National Research
FLAGSHIPS

CSIRO

www.csiro.au

Torres Strait Hand Collectables, 2009 survey: Sea cucumber

Wealth from Oceans Flagship

FINAL REPORT
March 2010

• Tim Skewes • Nicole Murphy
• Ian McLeod • Elliot Dovers
• Charis Burridge • Wayne Rochester

Australian Government

Torres Strait Regional Authority

Australian Government
Australian Fisheries Management Authority

ACKNOWLEDGEMENTS

This project benefitted greatly from the guidance and input form TSRA and AFMA staff, members of the TS Hand Collectables Working group, and the CFG, PBC and Councillors of the East Torres Strait communities. Traditional Owners from Mer, and Erub Islands also participated in the survey. The final report was improved by review and comments by AFMA and BRS staff. The project was funded by AFMA and CSIRO. We would also like to thank the Captain and crew of the vessels MV San Miguel for their able assistance during the survey.

National Library of Australia Cataloguing-in-Publication entry
Author: Skewes, Timothy.
Title: Torres Strait hand collectables [electronic resource] :
2009 survey and decision support tool / Timothy Skewes, Nicole Murphy.
ISBN: 9781921605338 (pdf)
9781921605321 (pbk)
Notes: Includes index.
Bibliography.
Subjects: Trepang fisheries--Torres Strait.
Trochus shell fisheries--Torres Strait.
Dewey Number: 338.3723960916476

This publication should be cited as:
Skewes, T.D., Murphy, N.E., McLeod, I., Dovers, E., Burridge, C., Rochester, W. 2010. Torres Strait Hand Collectables, 2009 survey: Sea cucumber. CSIRO, Cleveland. 70pp.

Enquiries should be addressed to:

Tim Skewes
P.O. Box 120
Cleveland, 4163
Ph 07 3826 7181

Distribution list

Annabel Jones, Paul Seden AFMA

Copyright and Disclaimer

Important Disclaimer

Contents

List of Figures

List of Tables

PROJECT SUMMARY

Torres Strait has two important Hand Collectable Fisheries – trochus and bêche-de-mer (sea cucumber). They have a modest value, but are potentially an important source of income for local Islander communities, especially for east Torres Strait communities. Both fisheries have been characterised by boom and bust cycles as the result of resource depletion or price fluctuations. The sea cucumber fishery in Torres Strait has recently been in abeyance, caused mostly by the closure of important fishery species, but also due to a low level of ownership of the fishery by Torres Strait Islanders.

Previous research has resulted in the closure of three highly targeted species (Sandfish, Black teatfish and Surf redfish), and catch limits for two other high value species (White teatfish and Prickly redfish). However, the populations had not been assessed since 2005, and given the likely low fishing activity since then; there was a possibility of a recovery for depleted species.

The sea cucumber populations were surveyed at 113 sites in 5 out of 6 zones in east Torres Strait during a 10 day survey in March 2009. Islander trainees participated in the survey at Murray and Darnley Islands. The aim of the survey was to assess the current size and status of sea cucumber stocks, especially focussed on the recovery of closed species, Black teatfish and Surf redfish, and to determine the species split for the Actinopyga clade, with particular emphasis on the Deepwater redfish – Surf redfish split.

Sixteen commercial species were observed during the 2009 survey. The overall average density of commercial holothurians on the reefs of the 2009 study area was 329.1 per Ha (± 144.9, 90 % CI), which equated to a total live wet weight of 18,828 t (+/- 9,014 t, 90% CI). The overall species composition in 2009 was similar to previous surveys. The most abundant commercial species in the study area was the low value Lollyfish (*Holothuria atra*), followed closely by Greenfish (*Stichopus chloronotus*) — together these two species make up 79.1% by number and 50.7% by weight of the commercial sea cucumbers in the study area.

The survey found that the density of Black teatfish had increased significantly since 2005, and was greater than that observed in 1995. Their average size was also the largest of any survey carried in Torres Strait. Comparisons with regional density data indicate that the Black teatfish populations in Torres Strait have recovered to near natural (unfished) densities, and corroborate with islanders reports of a widespread recovery for this species since it was closed in 2003. This is an important example of the recovery of a depleted sea cucumber population, a recovery period of 7 years, and one of the few thus far documented.

Other high value species, White teatfish and Prickly redfish, and an important medium value species, Deepwater redfish, were either at stable or higher densities than in previous surveys, therefore this represents a healthy fishery with the potential to

provide moderate long term income to local Islander communities, provided it is managed carefully.

Surf redfish were still uncommon, however, it is now unlikely that this species was ever a large component of the catch. It is more likely that the Surf redfish reported in the catch was made up of Deepwater redfish and Blackfish. These two later species were observed at moderate but highly variable densities. Their distribution is likely to include Warrior Reef and therefore a full account of these populations cannot be made until Warrior Reef is surveyed in 2010.

We consider that most other species are still at virgin or near virgin biomass levels, however, some may have a relatively low fishery stock biomass, and the status of Brown sandfish (*Bohadschia vitiensis*) is very uncertain due to the burrowing of this species during the day.

We used the density trend and fishery stock estimate data to recommended conservative Torres Strait wide TACs that could be used in conjunction with developing co-management harvest strategies. Re-opening Black teatfish will likely see renewed interest in the fishery. However, the open ended nature of fishing effort (any Torres Strait Islander can theoretically fish the fishery), and the possibility of large pulses in fishing effort due to community interest and momentum partially spurned on by buyer interest, could see at least localised overexploitation of sea cucumber populations.

The introduction of co-management harvest strategies that limit effort pulses, mitigate localised depletion and collect fishery and fishery-independent data should be part of an ongoing harvest strategy. Such strategies could provide the necessary protection to sea cucumber populations.

Management recommendations

1) Total allowable catches (TACs) are recommended for the following highly targeted species. We also recommend that a trigger limit of 5 t per year be implemented for all species that do not have a species specific TAC. Exceeding the trigger limit will result in a review of the catch data for that species, and a recommendation for future exploitation levels and/or data requirements for that species.

Annual TAC recommendations for Torres Strait beche-de-mer species.

Species	Proposed TAC (t)	Current TAC (t)
Black teatfish	25	0
White teatfish	15	15
Prickly redfish	20	20
Deepwater redfish	25	80*
Surf redfish	0	0
Blackfish	5	80*
Other species	80†	80*

* Currently fished as “other species” TAC = 80 t

† But with a 5 t trigger limit that will initiate species review.

2) Produce a suitable species guide to facilitate the collection of accurate fishery catch data.

3) Implement co-management harvest strategies with Island communities that limit effort pulses, mitigate localised depletion and collect fishery and fishery-independent data.

1. BACKGROUND

Torres Strait has two major Hand Collectable Fisheries – trochus and bêche-de-mer (sea cucumber). They have a small combined GVP ($321,000 in 2005) but are an important source of income for local Islander communities, especially for east Torres Strait communities that do not have easy access to the Tropical Rock Lobster Fishery. Both hand collectable fisheries have been characterised by boom and bust cycles as the result of resource depletion or price fluctuations. The small gross value of these fisheries means regular stock assessments are hard to justify and the Torres Strait Islander open access rights and artisanal nature of fishing makes regulatory control very difficult.

Twenty-three commercial sea cucumber species have been recorded in Torres Strait (Appendix A), however, only a small proportion of higher value species have been targeted. The (modern) Torres Strait beche-de-mer fishery began in about 1990. Sandfish (*Holothuria scabra*) on Warrior Reef (Figure 1-1) provided the bulk of the early catches in the fishery, with catches peaking at over 1200 t (wet gutted weight) in 1995, however a survey in 1998 (Skewes *et al.*, 1998) found that the population was severely depleted and the Sandfish fishery was closed. The most recent survey of Sandfish in 2004 found the population was still depleted (Skewes *et al.*, 2006). Subsequent surveys in January 2000 and October 2002 found a small recovery in the population, especially of the breeding cohort, but it was still considered heavily depleted.

After the closure of Sandfish in 1998, the fishery mostly targeted Black teatfish (*H. whitmaei*), "Surf redfish" (now thought to be primarily Deepwater redfish, *Actinopyga echinites*), Blackfish (most likely mostly *A. miliaris*) and White teatfish (*Holothuria fuscogilva*). However, a survey in March 2002 found that Black teatfish and (actual) Surf redfish (*A. mauritiana*) were considered as overexploited (Skewes *et al.*, 2003), and a prohibition on the harvest of these species was introduced in January 2003. Other targeted species, such as Prickly redfish (*Thelenota ananas*) and White teatfish were not considered overexploited at the time, but it was recommended that catch limits be imposed (15 t for White teatfish and 20 t for Prickly redfish) and that the populations be closely monitored. Several other species, mostly of low value but often having a large standing stock, were considered to be at near virgin biomass levels (Skewes *et al.*, 2003).

Subsequent surveys in 2004 (Warrior Reef) and 2005 (east Torres Strait) found that the three closed species, Sandfish, Black teatfish and Surf redfish, had not recovered from their previous low densities (Skewes *et al.*, 2006). Black teatfish was actually less abundant in 2005 than in 2002, and no Surf redfish were observed at all during the 2005 survey. Of the remaining fished species, Prickly redfish and White teatfish showed decreases in average density and/or average size. However, given the likelihood of very low catches since the 2002 survey, the study did not propose any changes to the current TACs (which were considered quite conservative in any case).

Given the elapsed time since the last survey in 2005, and the possibility of a recovery of closed species, a new survey of east Torres Strait was carried in March 2009 to assess the current size and status of sea cucumber stocks, especially focussed on the recovery of closed species, Black teatfish and Surf redfish.

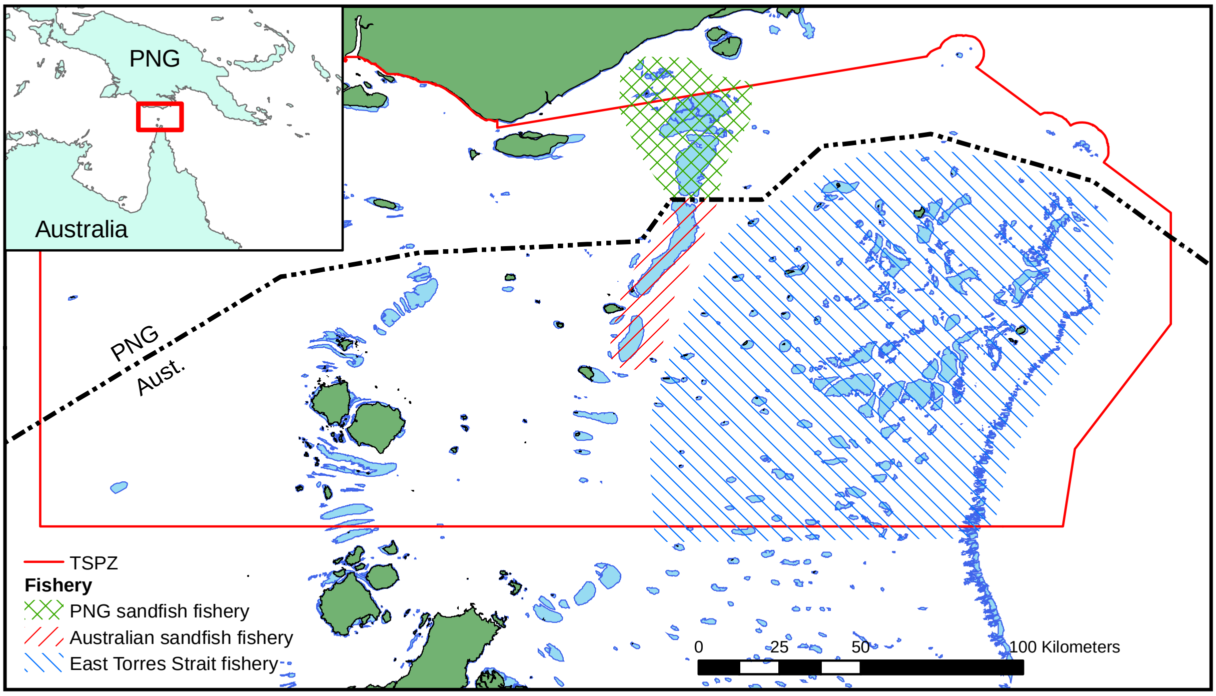


Figure 1-1. Map of Torres Strait showing the approximate location of the three sea cucumber fisheries in Torres Strait mentioned in this report.

1.1 Management arrangements

Sea cucumbers form part of the Torres Strait Hand Collectables Fishery. Management arrangements include: participation limited to Torres Strait Islanders; collection by hand without the use of underwater breathing equipment; competitive TACs (Table 1-1); and size limits (PZJA).

Torres Strait Islander community representatives and AFMA have both expressed a desire to move towards a management system that incorporates both classical modern harvest strategies and traditional fisheries practices and local decision making (Community Based Management). Where appropriate a move towards adaptive co-management would require communities to take some responsibility for issues such as catch monitoring (preferably in a joint system with AFMA which has its own catch reporting requirements), resource stock assessment and resource allocation, that co-exists with-in overall fisheries regulatory mechanism such as total allowable catches or other management initiative such as size limits. This research could assist communities and the PZJA to develop appropriate management strategies within a CBM framework (including TAC etc.).

Table 1-1 Total Allowable Catch (TAC) (wet weight gutted) for sea cucumber species in Torres Strait in from 2003 to 2009.

Species:	TAC
Sandfish	Zero
Black teatfish	Zero
Surf redfish	Zero
Prickly redfish	20 t
White teatfish	15 t
Other sea cucumbers (combined)	80 t

1.2 Indigenous training and community consultation

The project also sought to transfer skills for Torres Strait islanders to carry out monitoring of resources and the environment, and feed appropriate information to Islanders to co-manage their fisheries resources. The project therefore included a training component that involved two indigenous fishers from six Torres Strait Communities and covered fishery surveys and benthic sampling. Trainees attended a workshop which was held over two days on Thursday Island (see separate report, Murphy *et al.*, 2009).

The consultation phase intended to gain an understanding of the needs and opinions of Traditional Property Owners regarding the status and management of the sea cucumber and trochus resources in Torres Strait; to transfer knowledge of past research and get direct input into the survey.

AFMA and the TSRA conducted extensive community consultation regarding this research proposal during 10-13 June 2008. AFMA consulted with community representatives on Murray, Yorke, Yam and Warraber Islands. Fishery representatives from Darnley Island also attended the Murray Island presentation. All community groups expressed in-principle agreement with the proposed research.

Further community consultation was conducted by CSIRO staff prior to field sampling in February 2009. Consultation visits were planned for all communities that had previously expressed support for the project. AFMA staff on Thursday Island were instrumental in planning and liaising with Islander fisheries, local government and native title holder representatives.

2. METHODS

2.1 Study area

The east Torres Strait fishery is a 16,844 km^2 area 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 700 km^2 of shallow reeftop habitat, 504 km^2 of shallow reeftop buffer habitat, and 185 km^2 of reef edge (<20 m deep) habitat, which accounts for about 64 % of all the reefs in Torres Strait (Table 2-1).

Given the large extent of shallow reefs distributed over the area, the study area was divided into 7 zones (Figure 2-1, Table 2-1), which have been used for some years as the basis for the collection of fishery catch data (logbook areas) and are based on available catch information, likely holothurian abundance and physiographic characteristics of the fishery habitats. These zones are very similar to those used in previous studies (Skewes *et al.*, 2006) and formed the basis for the sample design and stratified analysis.

A marine habitat map that delineated shallow reefs was used as the basis for the survey. This was imported into a GIS and the zones superimposed onto the map (Figure 2-1). The Cumberland Passage zone had the highest area of shallow reef in the fishery (35 %) followed by Darnley (22 %). Most other zones had about 10% of the total reef area (Figure 2-1, Table 2-1).

Each zone was further divided into 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 (Table 2-1). During previous surveys the reef top buffer was identified as an area likely to contain higher quantities of targeted species, especially Surf redfish and Black teatfish (Skewes *et al*., 2003).

Table 2-1. Area (km^2) of shallow reeftop, reef top (Top) buffer (Buffer) and reefedge (Edge) habitat in the East Torres Strait study area for each zone.

Zone (km^2)	Top	Buffer	Edge	Non-reef	Total
Barrier	26.00	93.41	42.63	3,629.00	3,791.04
Cumberland Passage	309.39	133.68	46.79	1,471.85	1,961.71
Darnley	161.69	107.03	39.68	2,921.24	3,229.64
Don Cay	52.14	69.37	24.52	1,710.92	1,856.95
Great North East Channel	77.00	50.57	17.16	4,304.71	4,449.44
Seven Reefs	73.84	49.85	13.74	1,418.26	1,555.69
Total	700.05	503.91	184.53	15,455.99	16,844.48

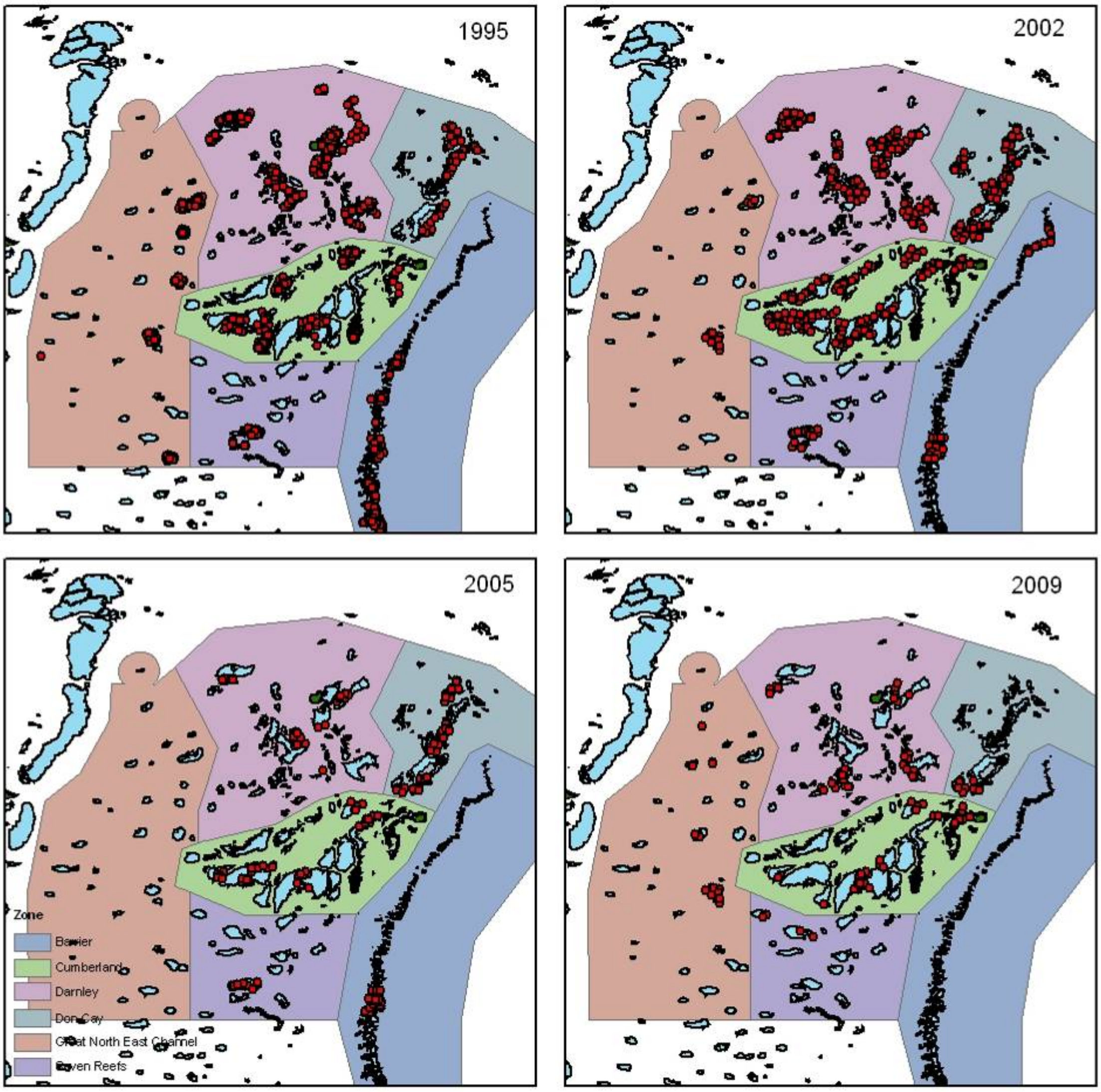


Figure 2-1 Sample sites sampled in 1995/96, 2002, 2005 and March 2009 with fishery zones and shallow reefs delineated.

2.2 Sample design

The selection of sample sites for the survey was based on four considerations: 1) logistic constraints with respect to the amount of sampling that could be done in one day from the support vessel; 2) exclusion of sites with unsuitable habitat sites (eg. >80% sand) were not included as they were unlikely contain high value species 3) optimal allocation of sampling effort to the habitat strata based on the density of closed species (Black teatfish and Surf redfish) and trochus, and 4) areas identified by traditional inhabitants as being worthy of inclusion.

The 2009 survey was an abbreviated survey that concentrated on the Black teatfish habitats in particular. This followed from an abbreviated survey in 2005 (Skewes *et al.*, 2006) and two full scale surveys in 1995/96 (Long *et al.*, 1996) and 2002 (Skewes *et* *al.*, 2003). As a result of the sample design criteria and logistic constraints, we were able to survey 113 sites including 44 reef edge and 69 reef top sites (Figure 2-1, Table 2-2). Of these sites, 111 have been visited in previous surveys, allowing for repeated measures that will give power to statistical analyses of abundance and size.

A lower number of sites were sampled in comparison to previous surveys due to time spent visiting the Torres Strait Islands of Mer and Erub to pick up workshop participants to participate in local sampling and to further interact with community representatives.

Table 2-2 Sample coverage for the four surveys of East Torres Strait sea cucumber habitats.

Year	N	Zones	Area (Ha)
1995	844	6	138849.4
2002	434	6	138849.4
2005	129	4	121777.3
2009	113	4	110276.3

2.3 Fieldwork

The east Torres Strait fishery was surveyed over a 10 day period from the 19 to 28 March 2009, following the trochus and bêche-de-mer survey training workshop (17-18 March) (Murphy *et al.*, 2009). The timing of the survey was planned to coincide with the seasonal timing of previous surveys undertaken in 2002 and 2005 in order to reduce differences in survey observer rates resulting from changes in sea cucumber burrowing behaviour, caused by seasonal and tidal factors.

Some participants of the workshop (Mer and Erub Islands) also assisted CSIRO researchers during the subsequent survey. Sampling was conducted from the vessel ‘San Miguel’.

Rapid marine assessment techniques developed, improved and applied by CSIRO for reef resource and habitat surveys in several areas of Australia, Papua New Guinea and the Seychelles were used Skewes et al, 2001; Leeworthy and Skewes 2009).

Field work was undertaken by a small 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 and recorded resource and habitat information 1-2m either side of the transect line. On the reef edge, a diver swam along a measured length transect between 1m and 15m water depth. Sea cucumbers, trochus and other benthic fauna of commercial or ecological interest were counted and where possible, returned to the dinghy where total length was measured before being returned to the water.

At each site, 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 seagrass and algae were also recorded.

2.4 Data analysis

Transect and sample data collected during the field survey was entered into an Access database on board the vessel to reduce transcription errors and clarify uncertainties. Once back at the laboratory in Cleveland, the database was imported into a centralised Oracle database for analysis and long term storage. We also took the opportunity to import all previous survey data into the same database, including data from the original 1995/96 reef resource inventory (Long *et al.*, 1996), much of which had to be imported from excel tables and even original datasheets.

Area estimates of the reef top strata for each zone were output from the GIS based on a spatial join of the satellite derived habitat map and zone map. Area of the reef edge habitat for each zone was derived from an edge length statistic of the shallow reef habitat output from the GIS and the average edge width (to 20 m depth) from the field survey data. Edge lengths for each zone were calculated by densifying the outline of the shallow reef habitats with nodal distance set to 150 m. Topology was then used to limit the selected nodes to: those not adjacent to land or other reef polygons. The number of selected nodes were then counted for each strata and zone, and multiplied by 150 m to produce total edge length.

Estimates of mean density (count per hectare) were derived using a stratified analysis of transect counts based on 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. The combination of some small within stratum sample sizes; zero-inflation of 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. This was used to produce bootstrapped distributions for the estimates of mean density. Confidence intervals are simply set as the quantile corresponding to the desired percentile of the distribution. Smith (1997) suggests that these so-called percentile limits out perform bias corrected and accelerated confidence limits in trawl survey data – similar in nature (specifically those attributes mentioned previously) to that of the current study.

Though the survey was only designed as a relative density survey, we were still able to produce estimates of population standing stock for the 2009 survey zones, which, at 110,276 Ha, is about 80% of the total reef area in east Torres Strait. Population stock estimates were calculated as the product of estimates of density, reef area and average weight from size frequency data collected during the survey. As the fishery catch in Torres Strait is recorded as (mostly) landed (gutted) weight (Kung, 2002), we converted this estimate to landed (gutted) weight (referred to as fishery stock estimate) for comparison to catch data and to assist to formulate TAC recommendations, using conversion factors for each species from fishery derived information from Torres Strait and the GBR (Skewes *et al.*, 2004), or from the literature (Purcell *et al.*, 2009). We also calculated the bottom 90th percentile of the bootstrapped mean estimate distribution (this assumes that the real estimate would be 90% certain of being greater than this value) as a conservative stock estimate for formulating TAC recommendations. While this data is useful for formulating TAC recommendations, it is not suitable for direct comparison with previous years sea cucumber biomass estimates due to the restricted coverage of the 2009 survey.

For investigating trends in species density, we compared survey sites within each zones and strata that were sampled in all comparison years only. For all surveys since 1995, only three zones were sampled consistently: Cumberland, Darnley and Don Cay zones. Four zones were consistently sampled in 1995, 2002 and 2009: Cumberland, Darnley, Don Cay and Great North East Channel.

We produced the following outputs from the data analysis:

1. Stratified mean densities and population estimates for 2009 for the areas surveyed and the bottom 90th percentile of the bootstrapped mean estimate distribution. This data is suitable for calculating standing stock estimates for the surveyed areas, but not for direct comparison between years.

2. Comparative average density data for between year comparisons using the three zones that have data for each sample year. This includes the Cumberland, Darnley and Don Cay zones and will be suitable for most of the species, especially Black teatfish.

3. Comparative average density data for between year comparisons using four zones that have data for 1995, 2002 and 2009 each sample year. This includes the Cumberland, Darnley, Don Cay and Great North East Channel zones and is most suitable for species that are mainly found in the GNEC strata, such as Deepwater redfish (*Actinopyga echinites*).

For the later two outputs, mirror-match bootstrapping was also used to construct sampling distributions for the difference in stratified means between pairwise combinations of years. By examining confidence intervals (1-α) derived from these bootstrapped distributions – particularly their zero coverage - we assessed whether significant changes in density had occurred between years (with test size α). This type of test is preferable to standard parametric tests due to the zero-inflation of counts and the skew and nonconformity of the distribution of observed densities.

A further modification to the comparative data analysis occurred due to our inability to sample the northern section of the Don Cay zone (Figure 2-1). This zone has historically contained high densities of White teatfish (Figure 2-2) and Prickly redfish so our comparison would have been confounded by this. Subsequently, we divided the Done Cay zone into a northern and southern section and used only the estimates from the southern section for our comparative analysis.

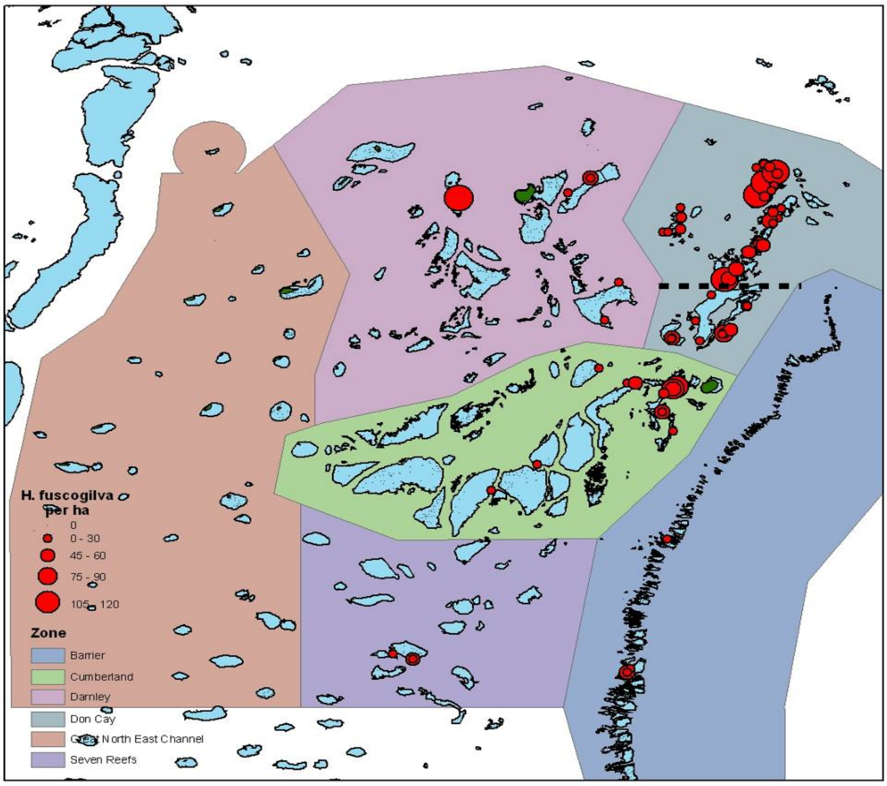


Figure 2-2 Density of White teatfish, *Holothuria fuscogilva*, for all survey years. Also shown is the dividing line for analysis of the Don Cay strata.

2.5 Redfish species split

The taxonomy of Actinopyga species that make up the redfish/blackfish group is poorly resolved. Surf redfish (*Actinopyga mauritiana*) and Deepwater redfish (*A. echinites)* have most likely been combined as redfish in the historical catch records, and early surveys may have made the same error. This is partly due to Torres Strait Surf redfish being the all red form (Appendix G).

There are at least three species of Blackfish now recognised by most holothurian taxonomists; *Actinopyga miliaris*, *A spinea* and *A. palauensis*, though a definitive description of the group is yet to be completed. Previous surveys have not distinguished these species adequately, and the species split information is essential for sustainable harvest strategies.

During the 2009 survey, we used improved diagnostics to determine the species split for the Actinopyga clade, with particular emphasis on the Deepwater redfish (*A. echinites*) – Surf redfish (*A. mauritiana*) split. We also endeavoured to distinguish the several species of Black fish. Our survey included a large sampling exercise on Campbell Islet, a place where we have seen large densities of “redfish” in the past.

3. RESULTS

3.1 Survey density and stock estimates

Sixteen commercial species were observed during the 2009 survey (Figure 3-1, Table 3-1), out of potentially 23 species observed in all Torres Strait in all surveys (Appendix A). One non-commercial species, *Holothuria leucospilota*, was also recorded. The overall average density of commercial holothurians on the reefs of the 2009 study area was 329.1 per Ha (± 144.9, 90 % CI), which equated to a total live wet weight of 18,828 t (+/- 9,014 t, 90% CI) (Table 3-1).

The most abundant commercial species in the study area was the low value Lollyfish (*Holothuria atra*) with an average density of 136.9 per ha and an estimated standing stock of 5,879 t (± 2250 t, 90 % CI), followed closely by Greenfish (*Stichopus chloronotus*) with an average density of 123.3 per ha and an estimated standing stock of 3,662 t (± 1627 t, 90 % CI) (Figure 3-1, Table 3-1). Together these two species make up 79.1% by number and 50.7% by weight of the commercial sea cucumbers in the study area. Other significant species by weight were Leopardfish (*Bohadschia argus*) (14% of total standing stock), Black teatfish (*H. whitmaei*) (10.3%) and Curryfish (*S. herrmanni*) (10%).

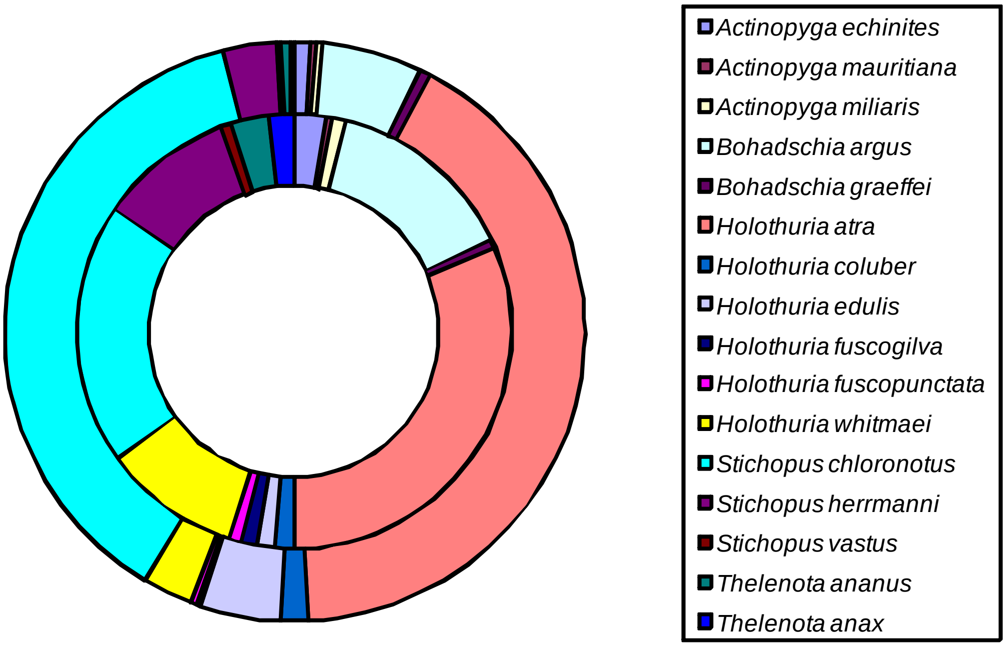


Figure 3-1. Multiple pie chart showing species composition of the commercial Holothurian population sampled in the study area by density (no per ha, outer ring) and wet weight (inner ring).

Table 3-1. For each species, the average density, s.e., bootstrapped lower 90th percentile, population stock estimate and lower 90th percentile of the stock estimate for the sampled strata (110,276 Ha) during the 2009 survey in whole live weight, and landed (wet gutted) weight (fishery biomass, B) (N = 113).

Species	Density (/Ha)	s.e.	L90th (/Ha)	Stock n	Stock (t)	B (t)	Stock (t) L90th	B (t) L90th
Actinopyga echinites	2.92	1.76	0.73	321904	441.4	305.4	110.1	76.2
Actinopyga mauritiana	0.98	0.98	0.00	108617	88.8	48.3	0.0	0.0
Actinopyga miliaris	1.23	1.23	0.00	135843	189.8	91.1	0.0	0.0
Bohadschia argus	18.26	4.55	12.41	2013291	2686.5	1461.5	1826.5	993.6
Bohadschia graeffei	1.94	1.22	0.47	213848	125.4	68.2	30.4	16.6
Holothuria atra	136.85	38.66	84.49	15091124	5879.3	3198.3	3629.9	1974.7
Holothuria coluber	4.88	2.84	0.77	538049	261.0	142.0	41.4	22.5
Holothuria edulis	14.92	3.96	9.87	1645218	246.2	133.9	162.9	88.6
Holothuria fuscogilva	0.73	0.37	0.27	80662	220.7	110.3	80.0	40.0
Holothuria fuscopunctata	0.89	0.48	0.27	97863	182.3	99.2	54.5	29.6
Holothuria whitmaei	9.26	5.15	2.99	1021372	1936.2	1225.6	624.5	395.3
Stichopus chloronotus	123.28	43.47	65.81	13594320	3662.5	1992.4	1955.1	1063.6
Stichopus herrmanni	9.70	3.34	5.31	1070199	1886.3	1026.1	1032.5	561.7
Stichopus vastus	0.80	0.49	0.19	88454	155.9	84.8	37.8	20.6
Thelenota ananus	1.70	1.24	0.13	188019	528.6	308.2	39.9	23.2
Thelenota anax	0.77	0.28	0.43	84372	337.3	183.5	188.3	102.4

3.2 Sea cucumber relative density

Relative density estimates for the repeated zones showed that the overall species composition in 2009 was similar to previous surveys in both the 3 zone, 4 year (Figure 3-2) and 4 zone, 3 year (Figure 3-4) analysis. Again in 2009, the population was dominated by Lollyfish (*Holothuria atra)* and Greenfish (*Stichopus chloronotus)* which made up over 80% of commercial species by number (Figure 3-2, Figure 3-4, Appendix B, C). However, there were some differences observed. *S. chloronotus* was at much higher densities than previous years (134 per Ha c.f. ~30-40 per Ha), though other Stichopids (*S. herrmanni* and *S. vastus*) were lower. *Holothuria coluber*, which was at very high densities in 2005, probably due to spawning behaviour (Skewes et al., 2006) was at lower densities in 2009 but similar to densities previous in 1995 and 2002.

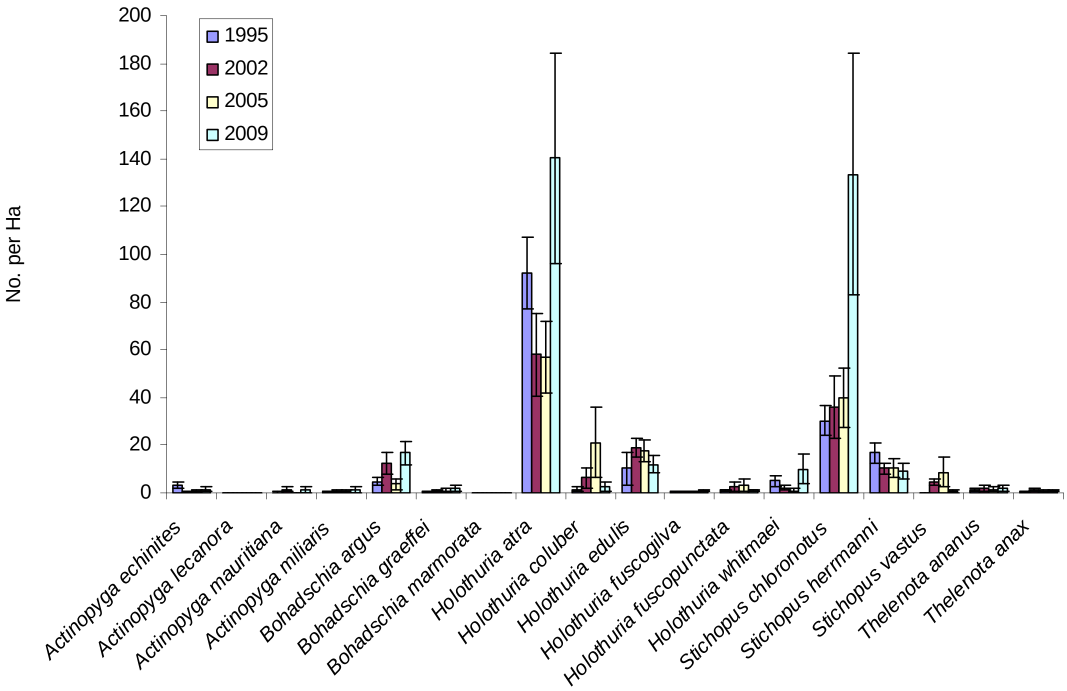


Figure 3-2 Density (stratified) estimates for commercial sea cucumber species found at sites within 3 common zones (Cumberland Passage, Don cay and Darnley) for 4 survey years (error bars are s.e.).

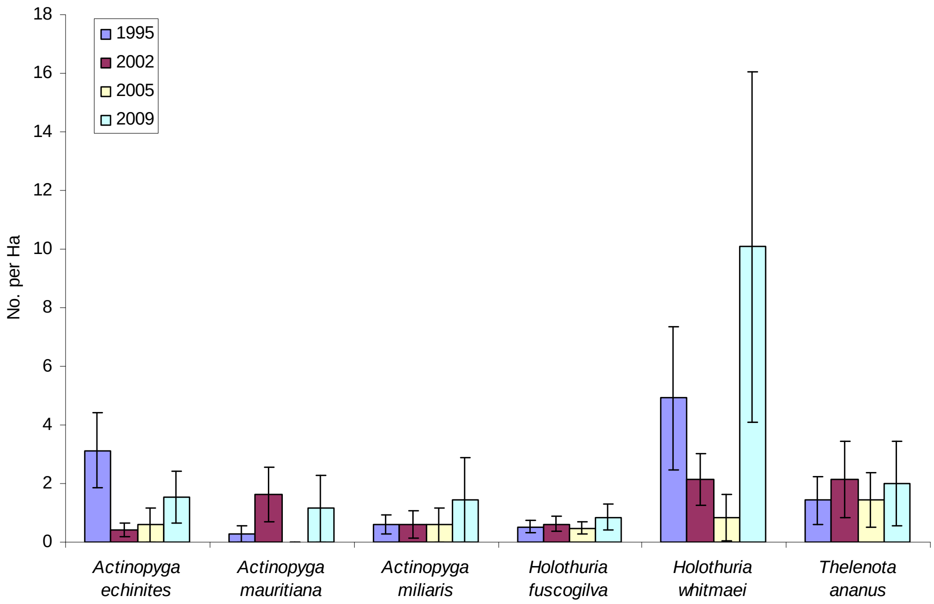


Figure 3-3 Density (stratified) estimates for high priority commercial sea cucumber species found at sites within 3 common zones (Cumberland Passage, Don cay and Darnley) for 4 survey years (error bars are s.e.).

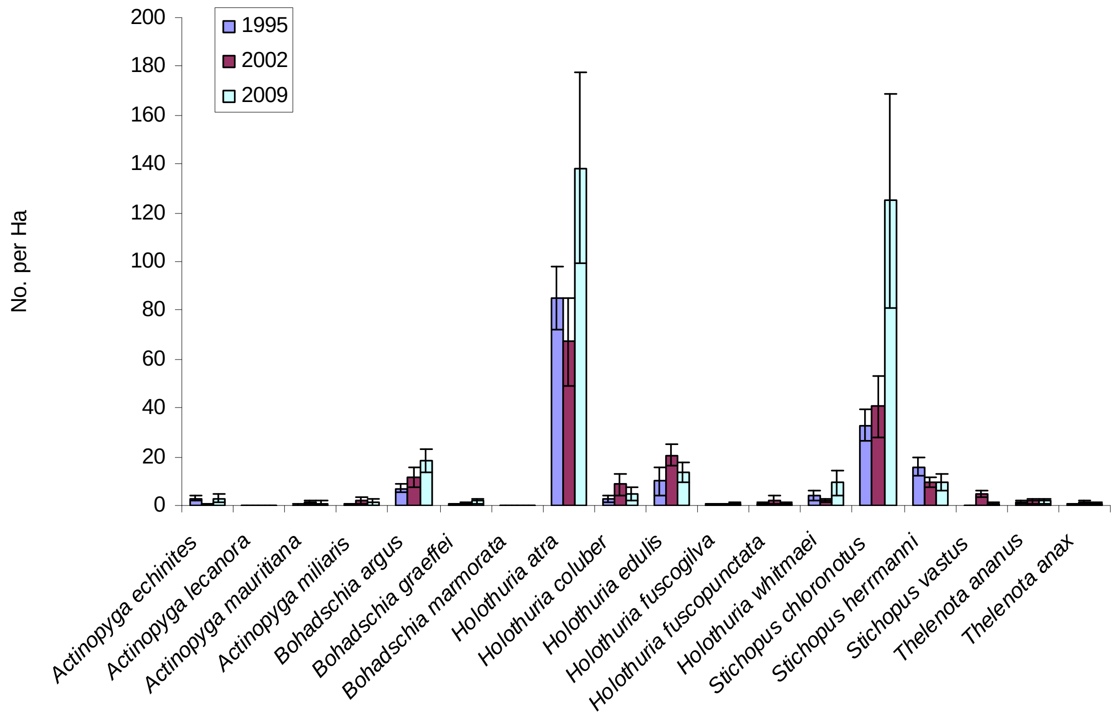


Figure 3-4 Density (stratified) estimates for commercial sea cucumber species found at sites within 4 common zones (Cumberland Passage, Don Cay, Darnley and GNEC) for 3 survey years (error bars are s.e.).

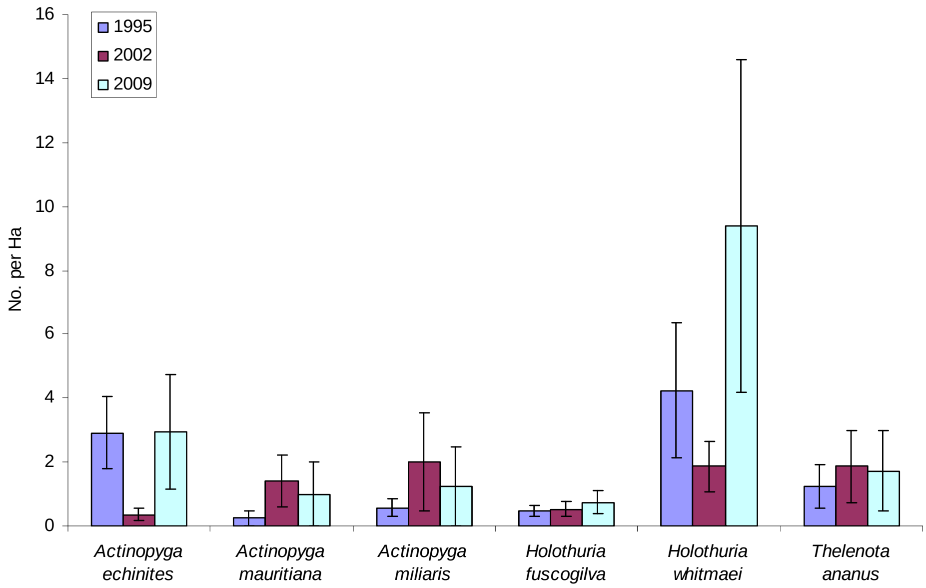


Figure 3-5 Density (stratified) estimates for high priority commercial sea cucumber species found at sites within 4 common zones (Cumberland Passage, Don Cay, Darnley and GNEC) for 3 survey years (error bars are s.e.).

3.3 Stock status

3.3.1 *Holothuria whitmaei* (Black teatfish)

The density of *Holothuria whitmaei* (Black teatfish) increased markedly since the last survey in 2005, and was approximately double that observed on the first survey in 1995 (Figure 3-6, Appendix B, C). Most of the increase was in the Cumberland strata (Figure 3-7), an area that had been heavily depleted during intense fishing pressure for Black teafish in the early 1990s (Kung, 2002; *pers. obs.*).

The average size, both in length and weight, of Black teatfish observed during the survey was also larger than previous surveys (Figure 3-8, Appendix D), with an increase of almost 7% in average length (P<0.05) and over 11 % by weight from 2005 (P<0.01).

This would appear to indicate a recovery of the previously depleted Black teatfish population in east Torres Strait. The population has been closed since January 2003, and there is low likelihood of illegal or unreported fishing on this population due to the low overall activity in the fishery and the distance from PNG communities (illegal fishing activities are generally restricted to Warrior Reef; AFMA *pers. comm.*).

The fishery stock estimate from area sampled during the 2009 survey amounted to 1,226 t landed weight, with a lower 90^{th} percentile of the bootstrapped probability distribution of 395 t (Table 3-1). This stock estimate does not include the Barrier zone which was not sampled in 2009 and has been previously shown to contain high densities and a significant proportion (26%) of Black teatfish during the 2002 full scale survey (Skewes *et al.*, 2003).

Assuming a recovery in the Black teatfish population, we need to try and determine the population status with respect to the carrying capacity (at virgin biomass) and make a recommendation for sustainable harvest. This is a difficult question and is not made any easier by the fact that unexploited Black teatfish populations have not been surveyed in a “whole of reef area” basis for comparison with our data. However, a review of survey data from throughout the west Pacific has concluded that densities above 12.5 per Ha represent a “natural density” in “suitable habitat” (Kinch *et al.*, 2008). Surveys from the GBR produced estimates of Black teatfish in the “main habitat” on the reef flat on closed reefs at 20.88 individuals/ha (n=6, 95% confidence interval [CI] = 16.3–25.73; Uthicke and Benzie, 2000). This compares to our overall average of about 10 per Ha for the 2009 analysis. However, our density is for the entire reef — if we restrict the sites sampled to <60% sand (i.e. to simulate good Black teatfish habitat), then the estimate increases to 16.81 per Ha, and for < 20% sand, 20.03 per Ha, though with large standard errors. These comparisons indicate that the Black teatfish populations in Torres Strait have recovered to near natural (unfished) densities.

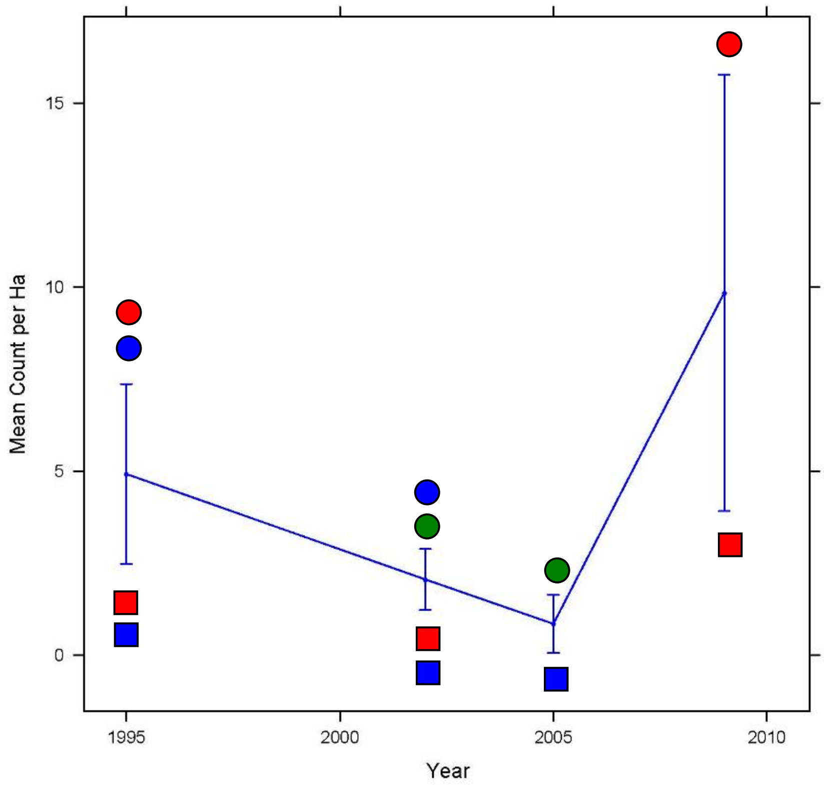


Figure 3-6 Stratified density of *Holothuria whitmaei* (Black teatfish) in repeated strata (Cumberland's, Don Cay and Darnley) for four survey years. Colours denote statistical groupings; circles (*P*<0.10), squares (*P*<0.05) (Error bars are bootstrapped 95% CI).

This apparent recovery should allow for the Black teatfish fishery to be reopened, provided there is some management strategy that will mitigate against an overshoot of the TAC and prevent localised depletion. However, we recommend that the total catch be kept at a modest level initially; 25 t, and that co-management harvest strategies be included that limits and spreads effort and gathers good quality spatial catch data. Other management strategies that are implemented for this fishery including size limits (25 cm total length) will also ameliorate overexploitation.

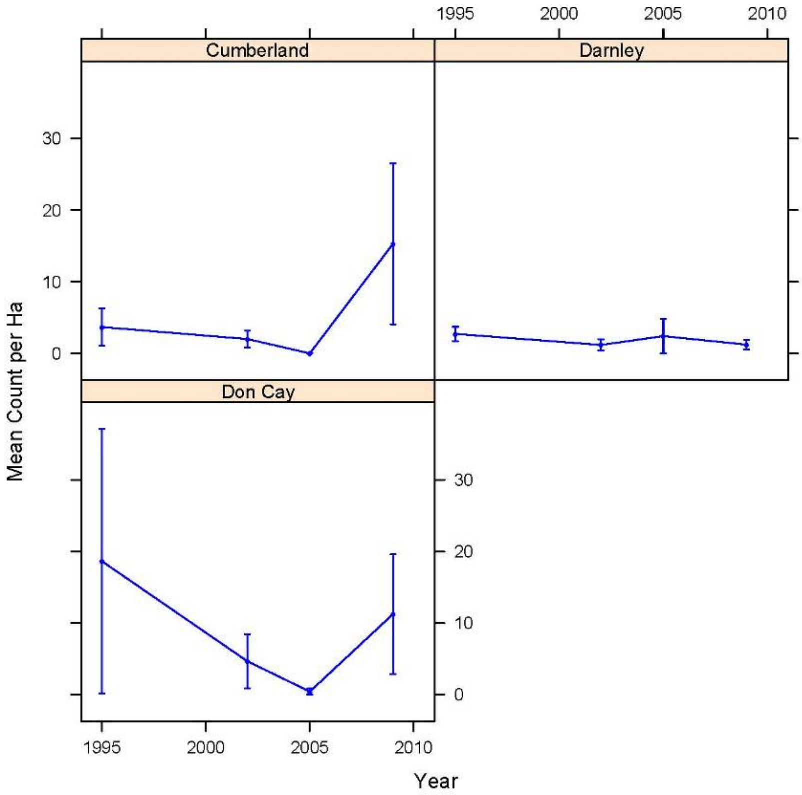


Figure 3-7 Stratified density of *Holothuria whitmaei* (Black teatfish) in ETS logbook zones for four survey years. (Error bars are bootstrapped 95% CI).

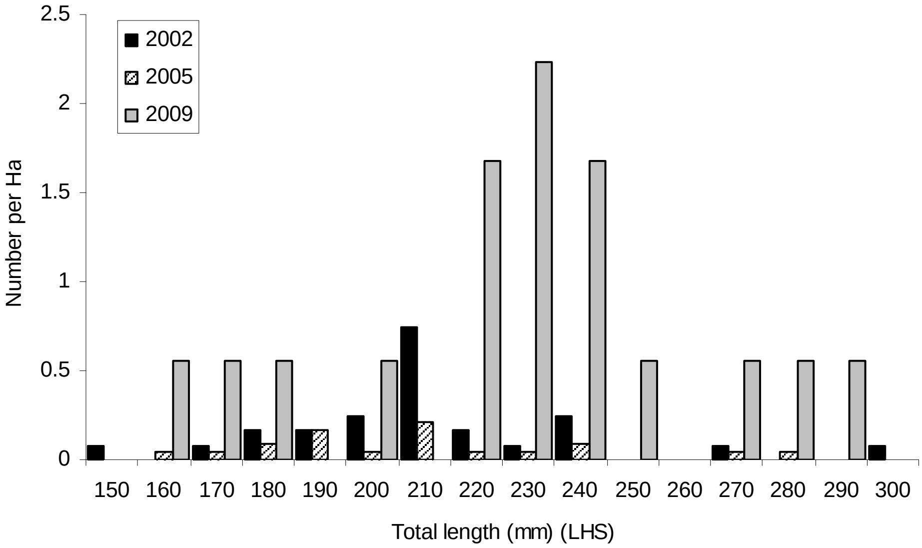


Figure 3-8 Length frequencies for Black teatfish, *Holothuria whitmaei*, collected during population surveys in east Torres Strait in 2002, 2005 and 2009. Frequency data standardised by density estimates observed during surveys.

3.3.2 *Actinopyga mauritiana* (Surf redfish)

This species has only been observed in very low densities on each sampling occasion (Figure 3-9). As stated previously, even though this species was listed as a major component of the catch in previous years (see Section 3.4, Catch data), anecdotal information suggests it is unlikely that it was ever caught in large quantities (*pers. obs.*; R. Torelli, *pers comm.*; Nyal Ledger, *pers. comm.*). It is likely that most of the catch listed as Surf redfish was in fact Deepwater redfish, *A. echinites* (though fished on the shallow reef flat).

This species was closed to fishing in 2003 due to concerns over declining catch rates of “Surf redfish” and low survey density, even though survey density in 2002 was greater than 1995 (Figure 3-9). It is now very likely that the declining catch rates were attributable to declining catches of Deepwater redfish (*A. echinites*). Even so, Surf redfish appears to be a low density species and therefore we recommend it should remain closed to fishing. However, an overfished status is probably not accurate in that Surf redfish are probably uncommon in Torres Strait in any case. This is supported by low density estimates before fishing (supposedly) began on this species in 1995 (Figure 3-9), and indeed its density is higher now than in 1995 (though not statistically significantly so).

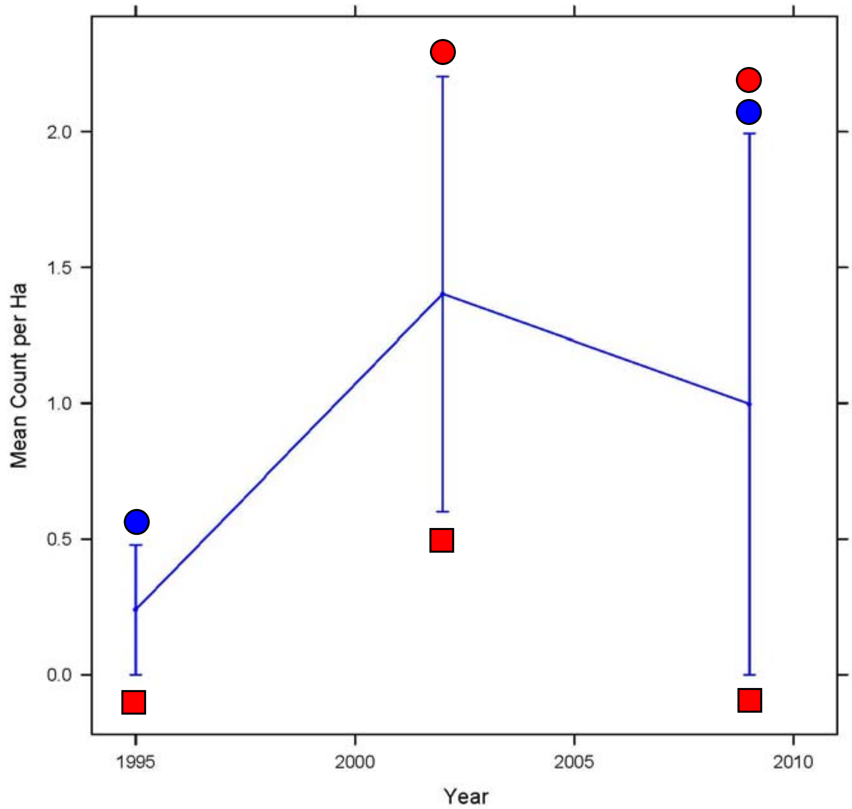


Figure 3-9 Stratified density of *Actinopyga mauritiana* (Surf redfish) in 4 repeated strata (Cumberland’s, Don Cay and Darnley) for three survey years. Colours denote statistical groupings; circles (*P*<0.10), squares (*P*<0.05). (Error bars are bootstrapped 95% CI).

3.3.3 *Actinopyga echinities* (Deepwater redfish)

This important fishery species had an average density in 2009 several times greater than in 2002 ($P<0.1$), after a significant decline from 1995 (Figure 3-10). It is likely that this species was fished heavily (and listed in the catch as “Surf redfish”) between 1996 and 2001 (Table 3-2), with potentially 200 t or more fished between 1996 and 2005. This indicates that the decline in density observed in 2002 was most likely the result of fishery related depletion. Densities appear to be back up to pre-fishing densities, given that the Warrior reef fishery was fishing almost exclusively Sandfish up until 1996 (Williams *et al.*, 1999).

The fishery stock estimate for the 2009 survey was 305 t, but with 76.2 t being the lower 90^{th} percentile of the probability distribution (Table 3-1). Additionally, during the full scale 2000 Sandfish survey on Warrior Reef (Skewes *et al.*, 2000), we also counted Deepwater redfish and an analysis of this data produced a population estimate of 169 t (being the lower 90% CI of the population estimate) for Warrior Reef alone, a population that has not been fished since 2000 — we examined photographs of the catch of illegal PNG fishers and found only very low proportions of redfish in their catch (Appendix E). The combination of the two populations equates to a conservative estimate of fishery biomass of approximately 245 t. Better estimates of fishery biomass will be available after the results of the 2010 Warrior Reef survey becomes available.

This species is currently open to fishing (though it probably hasn’t been fished since the Surf redfish closure), and may even be taken up to 80 t per year (if it were to make up the entire 80 t other species TAC — Table 1-1). As this species is a key target species in Torres Strait, we strongly recommend an individual TAC for this species, of the order of 25 t (being 10% if indicative conservative fishery biomass), and that it be monitored closely.

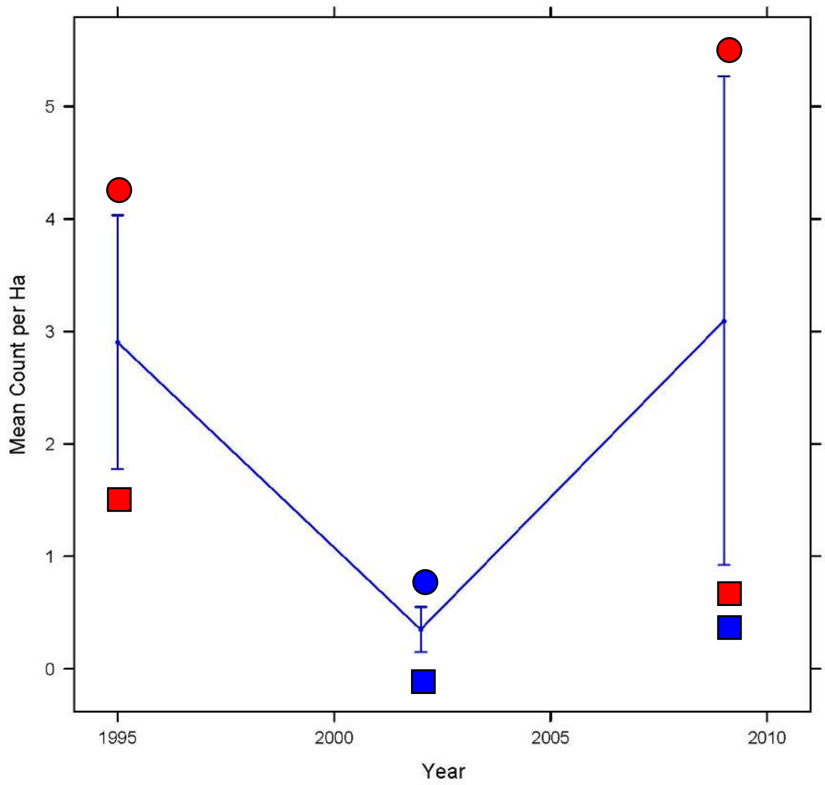


Figure 3-10 Stratified density of *Actinopyga echinites* (deep water redfish) in 4 repeated strata (Cumberland's, Don Cay and Darnley) for three survey years. Colours denote statistical groupings; circles ($P<0.10$), squares ($P<0.05$). (Error bars are bootstrapped 95% CI).

3.3.4 *Actinopyga miliaris* (Hairy blackfish)

The population density trend information for blackfish is very uncertain (Figure 3-11), with only a few sites in the north of the Great North East Channel having high densities. The resulting biomass estimate for the 2009 survey area was 91 t, however the lower 90th percentile of the bootstrapped probability distribution was zero (Table 3-1). The east Torres Strait population estimate from the 2002 full scale survey was 100 t (Skewes *et al.*, 2003), however, the lower 90% CI of this estimate was 10 t, and the population estimate for the 2000 survey on Warrior Reef was 103.4 t, however, this estimate also had wide confidence limits (+/- 105%).

Lobster surveys adjacent to Warrior Reef have found high densities of blackfish species, however, these are mostly Burrowing blackfish, *Actinopyga spinea* (CSIRO, unpublished data).

Therefore, it is difficult to recommend a catch for this species with any confidence. However, blackfish as a group has made up a significant component of the catch in the past (Table 3-2) and the species could be fished under a very restrictive TAC (ie 5 t) to facilitate the collection of spatial catch data and provide information on the range and species mix of the blackfish group.

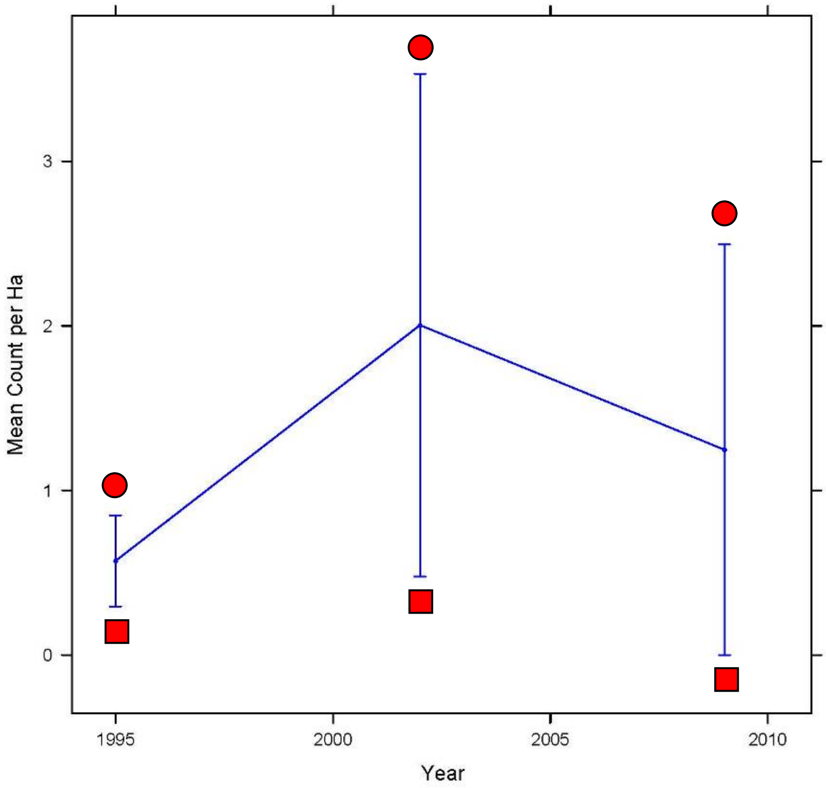


Figure 3-11 Stratified density of *Actinopyga miliaris* (blackfish) in 4 repeated strata (Cumberland's, Don Cay and Darnley) for three survey years. Colours denote statistical groupings; circles (P<0.10), squares (P<0.05). (Error bars are bootstrapped 95% CI).

3.3.5 *Holothuria fuscogilva* (White teatfish)

The density of White teatfish for repeated strata in 2009 appears to be increasing, though the density estimates have a high uncertainty and the change is not statistically significant (Figure 3-12). The average size of White teatfish was larger in 2009 than previous years, further adding support to a recovering population (Figure 3-13, Appendix D).

The fishery stock estimate from the 2009 survey was 110 t, with the lower 90th percentile of the bootstrapped probability distribution being 40 t; however, the survey area did not include the prime habitat for White teatfish in the northern Don Cay region (Figure 2-2). Additionally, White teatfish are found in a relatively depth range (0 to 40+m, and mostly found in >20 m depth - SPC) and our survey is limited to 20 m depth. Therefore the true fishery biomass is likely to be considerably greater than the 2009 survey estimate.

Given the positive density trends, the probable size of the fishery population and innate protection afforded to this species by its depth range, we propose that the current TAC of 15 t remain unchanged, but that the spatial fishery data be collected and harvest strategies that mitigate localised depletion be implemented.

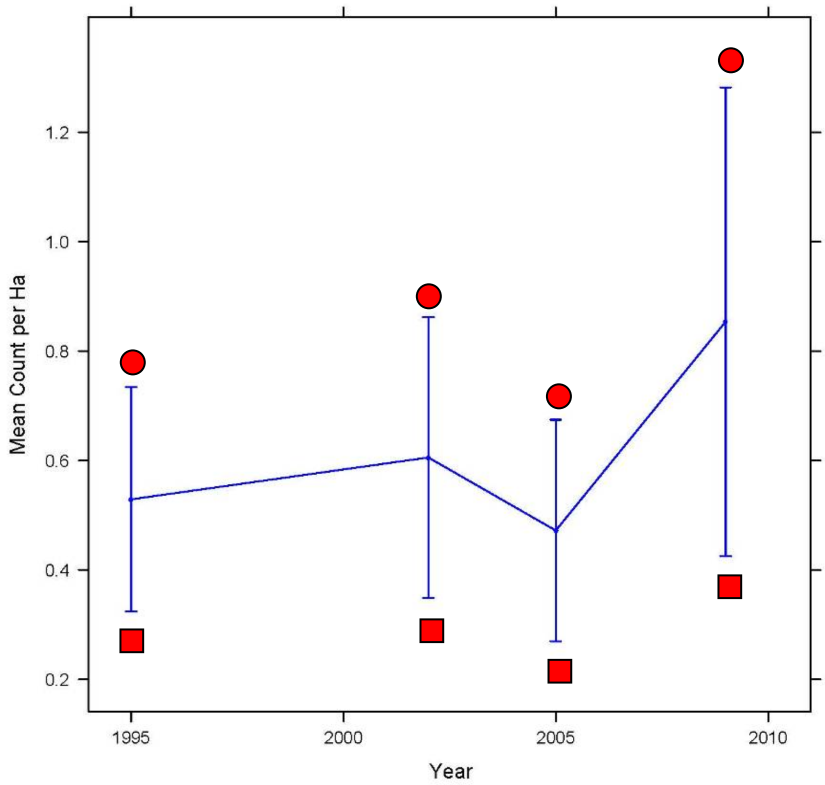


Figure 3-12 Stratified density of *Holothuria fuscogilva* (White teatfish) in repeated strata (Cumberland's, Don Cay and Darnley) for four survey years. Colours denote statistical groupings; circles (*P*<0.10), squares (*P*<0.05). (Error bars are bootstrapped 95% CI).

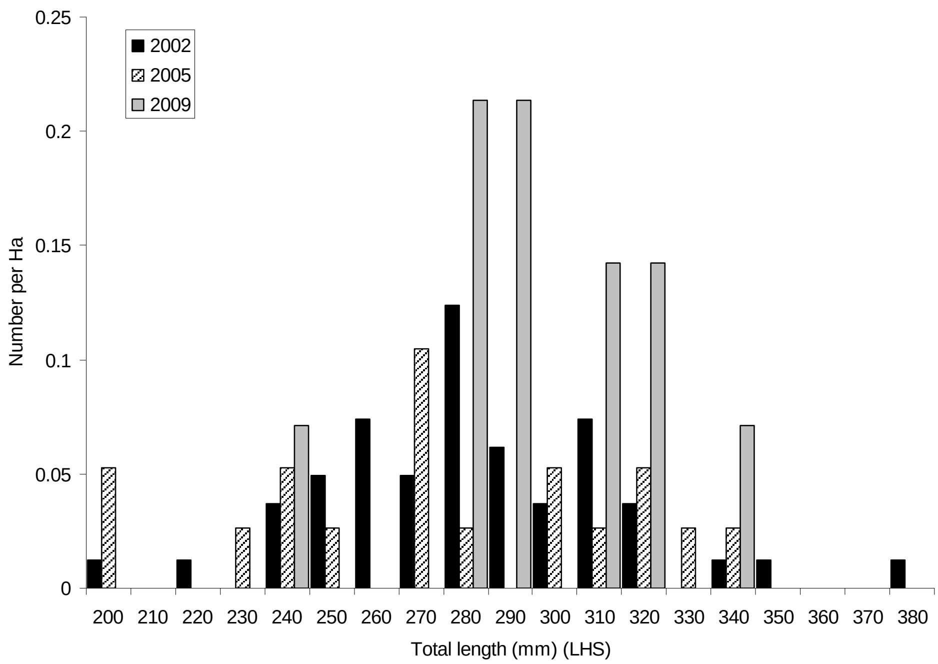


Figure 3-13 Length frequencies for White teatfish, *Holothuria fuscogilva*, collected during population surveys in east Torres Strait in 2002, 2005 and 2009.

3.3.6 *Thelenota ananas* (Prickly redfish)

The density of Prickly redfish appears to be stable (Figure 3-14) though the density estimates have a wide variance due to the patchy nature of Prickly redfish. The average size of Prickly redfish was larger in 2009 than previous years, though there were fewer small individuals (Figure 3-15; Appendix D).

The fishery stock estimate from the 2009 survey of 308 t had very wide confidence intervals with the lower 90th percentile of the bootstrapped probability distribution being 23 t. However, the estimated fishery biomass for Prickly redfish during the 2002 full scale surveys was 884 t for all east Torres Strait, with most of the stock located in the Don Cay and Southern Barrier zones (Skewes *et al.*, 2003), neither of which were sampled during this survey. Given the stable density trends and likelihood of very low catches of this species since 2002 (see Section 3.4, Catch Data) we see no reason to change the conservative TAC set for this species of 20 t.

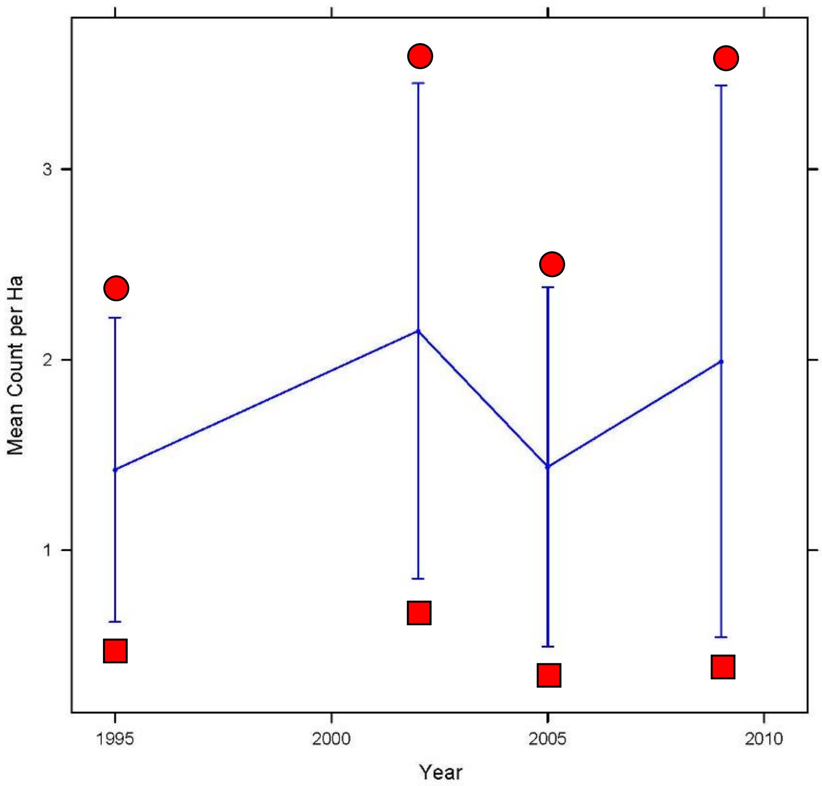


Figure 3-14 Stratified density of *Thelenota ananas* (Prickly redfish) in repeated strata (Cumberland's, Don Cay and Darnley) for four survey years. Colours denote statistical groupings; circles (P<0.10), squares (P<0.05). (Error bars are bootstrapped 95% CI).

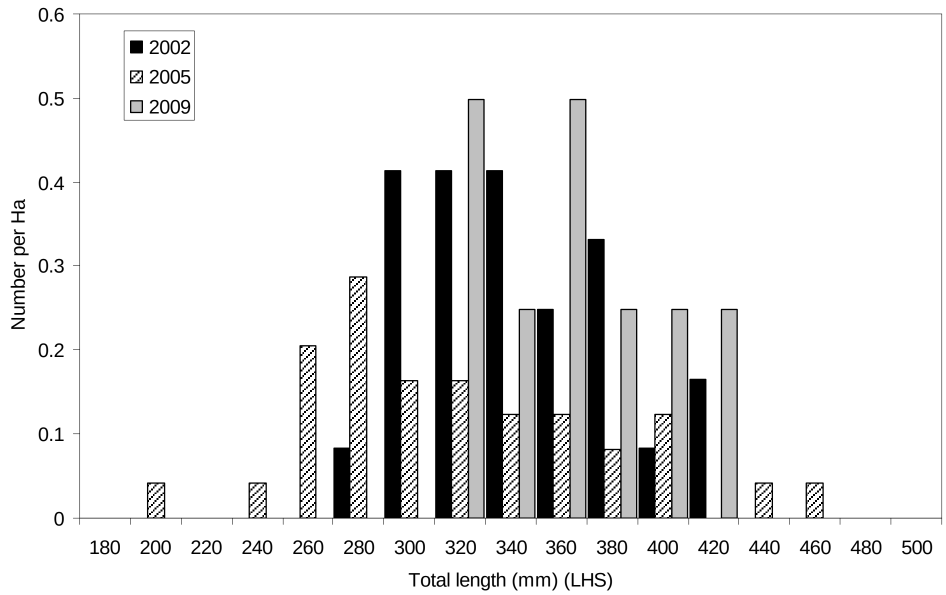


Figure 3-15 Length frequencies for Prickly redfish, *Thelenota ananas*, collected during population surveys in east Torres Strait in 2002, 2005 and 2009.

3.3.7 Other species

Apart from the primary fishery species discussed above, the Torres Strait fishery is recorded as taking 6 other species (Table 3-2). Generally, the level of catch, even considering some underreporting, is small in comparison to the estimated fishery stock (Table 3-1), with the exception of Brown sandfish (*Bohadschia vitiensis*) that has been observed in very low densities in previous surveys (none were seen during the 2009 survey) but has been a target species in recent years (Joe Faitefai, *pers. comm.*). However, this species is known to bury during the day (SPC) and can produce large catches despite low apparent survey densities (e.g. Timor Box fishery; Skewes *et al.*, 1999; Jim Prescott, *pers. comm.*).

We still consider that most “other” species stock are at virgin or near virgin biomass levels, however, some may have a relatively low fishery biomass, therefore we suggest a trigger point of 5 t be applied to all other species that if exceeded in any one year, would initiate a review of the exploitation levels for that species and recommend future action (from do nothing to implementing a moratorium pending a further stock assessment of the species).

3.4 Catch data

The available catch data for Torres Strait is shown in Table 3-2. Catch recording by islander fishers and processors is not compulsory in the Torres Strait fishery. Most of the catch data is from voluntary processor or buyers logbooks. The data from the early 2000s was from a single processing vessel in Torres Strait and the data is in all likelihood a reasonable estimate of the catch. Limited Island based buyers operated during the mid to late 2000s, and the catch during this time may be underestimated, however, the catch is unlikely to be significant, as only one or two fishing operations were active during this time. Reliable anecdotal information suggests there was no beche-de-mer fishing in east Torres Strait in 2008 and 2009 (*pers. obs.*; Joe Faitefai, Mer Is *pers. comm*; Kenny Bedford, Erub Is, *pers. comm.*).

There has been significant illegal fishing activity in Torres Strait by PNG fishers over the past decade or so, however this is highly likely to be restricted to the Warrior Reef and for Sandfish. A recent review by the authors of photos of the catch of illegal fishes apprehended since 2008 has shown that the catch is almost totally made up of Sandfish, with smaller quantities of Redfish and Black fish (Appendix E). Additionally, the reported beche-de-mer catch from Daru does not contain significant quantities of high value east Torres Strait species; Black teatfish, Prickly redfish or White teatfish (Appendix F).

Table 3-2. Estimates of the catch of the (Australian) Torres Strait sea cucumber fishery (in kg, gutted weight) from logbooks (QDPI, 1996 to 2002) and Torres Strait docket book program (AFMA, 2004 to 2005) – no data available for 2003, but catch likely to be negligible (Erik Raudzens, AFMA, *pers. comm.*). *It is highly likely that most of the catch of Surf redfish is actually Deepwater redfish.

Species catch (kg)	1996	1997	1998	1999	2000	2001	2002	2004	2005	Total
Amberfish						192				192
Black fish		65	1,211	1,675		28,502	10,663		186	42,301
Black teat fish	52,777	40,190	18,462	9,196		11,820	3,392			135,836
Brown sandfish				30		382	3,378			3,790
Deep water red fish		12		38	252					302
Deepwater black fish				223	160	470				853
Elephants trunk fish						374	389			763
Green fish			440			88	1,166			1,694
Leopardfish						30	9,643			9,673
Prickly red fish	7	41	620	3,332	347	160	10,451	1,188	5,576	21,721
Sand fish	10,717	29,955	48	39						40,759
Surf red fish*	34,990	51,658	60,289	1,497		59,655	6,487			214,576
White teat fish		123	855	1,064	1,207	3,023	147	25	367	6,811
Total	98,491	122,043	81,925	17,093	1,966	104,696	45,715	1,213	6,129	479,270

3.5 *Actinopyga* species split

During the 2009 survey, we used the most recent taxonomy and species diagnostics to determine the species split for the *Actinopyga* clade; with particular emphasis on determining the proportion of Deepwater redfish (*A. echinites*) compared to Surf redfish (*A. mauritiana*). We also endeavoured to distinguish and map the distribution of several species of Blackfish now recognised by most holothurian taxonomists (*A. miliaris/spinea/paluensis*) - though future work on this group is still warranted. Our survey included a large sampling exercise on Campbell Islet, a location where we have seen large densities of redfish and black fish in previous surveys (Skewes *et al.*, 2003).

We were able to distinguish the following provisional species in the *Actinopyga* clade during the 2009 survey and by using photographs and frozen samples from previous sea cucumber and rock lobster surveys in Torres Strait.

- Deepwater redfish, *Actinopyga echinites*
- Surf redfish, *Actinopyga mauritiana*
- Hairy Blackfish, *Actinopyga miliaris*
- Deep water blackfish, *Actinopyga spinea*
- Burrowing backfish, *Actinopyga palauensis*
- Stonefish, *Actinopyga lecanora*

We observed Deepwater redfish, Surf redfish and Hairy blackfish in east Torres Strait during the 2009 survey, all at relatively low densities (Table 3-1). Re-analysis of previous survey data has shown that most Actinopyga species have distributions covering the central and even western Torres Strait (Figure 3-16 - for individual species details, see Appendix G). Our observations and discussions with buyers and processors that have historically operated in Torres Strait indicates that Surf redfish was never an abundant species, nor was it a significant component of the catch (R. Torelli, *pers comm.*; Nyal Ledger, *pers. comm.*).

Most of the Redfish and Black fish catch was taken on the shallow banks on or adjacent to Warrior Reef and the Great North East Channel, and was likely mostly made up of “Deep water” redfish, *A. echinites*. The stock estimates for Deep water redfish and the three Blackfish species from this study therefore would underestimate the fishery stocks. A more accurate estimate of stock size for these species should be obtained from the results of future surveys of Warrior Reef in 2010.

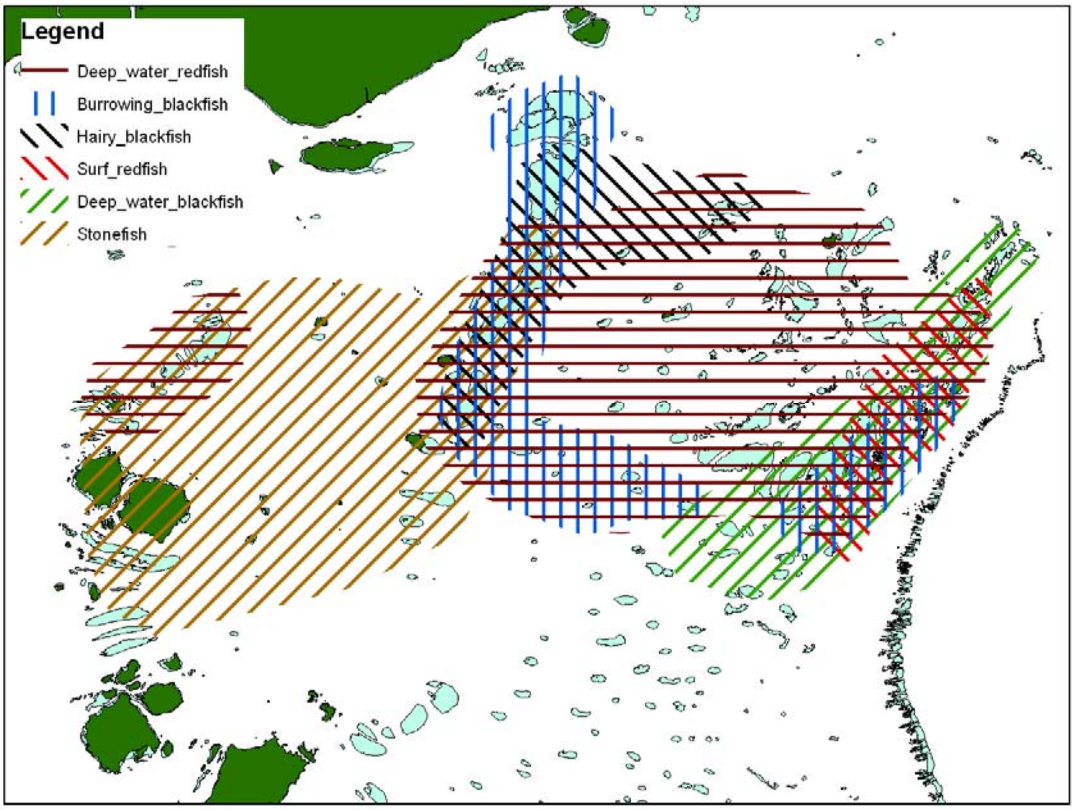


Figure 3-16. Distribution of *Actinopyga* species from 2009 and historical sea cucumber and rock lobster surveys.

4. DISCUSSION

The 2009 survey data allowed an assessment of the relative trends in the density of most sea cucumber species in east Torres Strait, however, the spatial extent and number of sample sites was limited resulting in high variance and considerable uncertainty in relative comparisons and fishery stock estimates. New diving regulations and the need for Islander community consultation and involvement, necessary for successful implementation of research, requires additional field time and this should be factored into future surveys.

The data gathered during the survey showed that Black teatfish, a previously depleted high value species, had recovered since it was closed to fishing in 2003 — a recovery period of 7 years. This is an important example of the recovery of a depleted sea cucumber population, and one of the few thus far documented. Other high value species, and an important medium value species (Deepwater redfish) were either at stable or higher densities than in previous surveys, therefore this represents a healthy fishery with the potential to provide moderate long term income to local Islander communities, provided it is managed carefully.

The sea cucumber fishery in Torres Strait has recently been in abeyance, caused mostly to the closure of important fishery species, but also due to a low level of ownership of the fishery by Torres Strait Islanders. Re-opening Black teatfish will likely see renewed interest in the fishery. However, the open ended nature of fishing effort (any Torres Strait Islander can theoretically fish the fishery) and the possibility of large pulses in fishing effort due to community interest and momentum partially spurned on by buyer interest, could see at least localised overexploitation of sea cucumber populations.

The introduction of co-management harvest strategies that limit effort pulses, mitigate localised depletion and collect fishery and fishery-independent data should be part of an ongoing harvest strategy. Such strategies could provide the necessary protection to sea cucumber populations, where they require Islander communities to take some responsibility for issues such as allocation of the resource within an overall Torres Strait wide co-management harvest strategy, spreading of fishing effort, and carry out catch monitoring and resource assessments. Individual community harvest strategies could incorporate both modern harvest strategies and traditional fisheries practices.

4.1 Management recommendations

1) We have used the density trend and fishery stock estimate data to recommended conservative Torres Strait wide TACs that could be used in conjunction with developing co-management harvest strategies. Total allowable catches (TACs) are recommended for the following highly targeted species (Table 4-1). We also recommend that a trigger limit of 5 t per year be implemented for all species that do not have a species specific TAC. Exceeding the trigger limit will result in a review of the catch data for that species and a recommendation for future exploitation levels and/or data requirements for that species.

Table 4-1 Annual TAC recommendations for Torres Strait beche-de-mer species.

Species	Proposed TAC (t)	Current TAC (t)
Black teatfish	25	0
White teatfish	15	15
Prickly redfish	20	20
Deepwater redfish	25	80*
Surf redfish	0	0
Blackfish	5	80*
Other species	80†	80*

* Currently fished as "other species" TAC = 80 t

† But with a 5 t trigger limit that will initiate species review.

2) Produce a suitable species guide to facilitate the collection of accurate fishery catch data.

3) Implement co-management harvest strategies with Island communities that limit effort pulses, mitigate localised depletion and collect fishery and fishery-independent data.

5. FUTURE RESEARCH

The research outputs from this project will be used in a current FRRF project; Reducing Uncertainty in Stock Status (RUSS) which will seek to evaluation the current harvest strategy through the development of an operating model for Torres Strait sea cucumber. This has the potential to greatly enhance our current assessment of stock status in Torres Strait.

A proposed survey of Warrior Reef will compliment the outputs of this project by including important population components for redfish and blackfish. The dynamics of the Sandfish population on Warrior Reef will also be assessed during this survey and will be of some interest, given the increase in border surveillance since 2008 and the recent closure of the entire PNG sea cucumber fishery.

Further surveys should be undertaken to determine the stock response to opening the fishery. Community participation and indeed, ownership, of monitoring projects is a aspiration that should accompany the development of co-management harvest strategies. Islander training exercises carried out in conjunction with this project (Murphy *et al.*, 2009) were very successful in transferring skills for carrying out surveys.

REFERENCES

Haywood, M.D.E., Browne, M., Skewes, T., Rochester, W., McLeod, I., Pitcher, R., Dennis, D., Dunn, J., Cheers, S., Wassenberg, T. (2007) Improved knowledge of Torres Strait seabed biota and reef habitats. Marine and Tropical Sciences Research Facility, Cairns. 96pp.

Kinch, J.; Purcell, S.; Uthicke, S.; Friedman, K. 2008. Population status, fisheries and trade of sea cucumbers in the Western Central Pacific. In V. Toral-Granda, A. Lovatelli and M. Vasconcellos. Sea cucumbers. A global review of fisheries and trade. FAO Fisheries and Aquaculture Technical Paper. No. 516. Rome, FAO. pp. 7–55.

Kung, J. (2002) Torres Strait beche-de-mer fishery. Annual status report for submission to EA. Protected Zone Joint Authority Report, September 2002. 12 pp

Long, B.G., T.D. Skewes, D.M. Dennis, I.R. Poiner, C.R. Pitcher, T. Taranto, F. Manson, P. Polon, B. Karre, C. Evans, D. Milton (1996) Distribution and abundance of beche-de-mer on Torres Strait reefs. CSIRO Division of Fisheries Final Report, March 1996, 99 pp.

Murphy N., T. Skewes, I. McLeod and A. Tawake (2009) Trochus and bêche-de-mer survey training workshop, 17-18th March, 2009. CSIRO Final Report. 62pp.

PZJA. Torres Strait Protected Zone Joint Authority, Torres Strait Bêche-de-mer Fishery. http://www.pzja.gov.au/fisheries/sea_cucumber.htm. Viewed March 2010.

Skewes, T.D., C.M. Burridge, B.J. Hill (1998) Survey of *Holothuria scabra* on Warrior Reef, Torres Strait. Report to Queensland Fisheries Management Authority. CSIRO Division of Marine Research Report, January 1998, 12 pp.

Skewes, T.D., D.M. Dennis, C.M. Burridge (2000) Survey of *Holothuria scabra* (Sandfish) on Warrior Reef, Torres Strait. January 2000 Report to Queensland Fisheries Management Authority. CSIRO Division of Marine Research Final Report. April 2000. 26 pp.

Skewes, T.D., Dennis, D.M., Koutsoukos, A., Haywood, M. Wassenberg, T., Austin, M. (2003) Stock survey and sustainable harvest strategies for Torres Strait beche-de-mer. CSIRO Division of Marine Research Final Report, Cleveland Australia. AFMA Project Number: R01/1343. ISBN 1 876996 61 7, 50pp.

Skewes T., L. Smith, D. Dennis, N. Rawlinson, A. Donovan, N. Ellis (2004) Conversion ratios for commercial beche-de-mer species in Torres Strait. AFMA Project Number: R02/1195. Australian Fisheries Management Authority Torres Strait Research Program Final Report. Canberra. ISBN 1 876996 74 9

Skewes, T.D., Taylor, S., Dennis, D.M., Haywood, M.E.D. Donovan, A. (2006) Sustainability Assessment of the Torres Strait Sea Cucumber Fishery, CRC-TS Project Task Number: T1.4, ISBN 1 921232 04 8, 50pp.

Skewes T.D., D.M. Dennis, D.R. Jacobs, S.R. Gordon, T.J. Taranto, M. Haywood, C.R. Pitcher, G.P. Smith, D. Milton, I.R. Poiner (1999a) Survey and stock size estimates of the shallow reef (0-15 m deep) and shoal area (15 - 50 m deep) marine resources and habitat mapping within the MOU74 box. Volume 1: Stock estimates and Stock status. CSIRO Final Report to the FRRF, March 1999. 88 pp.

Skewes, T., Kinch, J., Polon, P., Dennis, D., Seeto, P., Taranto, T., Lokani, P., Wassenberg, T., Koutsoukos, A, Sarke, J. (2002b) Research for sustainable use of beche-de-mer resources in Milne Bay Province, Papua New Guinea. CSIRO Division of Marine Research Final Report, Cleveland Australia. 40 pp.

Sitter, R. R. (1992) *A Resampling Procedure for Complex Survey Data.* Journal of the American Statistical Association **87** 419

Smith, S. J. (1997) *Bootstrap confidence limits for groundfish trawl survey estimates of mean abundance.* Canadian Journal of Fisheries and Aquatic Sciences. **54**

SPC. (1994) Sea cucumbers and beche-de-mer of the tropical Pacific. A handbook for fishers. Handbook N° 18. Secretariat of the Pacific Community, Noumea.

Uthicke, S., Welch, D., Benzie, J.A.H. (2004) Slow growth and lack of recovery in overfished holothurians on the Great Barrier Reef: evidence from DNA fingerprints and repeated large-scale surveys. Conservation Biology 18:5, 1395–1404

Williams, G, T. Skewes, P. Gaffney (1999) The Torres Strait Bêche-de-mer Fishery, 1998. Fisheries Assessment Report, edited by the Torres Strait Fisheries Assessment Group. Australian Fisheries Management Authority, Canberra, 13 pp.

APPENDIX A. SEA CUCUMBER SPECIES OBSERVED IN TORRES STRAIT, AND THEIR APPROXIMATE VALUE RANKING.

Scientific name	Common Name	Value
Actinopyga echinites	Deepwater redfish	M
Actinopyga lecanora	Stonefish	M-H
Actinopyga mauritiana	Surf redfish	M
Actinopyga miliaris	Blackfish	M
Actinopyga spinea	Burrowing blackfish	M
Actinopyga palauensis	Deep water blackfish	M
Bohadschia argus	Leopardfish	M
Bohadschia vitiensis	Brown sandfish	L
Bohadschia marmorata	Chalkfish	L
Holothuria atra	Lollyfish	L
Holothuria edulis	Pinkfish	L
Holothuria fuscopunctata	Elephants trunkfish	L
Holothuria fuscogilva	White teatfish	H
Holothuria lessoni	Golden sandfish	H
Holthuria leaucospilota	White threadsfish	-
Holothuria scabra	Sandfish	H
Holothuria whitmaei	Black teatfish	H
Stichopus chloronotus	Greenfish	M
Stichopus hermanni	Curryfish	M
Stichopus horrens (complex)	Dragonfish, Peanutfish	M
Stichopus vastus	Brown curryfish	M
Thelenota ananas	Prickly redfish	M
Thelenota anax	Amberfish	L

APPENDIX B. COMPARATIVE DENSITY ESTIMATES (3 ZONE, 4 YEAR)

Comparative density estimates for 3 common zones (Cumberland, Don Cay and Darnley) for the four survey years (N = 453, 303, 73 and 85 for 1995, 2002, 2005 and 2009 respectively).

Species	Year	Density	SE
Actinopyga echinites	1995	3.13	1.29
	2002	0.42	0.25
	2005	0.59	0.59
	2009	1.55	0.89
Actinopyga lecanora	1995	0.00	0.00
	2002	0.05	0.04
	2005	0.00	0.00
	2009	0.00	0.00
Actinopyga mauritiana	1995	0.28	0.28
	2002	1.62	0.93
	2005	0.00	0.00
	2009	1.15	1.15
Actinopyga miliaris	1995	0.61	0.32
	2002	0.61	0.47
	2005	0.59	0.59
	2009	1.44	1.44
Bohadschia argus	1995	4.68	1.59
	2002	12.42	4.64
	2005	3.62	2.41
	2009	16.72	5.04
Bohadschia graeffei	1995	0.40	0.12
	2002	0.89	0.30
	2005	0.85	0.79
	2009	1.93	1.40
Bohadschia marmorata	1995	0.16	0.10
	2002	0.01	0.01
	2005	0.00	0.00
	2009	0.00	0.00
Holothuria atra	1995	91.96	14.99
	2002	57.86	17.11
	2005	56.90	14.96
	2009	140.39	44.24
Holothuria coluber	1995	1.56	0.94
	2002	6.36	4.11
	2005	21.03	14.74
	2009	2.53	2.20
Holothuria edulis	1995	10.13	6.55
	2002	19.05	4.12
	2005	17.61	4.31
	2009	12.05	3.87
Holothuria fuscogilva	1995	0.53	0.21

Species	Year	Density	SE
	2002	0.61	0.26
	2005	0.47	0.20
	2009	0.85	0.43
Holothuria fuscopunctata	1995	1.05	0.50
	2002	2.61	1.77
	2005	3.28	2.76
	2009	1.04	0.56
Holothuria whitmaei	1995	4.92	2.45
	2002	2.14	0.89
	2005	0.85	0.79
	2009	10.07	5.97
Stichopus chloronotus	1995	30.18	6.16
	2002	36.02	13.01
	2005	39.79	12.33
	2009	133.55	50.57
Stichopus herrmanni	1995	16.85	4.17
	2002	10.36	2.21
	2005	10.57	3.79
	2009	9.17	3.35
Stichopus vastus	1995	0.00	0.00
	2002	4.79	1.38
	2005	8.75	6.37
	2009	0.76	0.57
Thelenota ananus	1995	1.42	0.80
	2002	2.15	1.30
	2005	1.44	0.94
	2009	1.99	1.45
Thelenota anax	1995	0.57	0.25
	2002	1.49	0.76
	2005	0.78	0.46
	2009	0.89	0.32

APPENDIX C. COMPARATIVE DENSITY ESTIMATES (4 ZONE, 3 YEAR)

Comparative density estimates for 4 common zones (Cumberland, Don Cay, Darnley and GNEC) for three survey years (N = 579, 319 and 106 for 1995, 2002 and 2009 respectively).

Species	Year	N	Density	SE
Actinopyga echinites	1995	579	2.90	1.13
	2002	319	0.36	0.21
	2009	106	2.96	1.79
Actinopyga lecanora	1995	0	0.00	0.00
	2002	319	0.04	0.03
	2009	106	0.00	0.00
Actinopyga mauritiana	1995	452	0.24	0.24
	2002	319	1.40	0.80
	2009	106	1.00	1.00
Actinopyga miliaris	1995	563	0.57	0.28
	2002	319	2.00	1.53
	2009	106	1.25	1.25
Bohadschia argus	1995	579	6.96	1.82
	2002	319	11.65	4.09
	2009	106	18.38	4.60
Bohadschia graeffei	1995	579	0.35	0.11
	2002	319	0.77	0.26
	2009	106	1.75	1.21
Bohadschia marmorata	1995	579	0.13	0.08
	2002	319	0.01	0.01
	2009	106	0.00	0.00
Holothuria atra	1995	579	85.13	13.04
	2002	319	67.12	18.12
	2009	106	138.26	39.15
Holothuria coluber	1995	563	2.57	1.22
	2002	319	8.64	4.60
	2009	106	4.94	2.87
Holothuria edulis	1995	579	10.00	5.67
	2002	319	20.49	4.42
	2009	105	13.53	3.84
Holothuria fuscogilva	1995	579	0.46	0.18
	2002	319	0.53	0.22
	2009	106	0.74	0.37
Holothuria fuscopunctata	1995	579	0.90	0.43
	2002	319	2.27	1.53
	2009	106	0.90	0.48
Holothuria whitmaei	1995	579	4.23	2.10
	2002	319	1.86	0.77
	2009	106	9.38	5.22
Stichopus chloronotus	1995	579	32.87	6.32
	2002	319	40.71	12.65

Species	Year	N	Density	SE
	2009	106	124.83	44.02
Stichopus herrmanni	1995	579	15.95	3.69
	2002	319	9.35	1.92
	2009	106	9.83	3.38
Stichopus vastus	1995	0	0.00	0.00
	2002	319	4.93	1.40
	2009	106	0.81	0.50
Thelenota ananus	1995	579	1.22	0.69
	2002	319	1.86	1.13
	2009	106	1.73	1.26
Thelenota anax	1995	579	0.49	0.21
	2002	319	1.29	0.66
	2009	106	0.77	0.28

APPENDIX D. AVERAGE SIZE DATA

For each survey year, average size, total length (mm), and weight (g) for surveyed species collected during three surveys of east Torres Strait from 2002 to 2009.

	Length (mm)			Weight (g)		
Species	2002	2005	2009	2002	2005	2009
Holothuria whitmaei	213.35	210.00	224.41	1655.87	1704.35	1895.69
(s.e.)	29.93	31.46	31.81	455.16	251.83	193.17
Thelenota ananus	349.42	324.86	370.00	2652.44	2147.15	2811.61
(s.e.)	38.69	60.08	38.17	902.58	666.10	731.04
Holothuria fuscogilva	284.33	276.11	296.25	2681.71	2341.39	2735.70
(s.e.)	32.11	42.13	25.86	640.98	930.16	278.96
Holothuria fuscopunctata	312.64	315.51	365.38	1798.26	1831.96	2657.38
(s.e.)	55.66	58.67	45.98	701.58	796.44	239.50
Holothuria atra	167.98	182.92	153.21	392.61	407.03	1414.96
(s.e.)	80.35	77.99	77.99	511.89	449.75	333.91
Holothuria edulis	149.92	157.34	150.43	156.97	164.81	1400.67
(s.e.)	36.99	36.39	43.91	70.25	87.12	278.91
Stichopus hermanni	332.91	338.24	312.31	1753.16	1965.97	2373.41
(s.e.)	52.30	52.49	46.87	678.28	637.25	256.68

APPENDIX E. CATCH OF APPREHENDED PNG FISHERS

In late 2009, AFMA sent 11 digital photographs of the catch of apprehended PNG fishers. The catch was taken from Warrior Reef. The following description of the catch were made by perusal of the digital images.

Photo	Estimates species split
1.	All Sandfish (*H. scabra*)
2.	All Sandfish (*H. scabra*)
3.	All Sandfish (*H. scabra*)
4.	Probably all Sandfish (*H. scabra*) (some decomposition)
5.	Probably all Sandfish (*H. scabra*) (some decomposition)
6.	All Sandfish (*H. scabra*)
7.	All Sandfish (*H. scabra*)
8.	All Sandfish (*H. scabra*)
9.	All Sandfish (*H. scabra*)
10.	Sandfish (*H. scabra*) ~95%, blackfish (*A. miliaris/spinea*) ~5%
11.	Sandfish (*H. scabra*) ~92%, redfish (*A. echinites*) ~1%, stonefish (*A. lecanora*) <1%, blackfish (*A. miliaris/spinea*) ~6%
12.	A single Prickly redfish (*T. ananas*)

APPENDIX F. REPORTED CATCHES FROM DARU, PNG

Species (kgs dry wt)	1990	1991	1992	1993	1994	1995	1996	1996	1997	1998	1999	2000	2001	2002	2003	2003	2004	2005	2006	**Total (t)**
Blackfish								8,875							3,045	560				**12.5**
Black teatfish								40						5	77	81				**0.2**
Brown sandfish															320	320	160			**0.8**
Curryfish															1,193	1,200	360			**2.8**
Deep-water redfish								600												**0.6**
Greenfish															913	913				**1.8**
Lollyfish														730			80			**0.8**
Prickly redfish																	40			**0.0**
Sandfish	109,380	192,647	159,760	39,302			97,572	18,139						21,564	6,506	8,007	23,529		?	**676.4**
Snakefish																	80			**0.1**
Surf redfish								880						1,036	7,355	4,309	1,460			**15.0**
Stonefish								1,000						4,503	2,323	2,888	1,844			**12.6**
Tigerfish															360	360	400			**1.1**
Unspecified			2,937	73,816			21,593													**98.3**
Total	109,380	192,647	162,697	113,118	0	?	119,165	29,534	?	?	?	0	?	27,838	22,092	18,638	27,953	?	43,722	**866.8**
Source	1	1	1	1	Clsd		2	3				Clsd		4	4	3	4		5	

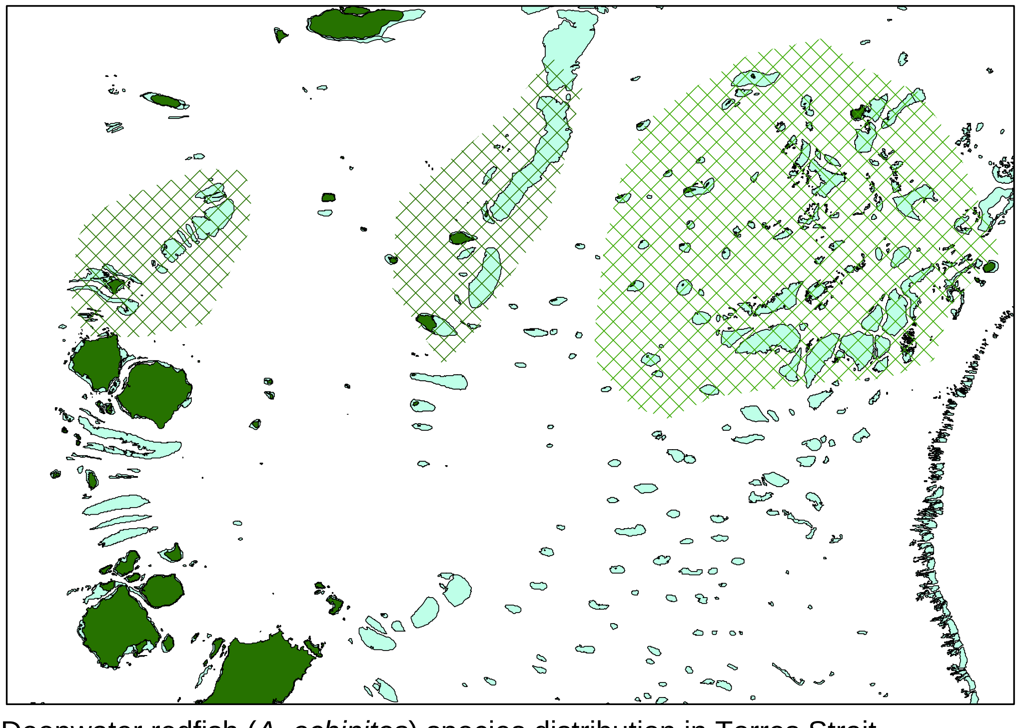
1 Western Prov. BdM Fishery Man Plan. PNG NFA. June 1995
2 Ministerial brief of the WP BdM fishery. PNG NFA. 1996
3 Kinch, 2004. PNG BdM Review
4 Catch data e-mailed by P. Polon, PNG NFA
5 “Mostly sandfish”, Information prepared by Mr. Odorri Kolonie, Enforcement Coordinator – PNG NFA
Clsd Fishery closed

APPENDIX G. ACTINOPYGA SPECIES GUIDE

Species:	**Deepwater redfish**
Scientific name:	*Actinopyga echinites*
Habitat:	Coastal reefs, in rubble, seagrass beds, or sand between corals. Depth: 0–3 m. (SPC)
Description:	Brown, darker on dorsal surface, which also has pimpled texture. Dorsal papillae long and slender. Anus terminal with 5 teeth. Often covered with sand. Commonly to 15 cm; max. 36 cm. (SPC)
Locations:	Moa Is., Orman Rfs, Darnley Is., Murray Is., Campbell Is., Aureed Is., Hannah Bank, Warrior Rf, Auwamaza Rf.
Comments:	Widespread in low densities throughout Torres Strait and Warrior Reef.

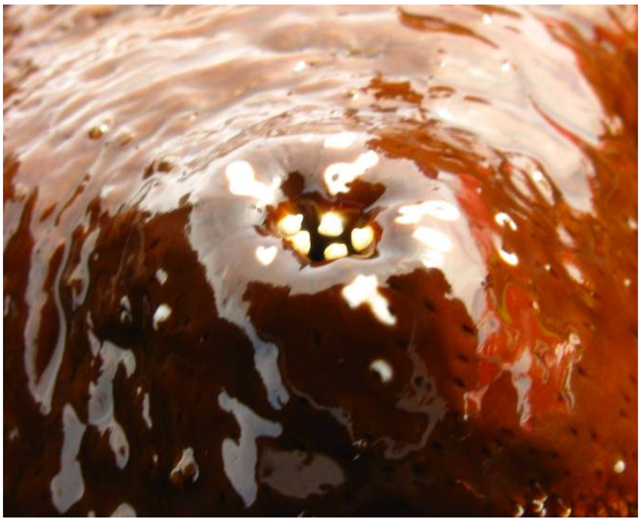
CSIRO, Hannah Bank, 2005

CSIRO, Campbell Island, 2009



Deepwater redfish (*A. echinites*) species distribution in Torres Strait.

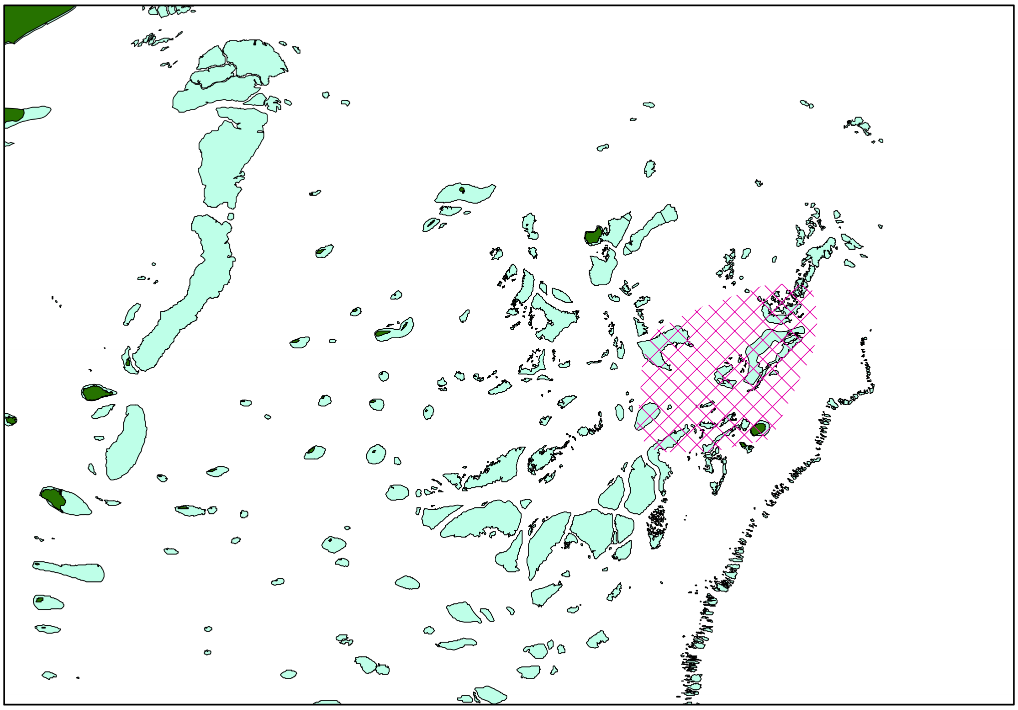
Species:	**Surf redfish**
Scientific name:	*Actinopyga mauritiana*
Habitat:	Oceanic-influenced reefs in wave-exposed zones. Depth: 0–10 m. (SPC)
Description:	Rusty brown with whitish blotches and spots. Rigid body with trapezoidal section; ventral surface with numerous podia. Anus terminal with 5 teeth. Commonly to 24 cm; max. 38 cm. (SPC)
Distribution:	Murray Island, Don Cay
Comments:	Relatively uncommon in Torres Strait. GBR and Coral Sea forms have more white variegations.



CSIRO, Murray Is., 2009

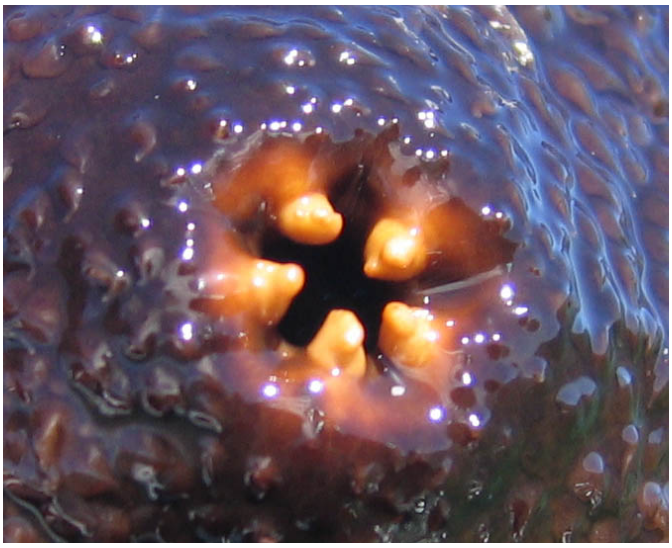
CSIRO, Seven Reefs, 2005

CSIRO, Murray Island, 2009



Surf redfish (*A. mauritiana*) species distribution in Torres Strait.

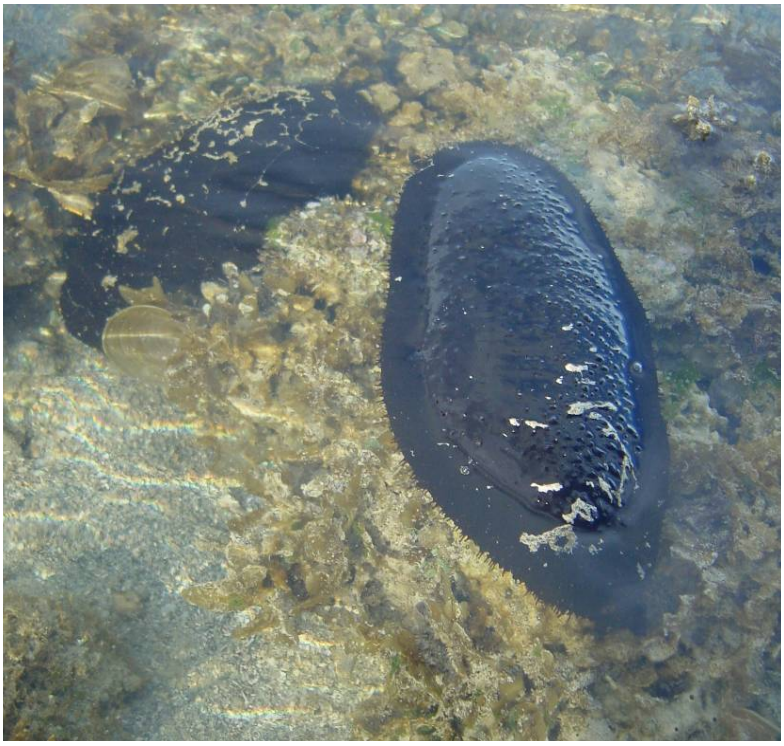
Species:	**Hairy blackfish**
Scientific name:	*Actinopyga miliaris*
Habitat:	Sandy lagoons and reef flats. Depth: 1–10 m, but mostly less than 4 m.
Description:	Dark brown with lighter ventral surface. Stout, cylindrical body. Anus terminal with 5 conical teeth. Numerous long, thin papillae. Contracts to a ball shape when disturbed. Commonly to 20 cm; max. 30 cm. (SPC)
Location:	Campbell Island, Warrior Reef.
Comments:	Not widespread but can be locally very abundant.



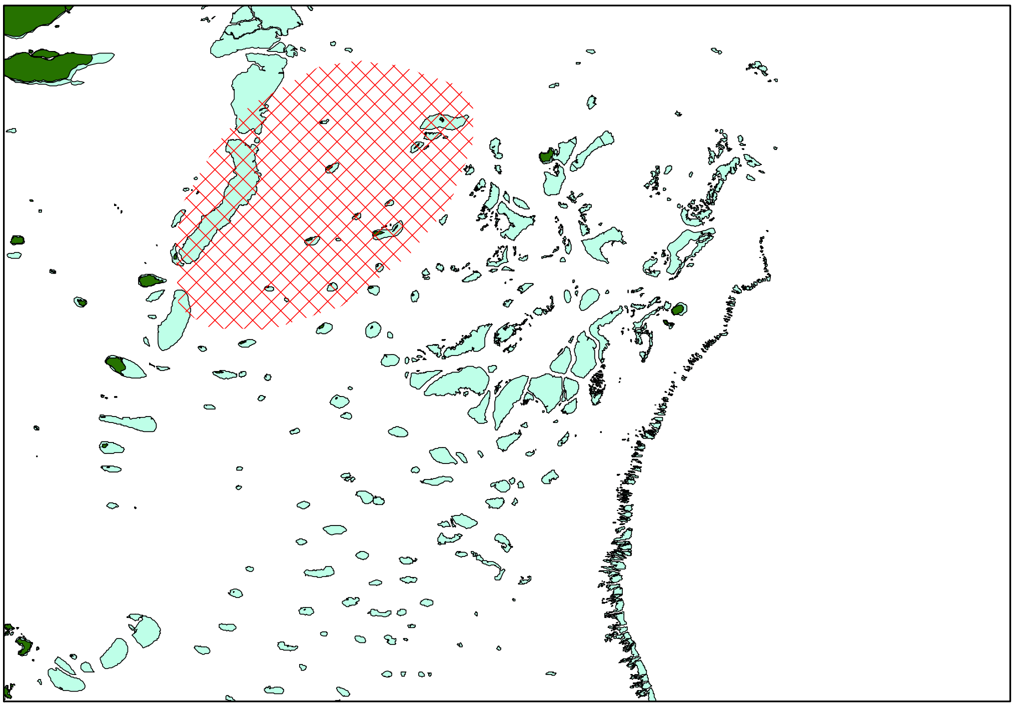
Purcell (Worldfish)

CSIRO, Campbell Island, 2005

CSIRO, Campbell Island, Mixture of hairy blackfish and Deepwater redfish, 2009.

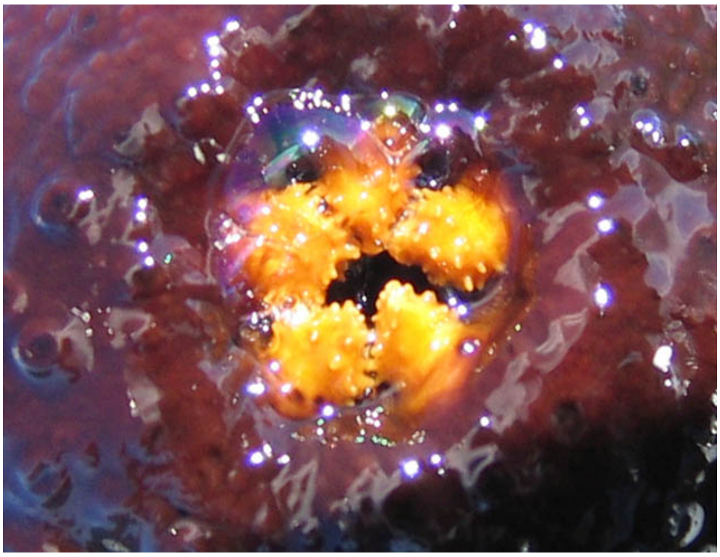


CSIRO, Warrior Reef, 2007

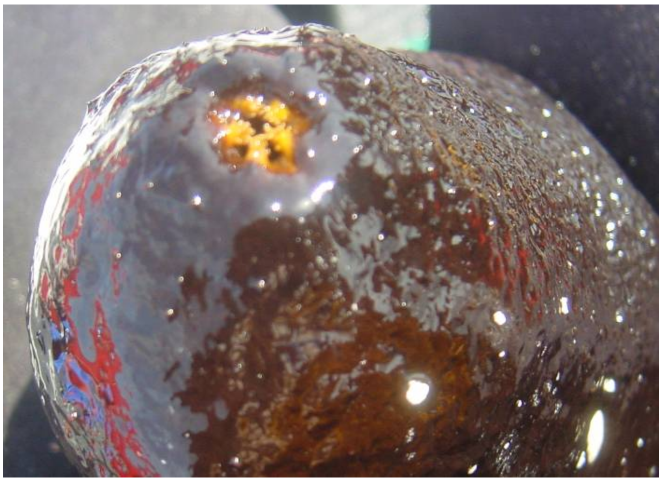


Hairy blackfish (*A. miliaris*) species distribution in Torres Strait.

Species:	**Burrowing blackfish**
Scientific name:	*Actinopyga spinea*
Habitat:	Muddy-sand lagoons and reef flats. Depth: 1–12 m.
Description:	Rusty brown to dark brown, often with fine sand dorsally. Sub-cylindrical body, more elongate than hairy blackfish (A. miliaris). Anus subdorsal with nodular teeth. Small thin papillae. Commonly to 30 cm; max. 40 cm.
Location:	Behind Warrior, Zuzin Island, Auwamaza Reef, Mabuiag Is.
Comments:	Focus of a large fishery on the GBR.



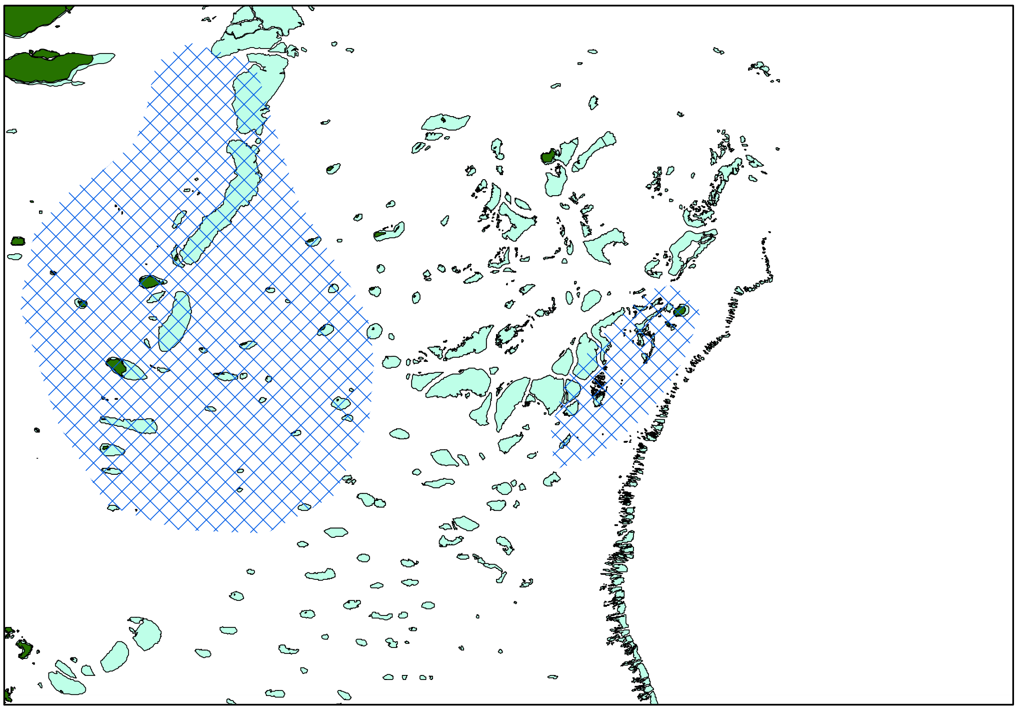
Purcell (Worldfish)



CSIRO, Murray Island, 2005

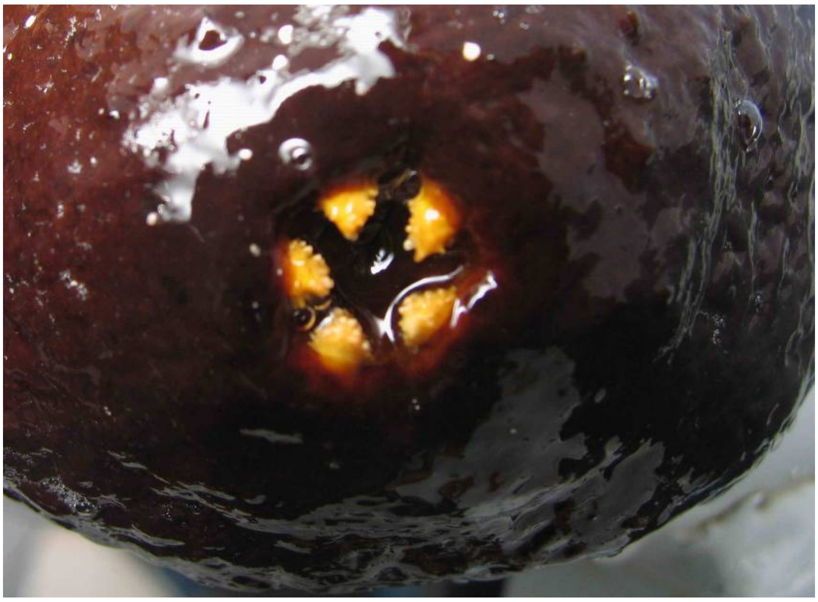
CSIRO, Auwamaza Reef, 2005.

CSIRO, Auwamaza Reef, 2005

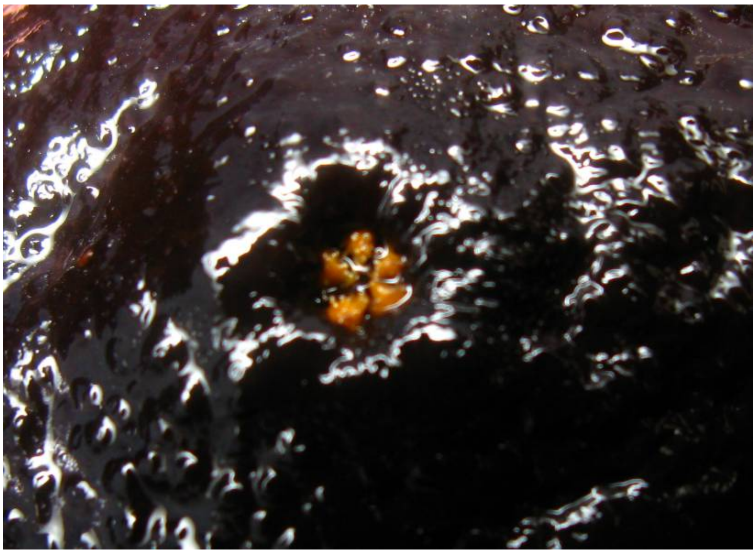


Burrowing blackfish (*A. spinea*) species distribution in Torres Strait.

Species:	**Deepwater blackfish**
Scientific name:	*Actinopyga palauensis*
Habitat:	Reef passes and forereef pavement. Depth: 4–18 m. (SPC)
Description:	Brownish-black over entire body. Bumpy dorsal surface, with sand covering. Relatively long, sub-cylindrical body. Buccal cavity (mouth) often projected, and noticeably trunk-like. Anus terminal with serrated or nodular teeth. Small papillae. Commonly to 30 cm; max. 35 cm. (SPC)
Location:	Don Cay, Murray Island, Seven Reefs.
Comments:	Uncertain ID from Torres Strait.

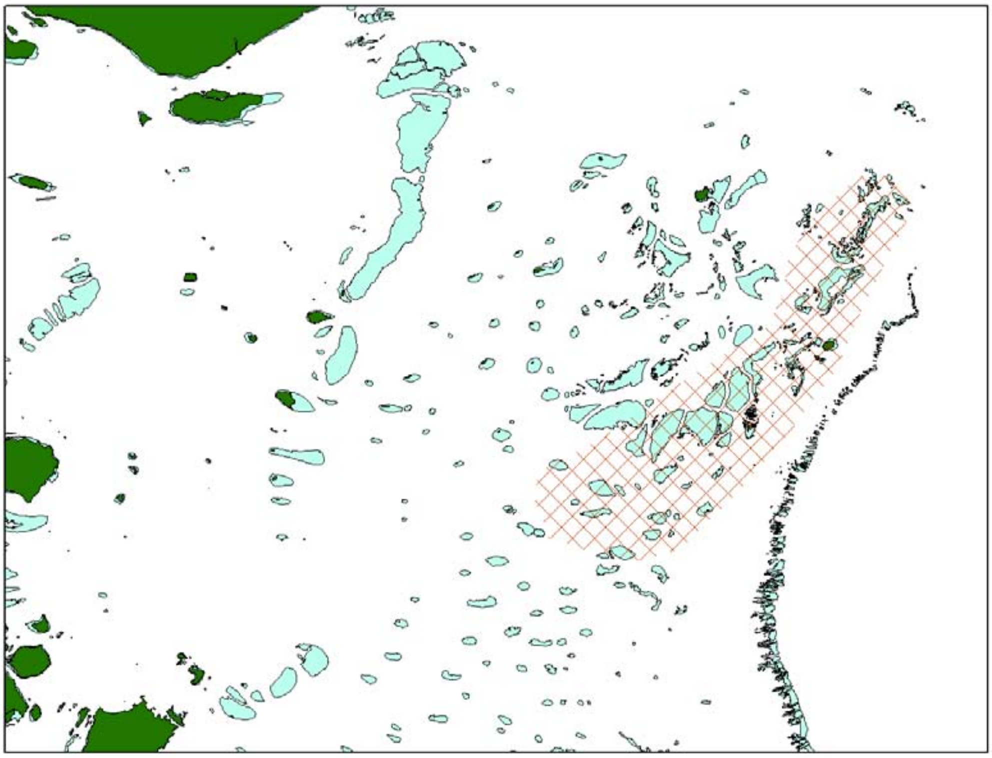


Purcell, (Worldfish)



CSIRO, Seven Reefs.

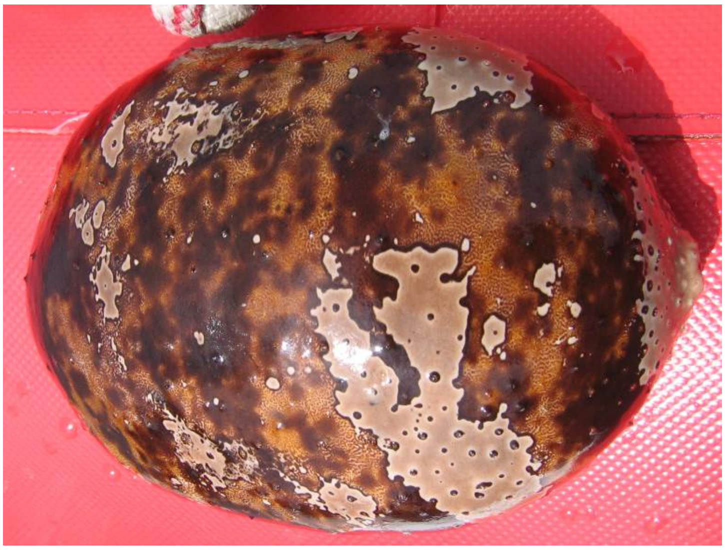
CSIRO, Don Cay



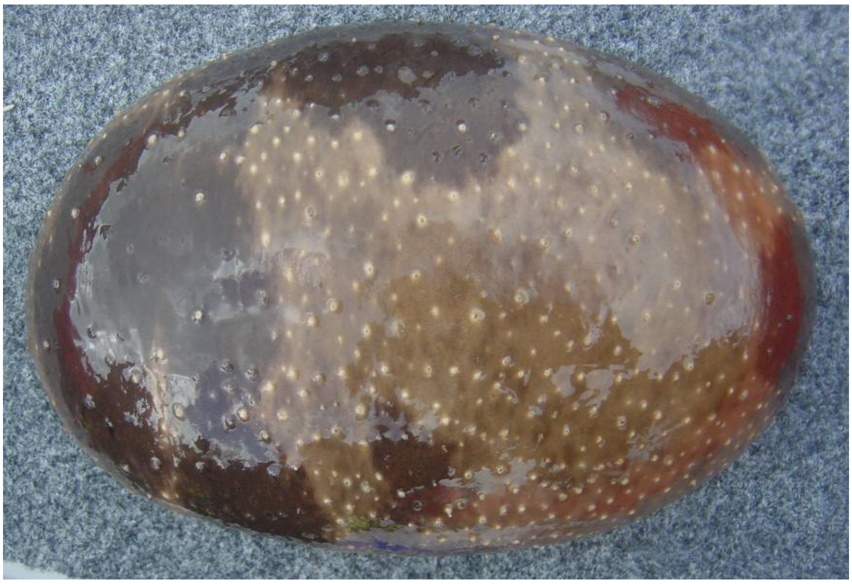
Deepwater blackfish (*A. palauensis*) species distribution in Torres Strait.

Species:	**Stonefish**
Scientific name:	*Actinopyga lecanora*
Habitat:	Areas with live coral and coral rocks, and reef ledges. Depth: 0.5–7 m. (SPC)
Description:	Sometimes marbled with whitish blotches; often has white patch around anus. Cylindrical body, slightly flattened ventrally. Anus terminal with five conical teeth. Commonly to 22 cm; max. 24 cm. (SPC)
Location:	Orman Reefs, Mabuiag Is., Bet Reef, Buru Is., Tudu Is., Nagai Is. Reasonably uncommon but found in deeper seabed from Warrior and western Torres Strait.
Comments:	There appears to be 3 different forms of this species – these may be even different species or hybrids. Type 1 is the most common. Are known to be relatively cryptic during the day so probably undersampled.

CSIRO

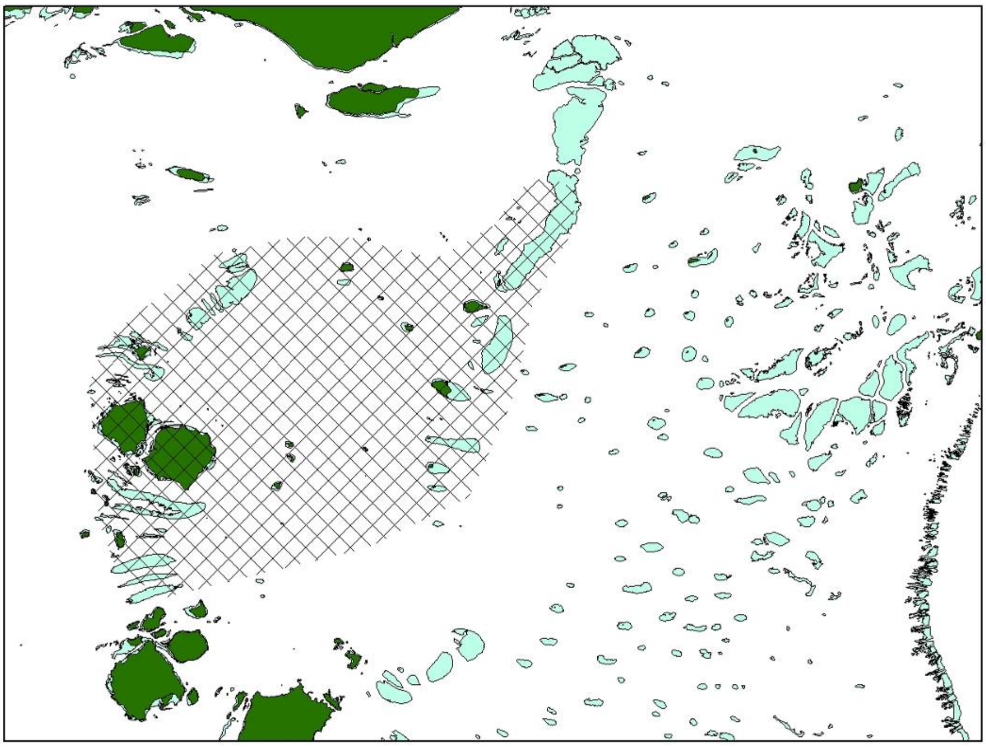


CSIRO, Type 1, Mabuiag Is.



CSIRO, Type 2, Mabuiag Is.

CSIRO, Type 3, Bet Reef



Stonefish (*A. lecanora*) species distribution in Torres Strait.

Contact Us

Phone: 1300 363 400
+61 3 9545 2176

Email: enquiries@csiro.au

Web: www.csiro.au