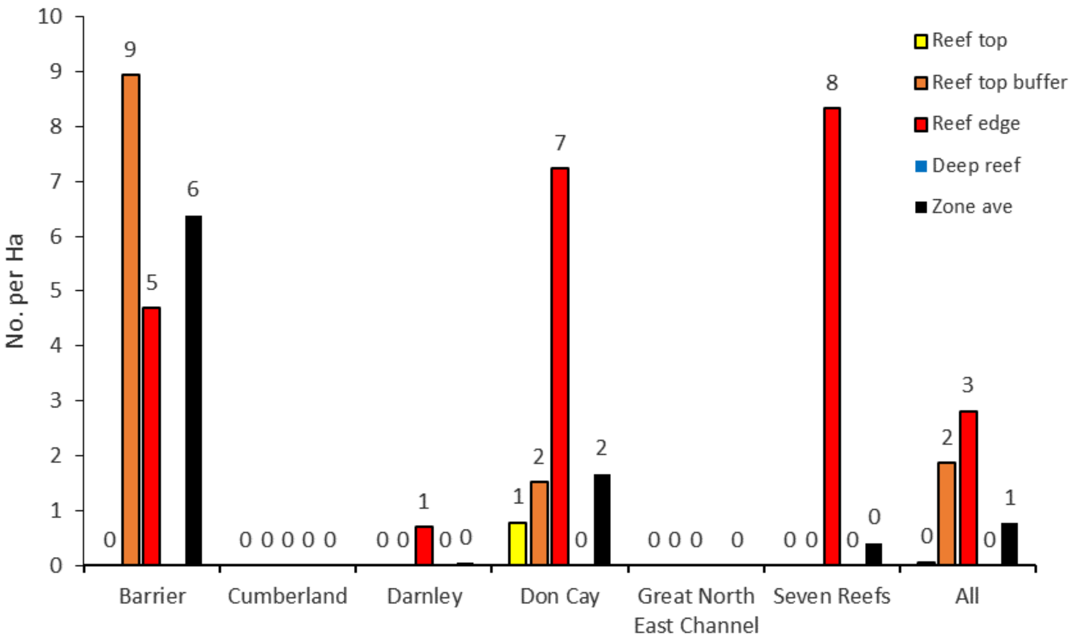


Figure 3-51. Zone and stratum average density (No. per ha) for Deepwater Blackfish (A. *palauensis*) in 2019/20.

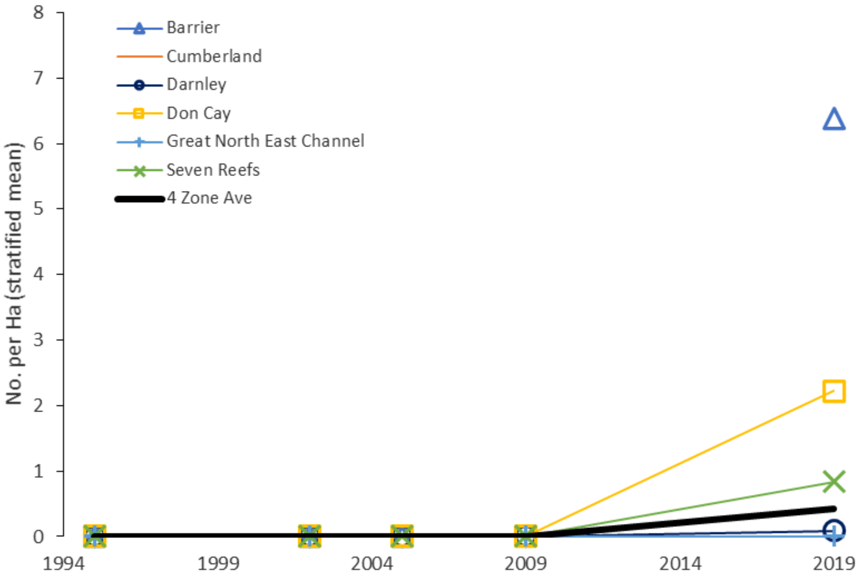
3.15.2 Density trends

The highest zone density for Deepwater blackfish was recorded at the Barrier zone (6.4 ind./Ha). Deepwater blackfish was not found in previous surveys (Table 3-47; Figure 3-52).

Table 3-47. Zone and East Torres Strait (4 zone= Cumberland, Darnley, Seven Reefs and Don Cay) average (stratified) density (No. per Ha) for reef stratum for Deepwater Blackfish (*A. palauensis*) for five surveys (does not include deep-reef strata) (GNE = Great North East).

Year	Barrier	Cumberland	Darnley	Don Cay	GNE Channel	Seven Reefs	4 Zone Ave
1995/96	0	0	0	0	0	0	0
2002	0	0	0	0	0	0	0
2005	0	0	0	0	-	0	0
2009	-	0	0	0	0	0	0
2019	6.4	0	0.1	2.2	0	0.8	0.43

A)



B)

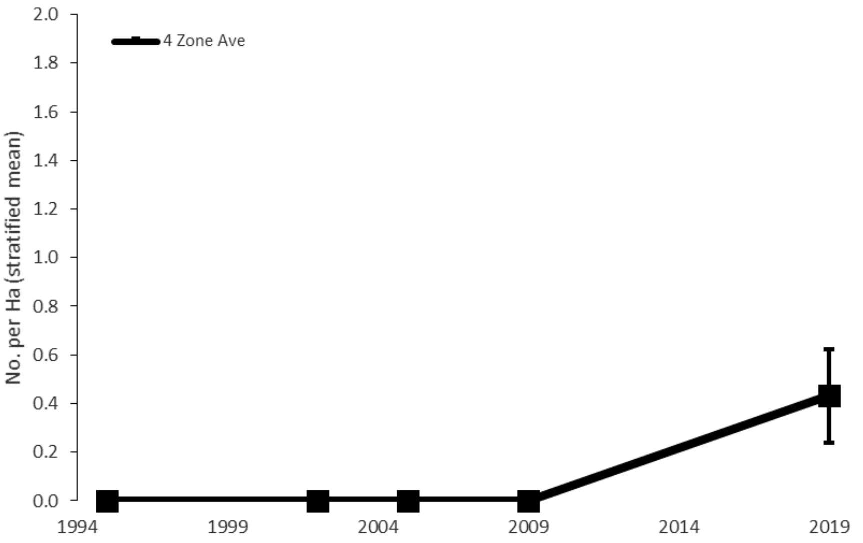


Figure 3-52. Zones (A) and East Torres Strait (4 zone = Cumberland, Darnley, Seven Reefs and Don Cay) (B) average (stratified) density (No. per Ha) for reef stratum for Deepwater blackfish (*A. palauensis*) from five surveys (error bars = 1 s.e.) (does not include deep reef strata).

3.15.3 Population estimate

The landed (wet gutted) weight of Deepwater blackfish in East Torres Strait in 2019/20 was 104 t (Table 3-48).

Table 3-48. Stock estimate for Deepwater blackfish (*A. palauensis*). For each Zone and for East Torres Strait (ETS), the number of sites, total area of fishery habitat, stratified mean density, stratified variance, population stock estimate in numbers (n), live weight (wt) and landed (wet gutted) weight (wt); and for all ETS, the bootstrapped lower 90th percentile of the landed (wet gutted) weight (B) (GNE = Great North East, ETS = East Torres Strait; MLS = Minimum Legal Size).

Zone	Sites	Mean density	Var (st)	Stock (n)	Live wt (t)	Landed wt (t)	B (t)	B (>MLS) (t)
Barrier	16	6.38	27.24	103387	148.7	71.4	-	-
Cumberland	50	0.00	0.00	0	0.0	0.0	-	-
Darnley	89	0.05	0.00	2756	4.0	1.9	-	-
Don Cay	104	1.67	0.96	32396	46.6	22.4	-	-
GNE Channel	6	0.00	0.00	0	0.0	0.0	-	-
Seven Reefs	33	0.41	0.08	11452	16.5	7.9	-	-
East Torres Strait	298	0.78	0.20	149991	215.7	103.5	-	-

*Weight statistics calculated using average weight data for species for survey year, or across survey years.

3.15.4 Length frequency

Length frequency for Deepwater blackfish showed that only a small number of individuals were counted across a range of sizes (Figure 3-53).

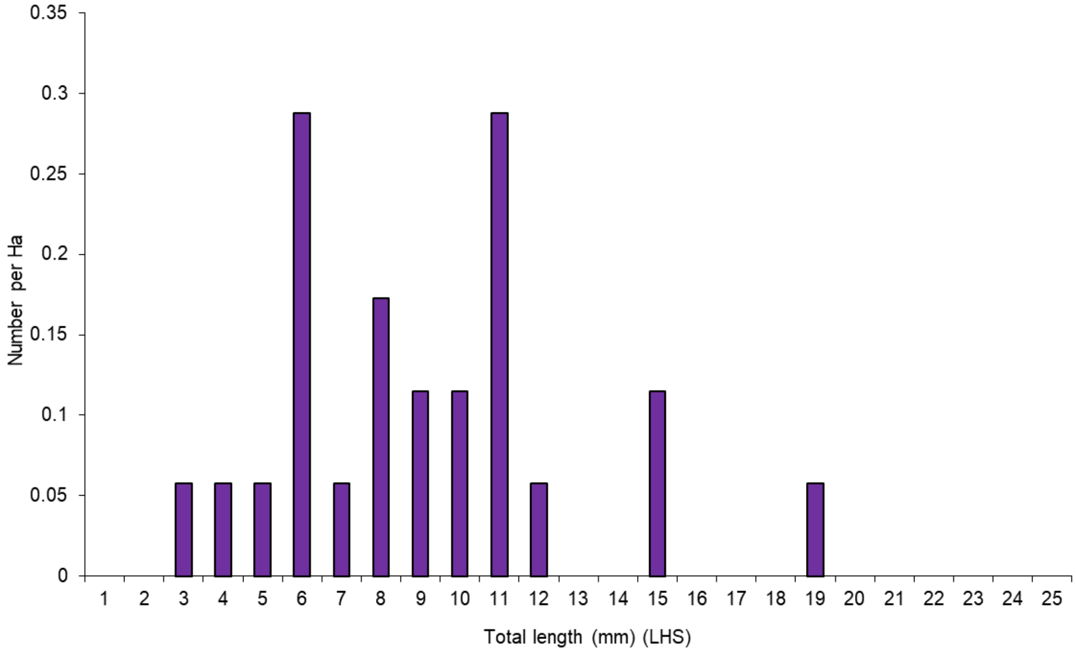


Figure 3-53. Length frequency for Deepwater blackfish (*A. palauensis*) collected during population surveys in east Torres Strait in 2019. LHS = minimum size of bin range.

4 Environmental

4.1 Depth profiles

Depths for sampling deep-reef sites were determined using diver depth gauge at the start of the dive, the deepest point of the reef slope and when the dive finished. Specific depth measurements were recorded during drift transects using a hand-held depth sounder, e.g. when a sea cucumber was seen in the controller unit screen and when watching recorded video from the Deep Trekker DTG3 ROV. The majority of sites occurred at depths between 20 m and 45 m (Figure 4-1).

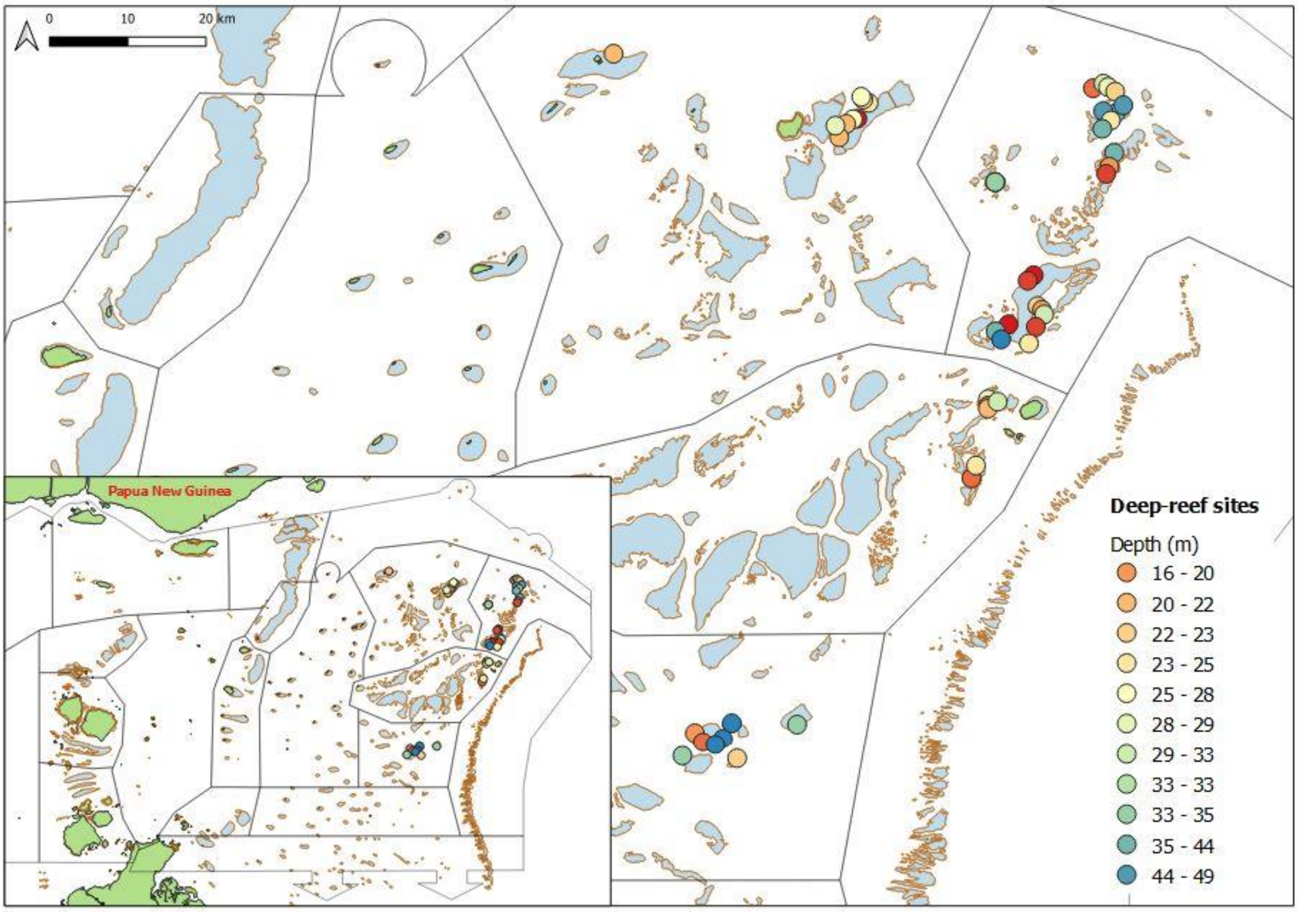


Figure 4-1. Depth profiles for deep-reef sampling sites for East Torres Strait.

4.2 Habitat

Representation of dominant substrate - Sand, Rubble, Boulder, Consolidated rubble, Hard substrate and Pavement, used average percent estimates for zones (Figure 4-2), with important biota - Live coral, soft coral, sponge, algae and seagrass cover also estimated and recorded at each zone (Figure 4-3).

4.2.1 Zone – Substrate

Sand was the dominant substrate for Reef top, Reef top buffer and Reef edge zones (Figure 4-2).

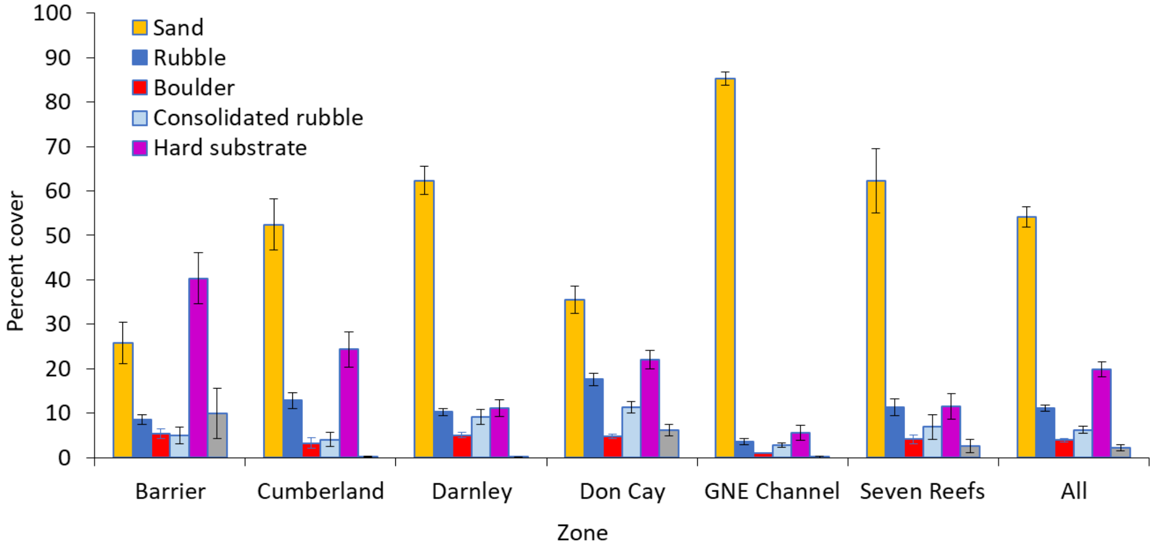


Figure 4-2. Mean percentage cover of substrate for zone (excluding deep-reef) (error bars = 1 s.e.) (GNE = Great North East).

4.2.2 Zone – Biota

Algae was the dominant biota for the majority of the zones, with the Barrier zone dominated by hard coral (Figure 4-3).

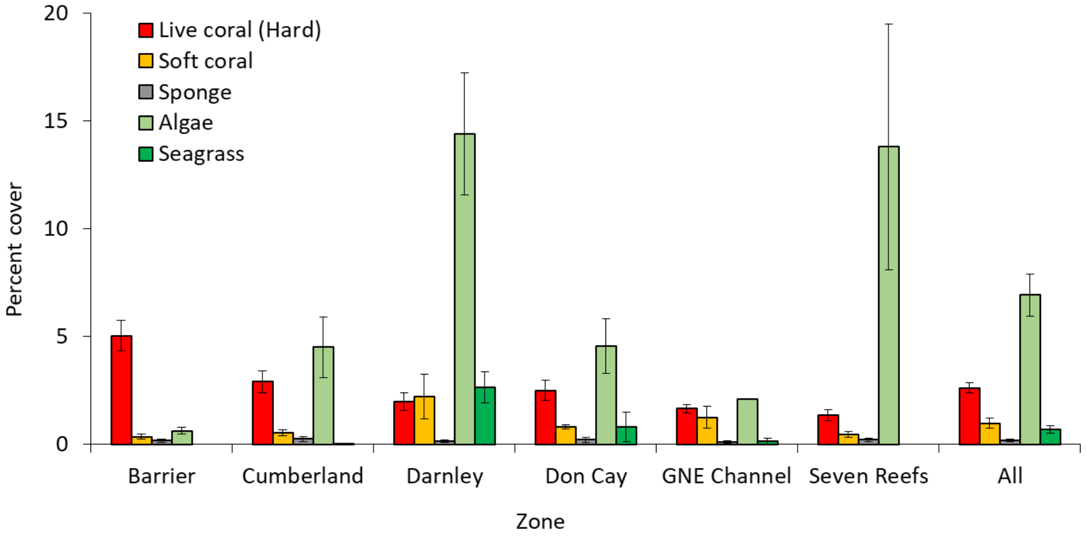


Figure 4-3. Mean percentage cover of biota for each zone (excluding deep-reef) (error bars = 1 s.e.) (GNE = Great North East).

4.2.3 Strata – substrate

Representation of strata type – Reef edge, Reef top, Reef top buffer and Deep-reef used average percent estimates for substrate Sand, Rubble, Boulder, Consolidated rubble, Hard substrate and Pavement) (Figure 4-4) and biota: Live coral (Hard), Soft coral, Sponge, Algae and Seagrass (Figure 4-5), Live coral (Hard), Soft coral, Sponge, Algae and Seagrass (Figure 4-6), Live Coral (Hard), Soft Coral and Fungids (Figure 4-7), Seagrass and Algae (Figure 4-8) and Gorgonians, Whips, Sponge, Urchins, Crinoids, Hydroids and Ascidians (Figure 4-9).

Sand was the dominant substrate across all strata, followed by Hard substrate (Figure 4-4).

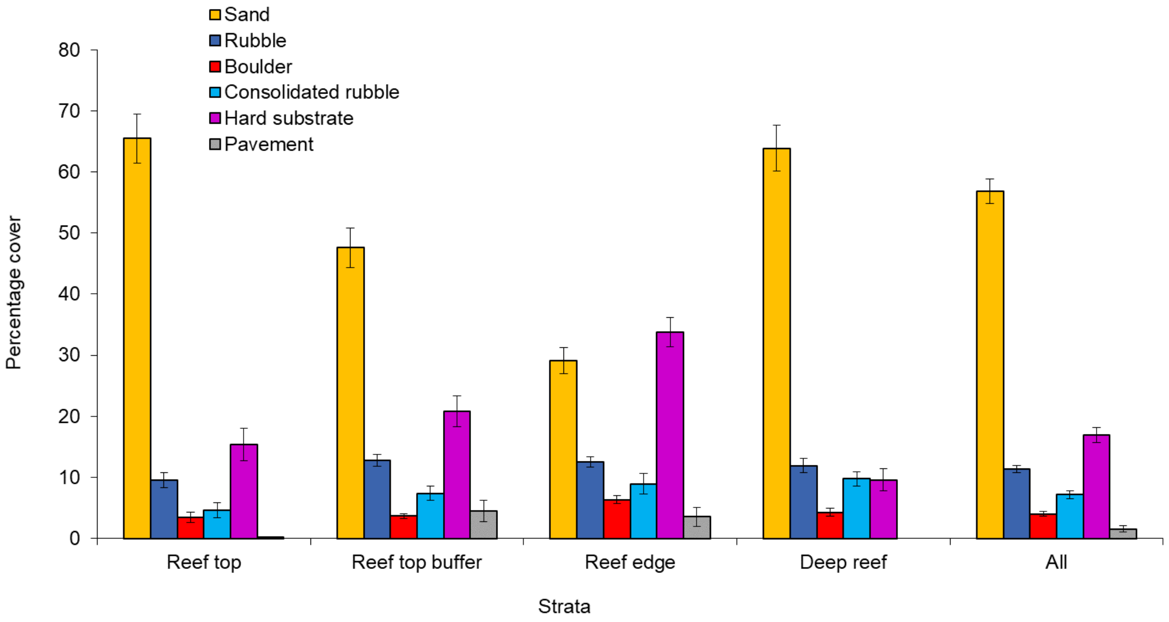


Figure 4-4. Mean percentage cover of substrate for strata type (error bars = 1 s.e.).

4.2.4 Strata – key biota

Algae was the dominant biota for reef top, reef top buffer and deep-reef strata types, with hard coral dominating reef edge (Figure 4-5).

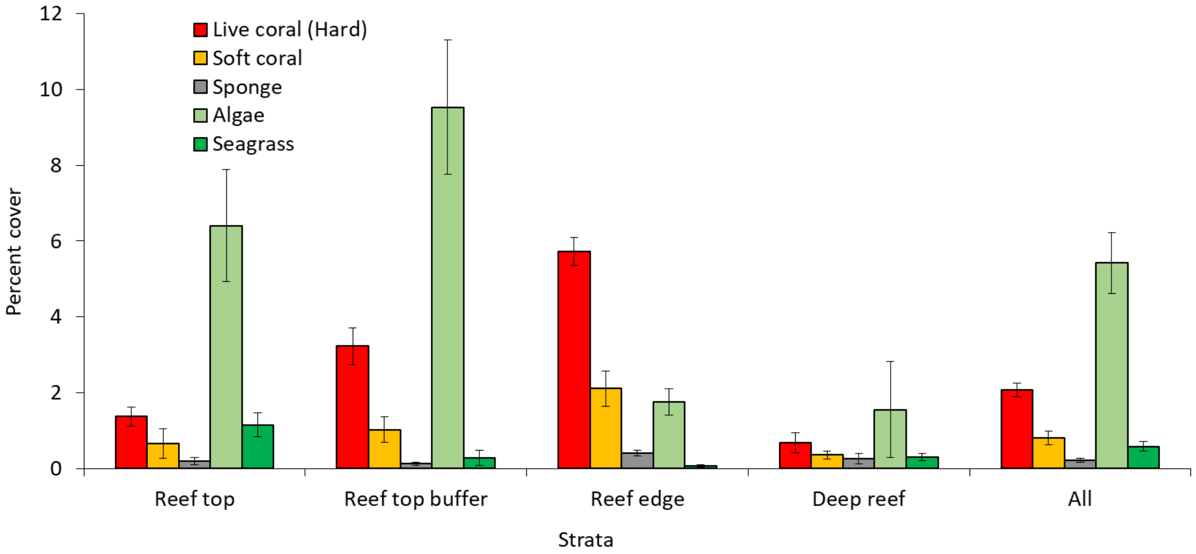


Figure 4-5. Mean percentage cover of biota for strata type (error bars = 1 s.e.).

4.2.5 Strata – coral

The distribution of hard and soft coral for strata type showed that hard coral was dominant across all strata (Figure 4-6).

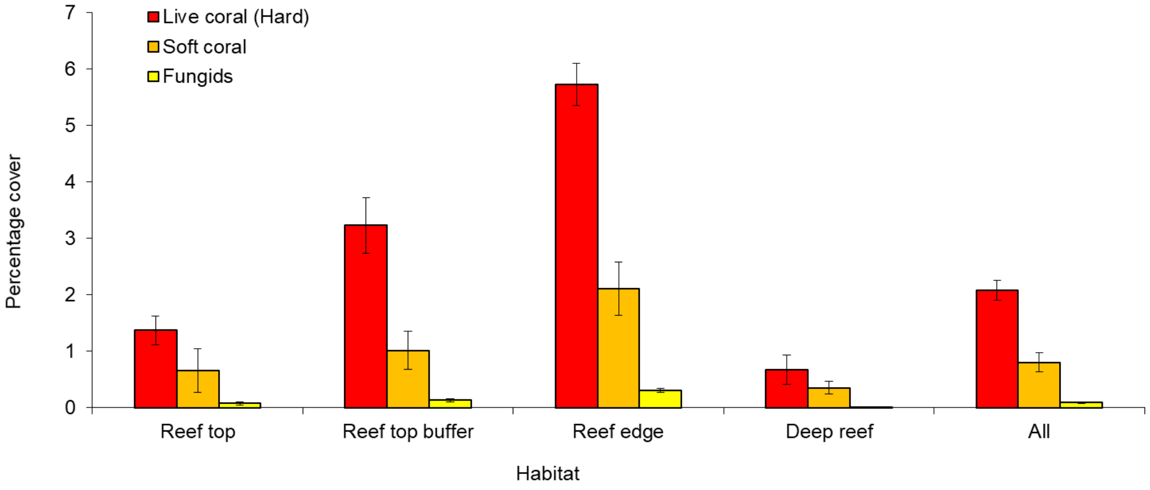


Figure 4-6. Mean percentage cover of coral for strata type (error bars = 1 s.e.)

4.2.6 Strata – flora

Algae was found to dominate strata type with seagrass also more prevalent on the Reef top (Figure 4-7).

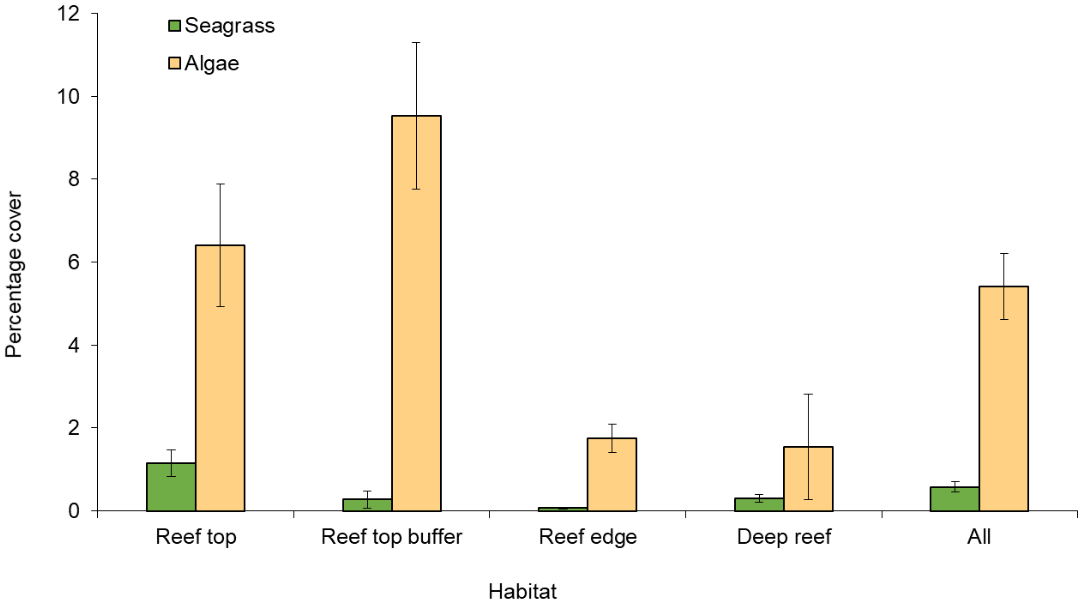


Figure 4-7. Mean percentage cover of seagrass and algae for strata type (error bars = 1 s.e.).

4.2.7 Strata – other biota

Sponge was found to dominate the reef top, with urchins, hydroids and sponge prevalent in the reef top buffer. The reef edge had higher proportions of gorgonians and sponge, with percentage cover of whips and sponges higher for the deep-reef strata (Figure 4-8).

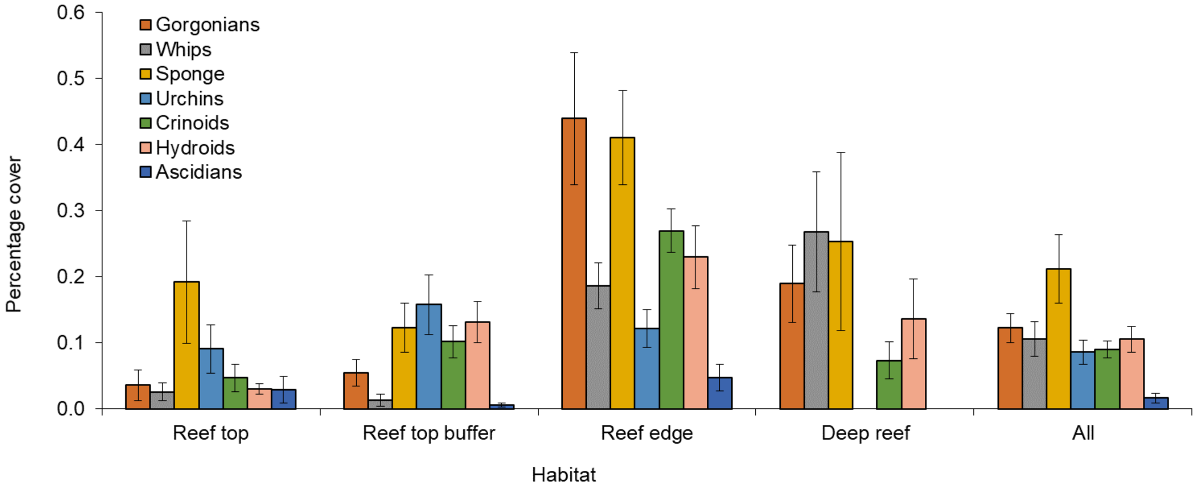


Figure 4-8. Mean percentage cover of biota for strata type (error bars = 1 s.e.).

4.3 Benthic trends

Trends for a number of key biota and benthos including Live coral (Hard) (Figure 4-9), Soft coral (Figure 4-10), Sponge (Figure 4-11), Seagrass (Figure 4-12), Algae (Figure 4-13), Clams (Figure 4-14), Sea stars (Figure 4-15) and Trochus (Figure 4-16) were compared between survey years using stratified means.

4.3.1 Live coral – hard

Live coral on the shallow reef strata has been gradually declining since 2002 and was found to have decreased notably (from 6.5% to 2.4% cover - a decline of 63%) from 2009 to 2019/20 (Figure 4-9).

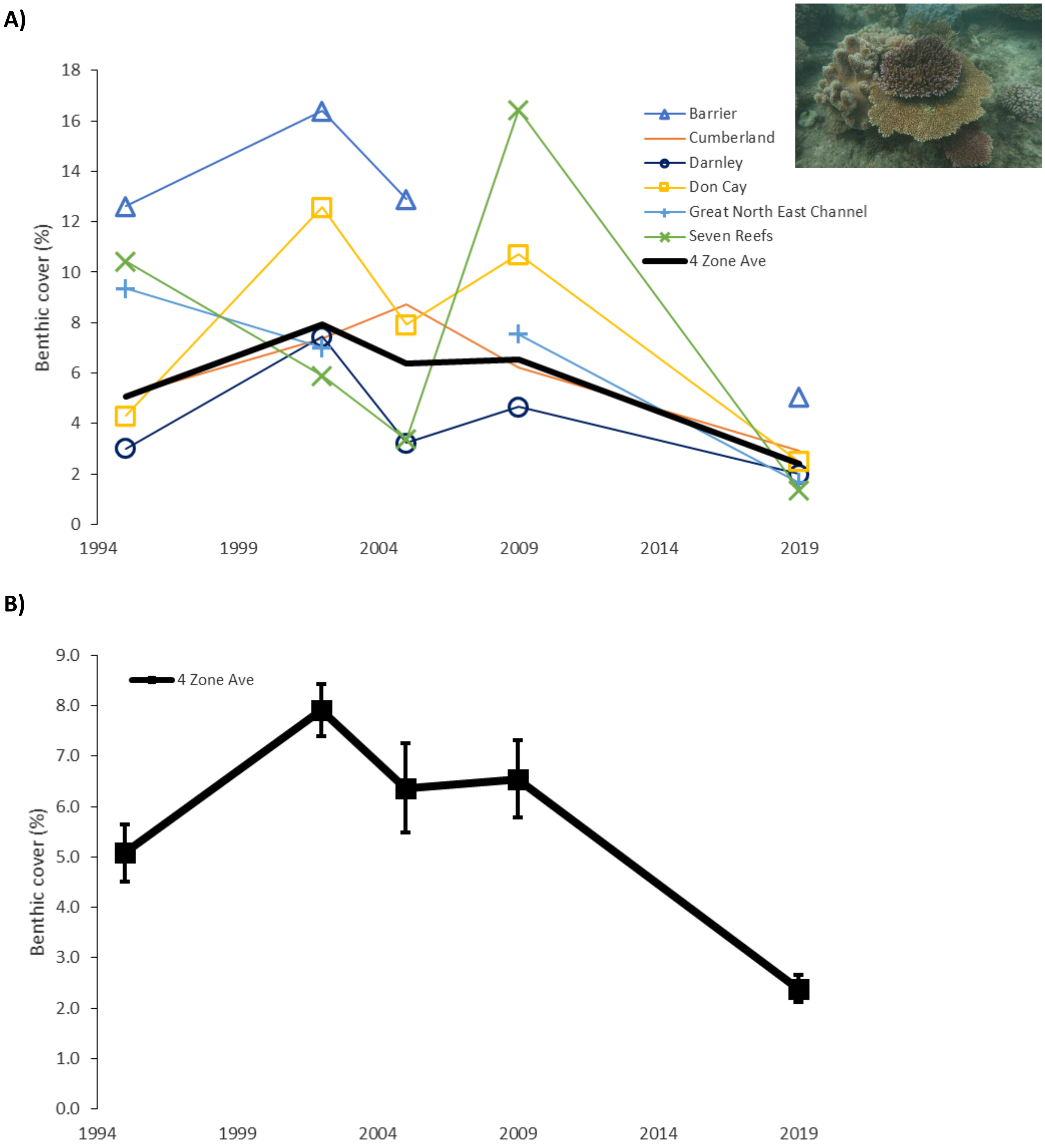


Figure 4-9. Zones (A) and East Torres Strait (4 zone) (B) average (stratified) benthic cover (%) for live coral (hard) from five surveys (does not include deep-reef strata) (error bars = 1 s.e.).

4.3.2 Soft coral

Soft coral has shown a decline from 2005, with the lowest levels observed for 2019 (Figure 4-10).

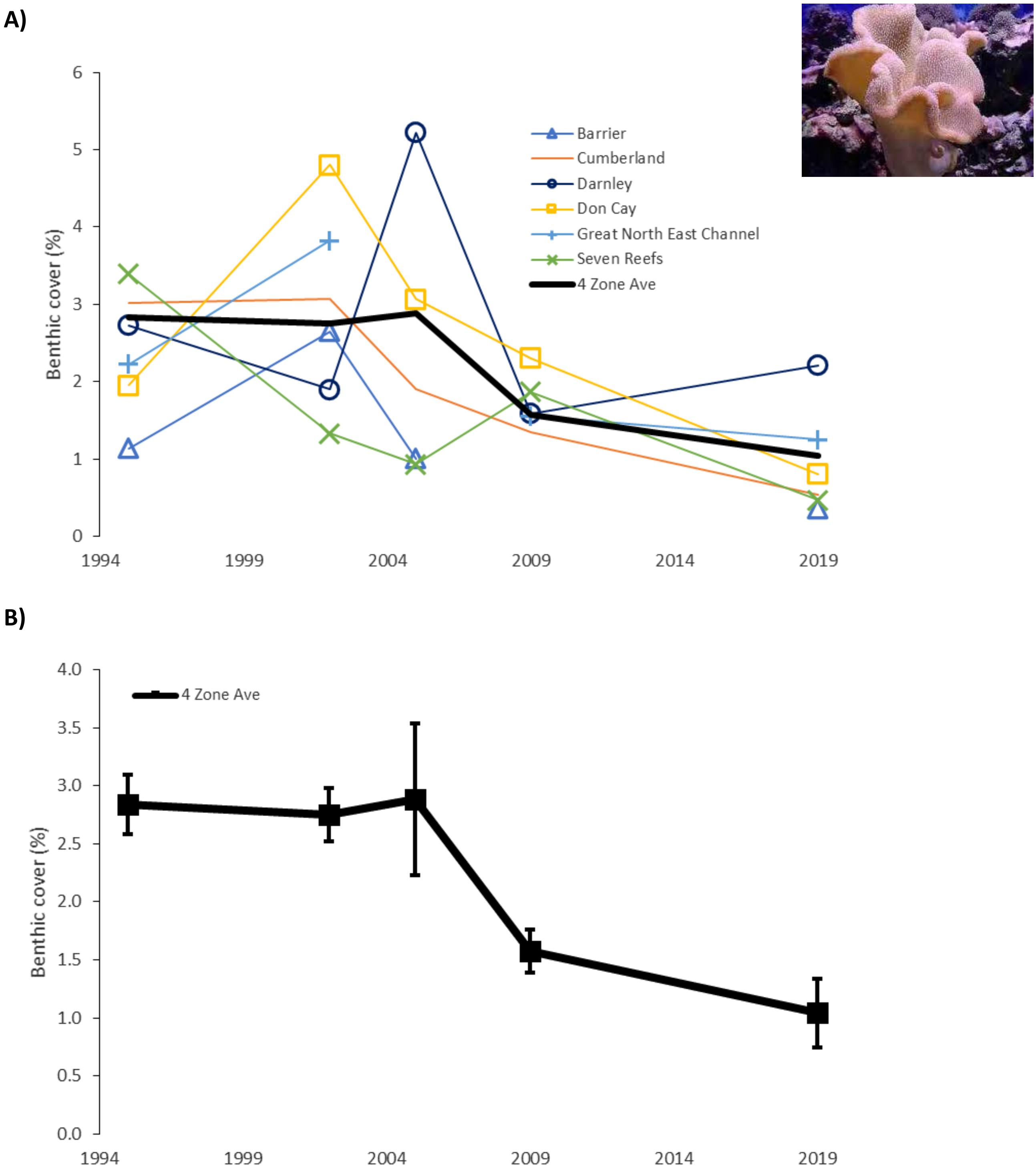
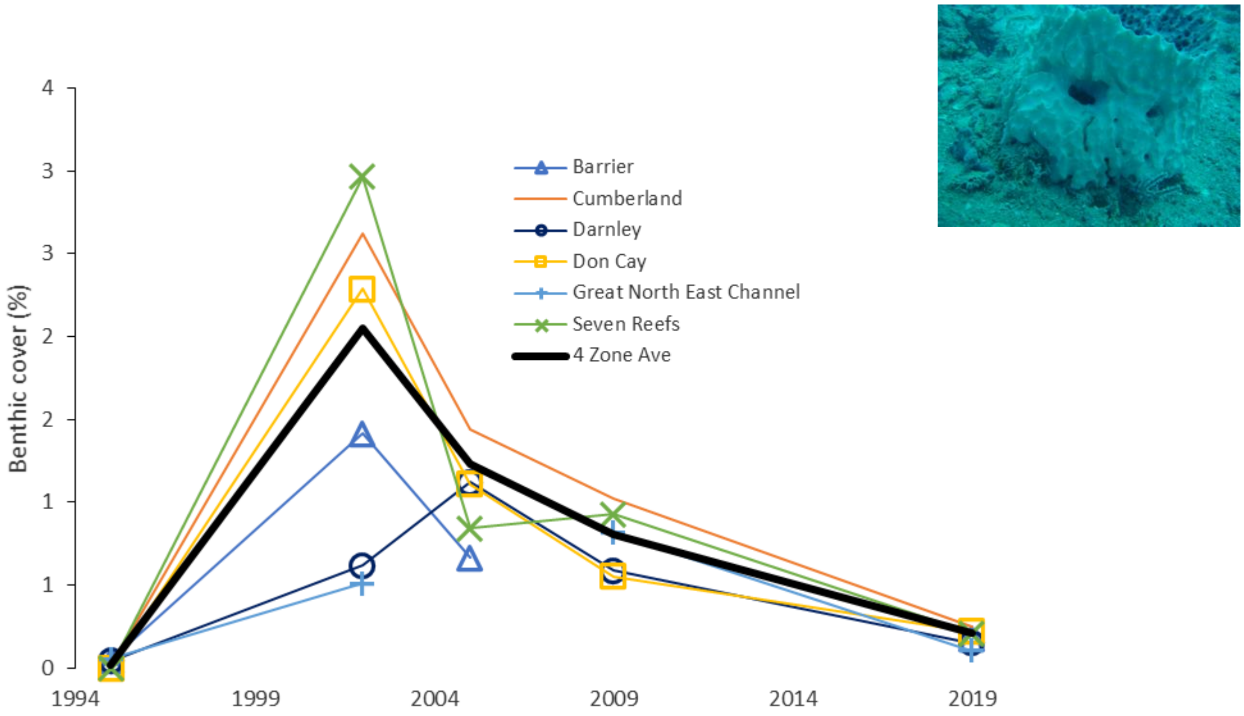


Figure 4-10. Zones (A) and East Torres Strait (4 zone) (B) average (stratified) benthic cover (%) for soft coral from five surveys (does not include deep-reef strata) (error bars = 1 s.e.).

4.3.3 Sponge

The percentage cover of sponges has been declining since 2002, with the lowest levels observed for 2019 (Figure 4-11).

A)



B)

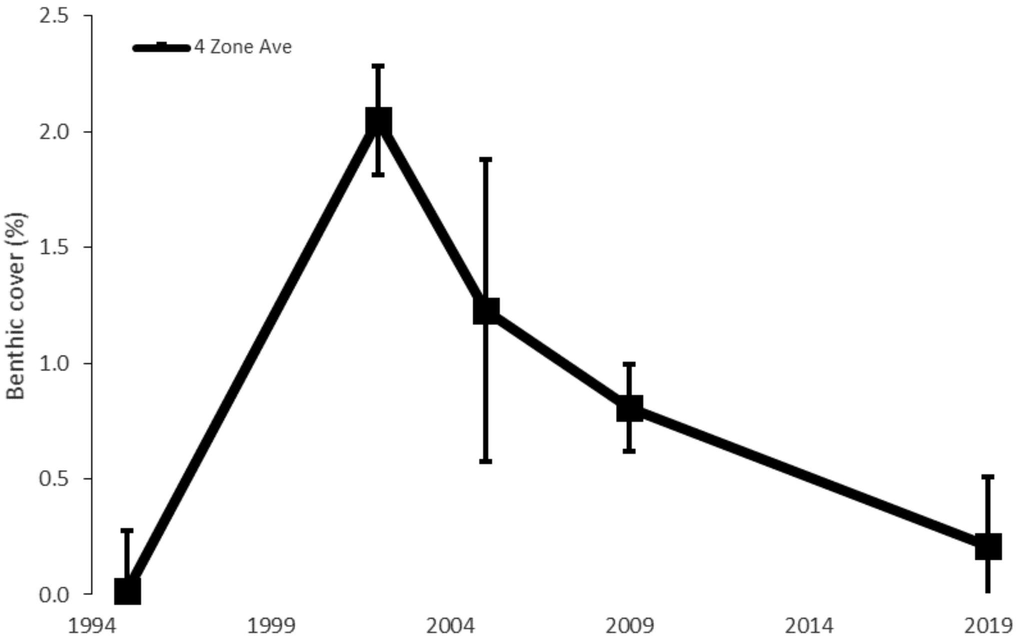
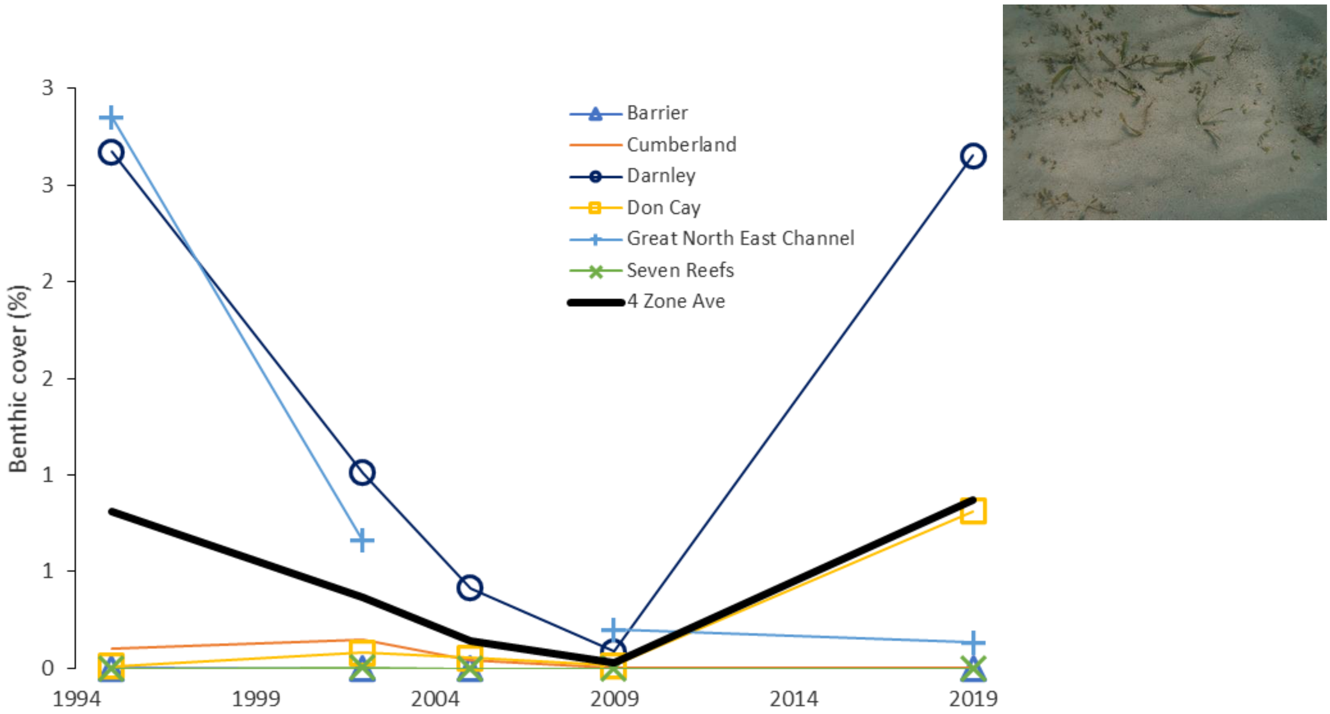


Figure 4-11. Zones (A) and East Torres Strait (4 zone) (B) average (stratified) benthic cover (%) for sponge from five surveys (does not include deep-reef strata) (error bars = 1 s.e.).

4.3.4 Seagrass

The percentage cover of seagrass showed a decline from 1995 to 2009, with an observed increase from 2009 to 2019 (Figure 4-12).

A)



B)

Figure 4-12. Zones (A) and East Torres Strait (4 zone) (B) average (stratified) benthic cover (%) for seagrass from five surveys (does not include deep-reef strata) (error bars = 1 s.e.).

4.3.5 Algae

The percentage cover of algae showed a decline from 1995/96 to 2002, then a steady increase since 2002 with variable both increasing or decreasing trends in each zone (Figure 4-13).

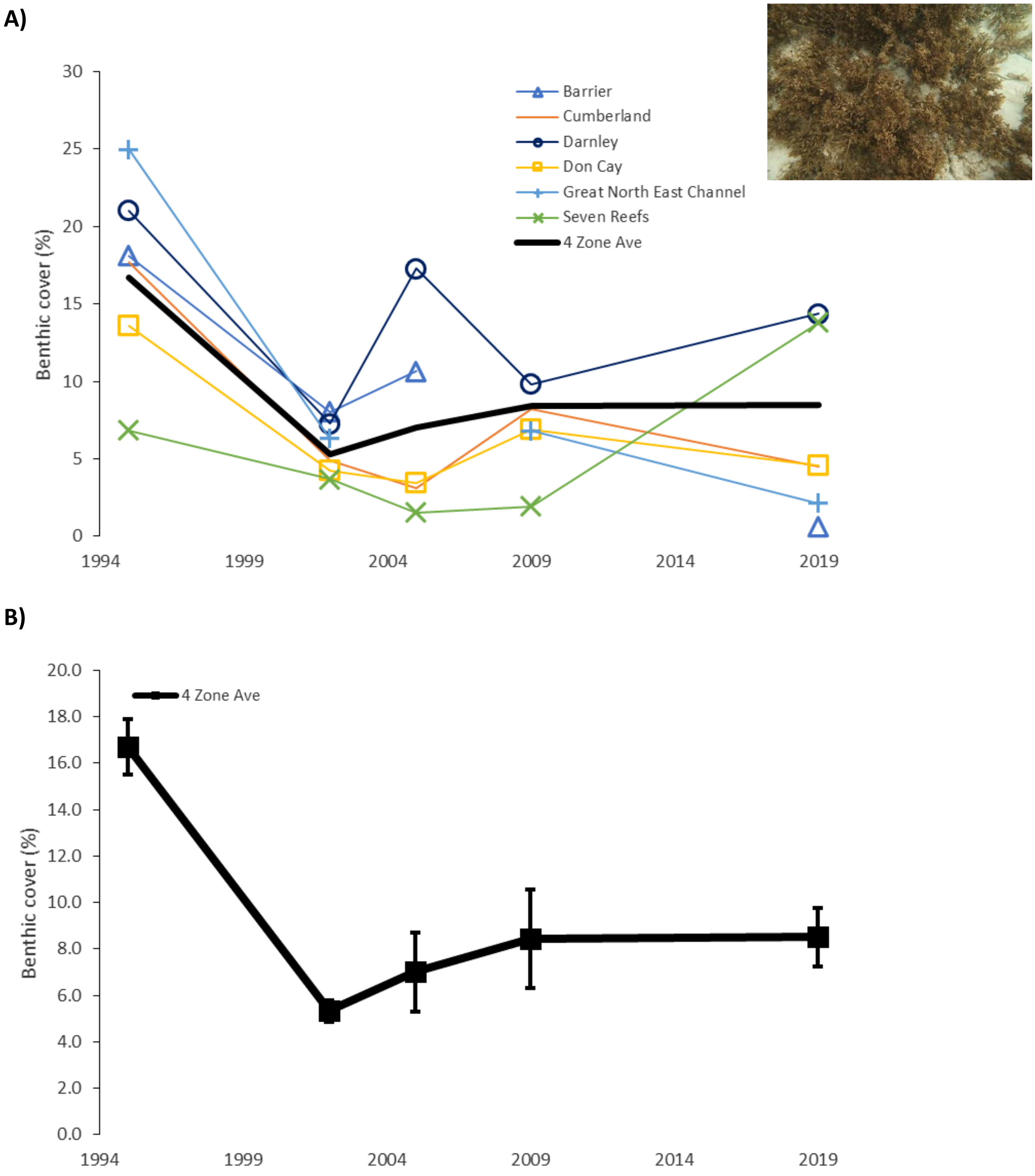


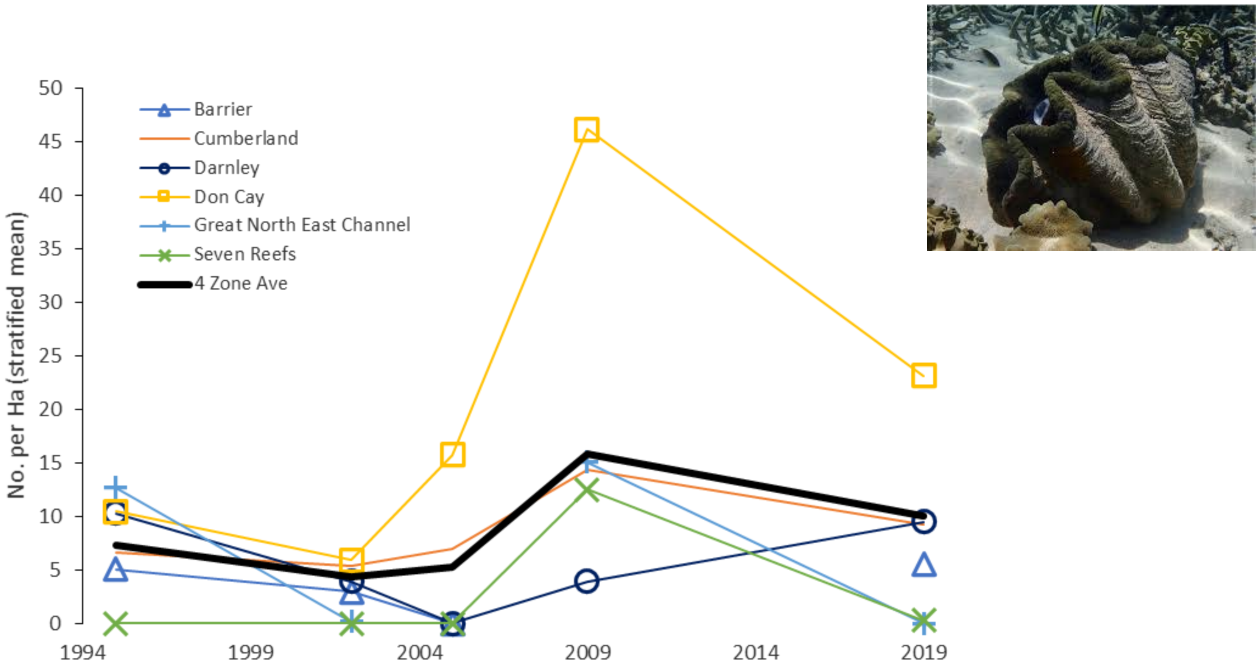
Figure 4-13. Zones (A) and East Torres Strait (4 zone) (B) average (stratified) benthic cover (%) for algae from five surveys (does not include deep-reef strata) (error bars = 1 s.e.).

4.3.6 Giant clam

Tridacna gigas

The density of Giant clams increased from 2005 to 2009, and then decreased from 2009 to 2019 (Figure 4-14).

A)



B)

Figure 4-14. Zones (A) and East Torres Strait (4 zone) (B) average (stratified) benthic cover (%) for Giant clams (*T. gigas*) from five surveys (does not include deep-reef strata) (error bars = 1 s.e.).

4.3.7 Sea stars

Acanthaster planci

The density of Crown of thorns increased in 2009 compared to previous years, and then decreasing to previous low levels in 2019 (Figure 4-15).

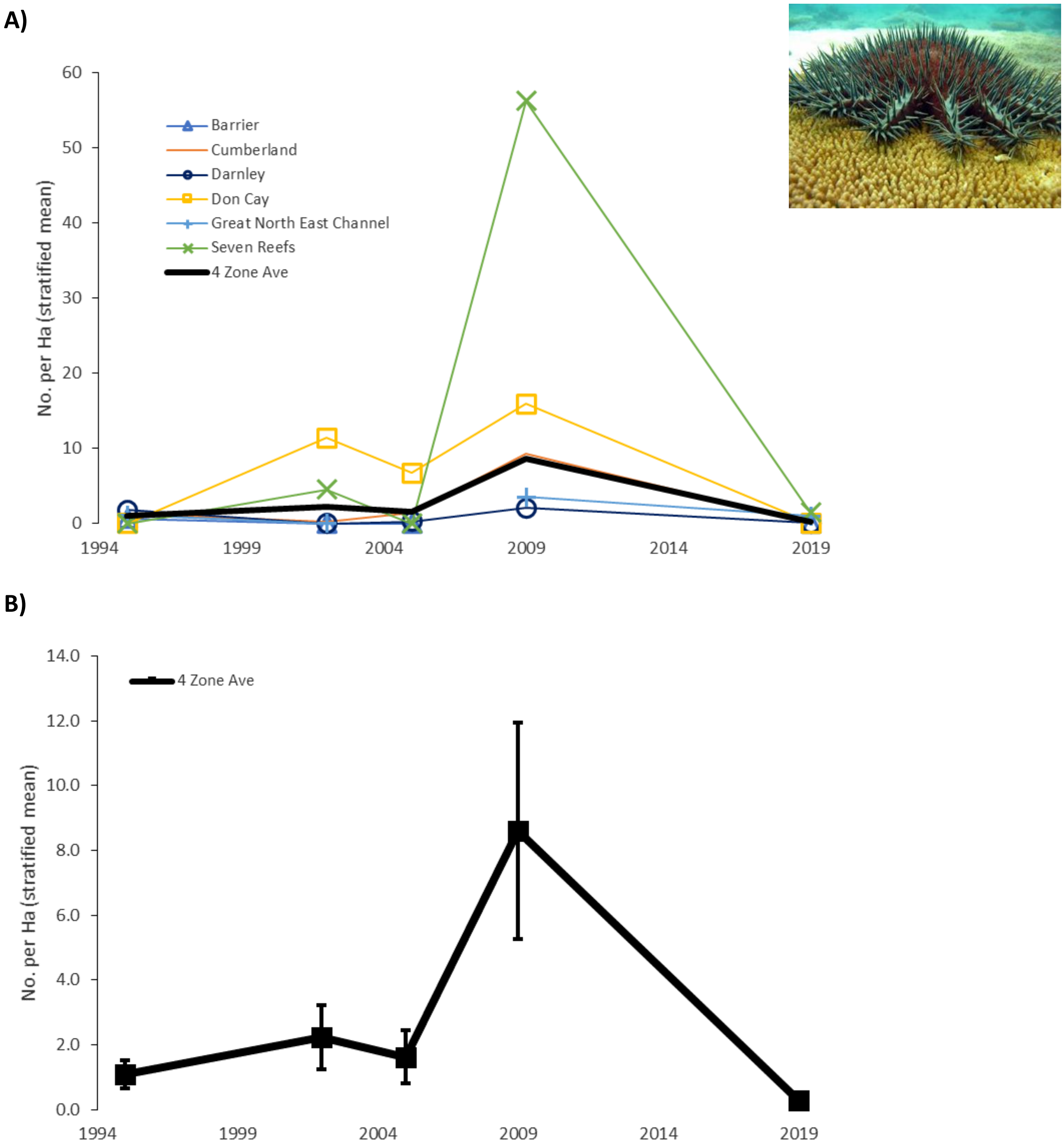


Figure 4-15. Zones (A) and East Torres Strait (4 zone) (B) average (stratified) benthic cover (%) for Crown of thorns (*A. planci*) from five surveys (does not include deep-reef strata) (error bars = 1 s.e.).

4.3.8 Trochus

Trochus niloticus

The density of Trochus increased from 2002 to 2005 and then decreased slightly in 2019 with strong variation (some increased and others decreased) between zones (Figure 4-16).

*As the survey focus was for sea cucumber and due to the specific habitat requirements and cryptic nature of trochus, we suggest caution with any interpretation for density trend information.

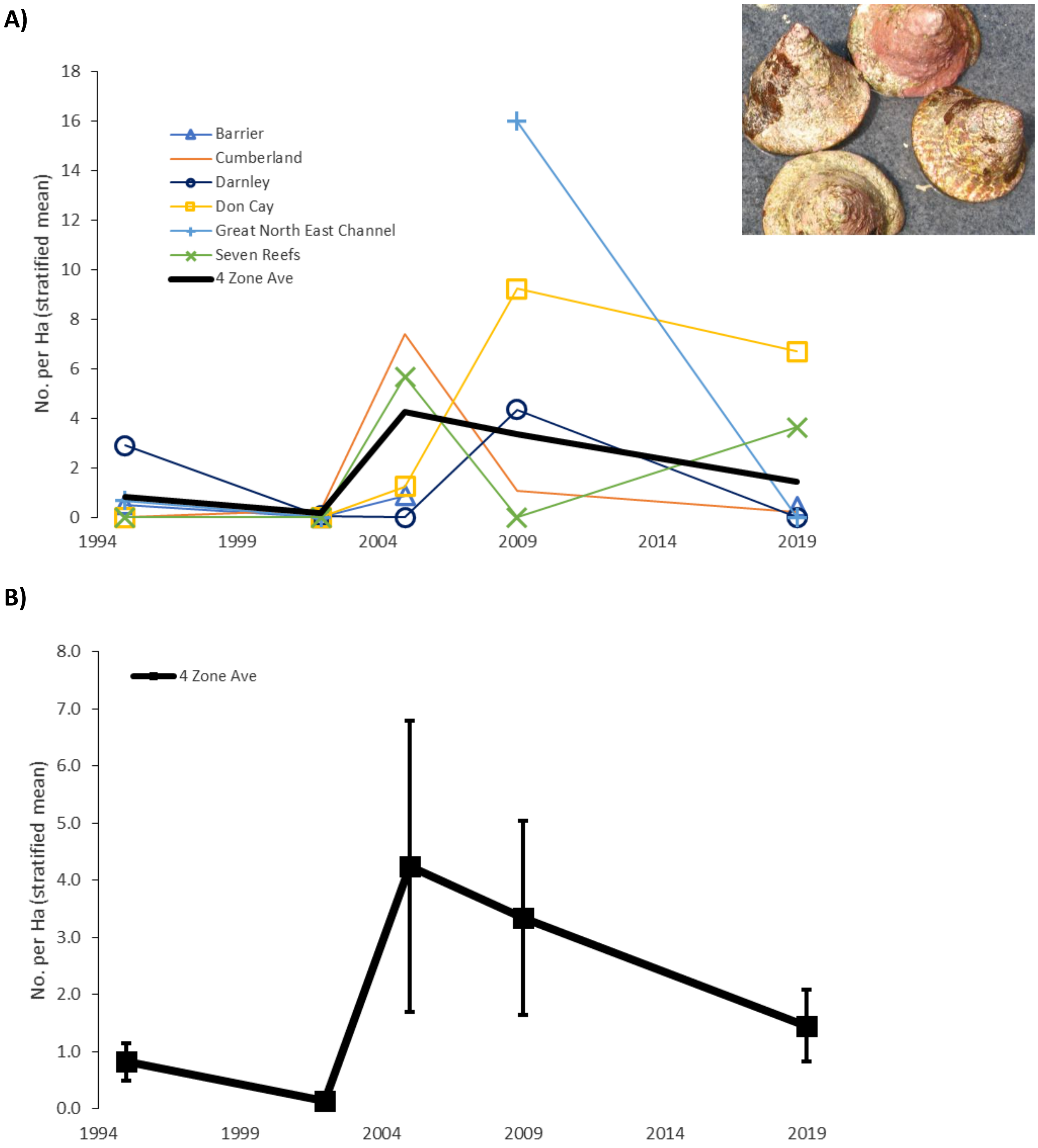


Figure 4-16. Zones (A) and East Torres Strait (4 zone) (B) average (stratified) benthic cover (%) for reef stratum for Trochus (*T. niloticus*) from five surveys (does not include deep-reef strata) (error bars = 1 s.e.).

5 Catch data

5.1 Catch Disposal Records

Catch data were obtained from Catch Disposal Records (CDR) as part of the Fish Receiver System implemented in 2017 for the TSBDMF. Catch per Unit Effort (CPUE) calculations used standard weight (conversion ratio applied). For multi-species fisheries, where species targeted change according to factors such as markets, locations and weather conditions, CPUE outcomes need to be interpreted with caution. Moreover, in most cases, there are currently too few data for these to be considered reliable.

5.1.1 Mean catch

Total catch recorded for sea cucumber species showed an apparent decline for combined Curryfish species (Figure 5-1).

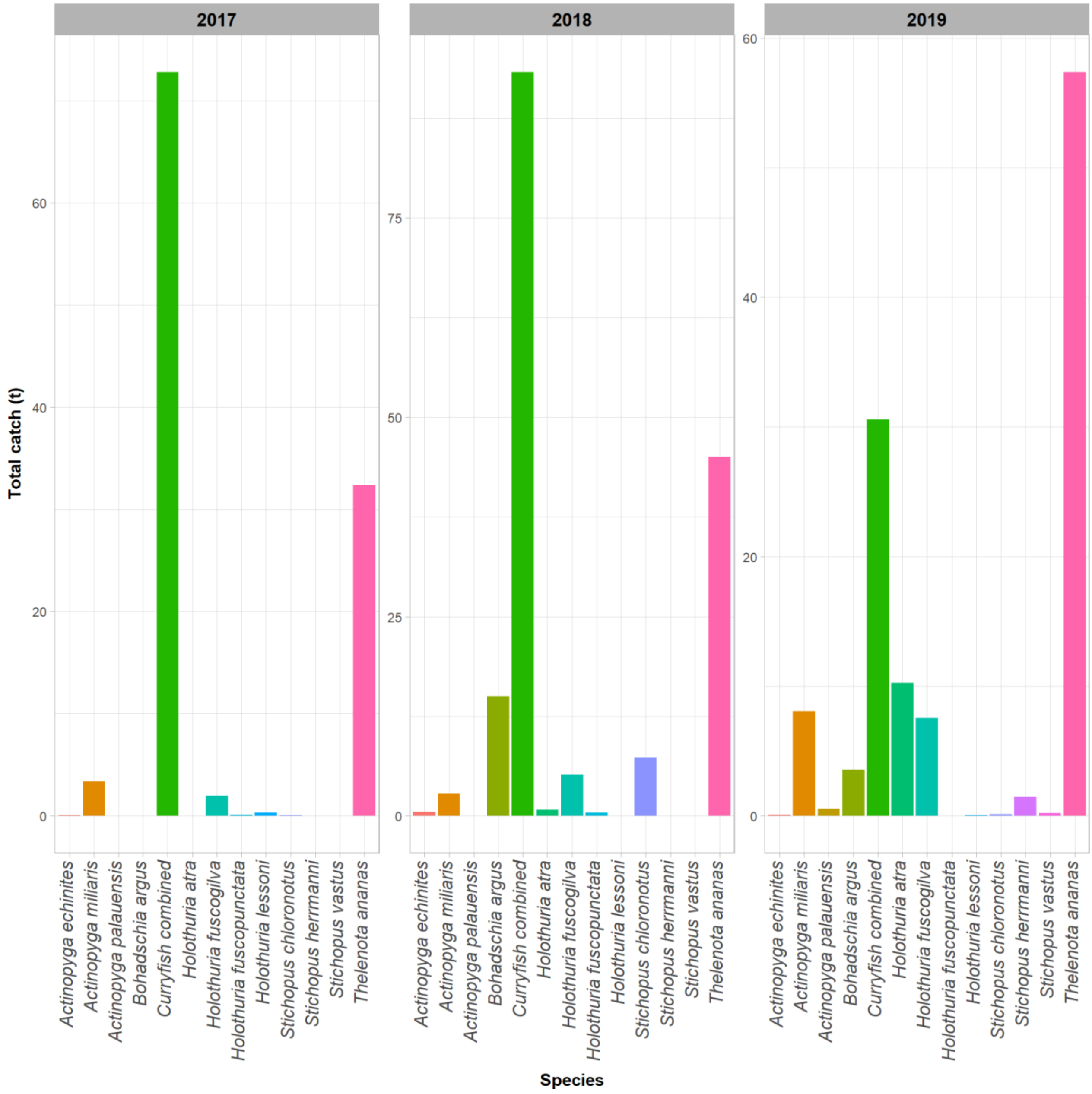


Figure 5-1. Total catch for sea cucumber species for year fished. Species are only shown for cases with >10 catch records to preserve data confidentiality.

5.1.2 Catch per Unit Effort (CPUE)

While CPUE trends are not particularly meaningful due to the small (three year) time series available, of note is the possible decline for Curryfish (combined species) and targeting of Prickly redfish (*T. ananas*) (Figure 5-2).

Also of note is the identification to species in 2019 for Curryfish – *Stichopus herrmanni* and *S. vastus*, given that the new TSBDM Harvest Strategy stipulates the need to separate target species (Figure 5-2).

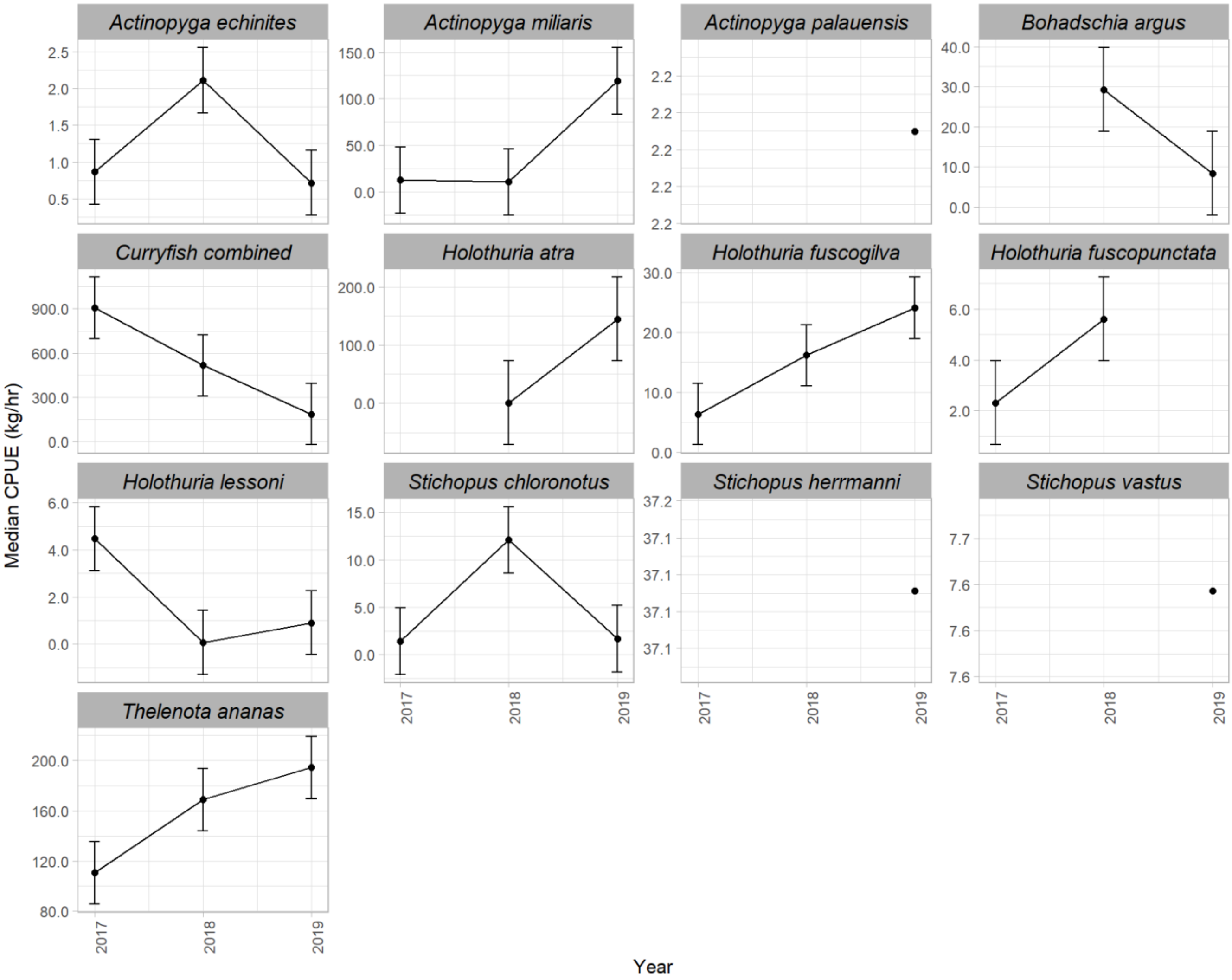
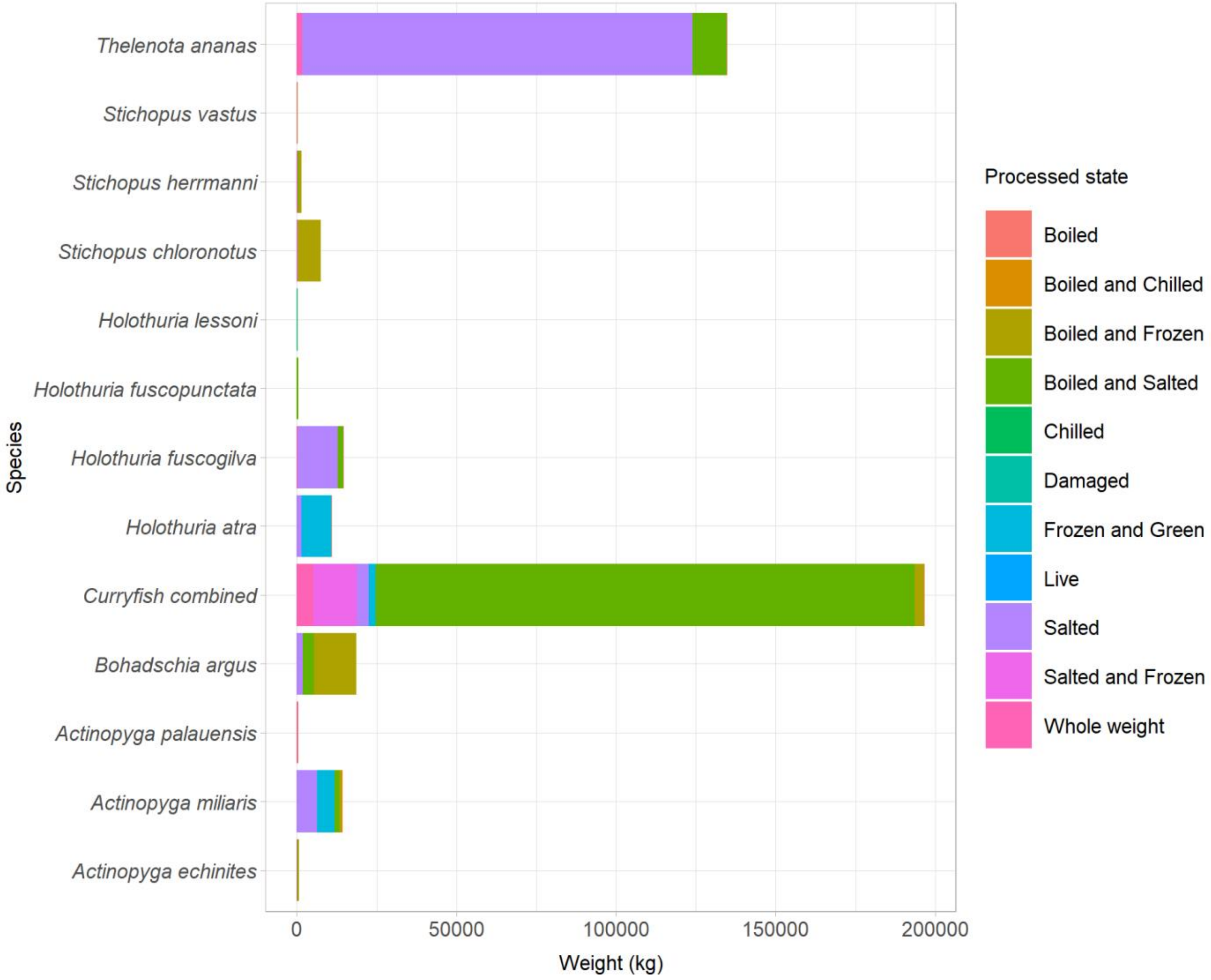


Figure 5-2. Catch per unit effort for sea cucumber species for yearly time series 2017, 2018 and 2019. Species are only shown for cases with >10 catch records to preserve data confidentiality.

5.1.4 Catch processing method

The majority of product was for Prickly redfish and Curryfish combined. The main processing method for sea cucumbers was ‘salted and boiled’ and ‘salted’ (Figure 5-3).

a)



b)

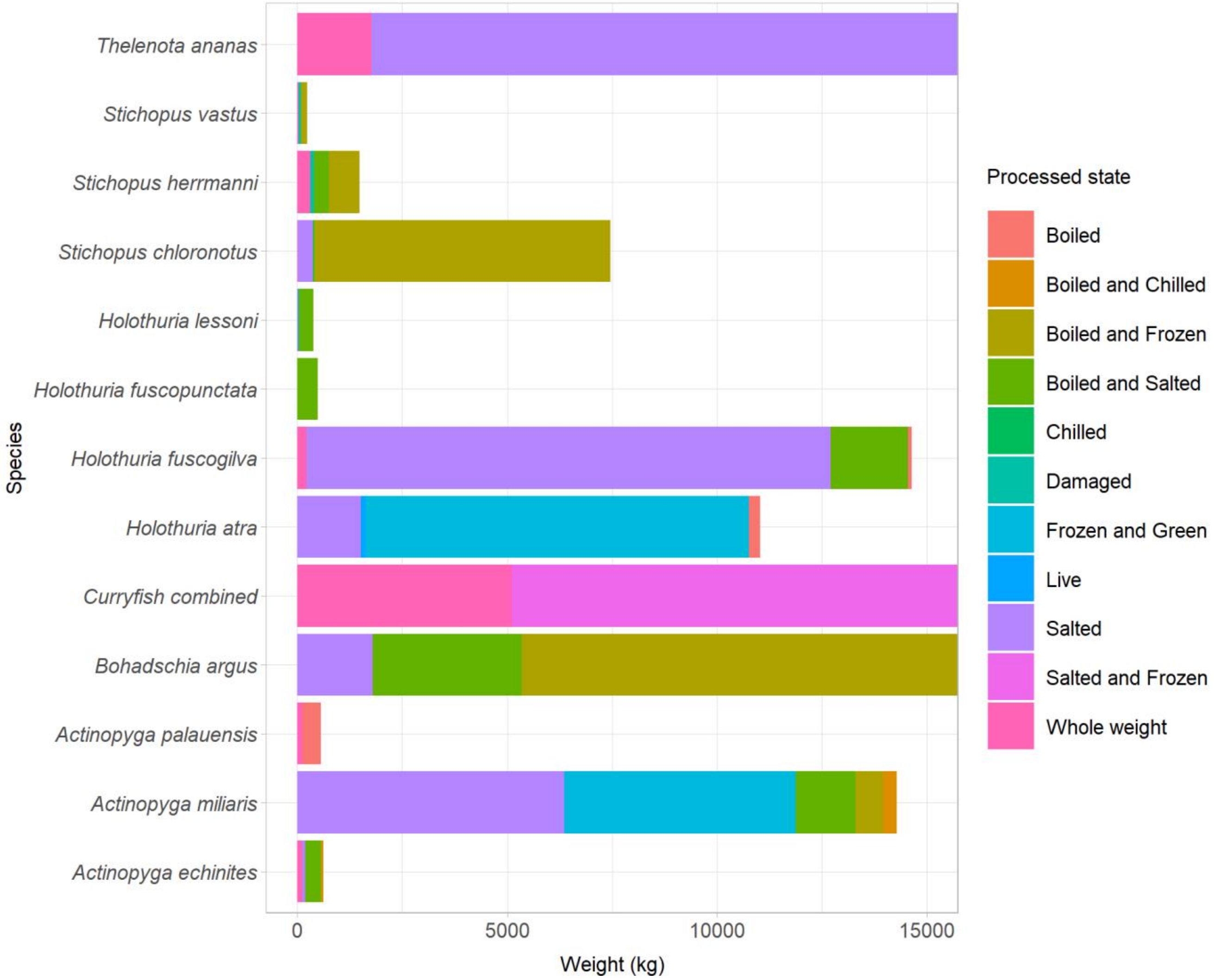


Figure 5-3. Catch processing methods used for sea cucumber species for Catch Disposal Records. Top plot (a): Overall values shown and Bottom plot (b): Prickly redfish (*T. ananas*) and Curryfish (*S. herrmanni* and *S. vastus*) combined are partly represented. Species are only shown for cases with >10 catch records to preserve data confidentiality.

6 Discussion

A field survey of sea cucumber species of East Torres Strait was undertaken in December 2019 and January 2020, in order to inform stock size estimates and distribution data for the Torres Strait Bêche-de-mer Fishery (TSBDMF).

Environmental monitoring undertaken as part of the survey, allowed for comparison to previous survey years which enabled trend estimates to be identified for important fishery biota and habitat. Results from the 2019/20 survey showed that the live cover of hard and soft coral has declined since 2002, which was also the same for sponges, with the density of giant clams down from 2009 but higher than preceding years. Seagrass cover was, in comparison, found to have increased in 2019 compared to lower levels recorded in previous years. Crown of thorn numbers were low with no suggestion of an outbreak. The density of Trochus was lower in 2019, but considered stable as trochus specific habitat was not surveyed. The decline of corals and other biota (sponges) is of concern because they provide key ecosystem functions, and may indicate a wider and ongoing environmental and physical effect occurring for Torres Strait.

The survey data allowed an assessment of the relative trends in the density of most sea cucumber species in East Torres Strait. Data showed Black teatfish, a high value species that was previously depleted and closed to fishing in 2003, has continued to recover following trial openings in 2014 and 2015, with a maximum catch of 15 t. On both occasions the catch limit was exceeded (with a combined estimate of 40 t (landed weight) caught) and the fishery therefore remained closed. High densities observed in the preferred Black teatfish habitats of Don Cay and Barrier for the reef top buffer strata, and observations of long-term Traditional Owner fishers, indicate the population is likely near virgin biomass levels. This is a significant example of the successful recovery of a depleted sea cucumber population, and one of the few documented world-wide.

Data for medium value species of Curryfish (*Stichopus herrmanni* and *S. vastus*) and Prickly redfish (*Thelenota ananas*) that are currently important targeted species, indicate a possible fishing decline compared to the previous survey in 2009. However, survey estimates suggest that current catch limits are sustainable. High value species such as Surf redfish (*Actinopyga mauritiana*) were found in higher numbers relative to previous surveys, which supports species recovery, being currently closed to fishing after mis-identification with Deepwater redfish (*A. echinites*).

Hairy blackfish (*A. miliaris*) densities were relatively lower than in previous surveys. This may be due to natural variability (e.g. their natural patchy distribution), or may indicate a possible ongoing decline. Targeted survey sampling may need to be factored into future fishery surveys. Deepwater blackfish (*A. palauensis*) were only properly identified in surveys and catch in 2019, after concerted review of taxonomy and working with Torres Strait Islander fishers (Murphy et al., 2019). A small number of Deepwater blackfish were found, however due to limited survey data for the species, future fishing should be very pre-cautionary. This is also the case for Burrowing blackfish (*A. spinea*) which were not recorded during the survey.

Uniquely, we also surveyed the deep-reef (>20 m) strata (habitat) to investigate deep-reef sea cucumber populations, using a Remotely Operated Vehicle. A total of 12 sea cucumber species were seen on the 53 deep-reef transects with White teatfish (*H. fuscogilva*) being the most common, followed by Amberfish (*T. anax*) (Figure 6-1).

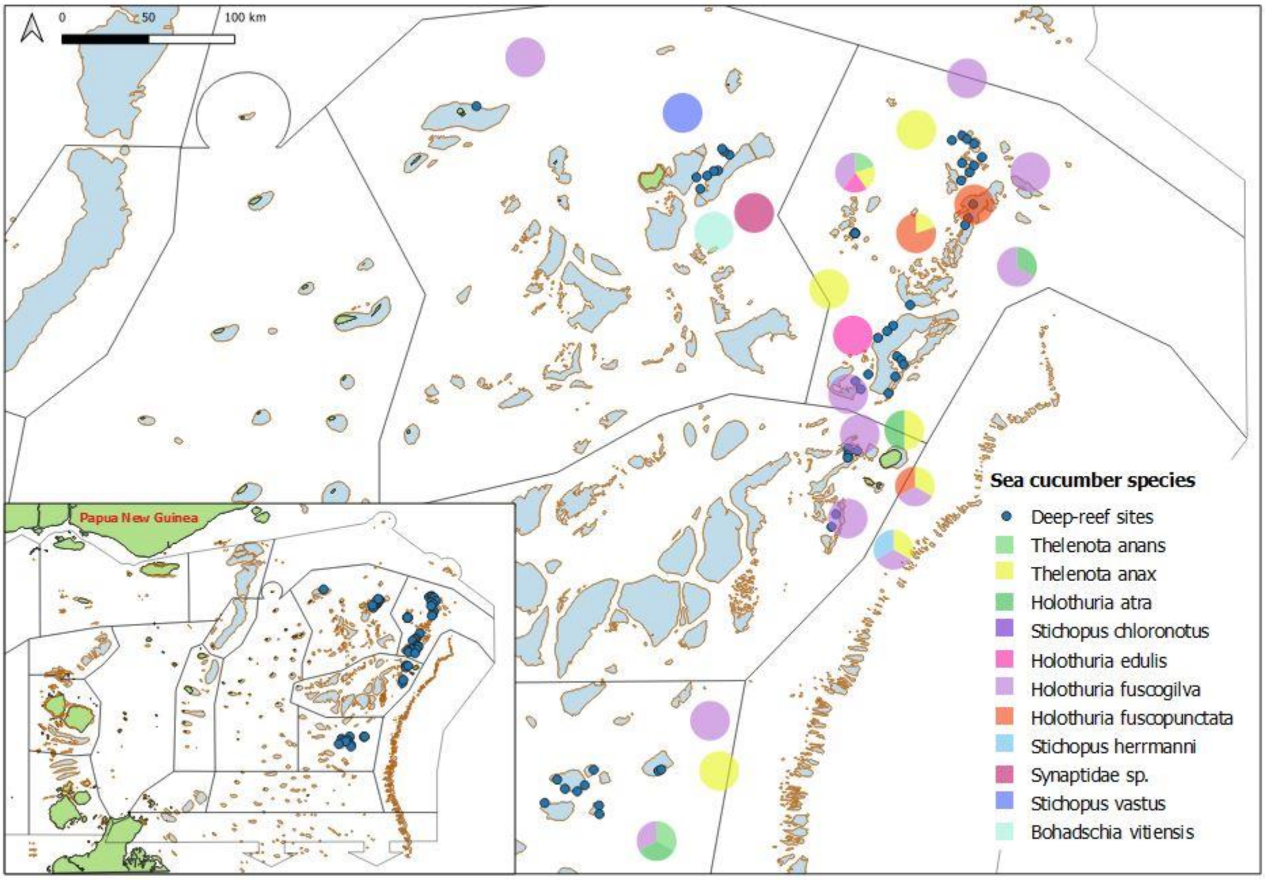


Figure 6-1. Sea cucumber species composition and distribution found at deep-reef sampling sites for East Torres Strait.

Of interest for the recent survey was investigating the full extent of the distribution of White teatfish (*Holothuria fuscogilva*), in order to quantify total stock biomass and evaluate the potential for further sustainable development of this fishery. Deep-reef surveys included sites adjacent to shallow reef edge sites continuing down the reef slope, and in the deeper lagoons of the sunken North-Easterly reefs of Torres Strait. The underwater camera system proved very successful at observing sea cucumbers. Although we surveyed habitats down to 50 m, we did not observe White teatfish deeper than 37 m.

The average density of White teatfish in the deep-reef habitat was the highest of any of the sampled strata, at about 14 per ha. Given the extent of the deep-reef habitat in East Torres Strait, the White teatfish in this habitat accounted for 72 % of the entire White teatfish population in the area. We are confident we have now delimited and quantified the deep-reef White teatfish population of East Torres Strait.

Overall, survey data show a healthy fishery with the potential to provide moderate long-term income to local Islander communities. Re-opening Black teatfish to fishing will likely see renewed interest in the fishery – the April 2021 trial opening with a 20 t TAC was filled in four days (https://www.pzja.gov.au/2021-black-teatfish-trial-opening). The open-ended nature of effort (any Torres Strait Islander can theoretically fish the fishery) and the possibility of large pulses in fishing due to community interest and momentum from buyer interest, could contribute to the risk of localised overexploitation and careful management is essential for stock sustainability.

The implementation of the newly endorsed Torres Strait Beche-de-mer Harvest Strategy, will help provide the necessary protection to sea cucumber populations through the key control of setting a cap on total catch limits for species. Other important controls allow for spreading of fishing effort, limiting effort pulses, mitigating localised depletion, collection of valuable fishery and fishery-independent data, and carrying out catch monitoring and resource assessments as required (Plaganyi et al., 2020).

This is particularly important for meeting recent listings of Teatfish species (*H. whitmaei* and *H. fuscogilva*) on CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora) Appendix II, with 'determination' of sea cucumber fishery status affecting trade in Beche-de-mer products globally (Shedrawi et al., 2019). Teatfish species can only be exported under a CITES export permit, issued by the Department of Agriculture, Water and the Environment (the Department) under the *Environment Protection and Biodiversity Conservation Act 199*9 (EPBC Act).

Outcomes of the 2019/20 survey have supported the current CITES *Non-Detriment* Finding for the Torres Strait Bêche-de-mer Fishery.

7 Harvest Strategy

The Torres Strait Beche de mer Harvest Strategy (TSBDMHS) was implemented in 2019 (Plaganyi et al., 2019). Data from the 2019/20 sea cucumber survey directly inputs into the TSBDMHS, supporting a number of decision-making processes for future management of the fishery (AFMA 2019).

Current sea cucumber species closed to fishing include Sandfish (*Holothuria scabra*), Surf redfish (*Actinopyga mauritiana*) and Black teatfish (*H. whitmaei*) (Table 7-1).

Table 7-1. Torres Strait Beche-de-mer species category definitions as at November 2019 (AFMA, 2019).

Category	Examples of species in category as at Nov 2019	Category definition
Closed	sandfish surf redfish black teatfish	Species closed to fishing due to concerns of overfishing or stock depletion, underreporting, or significant overcatch of the TAC

In order for a species to be opened to fishing as part of the TSBDMHS, the *Re-opening Decision Rule* applies for species that have been: *closed to fishing due to concerns of overfishing or stock depletion, significantly exceeding catches beyond the TAC, or in the absence of reported catches*.

7.1 Black teatfish

Black teatfish (*H. whitmaei*) stock is determined to be above *limit reference point level* from the use of *high quality survey data.* This meets parameters of the *Decision Rule* and allows the species to be opened with a *Trial 15 t* (Table 7-2).

Table 7-2. Starting Torres Strait Harvest Strategy TAC recommendations (TSBDMHS, 2019).

Common name	Scientific name	Commercial value	Pre-HS TAC (t)	Recommended HS Starting TAC (t)	Max middle tier TAC increase (based on indicators) before needing survey	Max recorded historical catch and year (not necessarily sustainable catch)
Black teatfish	*Holothuria whitmaei*	High	Closed	Trial 15t	25	52.7 t (1996)*

* Catch record data provided by AFMA

Additional population modelling undertaken of the survey data for Black teatfish (*H. whitmaei*) demonstrated that 21 t can be removed from the stock, which allows for a higher opening TAC (tier 3) for the fishery, with Torres Strait fishers deciding on 20 t (to allow for a buffer) at fishery stakeholder meetings.

7.2 Sandfish

Sandfish were not surveyed and the species therefore remains closed in accordance with the TSBDMHS.

7.3 Surf redfish

It is recommended that Surf redfish (*Actinopyga mauritiana)* remains closed. While the species is showing signs of recovery, biomass is low at 24 t and current densities of 0.3 per Ha are low in comparison to 1.54 per Ha recorded in 2002.

7.4 White teatfish

There may be a re-assessment of the current TAC for White teatfish (*Holothuria fuscogilva)*, as deep-reef survey results have provided sufficient confidence for quantifying White teatfish stocks for Torres Strait.

7.5 Notes

Close monitoring is recommended for Curryfish (*Stichopus herrmanni* and *S. vastus*) and Prickly redfish (*Thelenota ananas*), with survey results indicating a possible fishing decline.

A pre-cautionary approach is needed for Blackfish (*Actinopyga palauensis* and *A. spinea*) as their status still remains relatively unknown.

No other TSBDMHS decision rules were triggered for other sea cucumber species from input of the survey data.

8 Fishery information

8.1 Rotational fishing

Fishers have good knowledge of 'juvenile' and adult areas for sea cucumber species, where fishers choose not to fish areas where individuals are known to be smaller in size. Equally, grounds that have been recently fished are avoided, to shift effort around home reef areas.

Size length and distribution for species of Prickly redfish (*T. ananas*) and Curryfish (*S. herrmanni*) were displayed for sampling survey sites to further investigate potential areas for rotational fishing practices for Island communities.

Of note was the Barrier zone and Seven Reefs for Prickly redfish (Figure 8-1) and Darnley and Don Cay for Curryfish (*herrmanni*) (Figure 8-2).

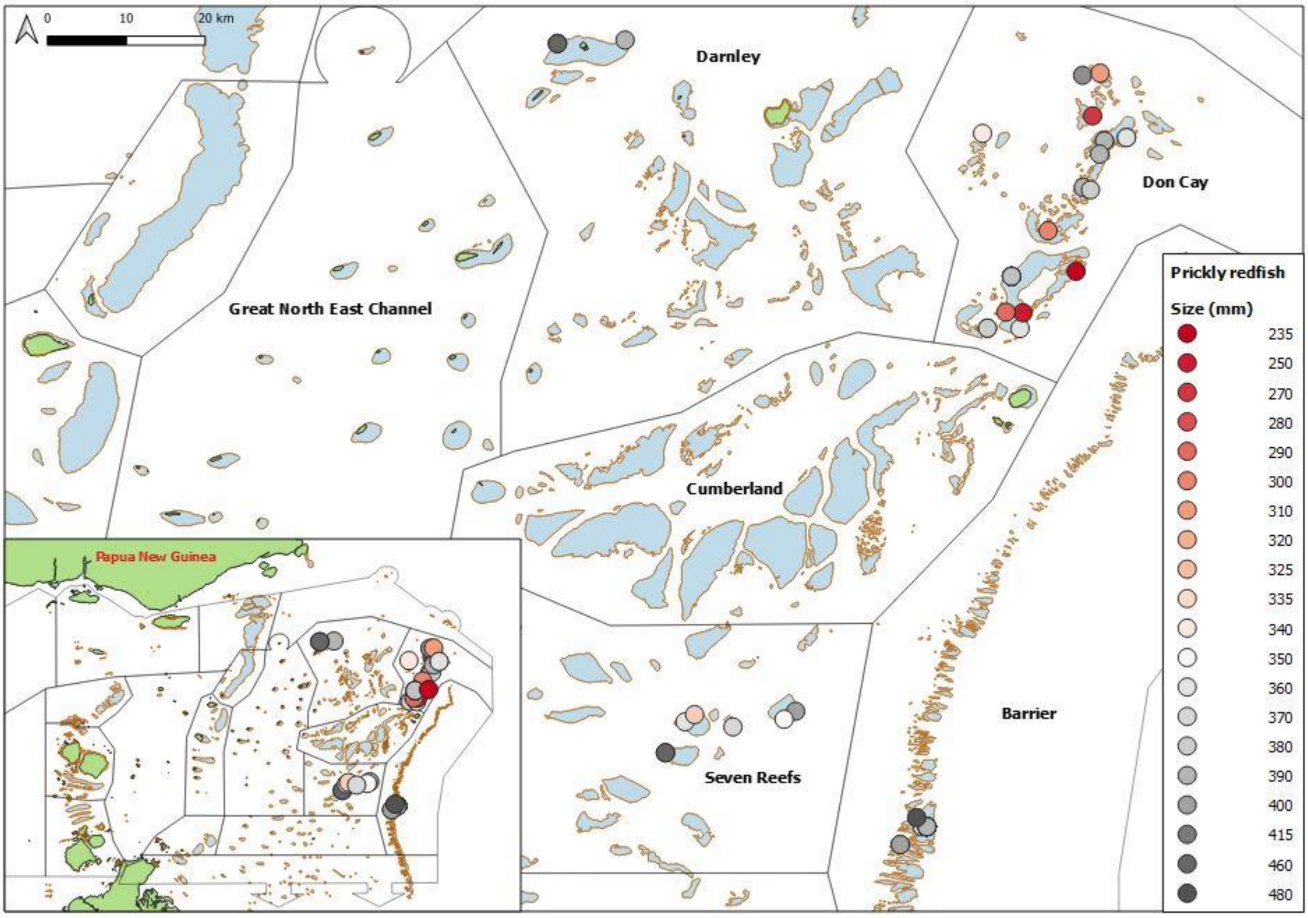


Figure 8-1. Size - length (mm) distribution for Prickly redfish (*T. ananas*) for all survey sampling sites for East Torres Strait.

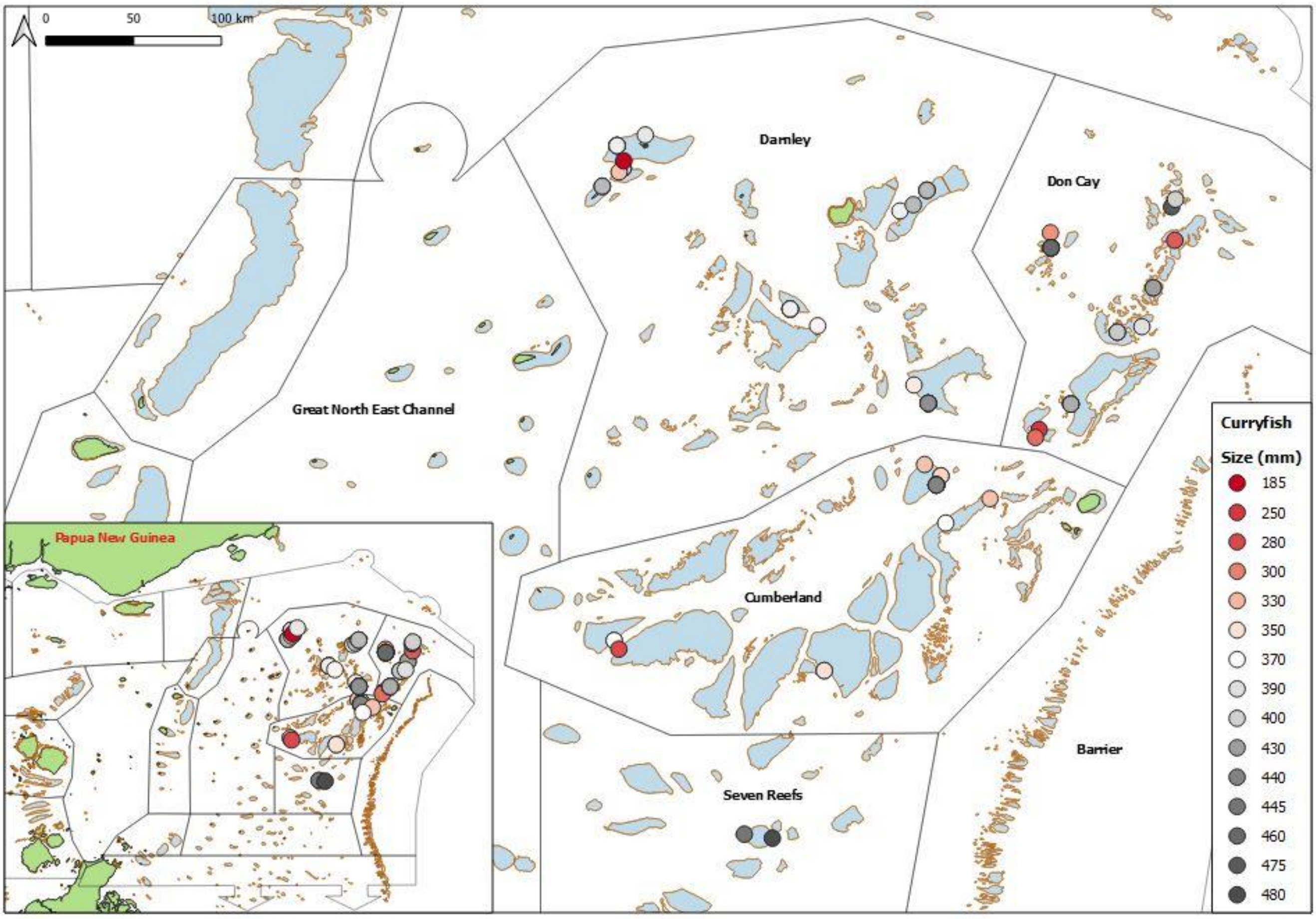


Figure 8-2. Size - length (mm) distribution for Curryfish (*S. herrmanni*) for all survey sampling sites for East Torres Strait.

8.2 Potential reserve area

Observations from the Barrier zone during the recent survey showed larger size animals of key species – White teatfish (*H. fuscogilva*), Black teatfish (*H. whitmaei*) and Prickly redfish (*T. ananas*) were present (Figure 8-3). The location of the Barrier zone may offer an inherent protection for species for fishing due to exposure and inclement weather.

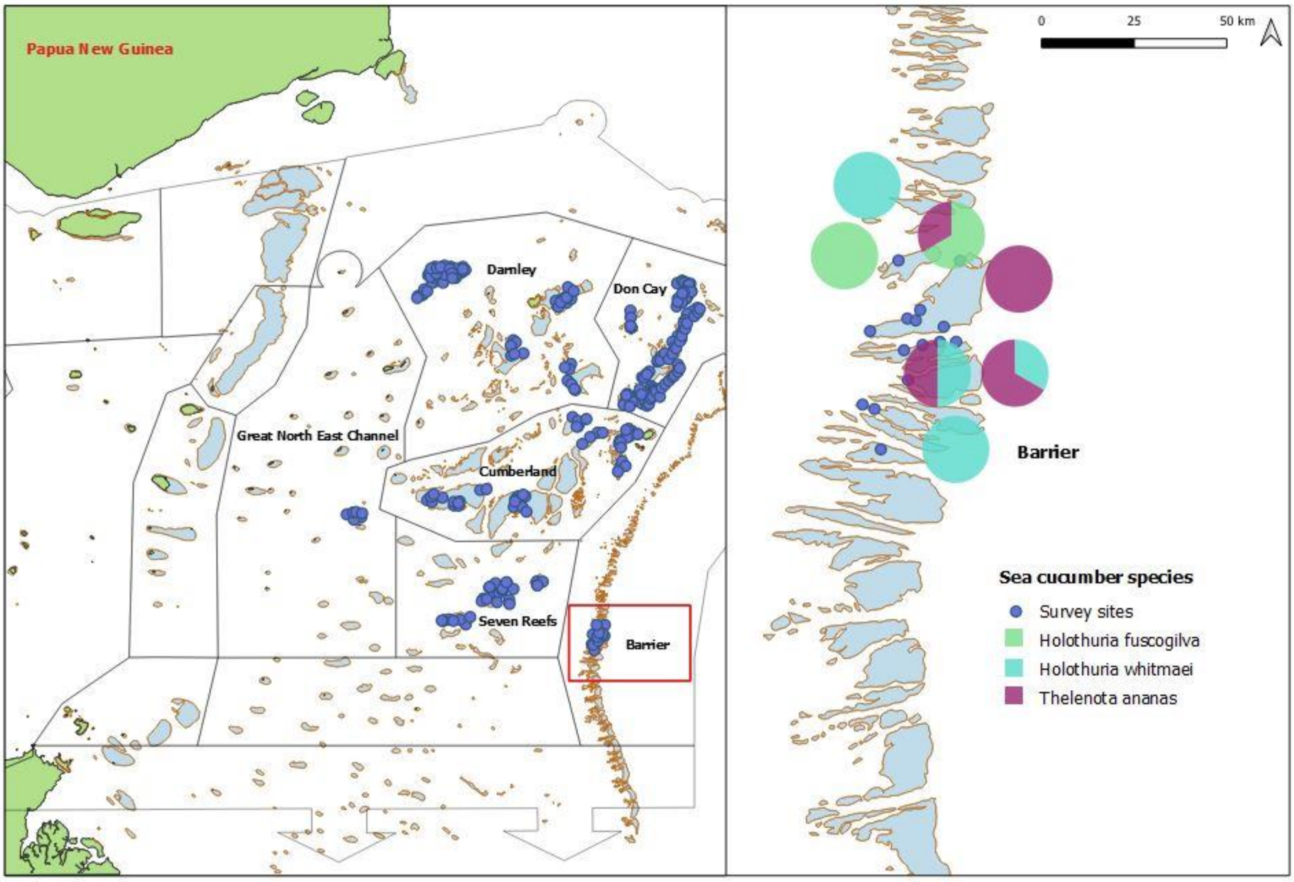


Figure 8-3. Key sea cucumber species for the Barrier zone for survey sampling sites for East Torres Strait.

In future, a reserve area could be established for the Barrier zone with modelling of currents for Torres Strait showing an East-West flow (Figure 8-4). The Barrier zone could potentially act as a source of sea cucumber species larvae for the East Torres Strait fishery area.

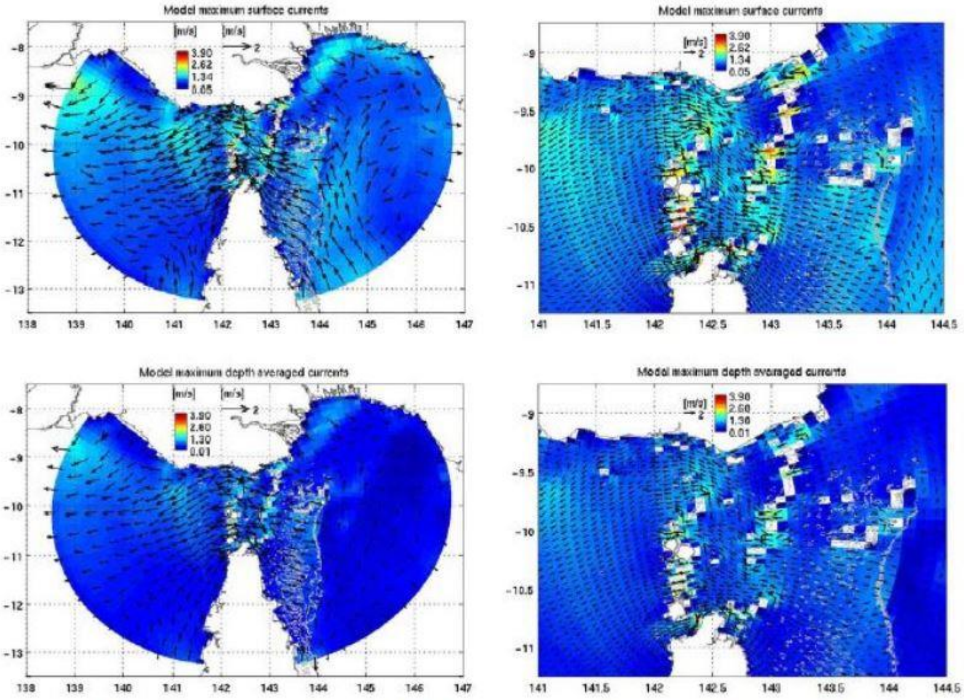


Figure 8-4. Current patterns modelled for Torres Strait (Saint-Cast and Condie, 2006)

9 Research needs

This study has addressed a number of key data and research gaps relating to the Torres Strait Beche-de-mer Fishery (TSBDMF). We briefly summarise some remaining research gaps, opportunities and needs for the ongoing development of the fishery:

9.1 Surveys

- The need for a dedicated sandfish (*Holothuria scabra*) survey on Warrior reef. This population was last surveyed in 2011 and the status is currently unknown. This includes collaboration with Papua New Guinea to look at opportunities to undertake a full scale survey (inclusion of northern Sandfish population).
- As part of discussions in response to preliminary survey results, it was recognised that there is the potential for better sharing of knowledge with Torres Strait Islander fishers and a need for a workshop/s for two-way sharing of information between fishers and scientists. This will help to inform future survey designs and gaps based on local knowledge. For example, further investigating the distribution of Prickly Redfish (*Thelenota ananas*) in regard to juvenile habitat areas.
- A desirable aspiration would be to further explore the potential of new more automated methods to survey deep water species, habitats and environmental variables - for example, drop down cameras or underwater gliders such as the Vertigo3 glider.
- Specialised/dedicated surveys for some species. Sea cucumbers such as Redfish (*Actinopyga echinites*) and Blackfish (*A. miliaris*) showed a possible decline from survey results, however these species also have a patchy distribution, so further research is needed to determine if the decline is real or the result of natural variability.

9.2 Catch sampling:

- There remains a number of gaps in conversion ratios for commercially more important species. These include Curryfish (*Stichopus herrmanni* and *S. vastus*), as well as Greenfish (*Stichopus chloronotus*), with Redfish (*A. echinites*) also having some information gaps.
    - Two-way workshops (alongside surveys) could also be used to discuss how best to undertake the previously planned conversion ratio project to engage Islanders and accommodate new COVID-19 pandemic and workplace restrictions.
- There is a need for data to be collected from subsamples of catches to help fill gaps in biological data, such as size at maturity, as well as for input to the HS (for example, size distribution of catch).
- For high value targeted species such as Black teatfish (*H. whitmaei*), it would be advantageous to collect high resolution data using data loggers that could be worn by

individual fishers/divers. This could provide (confidential) information on exact spatial locations of catches, as well as dive time spent on search versus capture etc.

9.3 Data analyses:

- There is a need for ongoing analyses of survey data to ensure best practise in terms of accounting for different habitats, averaging over larger areas, constructing standardised indices of abundance and analysing related environmental data.
- There is an ongoing need to analyse new data (especially for trial re-openings such as for Black teatfish (*H. whitmaei*) to inform application of the Torres Strait Beche-de-mer Harvest Strategy (TSBDMHS) rules.

9.3.1 Modelling:

- There is a need to use the survey and other data as inputs to population models that can be used to help support implementation of the TSBDMHS. Data-poor methods are needed in most cases.
- A desirable aspiration would be to revise and update the multispecies operating models that were used as part of an earlier Management Strategy Evaluation (Plaganyi et al., 2013).
    - The advantage of this framework is that (1) it included age-structure for the different species (e.g. this was recognised as an important consideration in analysing the size structure of a recovering population and hence what proportion is actually available to be fished); (2) it’s a state-of-the-art approach for accounting for uncertainty (noting that this is a data-poor fishery); (3) it can be used to simulation test alternative ways in which data can be used to help inform setting of TACs; (4) it is the preferred tool for rigorously evaluating how well a Harvest Strategy meets its stated objectives; (5) it can be used to explore how adding data reduces uncertainty and hence implications for management recommendations; and (6) more broadly, it can contribute to the aspirational development of an integrated ecosystem model that incorporates climate change (see below).

9.3.2 Social and Economic analyses:

- We recognise that the biological data are only one important consideration with respect to the TSBDMF, and that social and economic information are valuable also, and that there is a need to collect information on these dimensions to support management.
    - In particular, it is also extremely important to collect regularly updated data on prices per species, both to help understand the fishery given that this drives demand, but also as a way of having this information transparently available to support fishers planning their operations.
- The TSBDMF is almost entirely an export fishery, and hence there is a need, which has been highlighted particularly during the COVID-19 pandemic, to map and analyse the

supply chain, identify critical elements and strengthen the resilience of the supply chain (see e.g. Plaganyi et al. 2013; Purcell et al. 2017; Purcell et al., 2018; Barclay et al., 2016; Busilacchi et al., 2018). This also includes considerations of value adding.

9.4 Climate Change:

- Climate change is a major concern for Torres Strait Islanders and sea cucumbers have been highlighted as one of the most sensitive species (Johnson and Welch, 2016), hence there is a need for tools to support quantifying potential impacts as well as to evaluate alternative adaptation options.
    - The Climate Change impacts project currently led by Leo Dutra (CSIRO) is consolidating information and proposing a framework for future modelling.
    - We recommend that an integrated ecosystem model (i.e. linked with a regionally downscaled climate model for Torres Strait) be used for this purpose, with the added advantage that it can include all the major species and their biological and technical interactions as a basis for supporting ongoing management under a changing climate. Social and economic information as per above could also be incorporated in a model such as this.

9.5 Aquaculture:

- Survey and community monitoring on Ugar Island are being used to inform planning for potential aquaculture developments, and future monitoring will also need to be able to discern between wild production and supplements from aquaculture program e.g. using genetics. The project also has the potential to inform on finer habitat information between juvenile and adult sea cucumbers, as well as predation.
    - The aquaculture project also presents a future opportunity where conversion ratio information may be obtained by researchers working with the local community on Ugar.

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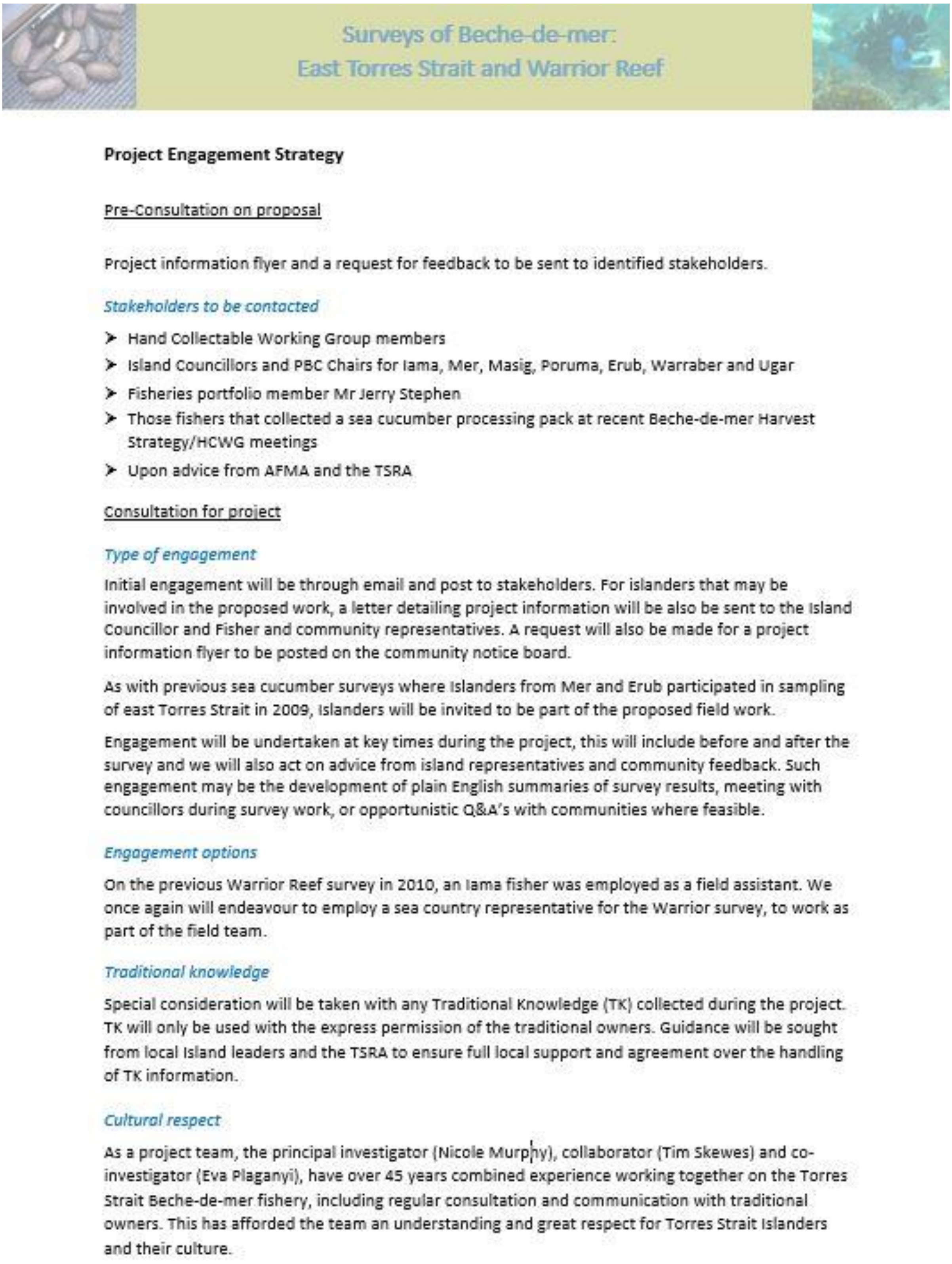
A.1 Community consultation



Surveys of Beche-de-mer:
East Torres Strait and Warrior Reef

Project Engagement Strategy

Pre-Consultation on proposal

Project information flyer and a request for feedback to be sent to identified stakeholders.

Stakeholders to be contacted

- Hand Collectable Working Group members
- Island Councillors and PBC Chairs for Iama, Mer, Masig, Poruma, Erub, Warraber and Ugar
- Fisheries portfolio member Mr Jerry Stephen
- Those fishers that collected a sea cucumber processing pack at recent Beche-de-mer Harvest Strategy/HCWG meetings
- Upon advice from AFMA and the TSRA

Consultation for project

Type of engagement

Initial engagement will be through email and post to stakeholders. For islanders that may be involved in the proposed work, a letter detailing project information will be also be sent to the Island Councillor and Fisher and community representatives. A request will also be made for a project information flyer to be posted on the community notice board.

As with previous sea cucumber surveys where Islanders from Mer and Erub participated in sampling of east Torres Strait in 2009, Islanders will be invited to be part of the proposed field work.

Engagement will be undertaken at key times during the project, this will include before and after the survey and we will also act on advice from island representatives and community feedback. Such engagement may be the development of plain English summaries of survey results, meeting with councillors during survey work, or opportunistic Q&A's with communities where feasible.

Engagement options

On the previous Warrior Reef survey in 2010, an Iama fisher was employed as a field assistant. We once again will endeavour to employ a sea country representative for the Warrior survey, to work as part of the field team.

Traditional knowledge

Special consideration will be taken with any Traditional Knowledge (TK) collected during the project. TK will only be used with the express permission of the traditional owners. Guidance will be sought from local Island leaders and the TSRA to ensure full local support and agreement over the handling of TK information.

Cultural respect

As a project team, the principal investigator (Nicole Murphy), collaborator (Tim Skewes) and co-investigator (Eva Plaganyi), have over 45 years combined experience working together on the Torres Strait Beche-de-mer fishery, including regular consultation and communication with traditional owners. This has afforded the team an understanding and great respect for Torres Strait Islanders and their culture.

Surveys of Beche-de-mer:
East Torres Strait and Warrior Reef

Project application - We would like community feedback for this proposed project.

Project Need

The Torres Strait Beche-de-mer Fishery (TSBDMF) has become an important source of income for Torres Strait islanders since early 1990s. While most beche-de-mer species are in good condition, several species are closed or recovering, such as Sandfish, Black teatfish and Surf redfish. Other species have been under increasing fishing pressure, such as Prickly redfish and Curryfish.

Fishery dependent data (logbooks) were introduced to the TSBDMF in December 2017. However, there is considerable uncertainty about the status of many beche-de-mer populations. The last surveys were carried out in 2009 for east Torres Strait and 2010 for Warrior Reef. A stock survey is the only way at present to find out the status of fished beche-de-mer populations in Torres Strait.

Proposed Survey Work

We are seeking feedback on the following proposed sea cucumber surveys:

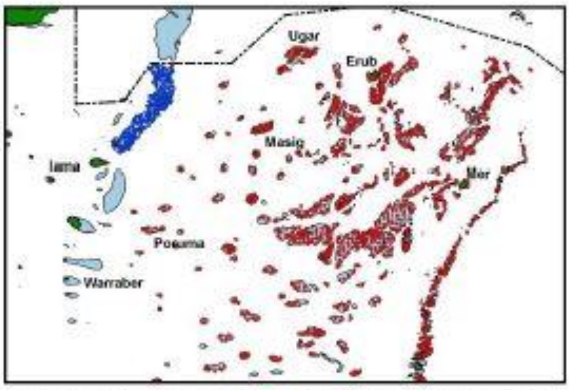
1. Survey of Sandfish on Warrior Reef.
2. Survey of east Torres Strait mainly focused on Prickly redfish, Curryfish, Black teatfish and Surf redfish.
3. Exploration of deeper habitats for additional white teatfish population (e.g. with cameras).

Timing

Surveys need to be done during the same months as past surveys, due to burrowing behaviour of sea cucumbers. Based on past surveys, the best time to survey the east Torres Strait is February or March, and January for surveying sandfish on Warrior Reef. We are also looking at a combined survey to reduce costs in late January or March, 2020.

Where

Sites will be selected from previous surveyed sites in Eastern Torres Strait and Warrior Reef. This will allow for direct comparisons of density to be made. We will also take advice from Torres Strait fishers on additional likely high-density areas for investigation. Any deep water sites for white teatfish will be highly targeted, using previous data records, habitat mapping and advice from fishers.



All previous survey sites in east Torres Strait (red) and Warrior Reef (blue)

Survey methods

The proposed surveys will be conducted using the same sampling methods as used in previous years. Divers will swim fixed length transects and count beche-de-mer and record habitat information.

The survey work being undertaken does not damage the environment in any way. At times sea cucumbers may be collected for length measurements. When this is done, the animals are measured on the spot, or if they are taken to the surface, they are measured and returned to the water as soon as possible and are not taken away from where they were found.

Community Involvement

As with previous sea cucumber surveys, we will be investigating ways to involve Islanders in the field work. We will endeavour to employ a local research assistant for the Warrior Reef survey at least, to work as part of the field team.

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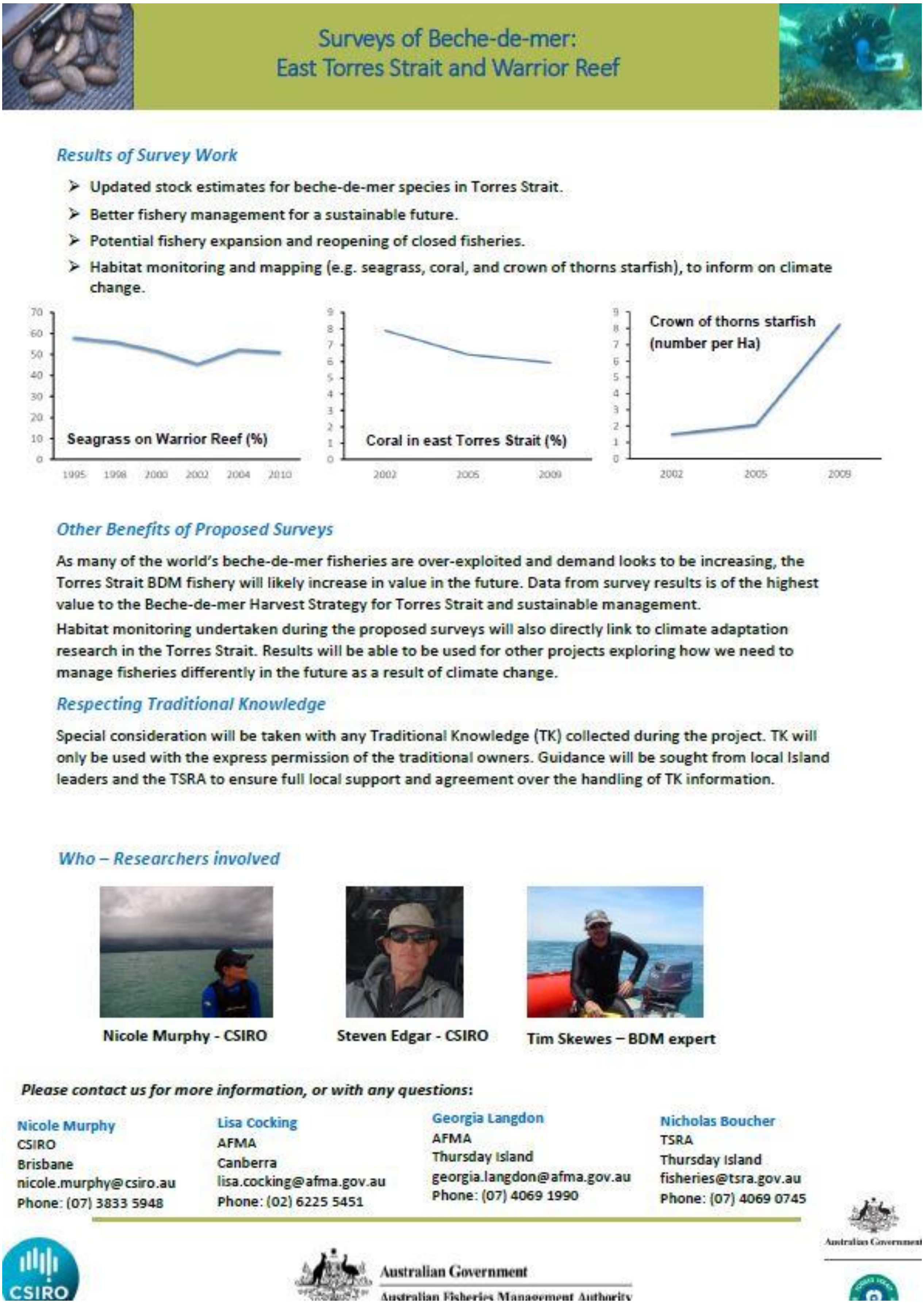

Surveys of Beche-de-mer: East Torres Strait and Warrior Reef

Results of Survey Work

- Updated stock estimates for beche-de-mer species in Torres Strait.
- Better fishery management for a sustainable future.
- Potential fishery expansion and reopening of closed fisheries.
- Habitat monitoring and mapping (e.g. seagrass, coral, and crown of thorns starfish), to inform on climate change.

Other Benefits of Proposed Surveys

As many of the world's beche-de-mer fisheries are over-exploited and demand looks to be increasing, the Torres Strait BDM fishery will likely increase in value in the future. Data from survey results is of the highest value to the Beche-de-mer Harvest Strategy for Torres Strait and sustainable management.

Habitat monitoring undertaken during the proposed surveys will also directly link to climate adaptation research in the Torres Strait. Results will be able to be used for other projects exploring how we need to manage fisheries differently in the future as a result of climate change.

Respecting Traditional Knowledge

Special consideration will be taken with any Traditional Knowledge (TK) collected during the project. TK will only be used with the express permission of the traditional owners. Guidance will be sought from local Island leaders and the TSRA to ensure full local support and agreement over the handling of TK information.

Who – Researchers involved

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Steven Edgar - CSIRO

Tim Skewes – BDM expert

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19th December 2019

HABITAT SURVEY OF UGAR ISLAND

Mr Sereako Stephen
Chairperson Ugar RNTBC
Ugar Island

Dear Mr Stephen

CSIRO is currently engaged to carry out a survey of Beche-de-mer (sea cucumber) in Torres Strait. We will be undertaking the second part of the survey from 9th – 22nd January 2020.

As part of this work, we seek permission please to undertake a habitat survey of Ugar Island to support the re-seeding proposal that Mr Rocky Stephens and CSIRO researcher Dr Leo Dutra are developing.

The habitat survey will involve a number of measured transects from 40m to 100m long, that a SCUBA diver or Snorkeller will swim along and record the following:

Water depth
Transect length
Substrate type - sand, rubble, rock
Coral
Seagrass
Algae
Sponges
Sea cucumbers
Urchins
Trochus

These transects will be undertaken around the perimeter of Ugar and will include sand and reef top areas, as well as reef edges. This information will be of high value to the re-seeding proposal as it will provide important data on zonation of habitat types. We are also happy to include any locations that may be of interest to the community and ask for you to please let us know.

We are planning to undertake the habitat survey over one day around the 10th or 11th of January 2020, with timing dependent on weather and sea conditions. We are also more than happy for anyone to come and see what we are doing and to answer any questions.

At the completion of the survey a map will be produced displaying habitat information surrounding Ugar Island, which will be provided to the community as well as to Mr Rocky Stephens and Dr Leo Dutra.

Kind Regards

Nicole Murphy
Experimental Scientist
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A.2 Bêche-de-mer Harvest Strategy supporting information - Species ecology, status and sampling approach.

Species (value)	**Location/habitat**	**Fishery status**	**Population status**	**Survey Approach**
Sandfish (high) *Holothuria* *scabra*	Sandfish are almost exclusively found on Warrior Reef. It is a shared stock with PNG, with approximately half the population on each side. Muddy-sand seagrass beds and reef flats. 0.5-20 m	The Australian fishery was closed in 1998, after a few years of heavy fishing pressure. The PNG sandfish fishery was closed in 2009, after it was severely depleted. It has recently reopened but we have not received any reports of the population status, or recent catch in that fishery.	The virgin biomass of the entire population was likely in the order of 6,000 tonnes (landed weight) or more. On the Australian side, several population surveys have been carried out since closure, the most recent being in February 2010 (survey) and March 2012 (experimental fishing). While these surveys showed there is a significant population of sandfish on Warrior Reef, they did not indicate a substantive recovery of the population at that time.	The most efficient way to determine the current status of the stock is to carry out a stock survey of Warrior Reef. Surveying the PNG side at the same time would provide a whole of population stock status estimate. Requires careful consideration of diurnal, seasonal, tidal and moon phase survey timing due to burrowing. Therefore, needs a dedicated survey.
Black teatfish (high) *Holothuria* *whitmaei*	Found on shallow reefs of east Torres Strait. It is almost entirely an Australian population. Reef flats, reef fronts and reef passes. 1-20 m	The Australian fishery was closed in 2001, after a decade of fishing pressure. This species has been recently reopened after a decade long closure, based on survey data from 2009. It has been fished in 2 of the last 6 years under a conservative TAC of 15 t.	The 2009 survey indicated that the BTF population had recovered to near virgin biomass levels. The fishing effort since the fishery has reopened has not been large (even though annual quotas have been exceeded in years that it has opened). There are recent anecdotal reports of high densities in east Torres Strait.	Stratified dive survey of shallow reefs in east Torres strait.
White teatfish	This species is found in deeper reef edge and reef pass waters in	Catches have been modest in recent years, and below the	Currently uncertain but likely to be above sustainable limits, due to	This species is difficult to survey as it is mostly found in deeper reef

Species (value)	Location/habitat	Fishery status	Population status	Survey Approach
(high) *Holothuria fuscogilva*	far east Torres Strait. There is no evidence it is found in deeper open water habitats (e.g. it was not observed during Torres Strait seabed surveys). Lagoons and passes on pavement or sand. 3-40 m	recommended TAC. The current ban on hookah gear in the fishery limits access to the population to fishing.	inaccessibility of most of the population to fishing.	edge and pass waters. A survey using remote cameras could be trialled (as a pilot study first). A targeted sample design would be essential for a feasible survey approach, using previous survey and fishery data. Habitat estimation will also be a critical component of this study. Note: This species is also the focus of an effort to carry out a survey on the Qld east coast fishery.
Prickly redfish (medium) *Thelenota ananas*	This species is found in reef edge and pass waters in east Torres Strait. Lagoons, in areas with rubble and passes. 1-35 m	This species has been heavily targeted in recent years, with a likely overshoot of the TAC.	The most recent survey in 2009 indicated that the population was above sustainable population levels. However, the population has been heavily targeted in recent years, and there are anecdotal reports of at least localised depletion. There is the possibility of some protection of this species due to inaccessibility of deepwater populations.	Stratified dive survey of reef edges and passes in east Torres strait. This information would be comparable to previous surveys. Potential for deeper populations could also be investigated using remote cameras.
Surf redfish (medium) *Actinopyga mauritiana*	High energy zone on the front of east Torres Strait reefs. Murray Island, Don Cay. 0-10 m	This species is currently closed. Catches of deepwater redfish was mistakenly reported as surf redfish early in the modern Torres Strait fishery, adding uncertainty to population status assessment.	Generally unknown. Previous survey data is uncertain due to sampling difficulties and identification problems. There have been anecdotal reports of high densities of surf redfish on east Torres Strait reefs.	Difficult to survey due to high energy habitat and cryptic nature. Will require a dedicated survey approach – if one can be formulated that is feasible.

Species (value)	**Location/habitat**	**Fishery status**	**Population status**	**Survey Approach**
Deepwater redfish (medium) *Actinopyga echinites*	Shallow reef habitat in central Torres Strait and Warrior Reef. Coastal reef in rubble, seagrass beds or sand between corals. 0-10 m	Previously important fishery species in Torres Strait. Current catch still uncertain due to identification and reporting issues.	Unknown	Stratified dive survey of shallow reefs in central Torres Strait and Warrior Reef.
Blackfish (medium) *Actinopyga miliaris* *A. spinea* *A. palauensis*	Broad distribution. High density on shallow reef habitat in central Torres Strait and Warrior Reef. Muddy-sand lagoons, reef flats, fore reef pavement. 1-20 m	Significant catches at times throughout fishery. Catch history uncertain due to identification and reporting issues.	Unknown	Stratified dive survey of shallow reefs in east Torres strait and Warrior Reef. Species ID an important component of research.
Curryfish (medium) *Stichopus herrmanni* *S. vastus* *S. ocellatus*	Protected reef edges in central, east Torres Strait and Warrior Reef. 1-30 m	Recent increased commercial interest in these species. Currently being heavily targeted. Requires specialised processing techniques.	Unknown? Surveys have indicated a large population estimate for the common Curryfish (*S. herrmanni*) but lowered for other species.	Stratified dive survey of protected reef edges in central and east Torres strait and Warrior Reef. Spatial catch information from fishers critical for guiding surveys.

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Australia's National
Science Agency

Ugar Island sea cucumber survey

Field survey and results

Nicole Murphy, Tim Skewes, Eva Plaganyi, Steven Edgar and Kinam Salee

July 2020

AFMA Project 2019/0826

Multi-Use Ecosystems

OCEANS & ATMOSPHERE

Citation

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Acknowledgements

This project is funded by the Torres Strait Regional Authority (TSRA), the Australian Fisheries Management Authority (AFMA) and The Commonwealth Scientific and Industrial Research Organisation (CSIRO).

We would like to thank the Captain and crew of the MV Wild Blue and staff of Rob Benn Holdings for their valuable support and assistance during the survey.

Thank you to Leo Dutra for comments on the report.

Thank you to all Torres Strait Traditional Owners for regularly hosting us on their land and supporting this research.

Summary

Scientific surveys of Torres Strait sea cucumbers were conducted during December 2019 and January 2020. This report summarises the findings of intensive sampling of Ugar Island and Campbell reefs to investigate sea cucumber populations and their habitats, in order to identify suitable species and locations for reseeding research.

A number of high value commercial sea cucumber species including Teatfish, Curryfish, Sandfish, Redfish, Blackfish and Prickly redfish were found at Ugar and Campbell reefs, and the sizes of animals was generally large. The survey data also show there are suitable habitats to release hatchery-produced sea cucumbers, which supports the development of future aquaculture prospects for the Ugar community. The survey also provided information for clam species, in particular the Giant clam, a species of interest to the Ugar community.

1 Ugar Island habitat survey

Surveys of Ugar Island and Campbell Reef to map habitats and quantify populations of sea cucumbers and giant clams were undertaken in order to provide information to the community, and for support of a sea cucumber reseeding proposal currently being developed by Mr Rocky Stephens and CSIRO researcher Leo Dutra. This work will help improve sea cucumber stocks for the benefit of local communities in Torres Strait.

This survey received approval from Mr Sereako Stephen, Chair of the Ugar RNTBC, Councillor Rocky Stephen and had community support following survey consultation (see Appendix A.1).

1.1 Objective

The objective of the sea cucumber survey was to map the reef and quantify habitats and sea cucumber populations of Ugar home reef, to support the potential sea cucumber re-seeding proposal (see Figure 1-1).

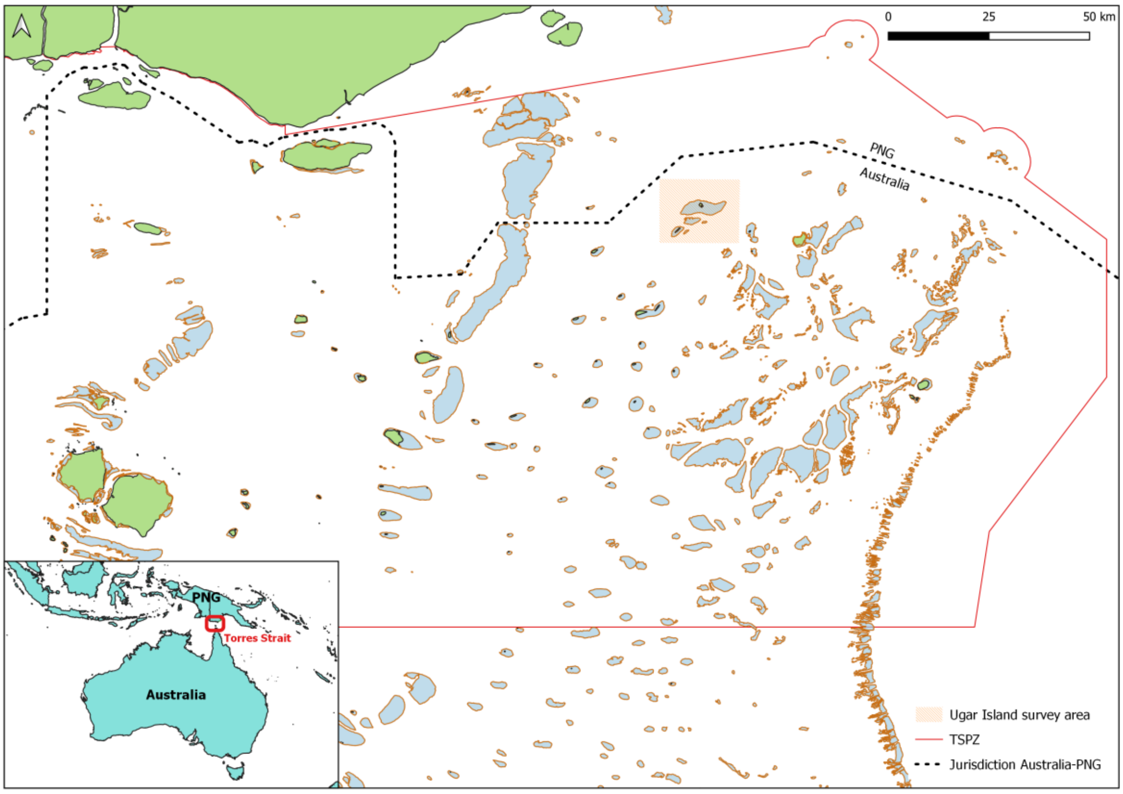


Figure 1-1. Map of Torres Strait showing location of Ugar Island and the survey area.

1.2 Sample design

The survey involved intensive sampling of Ugar Island and Campbell reefs to investigate sea cucumber populations and their habitats, in order to identify suitable species and locations for the re-seeding research.

1.2.1 **Ugar Island survey**

Sixty snorkel and dive transects were undertaken as part of the surveys carried out in December 2019 and January 2020. Of the sites sampled, 38 were previously surveyed in one or more surveys carried out in 1995/96, 2002, 2005, 2009 (repeated measures), with 22 new sites that included reef top, reef top buffer and representative reef edge sites to inform on sea cucumber species, distribution and habitat (Table 1-1; Figure 1-2).

Table 1-1. Survey sites for survey year.

Survey year	Site number
1995/96 & 2019/20	23
1995/96, 2002, 2019/20	1
2002, 2005, 2019/20	2
2002, 2009, 2019/20	3
2002, 2019/20	9
2019/20	22

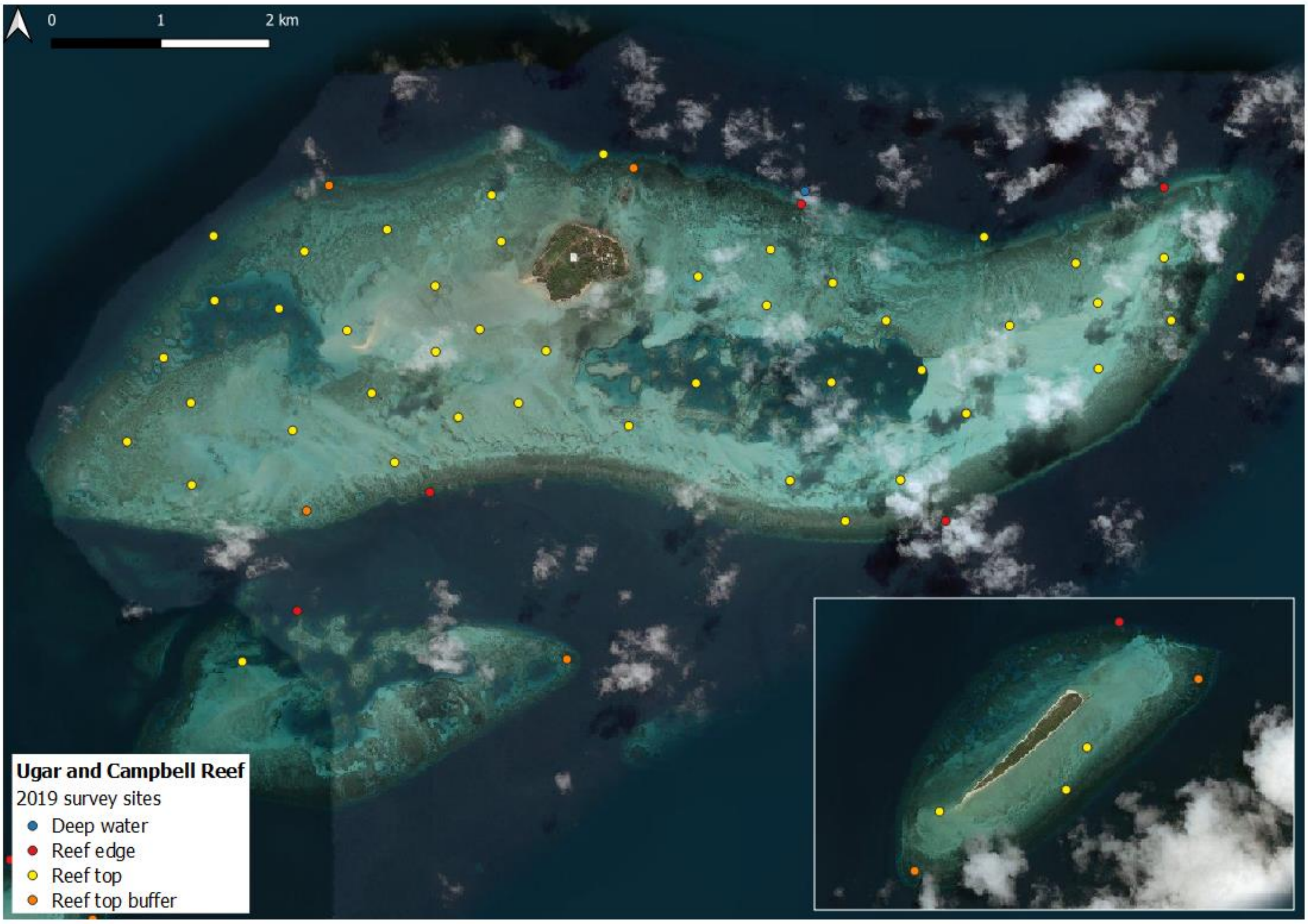


Figure 1-2. Survey sites at Ugar Island and Campbell Reef for the 2019/20 field survey, Torres Strait.

1.3 Survey Methods

A marine habitat map that delineated shallow reefs was used as the basis for the survey. This was imported into a Geographical Information System (GIS) software (QGIS) and the area surveyed superimposed onto the map. The area was further divided into the following three habitat strata:

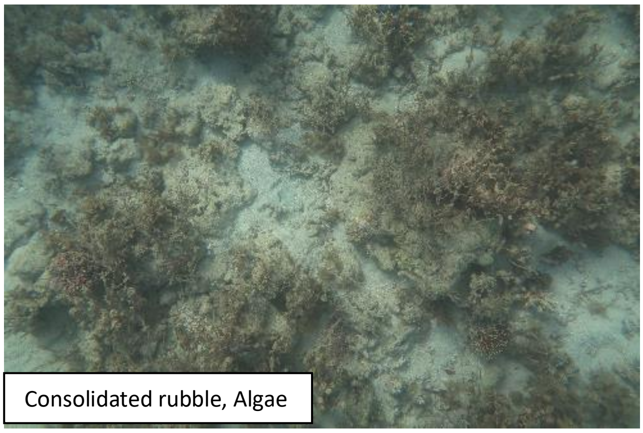
- the reef edge,
- the reef top, and
- a reef top buffer stratum, being a 200 m wide buffer around the inside of the reef margin.

The survey was conducted using rapid marine assessment techniques consistent with previous Torres Strait beche-de-mer surveys undertaken in 1995-96, 2002, 2005 and 2009 (Skewes et al., 1999; Skewes et al., 2004; Skewes et al., 2010). Two of the survey staff - Nicole Murphy and Tim Skewes, have led or participated on all previous sea cucumber surveys.

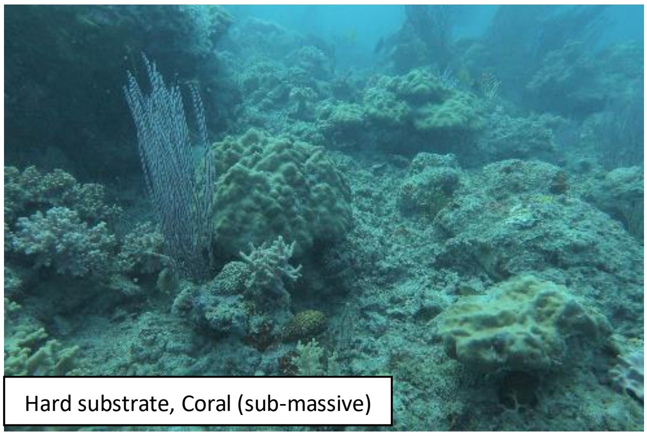
The survey was undertaken by a team of divers operating from a dinghy and locating sample sites using hand-held GPS. On the reef top, divers swam along a 40m-100m transect line recording resource and habitat data from the line out to 1-2m either side. On the reef edge, a diver swam along a measured length transect between 1m and 15m water depth. Sea cucumbers, and other benthic fauna of commercial or ecological interest (e.g. clams and pearl oysters) were counted. Where possible, sea cucumbers were collected for total length and weight measurements taken in the dinghy and subsequently returned to the water, at or near the site collected.

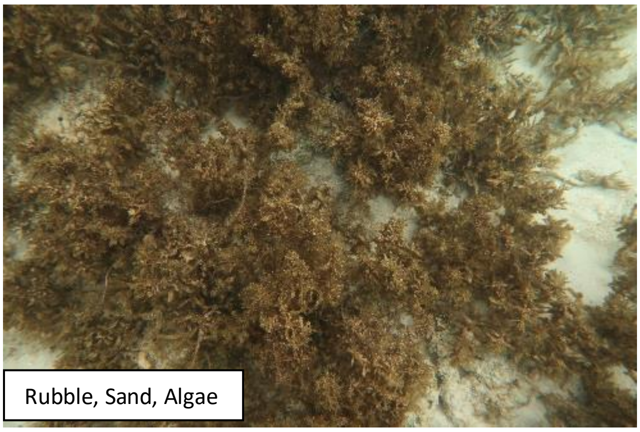
For each site, substrate was described in terms of the percentage of unconsolidated (sand, rubble) and consolidated (consolidated rubble, pavement and live coral) substrate. The growth forms and dominant taxa of the live coral component and the percentage cover of all other conspicuous biota such as seagrass and algae were also recorded (see Figure 1-3).

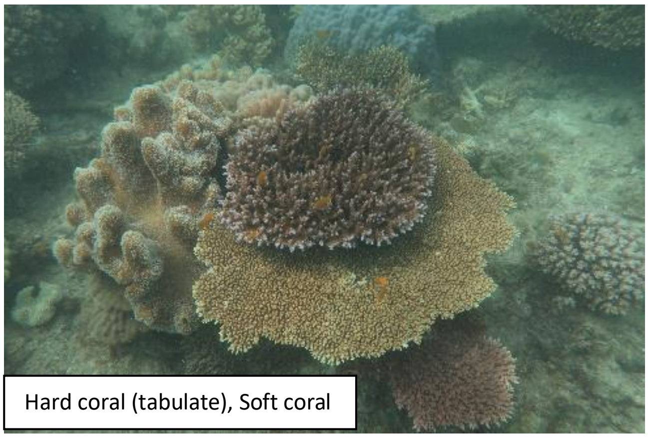
The timing of the survey was planned to coincide with the seasonal timing of previous surveys to reduce biases related to differences in survey observer, resulting from changes in sea cucumber burrowing behaviour, caused by seasonal and tidal factors.

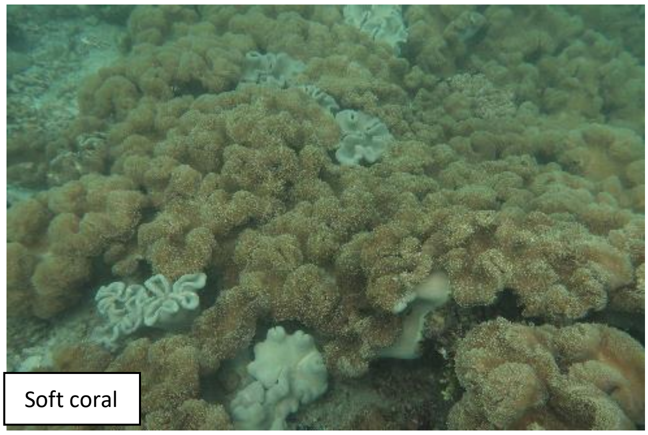

Consolidated rubble, Algae

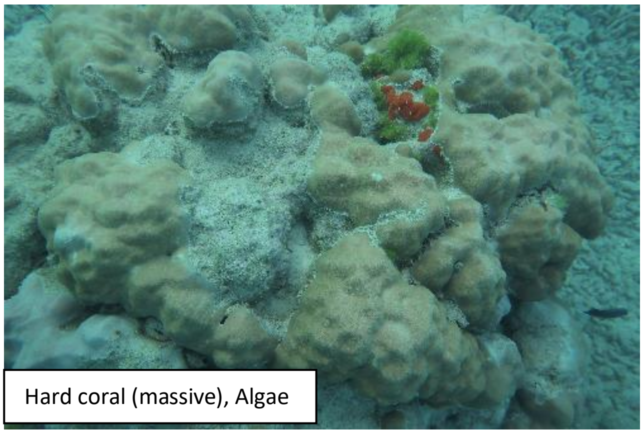

Sand, Seagrass

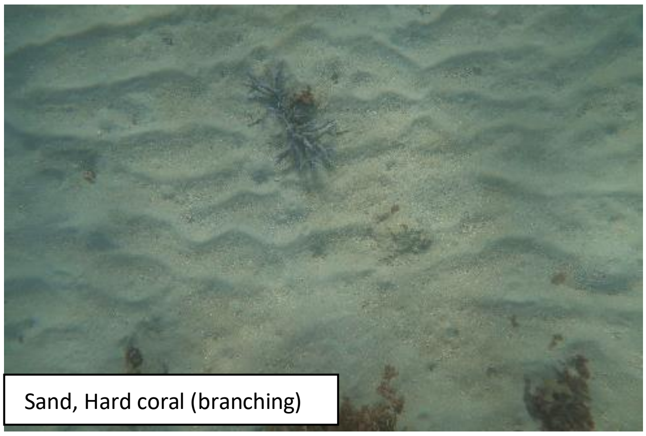

Hard substrate, Coral (sub-massive)

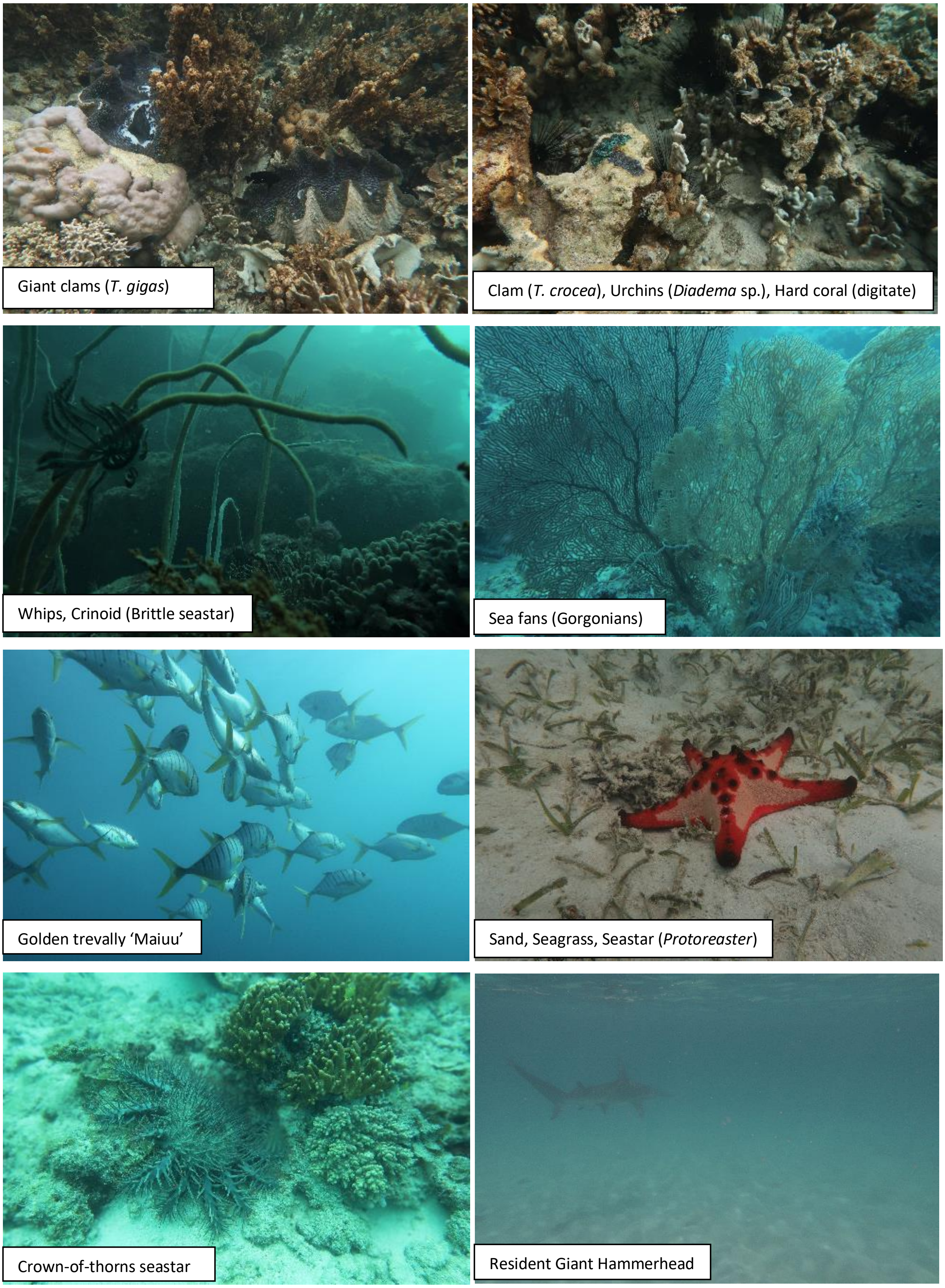

Rubble, Sand, Algae


Hard coral (tabulate), Soft coral


Soft coral


Hard coral (massive), Algae


Sand, Hard coral (branching)



Giant clams (*T. gigas*)

Clam (*T. crocea*), Urchins (*Diadema* sp.), Hard coral (digitate)

Whips, Crinoid (Brittle seastar)

Sea fans (Gorgonians)

Golden trevally ‘Maiuu’

Sand, Seagrass, Seastar (*Protoreaster*)

Crown-of-thorns seastar

Resident Giant Hammerhead

Figure 1-3. Substrate and biota examples.

1.4 Data Analyses

Transect and sample data collected during the field survey have been entered into an Access database and imported into a centralised Oracle database for long-term storage. The data have also been used as input into statistical and GIS software for analysis.

1.4.1 **Maps**

Estimates of mean density (count per hectare) were derived using a stratified analysis of transect counts based on reef strata. This calculation takes into account heterogeneity in the variance of observed counts and is representative of the physical size differences of the varying habitats in the survey. Mean densities for sea cucumbers species, dominant substrate and biota cover, and species of interest were represented in maps using coloured composition (see Figure 2-1; Figure 2-2; Figure 2-3).

1.4.2 **Data outputs**

Size frequency estimates were produced for combined sea cucumber species and for species groups (see Figure 2-4; Figure 2-5; Figure 2-6; Figure 2-7).

Stratified estimates for sea cucumber species for reef strata (reef top, reef top buffer and reef edge) were represented using plots of sea cucumber species mean density (see Figure 2-8; Figure 2-9; Figure 2-10).

Representation of dominant habitat and biota used average mean percent estimates of count data shown on *Lollipop* plot for substrate (see Figure 2-11), represented as substrate categories on the y axis and percentage cover on the x-axis, with hierarchical biota data represented as proportionate triangles (*Treemap* plot in RStudio) (see Figure 2-12).

A further finer representation of seagrass, algae and clam species used donut plot showing proportional break down of substrate and biota for reef strata - reef top, reef top buffer and reef edge (see Figure 2-13; Figure 2-14; Figure 2-15).

2 Results

2.1 Sea cucumber species

Nineteen species were recorded during the Ugar and Campbell reefs survey (Figure 1-2; Table 2-1). Twenty-three commercial sea cucumber species occur in Torres Strait, with fifteen recorded from Ugar and Campbell reefs.

Table 2-1. Species list of recorded sea cucumbers.

Species	Common name	Erub-mer Language
Actinopyga echinites	Deepwater redfish	‘Mamam Aber’
Actinopyga miliaris	Hairy blackfish	Musmus Aber’
Actinopyga palauensis	Deepwater blackfish	‘Goleh-Goleh Aber’
Bohadschia argus	Leopardfish	‘Kepkep Aber’
Bohadschia ocellata	Polka-dotted or Ocellated sea cucumber	
Bohadschia vitiensis	Brown sandfish	‘Parak Aber’
Holothuria edulis	Pinkfish	
Holothuria fuscogilva	White teatfish	‘Zarzer Pauraber’
Holothuria fuscopunctata	Elephant trunkfish	“Berber Aber’
Holothuria lessoni	Golden sandfish	‘Susus Aber’
Holothuria scabra	Sandfish	‘Burbur Aber’
Holothuria whitmaei	Black teatfish	‘Pauraber or Goleh-Goleh Pauraber’
Pearsonothuria graeffei	Black-spotted or Graeffe’s sea cucumber	
Stichopus chloronotus	Greenfish	Kerir Aber’
Stichopus herrmanni	Curryfish (common/yellow)	‘Bambam Aber’
Stichopus vastus	Curryfish (vastus/green)	‘Warwarr Aber’
Thelonota ananas	Prickly redfish	‘Seker Aber’
Thelonota anax	Amberfish	
Holothuria atra	Lollyfish	“Wehwehsor Aber’

2.2 Mapping of species composition

2.2.1 Main outcomes

- The most common species (found for most sites) for the survey was Lollyfish (*H. atra*) (Section 2.2.2; Figure 2-1).
- The least abundant species was Graeffe's sea cucumber (*P. graeffei*) (Section 2.2.2; Figure 2-1).
- Most of the sites surveyed had predominantly soft sediment (Section 2.2.3; Figure 2-2).
- Lollyfish (*H. atra)* had the smallest size class for length frequency distribution, with Prickly redfish (*T. ananas*) having the largest (Section 2.3.1; Figure 2-7).
- A mix of juveniles and adults of Golden sandfish (*H. lessoni*) was found at one particular area of the reef top (Figure 2-1), close to the east side of Ugar island - predominantly dominated by sand (Figure 2-2) (see details for implications to re-seeding in Section 3).
- One adult sandfish (*H. scabra*) was found off transect where Golden sandfish (*H. lessoni*) were observed (Figure 2-1) (see details for implications to reseeding in Section 3).
- Lollyfish (*H. atra*) was the most abundant species for the reef top buffer and reef top strata (Figure 2-8; Figure 2-10).
- Pinkfish (*H. edulis)* was the most abundant species for the reef edge strata (Figure 2-9).
- Soft (sandy) substrate was the most common substrate for all strata for sites surveyed, followed by 'consolidated rubble' for the reef top buffer, 'hard' for the reef edge, and 'rubble' for the reef top (Figure 2-11), suggesting a relative high energy.
- Soft coral was the dominant biota for both reef edge and reef top strata, where the reef top buffer was equally dominated by sea urchins, soft corals and Fungiid corals (Figure 2-12).
- *Thallassia emprichi* was the dominant seagrass species for reef top and reef top buffer strata, followed by *Halophila ovalis* (Figure 2-13).
- The reef top, reef top buffer and reef edge strata were dominated by algae *Sargassum* spp. (Figure 2-14).
- *T. crossea* was the most frequent clam species. Most sites surveyed had one species of clam, but three species of clam were found at one site at Campbell reef (Section 2.2.4; Figure 2-3; Figure 2-15).

2.2.2 Sea cucumber species

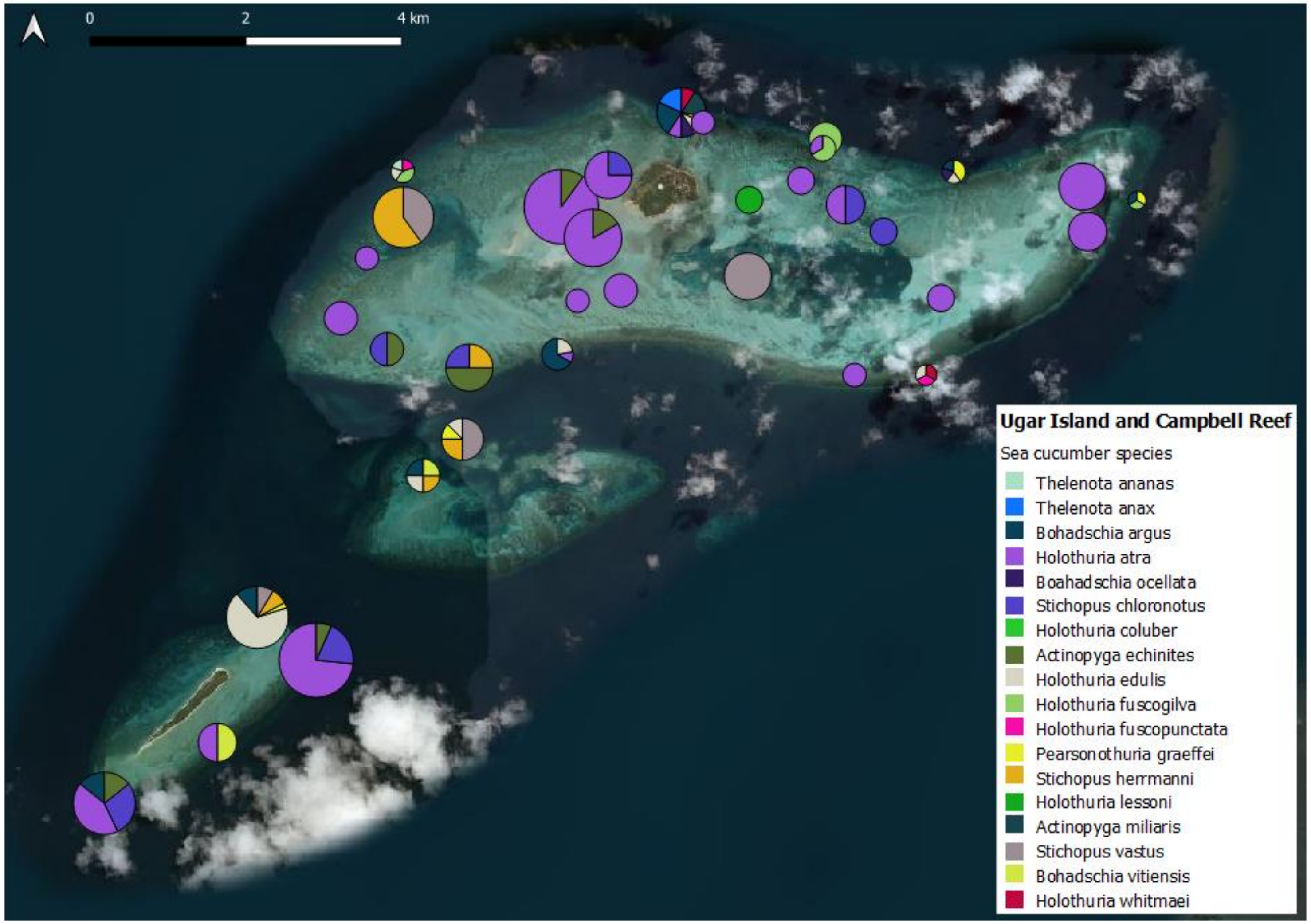


Figure 2-1. Relative abundance of sea cucumber species for survey sites.

2.2.3 Substrate and biota

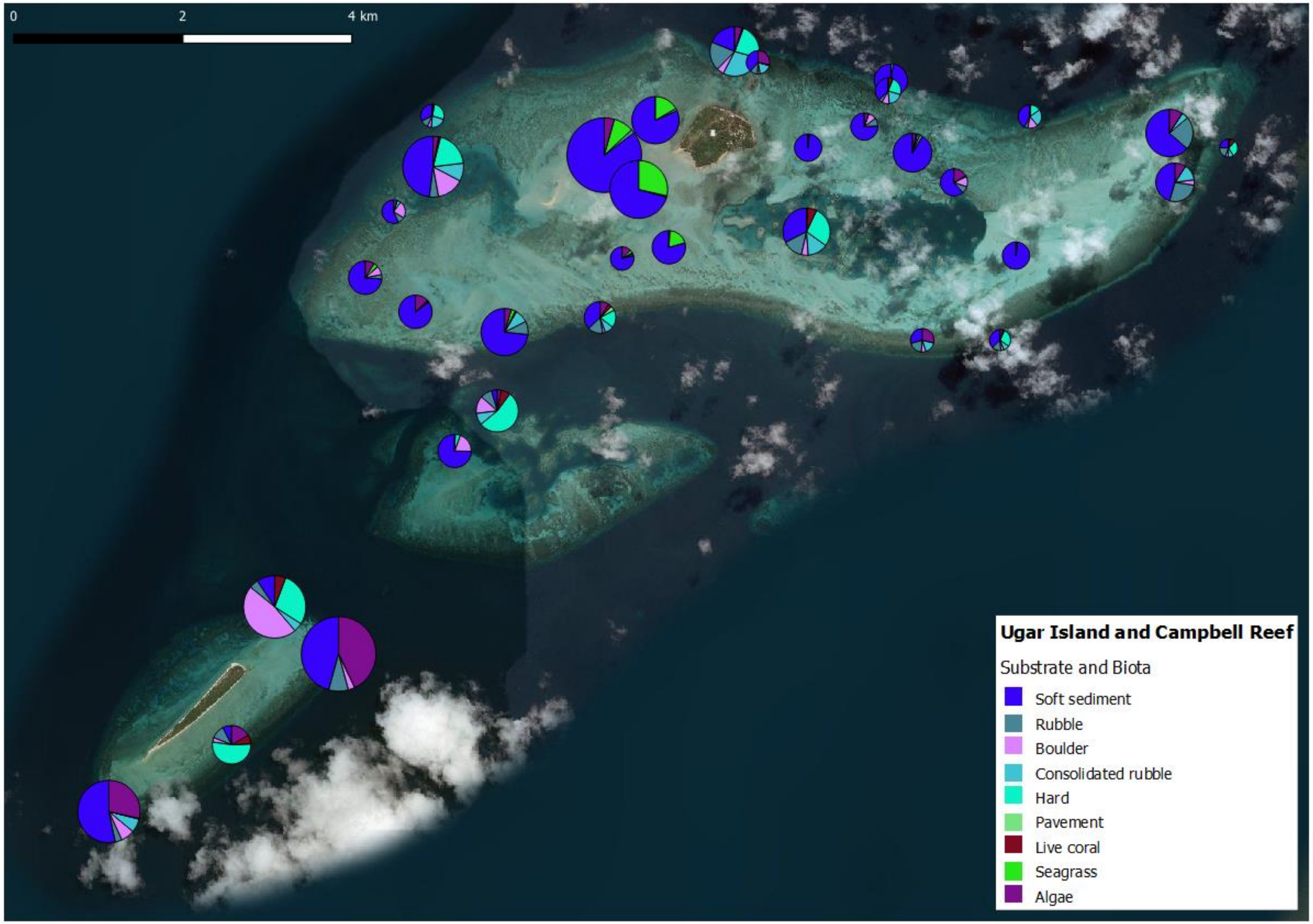


Figure 2-2. Percentage cover of substrate and biota for survey sites.

2.2.4 Clam species

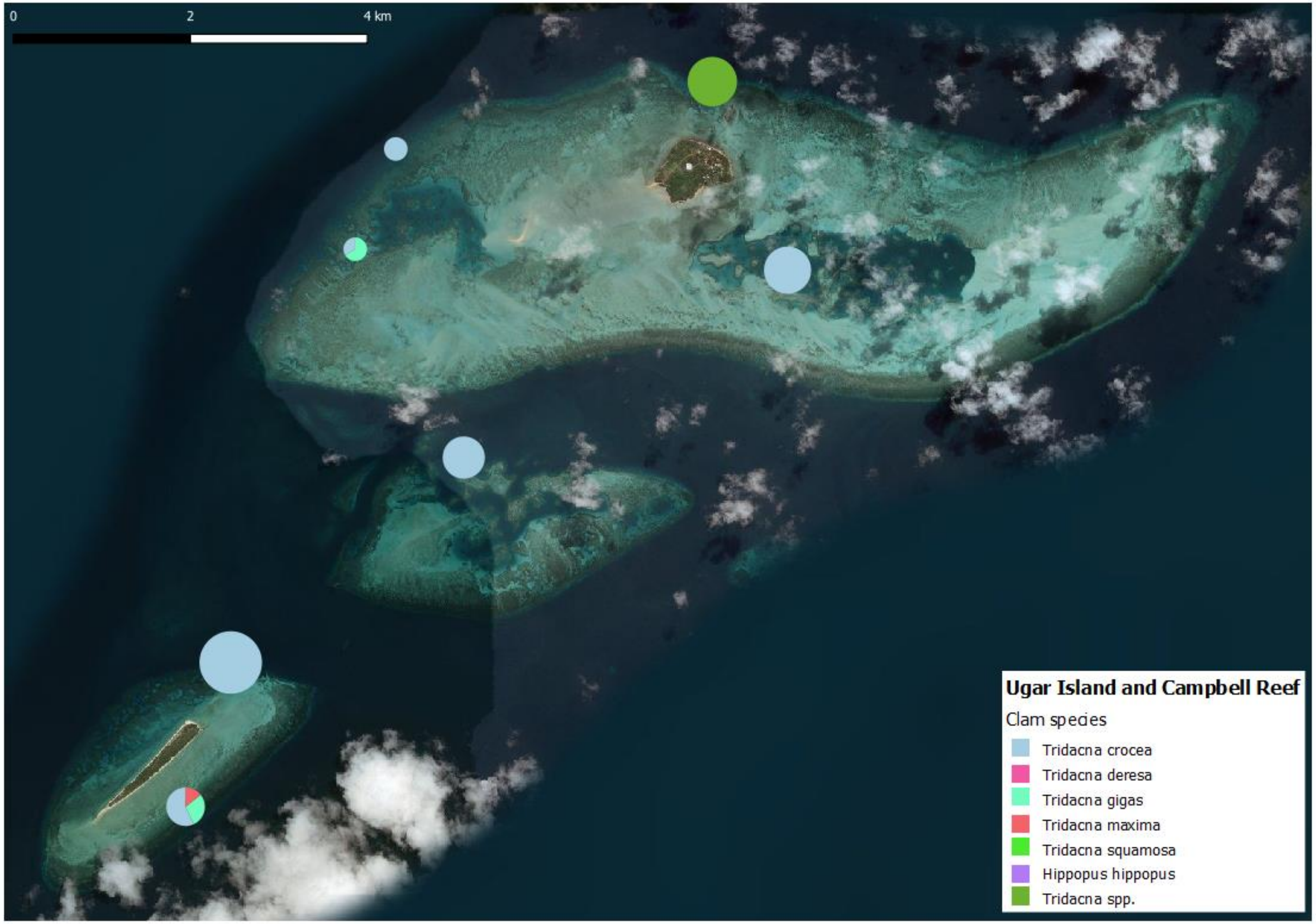


Figure 2-3. Percentage cover of clam species for survey sites.

2.3 Data outputs

2.3.1 Length frequency for grouped sea cucumber species

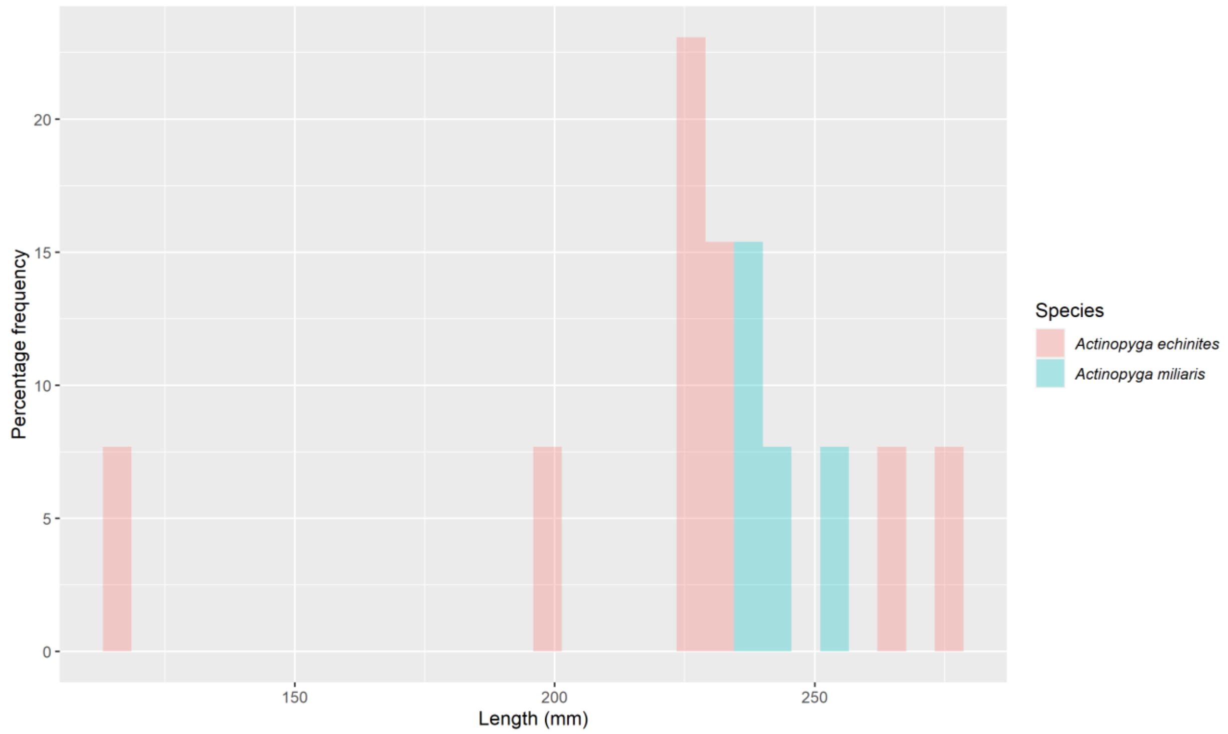


Figure 2-4. Length frequency for *A. echinites* and *A. miliaris*.

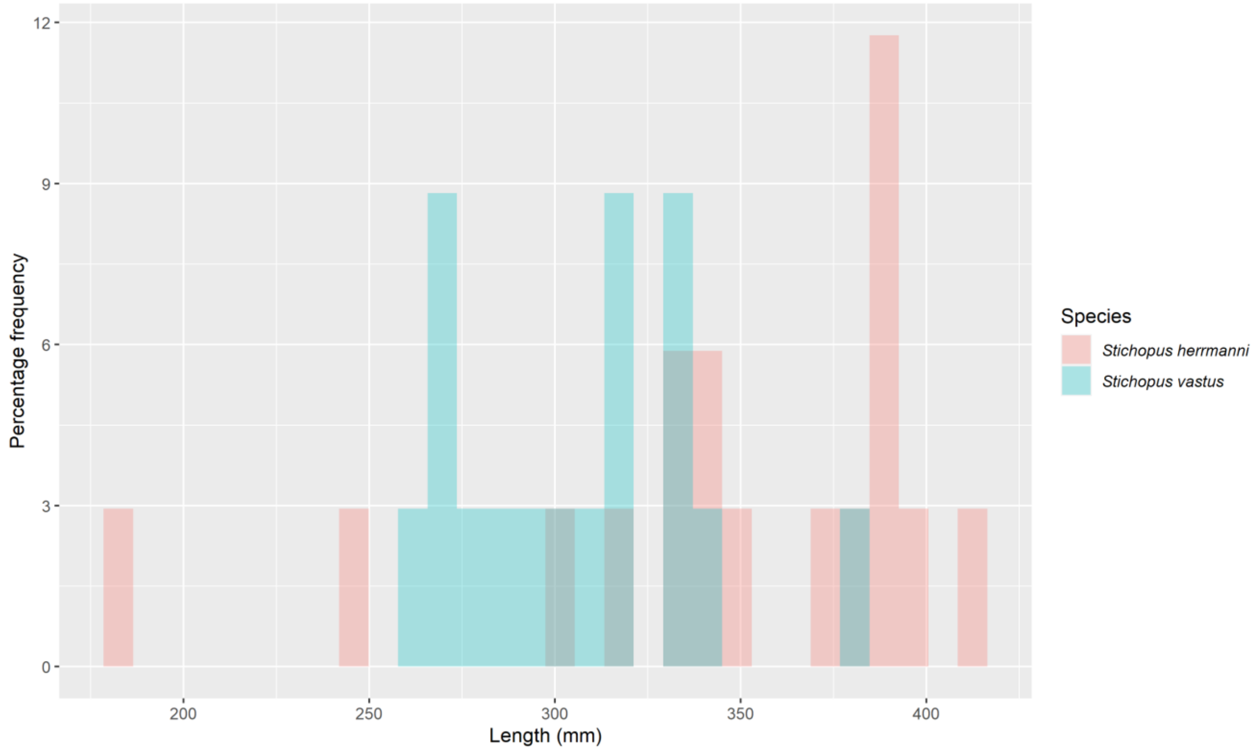


Figure 2-5. Length frequency for *S. herrmanni* and *S. vastus*.

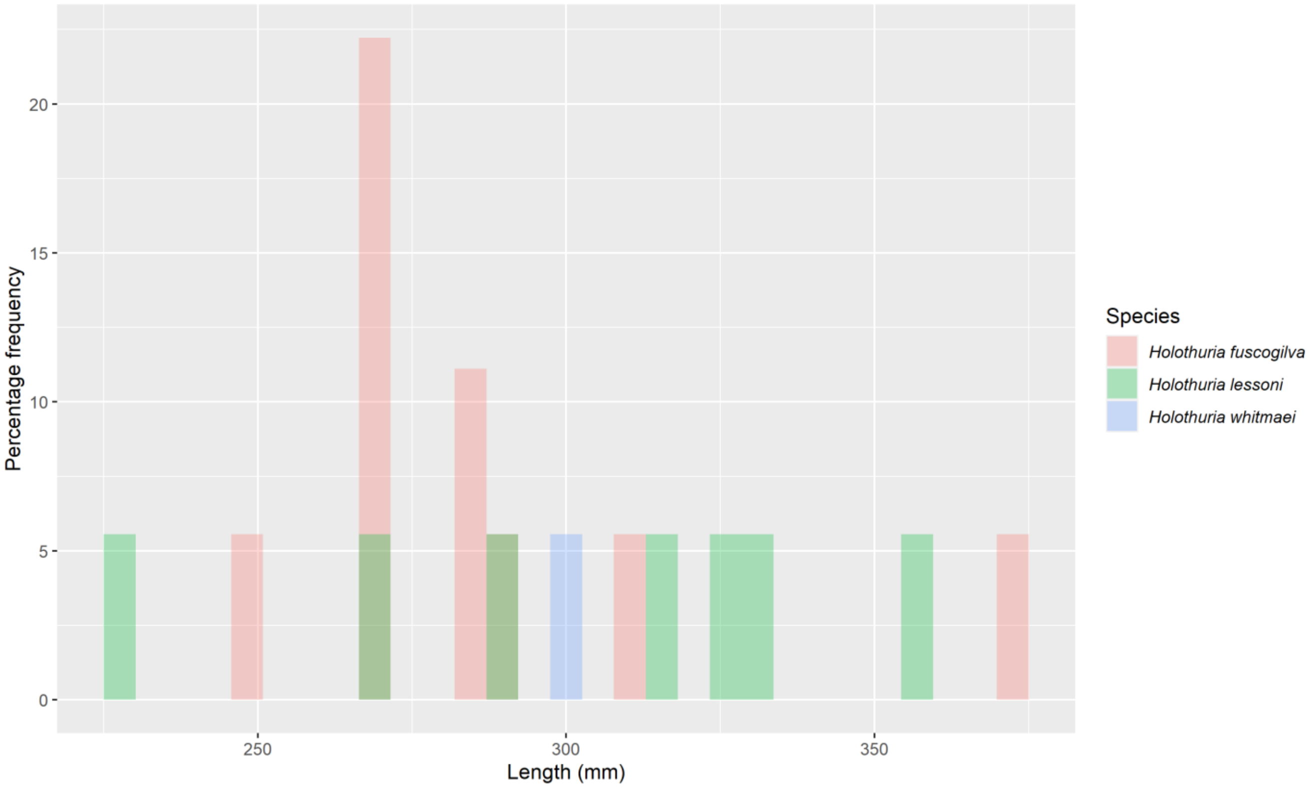


Figure 2-6. Length frequency for H. *fuscogilva*, *H. whitmaei and H. lessoni*.

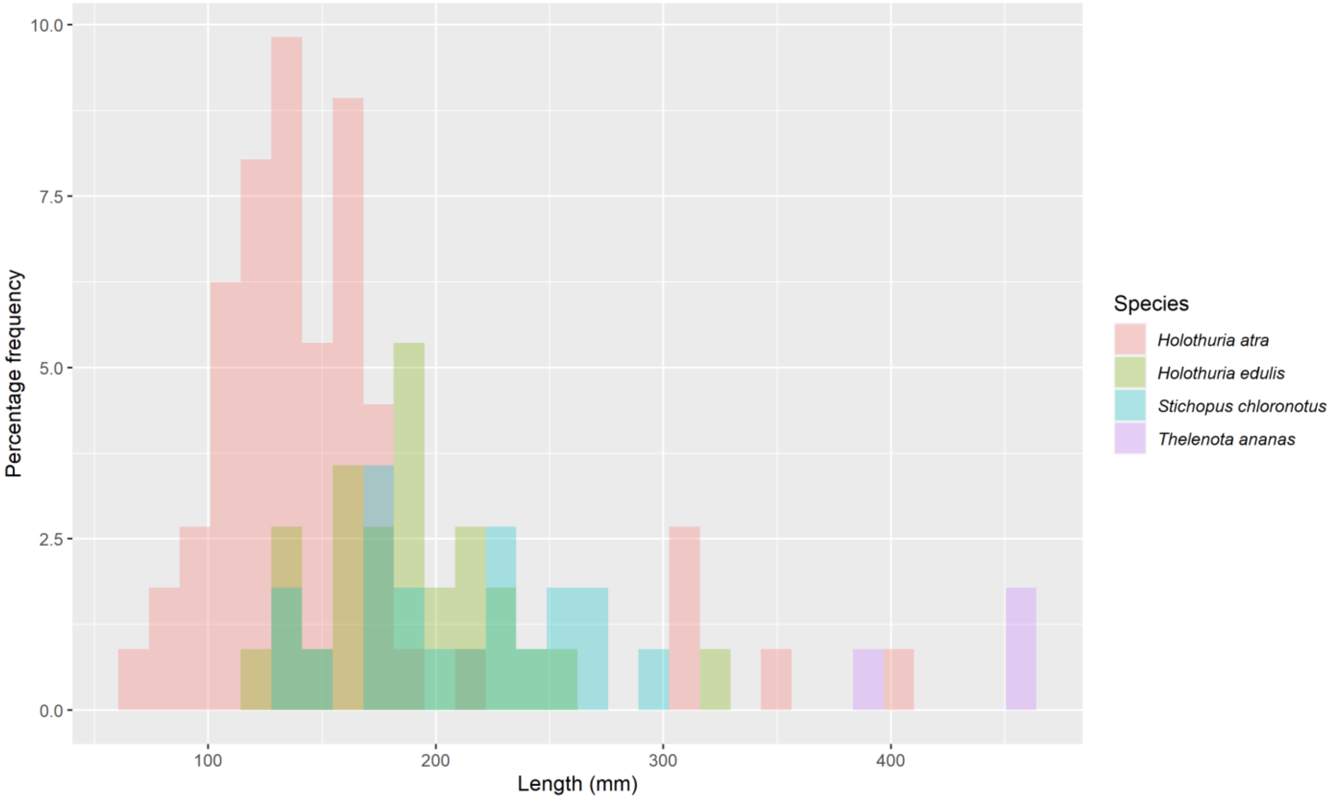


Figure 2-7. Length frequency for *H. atra*, *H. edulis*, *S. chloronotus* and *T. ananas*.

2.3.2 Stratified density - strata

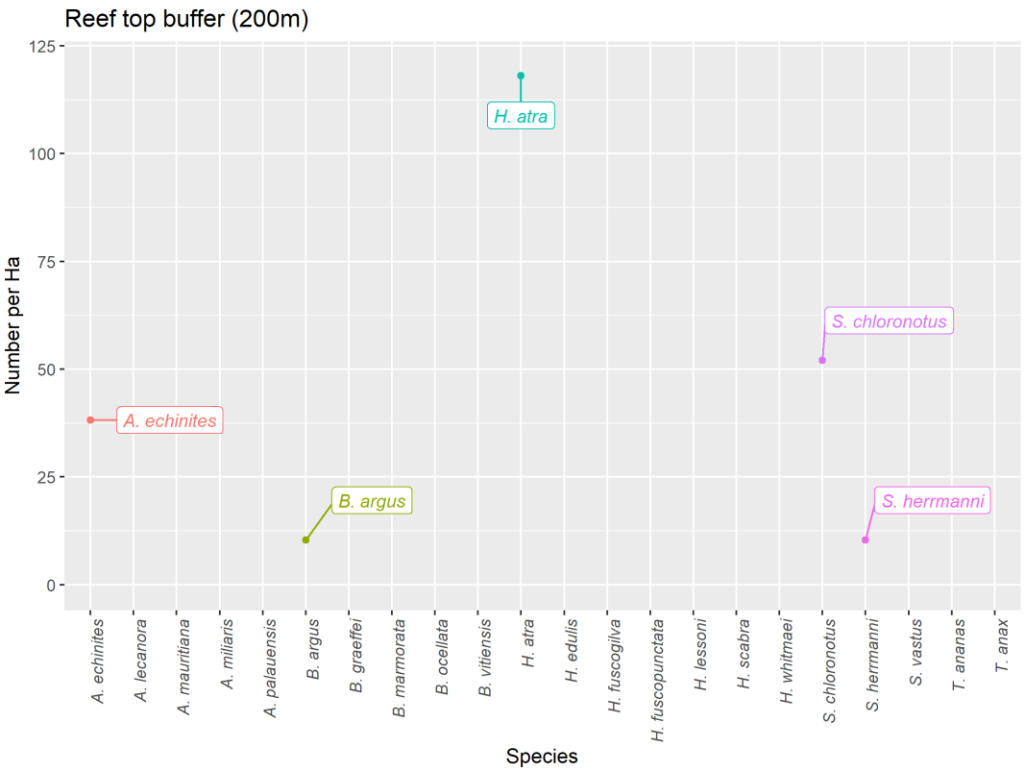


Figure 2-8. Stratified density for reef top buffer.

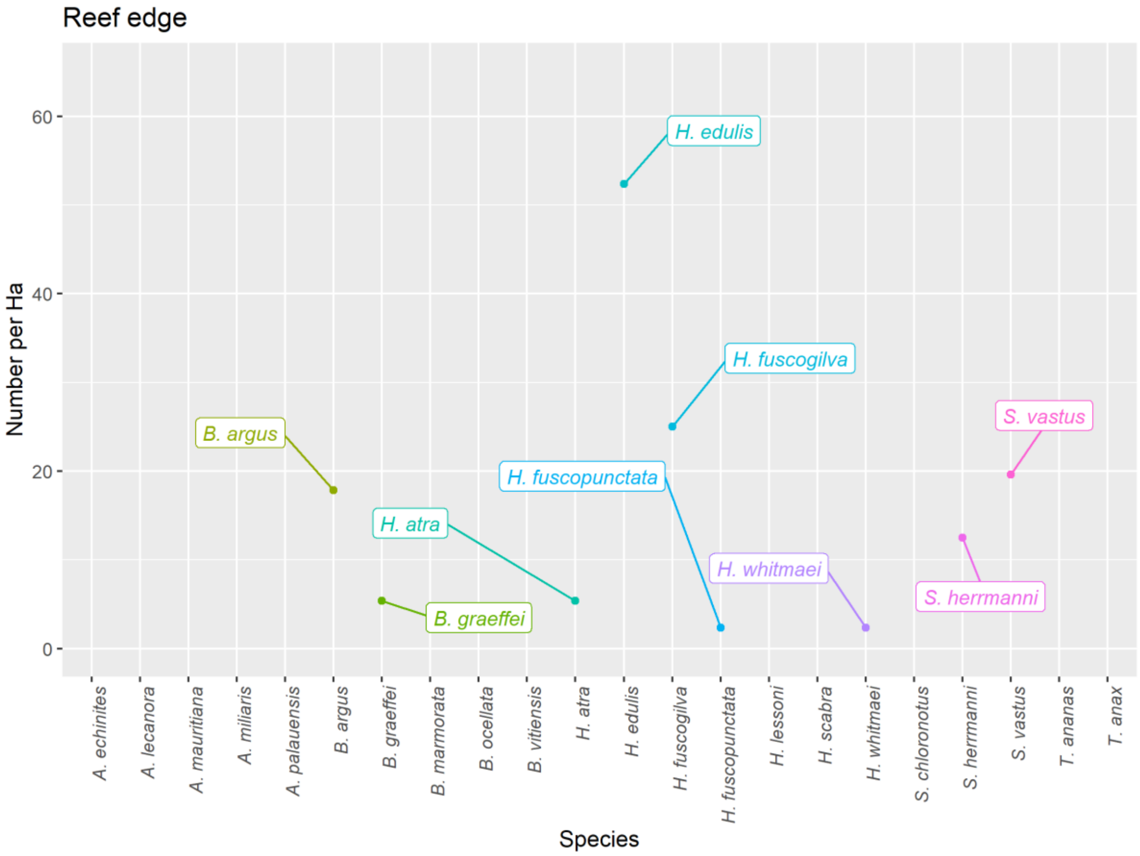


Figure 2-9. Stratified density for reef edge.

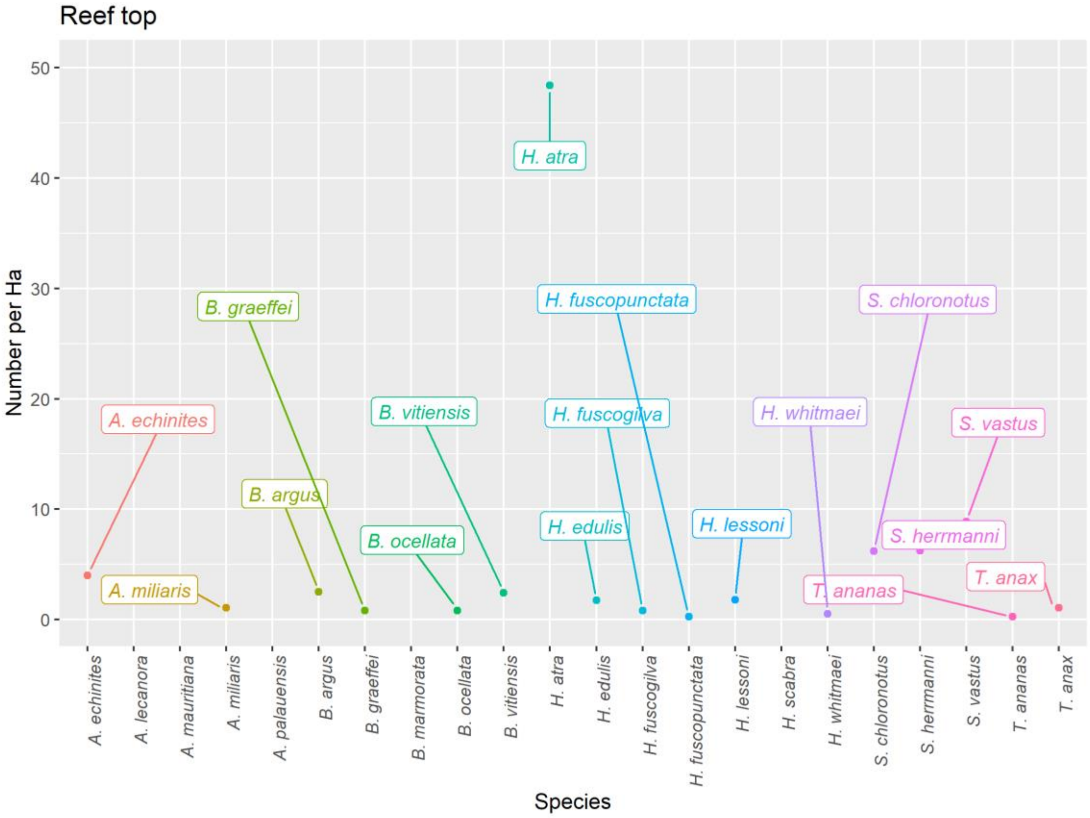


Figure 2-10. Stratified density for reef top.

2.3.3 Substrate

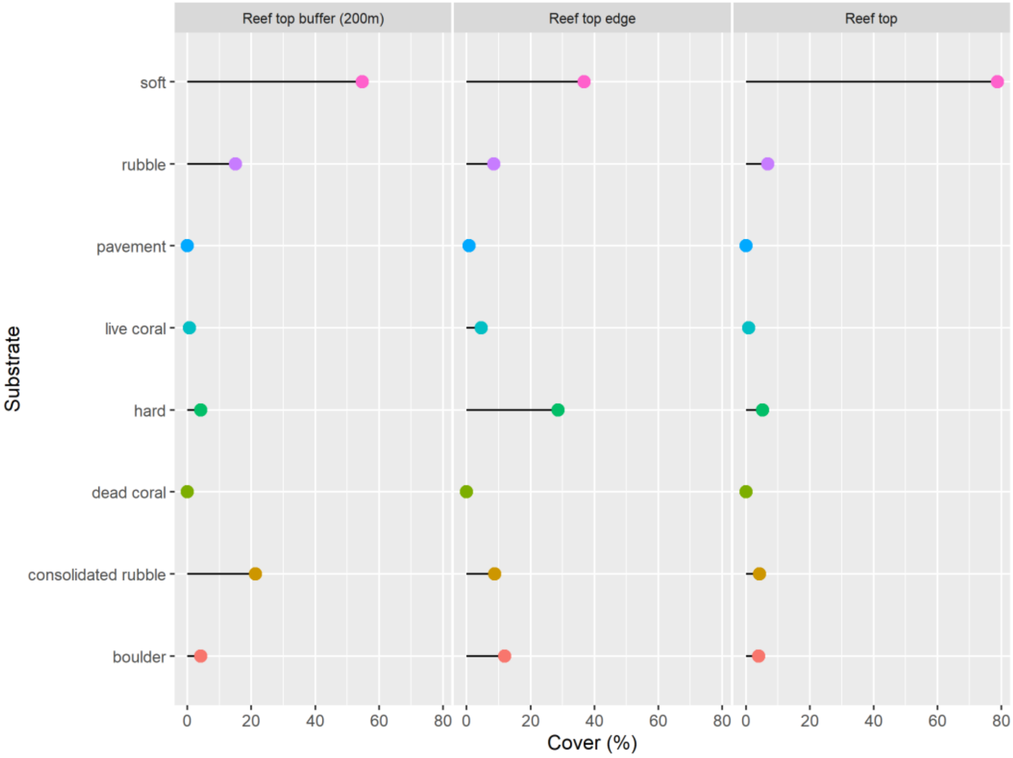


Figure 2-11. Mean percentage cover of substrate for strata.

2.3.4 Biota

Figure 2-12. Proportion of dominant biota for strata.

2.3.5 Seagrass

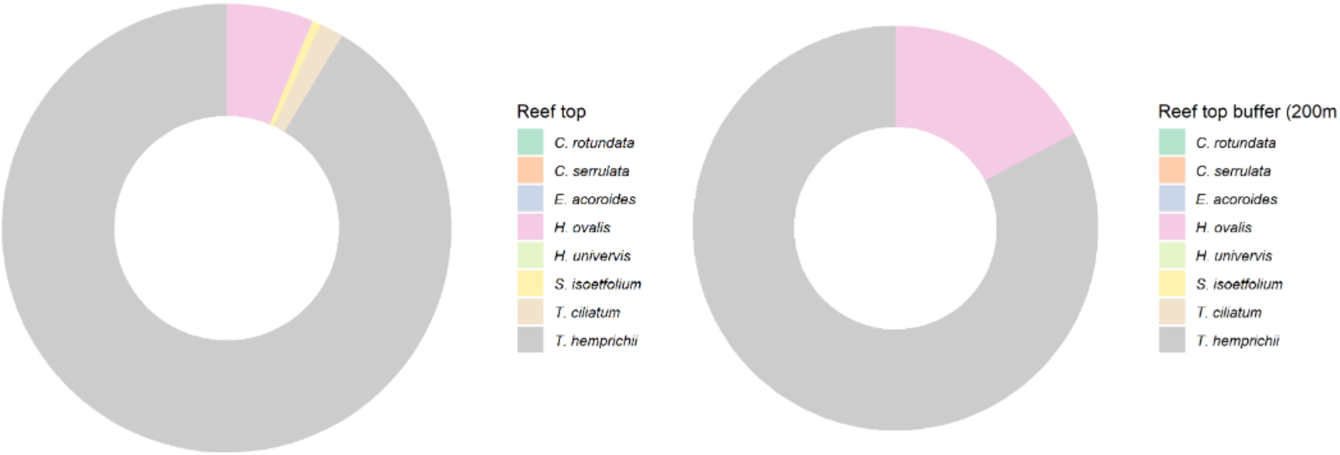


Figure 2-13. Composition of seagrass species for strata.

2.3.6 Algae

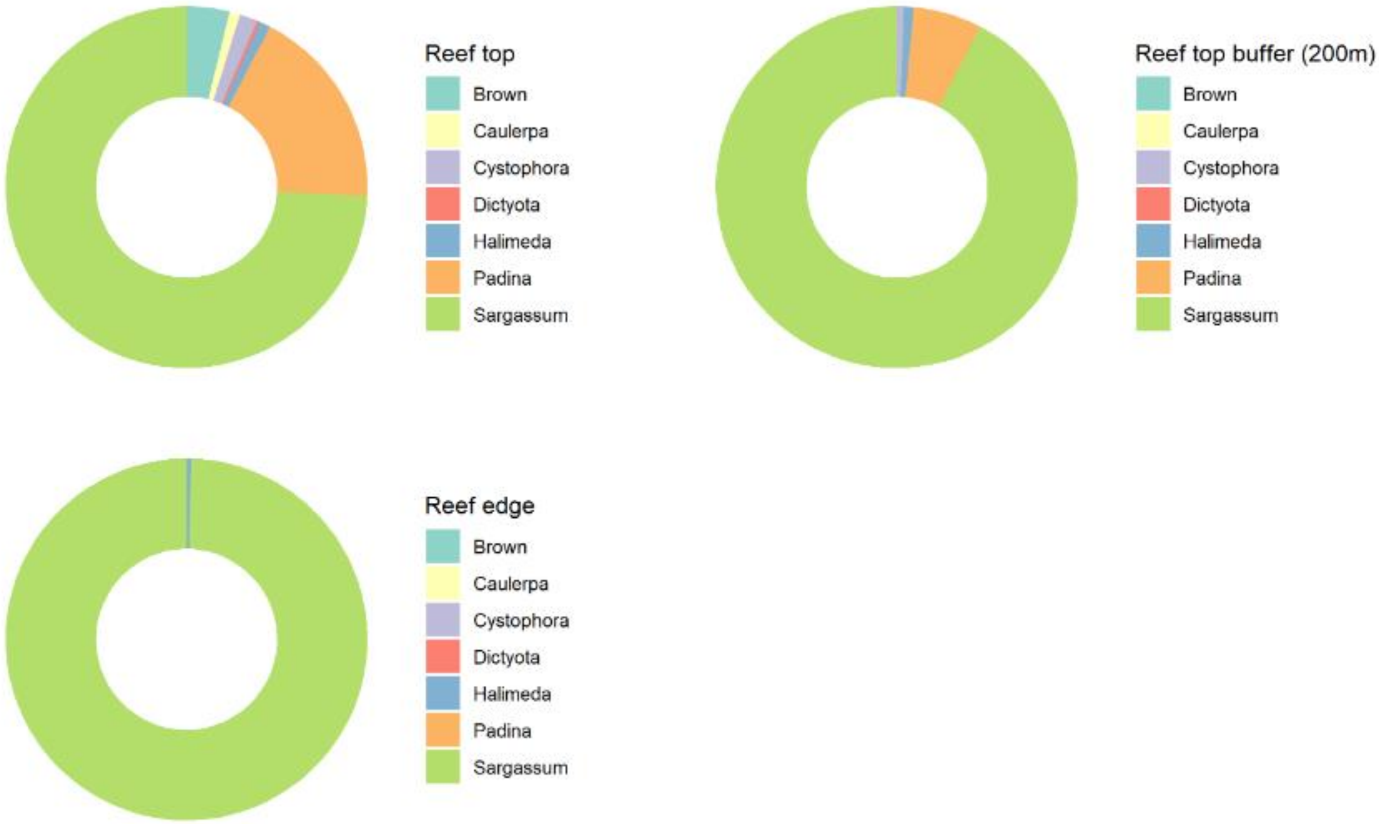


Figure 2-14. Composition of algae species for strata.

2.3.7 Clam

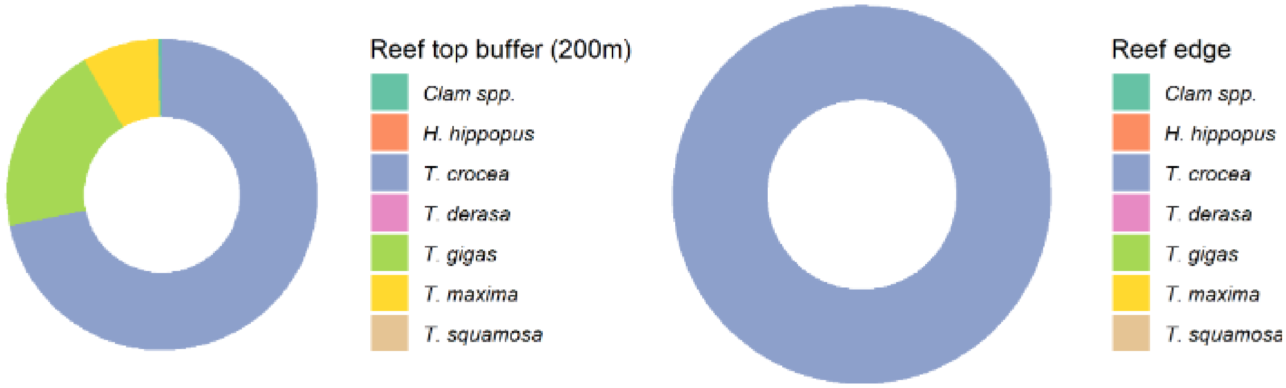


Figure 2-15. Composition of clam species for strata.

3 Key findings – reseeding

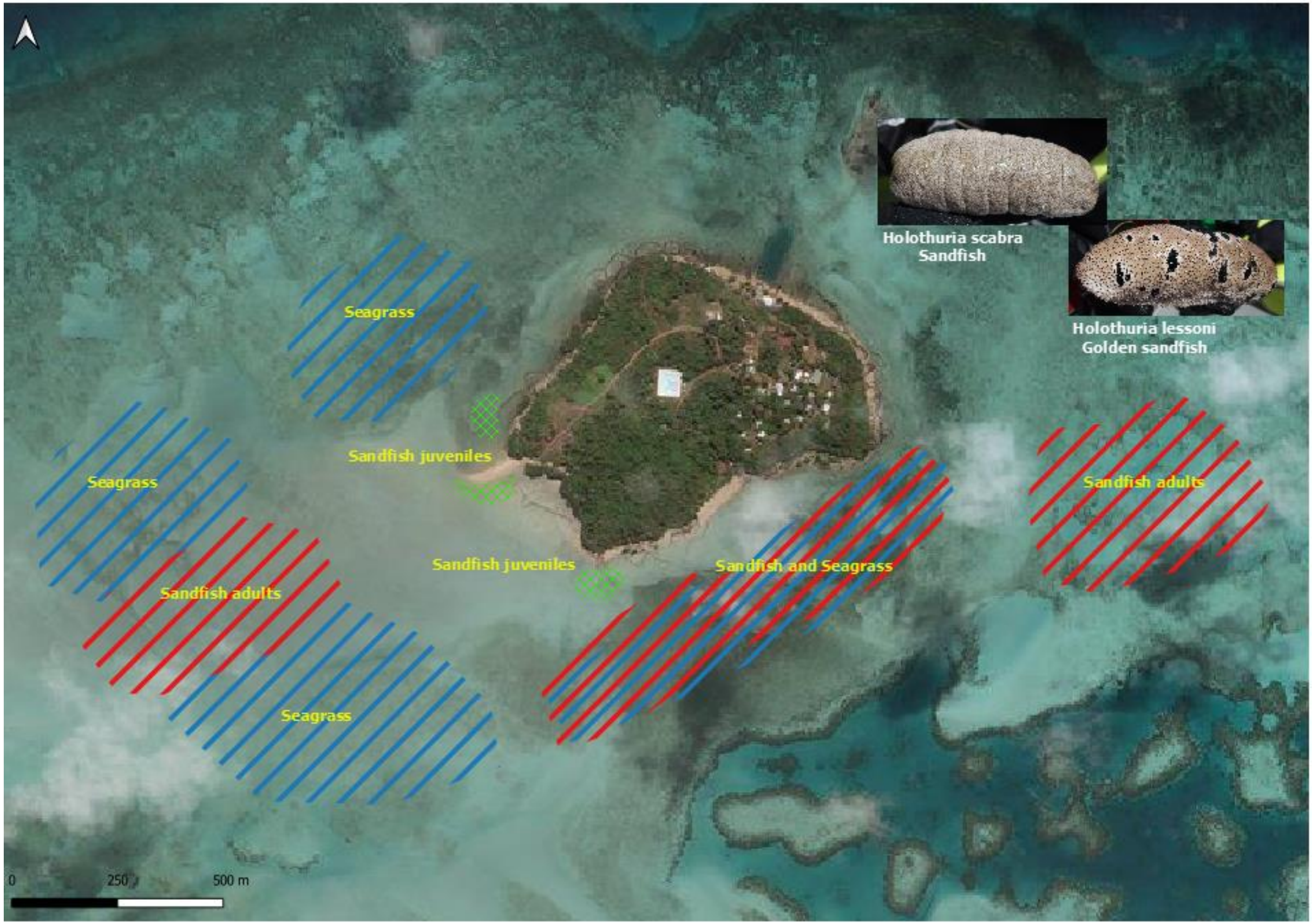


Figure 3-1. Sandfish locations and seagrass areas of interest for Ugar Island.

3.1 Survey notes

- A number of high value commercial sea cucumber species including Teatfish, Curryfish, Sandfish, Redfish, Blackfish and Prickly redfish were found at Ugar and Campbell reefs. Length frequency ranges for species showed sea cucumber populations to be above fishery size limits (Table 3-1).

Table 3-1. Sea cucumber species length frequency range and fishery limits.

Species	Common name	Length frequency (mm)	Size limit (mm)
Holothuria fuscogilva	White teatfish	250-425	320
Holothuria whitmaei	Black teatfish	250-300	250
Stichopus herrmanni	Common Curryfish	185-415	200
Stichopus vastus	Curryfish (vastus)	265-380	200
Holothuria lessoni	Golden sandfish	225-355	220
Holothuria scabra	Sandfish	240	200
Thelenota ananas	Prickly redfish	390-460	350

*Size limits set in The Torres Strait Beche-de-mer Harvest Strategy.

- Adults and juveniles of Sandfish species were identified from the current survey and from discussions with fishers providing photos (Figure 3-1).

- A number of Golden sandfish (*H. lessoni*) were located at an area to the East of Ugar island and were either almost fully or partially buried (Figure 3-1; Figure 3-2).

- One adult Sandfish (*H. scabra*) was found (off transect) at the same location as Golden sandfish (Figure 3-1).

- Golden sandfish (*H. lessoni*) measured during the survey were from various class sizes, suggesting the area provides suitable habitats for both adults and juveniles (Table 3-1).

- The Sandfish site was re-visited at different times of the day to account for sea cucumber burying behaviour, with more observed past early morning.

Figure 3-2. Golden sandfish (*Holothuria lessoni*), partially or almost fully buried.

- A remarkable clam garden was found at Campbell reef with three species of clam recorded - *Tridacna crocea*, *T. maxima* and *T. gigas*. Of note for the Giant clam (*T. gigas*) was the presence of a number of juveniles and adults (Figure 2-3).
- Two Crown-of-thorn seastars (*Acanthaster planci*) were found.
- Live coral looked healthy – no bleaching or disease was seen.
- Larger amounts of soft coral at sites may have resulted from recovery of a previous mortality event (Norstrom et al., 2009) eg. mass bleaching event recorded in 2017; or from elevated inorganic nutrient concentrations (Bednarz et al., 2012), from the possible influence of Fly River waters in the south-east trade wind season every few years for Torres Strait (Waterhouse et al. 2018).

3.2 Conclusions

The field survey of Ugar Island and Campbell Reef quantified the abundance of sea cucumber species and identified a number of habitats supporting high value sea cucumber species. The survey also provided information for clam species, in particular the Giant clam (*T. gigas*), a species of interest to the Ugar community.

The survey data provides essential information for the development of the re-seeding initiative for Ugar island. The data provides evidence of the occurrence of Sandfish species (*H. lessoni* and *H. scabra*) of different class sizes at Ugar, suggesting the habitat is suitable and hence they reproduce and grow in the area. Consequently, there is a strong potential to reproduce and rear these naturally occurring species in a local hatchery. The survey data also show there are suitable habitats to release hatchery-produced sea cucumbers, which supports the development of future aquaculture prospects for the Ugar community.

New understanding for species occurrence and knowledge of ecological systems is also of community benefit for future fishing and for safe-guarding important habitat area.

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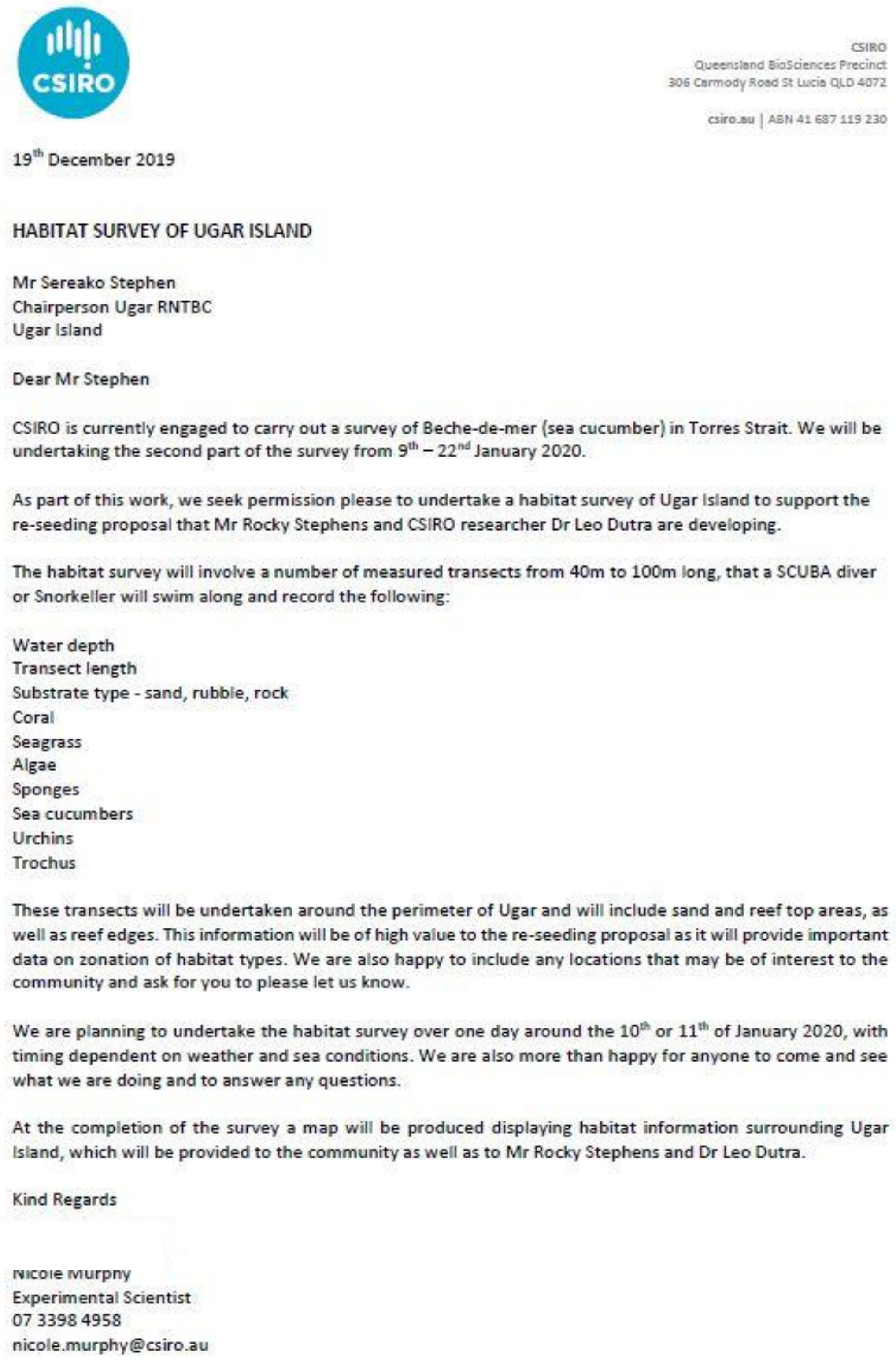
A.1 Community consultation



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19th December 2019

HABITAT SURVEY OF UGAR ISLAND

Mr Sereako Stephen
Chairperson Ugar RNTBC
Ugar Island

Dear Mr Stephen

CSIRO is currently engaged to carry out a survey of Beche-de-mer (sea cucumber) in Torres Strait. We will be undertaking the second part of the survey from 9th – 22nd January 2020.

As part of this work, we seek permission please to undertake a habitat survey of Ugar Island to support the re-seeding proposal that Mr Rocky Stephens and CSIRO researcher Dr Leo Dutra are developing.

The habitat survey will involve a number of measured transects from 40m to 100m long, that a SCUBA diver or Snorkeller will swim along and record the following:

Water depth
Transect length
Substrate type - sand, rubble, rock
Coral
Seagrass
Algae
Sponges
Sea cucumbers
Urchins
Trochus

These transects will be undertaken around the perimeter of Ugar and will include sand and reef top areas, as well as reef edges. This information will be of high value to the re-seeding proposal as it will provide important data on zonation of habitat types. We are also happy to include any locations that may be of interest to the community and ask for you to please let us know.

We are planning to undertake the habitat survey over one day around the 10th or 11th of January 2020, with timing dependent on weather and sea conditions. We are also more than happy for anyone to come and see what we are doing and to answer any questions.

At the completion of the survey a map will be produced displaying habitat information surrounding Ugar Island, which will be provided to the community as well as to Mr Rocky Stephens and Dr Leo Dutra.

Kind Regards

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Experimental Scientist
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