DEPARTMENT OF LAND RESOURCE MANAGEMENT

ASSESSMENT OF DARWIN HARBOUR FISH COMMUNITIES USING BAITED REMOTE UNDERWATER VIDEO STATION (BRUVS)

September 2012

This document was prepared for the Department of Land Resource Management. Contributing author Dr Victor Gomelyuk

ISBN: 978-1-74350-017-0

Further information
Contact:
Dr Victor Gomelyuk
Marine Ecosystems, Flora and Fauna Division
Dept. of Land Resource Management
564 Vanderlin Drive BERRIMAH NT 0828
Mail to:
PO Box 496, PALMERSTON, NT 0831, Australia
Ph: +61 8 8995 5024
fax +61 8 8995 5099

Cite report as:
Gomelyuk, Victor Eugene (2012). Assessment of Darwin Harbour fish communities using baited remote underwater video station (BRUVS). Report to Department of Land Resource Management, Darwin.

Executive summary

Fishes play an important role in marine ecosystems and Darwin Harbour is home to a diverse and abundant fish community: the most recent checklist of fishes lists 415 species. Some of these species support an important local recreational fishery. However, the fish composition, structure and dynamic are poorly known and there is a growing need to describe them and to assess spatial and temporal changes and trends through monitoring to assist with management of the Harbour.

The study used Baited Remote Underwater System (BRUVS), which uses “video fishing” - recording fish attracted to a camera by standard bait and has been shown to be an effective non-extractive survey method. Because of the non-impact nature of visual surveys they can be used in long-term environment monitoring at reference sites. BRUVS were employed at 22 sites during May-September 2011 in the Harbour and 200 60-minutes video samples were taken, stratified by four types of habitat: “Lower littoral. Coral” habitat at the depth ≤6 m (9.4% of all stations); “Lower littoral. No coral” habitat at the depth ≤6 m with a variety of bottom cover (and absence of bottom cove, 17.3% of all stations); “Deep filter feeders” habitat with sponges, sea whips, gorgonians, hydroids and algae at the depth 6-16 m and deeper (45.7% of all stations); and “Deep no cover” habitat (areas of bare gravel, pebbles, silted sand or silt at the depth 6-16 m and deeper, 27.6% of all stations).

A total 3075 individuals of 108 fish species from 41 families were recorded. This study added 17 species to Darwin Harbour fish list, and two species are likely to be the first records in Northern Territory waters. Both coral and deeper filter feeders communities in the Harbour contain the most diverse and abundant fish assemblages. The highest fish biodiversity and abundance values were found at Darwin Harbour entrance, in the area to the south-west from Channel Island and at South Shell Island. The distribution of fishes targeted by recreational fishers over the Harbour is generally similar to other species distribution.

Comparison of the data collected in Darwin Harbour with other BRUVS survey in northern Australia indicated that the mean number of species and the number of fish individuals were higher in Port Essington (Cobourg Marine Park, Northern Territory) and at James Price Point (Western Australia). Fish abundance and species richness were higher in Darwin Harbour comparing to Great Barrier Reef Marine Park lagoon. BRUVS is a shown to be a useful method for fish assemblages monitoring in Darwin Harbour.

Contents

List of Figures

List of Tables

1. Introduction

1.1 Background

Reef fishes are important component of tropical inshore marine ecosystems. Fishes play an important role in the marine ecosystems functioning. Fish species inhabiting water column are either predatory or feeding on zooplankton. Demersal fish are major consumers of benthos. They are links between lower and upper levels of the food web and are common prey of predatory fish, birds and cetaceans. Changes in the lower level of the food web cascade through all ecosystem affecting fish assemblages abundance and composition. Changes in fish abundance often result in major changes in ecosystem (Lynam et al. 2006, Brotz et al. 2012).

Several commercial fish species in the Territory were intensively studied by Fisheries scientists (Walters and Buckworth 1997; Newman et al. 2000; Ovenden et al. 2002; Hay et al. 2005; Knuckey et al. 2005; Buckworth et al. 2007). Still, there is very little or no data on inshore fish assemblages structure (species composution, trophic and functional groups) and seasonal and annual dynamics in fish assemblages in the Northern Territory and generally at Top End. Darwin Harbour is an important location for recreational fishing in the Northern Territory and more than 30% of all recreational fishing in the Territory takes place in Darwin Harbour, Shoal Bay and nearby areas (Coleman 2004). It is important therefore to protect biodiversity and maintain fish resources of the Harbour on sustainable level so people can enjoy a good fishing in the future.

A key issue in fish survey is gear selectivity. Too selective gear use may results in biased study result: some species will be overrepresented while the others underrepresented or not recorded at all. A recent addition to surveying fish is the development of underwater video using either baited or unbaited stations. Cappo et al. (2007) reviewed the use of baited video systems for fish surveys and highlighted an important issue of what fish species are attracted to underwater video? Differences in observed fish species between baited and unbaited fish traps (Cappo & Brown 1996) created the presumption that baited underwater video are also biased towards scavenging and predatory species and exclude herbivorous and omnivorous species. However, comparison of baited and unbaited remote video stations showed that baited video appears to be the most appropriate technique to obtain recordings of a large number of species and individuals (Willis & Babcock 2000; Watson et al. 2005). Use of bait actually increased the ability to discriminate fish assemblages in distinctive benthic habitats in tropical and temperate Australia due to the increased number of individuals and species sampled at the baited stations (Watson et al. 2005; Cappo et al. 2007; Harvey et al., 2007). Baited video consistently sampled more individuals and species of the fish recognised as herbivores, feeders on invertebrates and algae than unbaited stations (Cappo et al., 2007) without decreasing the abundances of herbivorous or omnivorous fish (Harvey et al., 2007). Omnivore and planktivore species were among regular visitors at the bait during the underwater video surveys in the western Mediterranean (Stobart et al. 2007). This can be resulted from a ‘sheep effect’ when a few individuals that approached the bait attracted others individuals (Watson et al. 2005) compared to an aggregation response where other fish activity is detected (Manteifel 1970; Priede & Merret 1996, 1998). That is why fish ignoring bait such as herbivorous Surgeonfish *Acanthurus grammoptilus* and Ponyfishes were highly ranked in the recorded species list when this technique was used in study at Cobourg Marine Park (Gomelyuk 2009).

A limitation of this method is sensitivity to low water clarity. When the underwater visibility is lower when 1.5- 2.0 m result obtained by BRUVS is dubious. Stll, in suitable environment use of this technique for fish surveys provides an effective yet non-destructive approach in the areas, where extractive sampling is unsuitable. As a non- extractive method this type of video sampling is particularly suitable for monitoring of fish assemblages at permanent seleted sites.

1.2 Physical and biological characteristics of Darwin Harbour

Darwin Harbour embraces 3,227 square kilometres of land and water and is one of the largest harbours and deep water ports in Australia. It is an estuarine system where the water from Timor Sea mixes with runoff from northern Australian land surface (Wilson et al. 2004). The Harbour is macrotidal with a maximum tidal range of 7.8 m (5.5 m mean spring range and 1.9 m mean neap range). Despite strong currents of up to 2 m per second, the Harbour, in parts, remains poorly flushed (Byrne 1988). The water is naturally turbid and standing stocks of nutrients are low (Padovan 1997).

The Harbour is composed of three main arms: the large East and Middle Arms and the smaller West Arm. Water depth in the main channel at the mouth of the Harbour ranges from 20-30 m, with this decreasing to 5-10 m in the arms of the Harbour. The prominent features of the coastal and marine habitats in Darwin Harbour are the expansive mudflats backed by mangroves which contain considerable biodiversity (Hanley 1988). The hard substrates cover less than 20% of the intertidal and subtidal area of the Harbour. These hard substrates display a distinct zonation of flora and fauna composition, caused by the combined effect of physical, biological and environmental parameters (McKinnon et al. 2005). On the lower intertidal/subtidal interface, rock substrate can be covered with hard and soft corals, sponges, crustaceans, anemones and many species of macroalgae.

The Harbour is the ultimate receiving environment for all stormwater and wastewater discharge from Darwin and Palmerston urban areas, which support a population of approximately 110,000 people. Recent research has identified that although the Harbour is considered to be in near pristine condition with good water quality, the impacts of urban stormwater runoff and wastewater discharges are evident. Wastewater discharges are resulting in localised degradation within the estuarine tributaries of the Harbour and during the wet season, stormwater runoff from urban areas is resulting in high loads of sediments, nutrients and heavy metals entering local waterways (Leinster et al. 2007).

1.3. A history of Darwin Harbour fish fauna studies.

The earliests records of fish collection in Darwin Harbour came from t*he crew of HMS Beagle* that made the first scientific collection of fishes in September, 1839*.* The most recent attempt to summarise the Darwin Harbour fish fauna was that of Larson (1988), who recorded 408 nominal species from the harbour and estimated that 340 of these (comprising 95 families) were probably valid. A beam trawl survey at 40 stations within Darwin Harbour was conducted as a part of the Sixth International Marine Biological Workshop held in Darwin in 1993. Three new records for the Northern Territory were made as a result of this survey*.* An annotated list of Darwin Harbour fishes summarising all previous survey results contains 415 fish species known for the Harbour and includes 31 new records for the Northern Territory (Larson & Williams 1997).

A study of the fishes of Darwin Harbour mangrove forest habitats, including Elizabeth River, was conducted between March 1999 and January 2001. This study was the first to document the relative abundance, distribution and trophic ecology of the fish inhabiting mangrove forests habitats in Darwin Harbour (Martin 2005). A total 46 species from 21 families were captured in mangrove forests. The most abundant species were from four families: Clupeidae, Engraulidae, Ariidae and Mugilidae. All species were coastal, estuarine or mangrove associates. The most abundant species, *Anodontostoma chacunda*, was represented entirely by juveniles. In addition, some of the most commonly harvested species in the recreational fishery in Darwin Harbour were found as juveniles in the mangroves. The most numerous of these were species from the families Carangidae, Polynemidae and Mugilidae and the centropomid, *Lates calcarifer* (Martin 2005). In August 2003 Australian Institute of Marine Science carried out the first BRUVS study in Darwin Harbour and surrounding areas. No formal reports were produced, however survey data was provided to Atlas of Living Australia database http://biocache.ala.org.au

1.4. Aims

Present fish survey was a baseline study of Darwin Harbour fish assemblages with aims:

1. To describe the spatial patterns in species richness and fish abundance over the Harbour.
2. To assess the responses of fish species occurrence at different sampling sites to the depth, position and epibenthic cover.
3. To provide base line data for further fish biodiversity monitoring.
4. To identify areas and sites with high fish biodiversity and abundance suitable for monitoring.

2. Methods

2.1 Study area

The study area was concentrated in the central part and entrance of Darwin Harbour. Upper estuary areas of Darwin Harbour (Elizabeth River and Blackmore River) were excluded from survey program due to extremely high water turbidity in these areas in May-September 2011. It was found that due to very low water clarity it is impossible to continue use Baited Remote Underwater Video Stations (BRUVS) to the south-east beyond Channel Island at Middle Arm and beyond South Shell Island (Fig. 1).

Inshore tropical marine ecosystems have very high spatial habitat heterogeneity and consist of a mosaic of habitat patches with distinct associated fish fauna. Therefore, a randomised stratified design was used. Depth (three strata) and habitat type (two strata) were used to identify sites in the Harbour for this survey. Using available sea charts, bottom maps, local divers and fisher knowledge we identified next three main stratums:

1. Harbour entrance sites with (the depth from 5 to 16 m (12 sites).
2. Shallow (3-5 m depth) rock reefs and coral habitats throughout the Harbour (15 sites).
3. Deeper sites (the depth 10-30 m) and wreck sites throughout the Harbour (15 sites).
4. Existing and upgraded artificial reefs off Lee Point – "Bottle Washer Reef" and "Rick Mills Memorial Reef".

We used a random numbers generator to "select" 16 sites (5 for each stratum +1 for deeper wreck sites), Fig. 1, Table 1.

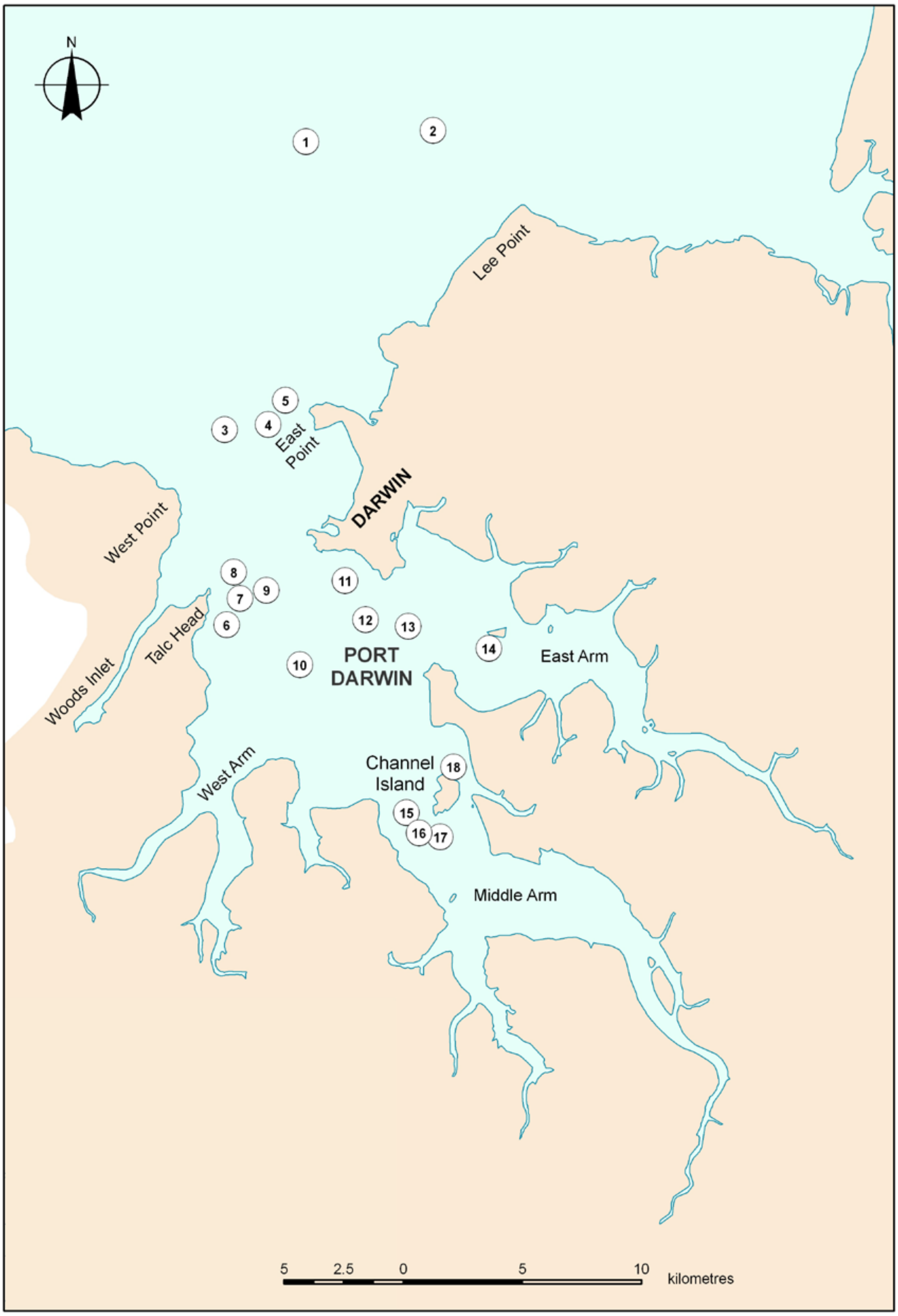

Figure 1. Sampling sites in BRUVS Darwin Harbour fish survey in May-September 2011.

2.2 Study design

2.2.1 Baited Remote Underwater Video Station (BRUVS) description

Three BRUVS were used for all samples, with both consisting of a galvanized roll-bar frame enclosing a simple camera housing with acrylic front and rear ports (Fig. 2, 3) designed in Australian Institute of Marine Science (AIMS) (Cappo et al. 2004). SONY Handicam HDR-CX350E cameras were used for fish recording. Exposure was set to ‘Auto’, focus was set to ‘infinity/manual’, date/time codes were overlaid on footage. 1.5 m bait arms (20 mm plastic conduit) were attached during deployment. The bait arm held a plastic mesh bait canister containing one kilogram of crushed pilchards, *Sardinops neopilchardus* (Cappo et al. 2003, 2004). BRUVS were deployed with 6 mm Spectra ropes and two 30 cm surface floats bearing a flag to make a buoy more visible from the distance.

Figure 2. Launching BRUVS from the boat during fish BRUVS survey in May-September 2011 in Darwin Harbour.

Table 1. List of sites surveyed in Darwin Harbour during BRUVS study in May-September 2011.

Site Number	Station Name	Site Description
1	SS-1RM SS-2RM SS-3RM	"Rick Mills Memorial Artificial Reef" consists of heavy mining equipment, wreckage arranged in a rosette pattern approximately 250m diameter, first began in development in 2005, max. depth 13m, located approximately 8.5km NW of Nightcliff Jetty (this area includes three sites SS-1RM and SS-2RM located adjacent to artificial reef structures and SS-3RM located significantly outside the artificial reef structure approximately 700m).
2	SS-1BW SS-2BW SS-3BW	"Bottle Washer Artificial Reef" consists of a large bottle washing machine, concrete pipes and a boiler wreckage arranged in a rosette approximately 150m in diameter, first began development in 1996 max depth 13m, located 4.5km NW of Lee Point (area includes three sites SS-1BW,SS-2BW located adjacent to structure and SS-3BW located significantly outside Artificial Reef structure approximately 650m)
3	8_Rck	8 Rock, shallow ground located at mouth of Darwin Harbour near 6 Mile Marker Buoy.
4	DSAC_B	DSAC Barge, located west of Dudley Point is a collection of large items including a barge forming an artificial reef constructed in 1988 by the Darwin Sub Aqua Club, max. depth 22m
5	6_Rck	6 Rock, located west of East Point on edge of East Point Reef.
6	2_Rck	2 Rock, located near Stevens Rock on the western side of Darwin Harbour approximately 900m SSE of Talc Head.
7	OBST_Rck	Obstruction Rock, located near Plater Rock on the western side of Darwin Harbour approximately 700m WNW of Talc Head.

8	5_Rck	5 Rock, located 1000m NE of Talc Head, shallow ground near Kurumba Shoal on the western side of Darwin Harbour.
9	JoH_B	John Holland Barge Wreck, 18m in length max. depth 24m an artificial reef part of a group of three or four wrecks sunk in 1982, located on western side of Darwin Harbour.
10	COR_12	South-east corner of Weed Reef, located on the western side of Darwin Harbour.
11	USS_P	USS Peary Wreck, 96 metres, 1190 ton, Flush Deck Destroyer, sunk during WWII Japanese Air Raid on Darwin Harbour in1942, salvaged to water line in the late 1950’s, max. depth 30m.
12	BRIT_Mt	Briitsh Motorist Wreck, Commercial tanker 134m, 6891 tons, sunk in WWII Japanese Air Raid on Darwin Harbour, later raised and mostly salvaged in the 1950’s; now only rubble, max. depth 20m.
13	Luc_Dip	Lucky Dip, located on shallow ground, 3km NNW of Wickham Point and 2km SSE of Fort Point (Fort Hill Wharf).
14	S_Shell	South Shell Island is a rocky outcrop lying just south of the East Arm Port Development.
15	Bnk_1NCh	North Channel Bank 1, located 1000m WSW of the Channel Island Boat Ramp.
16	Bnk_2NCh	North Channel Bank 2, located 1300m S of the Channel Island Boat Ramp.
17	4_RckNCh	North Channel 4 Rocks, located on eastern edge of rocky outcrop exposed at low tides 1500m SWS of the Channel Island Boat Ramp.
18	Ch_Isl	Channel Island this site is located on the eastern coastal edge of Channel Island and is composed fringing estuarine reef opposite the mouth of Jones Creek.

2.2.2 Survey procedure

All surveys were conducted in May–September 2011 during neap tides to avoid high tidal currents and increased water turbidity during spring tides. Surveys were conducted in daytime (between 8:00 hours and 15:00 hours). Boat GPS was used to navigate to each site. The average accuracy of this device is ±5–7 m. One of the BRUVS apparatus was prepared for video survey (Cappo et al. 2003) and deployed. Depth was measured using the boat deep sounder. BRUVS remained on the sea floor for 60 minutes, and recorded fish attracted to the bait canister. Site name, date, the time when survey was started and finished, the depth and BRUVS device ID number were recorded. Because of relatively large distances between selected sites and because two BRUVS were never used at the same site, video replicates were independent (e.g. same fish were unable to visit more than one BRUVS during the survey).

In spite of all attempts to avoid making video surveys in low water transparency, 35 one-hour video records or 17.5% of all 200 records were considered unsuitable for analysis. In order to avoid a bias in fish identification and assessing fish abundance only 165 stations with appropriate visibility >1.5 m have been used in statistical analysis. Remaining 35 stations were analysed for presence-absence of fishes when fish identification was still possible.

2.2.3 Underwater video interrogation

An interrogation of video was done according to Cappo et al. (2003, 2004). All 60 minutes of video were screened and each new fish species arriving in the field of view of the camera was recorded. Only the maximum number of individuals of each species seen together in the field of view at one time (MaxN) was used in analyses to avoid the possibility of fish double counting. According to previous studies (Priede et al. 1994; Cappo et al. 2004; Watson et al. 2005), MaxN gives a conservative estimate of fish relative density. Images of the sea bottom were used to identify different types of bottom cover. In Darwin Harbour this can vary from hard coral, rocks, pebbles and gravel to sand, silted sand and silt, depending on the depth and location of survey station.

2.2.4 Fish identification

Where possible, fish were identified to species level. Atlas of Living Australia http://biocache.ala.org.au database was used as a main source of information on the previous records of fish species in Darwin Harbour and Northern Territory waters. International Code of Zoological Nomenclature (1999) and the list of standardised Australian fish names http://www.marine.csiro.au/caab/namelist.htm were used in this report. We were using Helen's Larson's 1997 paper "Checklist of Darwin Harbour fishes" and "Atlas of living Australia" http://biocache.ala.org.au/occurrences/search?taxa= as sources for the list of fish not listed for Darwin Harbour before our study.

2.3 Data analysis

All graphs in this report were created using original, non-transformed data on both species number and fish abundance. Fish abundance and species richness (species number within stations and sites) were compared using analysis of variance (ANOVA) (one-way estimate model). Statistical package SYSTAT 13 was used for all statistical analysis. Prior to analysis the data was checked for normality and homogeneity of variances using Kolmogorov-Smirnov test (Lilliefors) and Levene's Test. Both normality and variances homogeneity (Quinn & Keough 1996) of species number have been improved by Lg10 (n+1) of original data. Tukey's honestly significant difference (HSD) test was used for post-hoc comparison.
PRIMER 6.0 (Clarke & Warwick, 1994) was employed to run DIVERSE and SIMPER and analysis and to build MDS graph for fish assemblages from different bottom habitats.

Figure 3. Launching BRUVS from the boat during fish survey in May-September 2011 in Darwin Harbour.

3 Results

3.1 Fish assemblages composition in Darwin harbour according to BRUVS survey

The list of species recorded during BRUVS survey in May-September 2011 in Darwin Harbour with species percent occurrence, percent contribution and other parameters at each of the 165 of 60 minutes BRUVS stations is presented in Table 2. A total 3075 individual fish were recorded at 22 sites during 200 one-hour video stations.

A total of 108 fish species from 41 families was recorded during this study. Nineteen species were added to the Darwin Harbour list and two species are likely to be the first records in NT waters (Table 2). Only eight species recorded in the survey were more widely distributed and have been found at 25% - 50% of all stations (Table 2, 3). Northwest Threadfin Bream, *Pentapodus porosus* was found to be the most frequently observed fish found in ~50% of all stations. It is appear that some tendency exist in number of species decrease in areas closer to the Harbour estuary comparing to the Harbour entrance (Table 3).

Among the 108 recorded species 33 species contributed to 90% of total fish abundance. The top five species contributed to 51% of all recorded fish were trevallies, threadfin breams, ponyfishes and batfishes (Table 5). Fish species targeted by recreational fishers make up 26.2% of all fish recorded during our survey (Table 6.).

Table 2. The list of 108 fish species recorded during BRUVS survey in Darwin Harbour in May-August 2011. The % Occurrence presence/absence of species on 165 60-minutes BRUVS stations. %Contribution – percent contribution of each species to the overall data set (ΣΣMaxN = 3075 individuals) is shown in terms of numbers counted and prevalence on the BRUVS set.

Family	Common Name	Scientific Name	% 0ccurence	Number of fish recorded	% Contribution	Previous records *	
						Northern Territory	Darwin Harbour
Hemiscyllidae	Speckled Carpetshark	*Hemiscyllium trispeculare*	3.0	5	0.2	+	+
Hemiscyllidae	Grey Carpetshark	*Chiloscyllium punctatum*	4.2	7	0.2	+	+
Ginglymostomatidae	Tawny Shark	*Nebrius ferrugineus*	0.6	1	0.03	+	+
Carcharhinidae	Blacktip Reef Shark	*Carcharhinus melanopterus*	1.8	6	0.2	+	+
Carcharhinidae	Spot-tail Shark	*Carcharhinus sorrah*	1.2	2	0.1	+	**No**
Carcharhinidae	**White Cheek Shark**	***Carcharhinus dussumieri***	**13.9**	29	0.9	+	+
Carcharhinidae	Unidentified Whaler	*Carcharhinus sp.*	2.4	4	0.1	+	+
Carcharhinidae	Tiger Shark	*Galeocerdo cuvier*	1.2	2	0.1	+	+
Sphyrnidae	Great Hammerhead	*Sphyrna mocarran*	1.2	2	0.1	+	+
Rhinobatidae	Giant Guitarfish	*Rhynchobatus djiddensis*	3.0	5	0.2	+	**+**
Dasyatidae	Bluespotted Maskray	*Neotrygon kuhlii*	2.4	5	0.2	+	**No**
Dasyatidae	Reticulate Whipray	*Himantura uarnak*	4.2	8	0.3	+	+
Dasyatidae	Whipray	*Himantura sp.*	0.6	1	0.03	+	+
Dasyatidae	Cowtail Stingray	*Pastinachus sephen*	1.8	3	0.1	+	**+**
Muraenidae	Yellowgill Moray	*Gymnothorax longinquus*	1.2	2	0.1	+	**No**
Culpeidae	Smallspotted Herring	*Herklotsichthys lippa*	1.8	7	0.2	+	**+**
Ariidae	Giant Sea Catfish	*Netuma thalassina*	0.6	1	0.03	+	+
Plotosidae	Sailfin Catfish	*Paraplotosus butleri*	1.8	3	0.1	+	+
Platycephalidae	Yellowtail Flathead	*Platycephalus endrachtensis*	0.6	1	0.03	+	+
Latidae	Sand Bass	*Psammoperca waigiensis*	1.8	3	0.1	+	+
Ambassidae	Perchelet	*Ambassis sp.*	0.6	25	0.8	+	+
Serranidae	Brownbarred Rockcod	*Cephalopholis boenak*	7.3	23	0.7	+	+

Serranidae	Tomato Rockcod	*Cephalopholis sonnerati*	1.2	2	0.1	+	**No**
Serranidae	Rockcod	*Cephalopholis sp.*	2.4	7	0.2	+	+
Serranidae	**Goldspotted Rockcod**	***Epinephelus coioides***	**21.2**	46	1.5	+	+
Serranidae	Queensland Groper	*Epinephelus lanceolatus*	1.8	3	0.1	+	**+**
Serranidae	Bluespotted Coral Trout	*Plectropomus laevis*	1.8	2	0.1	+	+
Serranidae	Barcheek Coral Trout	*Plectropomus maculatus*	5.5	10	0.3	+	+
Serranidae	Barred Soapfish	*Diploprion bifasciatum*	1.2	2	0.1	+	+
Psuedochromidae	Yellowfin Dottyback	*Pseudochromis wilsoni*	0.6	1	0.03	+	+
Terapontidae	Fourline Striped Grunter	*Pelates quadrilineatus*	0.6	4	0.1	+	+
Terapontidae	Largescale Grunter	*Terapon theraps*	4.8	55	1.8	+	+
Apogonidae	Orbicular Cardinalfish	*Sphaeramia orbicularis*	6.7	21	0.7	+	+
Sillaginidae	Northern Whiting	*Sillago sihama*	7.9	18	0.6	+	+
Echeneidae	**Sharksucker**	***Echeneis naucrates***	**10.3**	28	0.9	+	+
Carangidae	Pennantfish	*Alectis ciliaris*	4.8	11	0.4	+	**No**
Carangidae	**Trevally**	***Carangoides sp.***	**15.2**	37	1.2	+	+
Carangidae	Onion Trevally	*Carangoides caeruleopinnatus*	0.6	4	0.1	**No**	**No**
Carangidae	**Bluespotted Trevally**	***Caranx bucculentus***	**11.5**	60	2.0	+	+
Carangidae	Golden Trevally	*Gnathanodon speciosus*	3.6	11	0.4	+	+
Carangidae	**Fringefin Trevally**	***Pantolabus radiatus***	**26.7**	471	**15.3**	+	+
Carangidae	Giant Queenfish	*Scomberoides commersonnianus*	0.6	1	0.03	+	+
Carangidae	**Yellowstripe Scad**	***Selaroides leptolepis***	**21.2**	406	**13.2**	+	+
Carangidae	Blackbanded Amberjack	*Seriolina nigrofasciata*	4.2	10	0.3	+	**No**
Leiognathidae	**Whipfin Ponyfish**	***Equulites leuciscus***	**32.1**	222	**7.2**	+	+
Leiognathidae	Common Ponyfish	*Leiognathus equulus*	1.2	3	0.1	+	+
Leiognathidae	Ponyfish	*Leiognathus sp.*	6.1	85	2.8	+	+
Lutjanidae	**Stripey Snapper**	***Lutjanus carponotatus***	**27.3**	98	3.2	+	+
Lutjanidae	Crimson Snapper	*Lutjanus erythropterus*	6.7	34	1.1	+	+
Lutjanidae	Blacktail Snapper	*Lutjanus fulvus*	0.6	1	0.03	+	+
Lutjanidae	Paddletail	*Lutjanus gibbus*	3.6	6	0.2	+	**No**
Lutjanidae	Golden Snapper	*Lutjanus johnii*	1.8	5	0.2	+	+

Lutjanidae	Saddletail Snapper	*Lutjanus malabaricus*	0.6	4	0.1	+	+
Lutjanidae	Moses' Snapper	*Lutjanus russelli*	0.6	2	0.1	+	+
Lutjanidae	Brownstripe Snapper	*Lutjanus vitta*	4.2	10	0.3	+	+
Nemipteridae	Ornate Threadfin Bream	*Nemipterus hexodon*	5.5	9	0.3	+	**+**
Nemipteridae	Yellowtip Threadfin Bream	*Nemipterus nematopus*	1.8	5	0.2	+	**No**
Nemipteridae	Threadfin Bream	*Nemipterus sp.*	19.4	75	2.4	+	+
Nemipteridae	**Northwest Threadfin Bream**	***Pentapodus porosus***	**49.7**	367	**11.9**	+	+
Nemipteridae	Monocle Bream	*Scolopsis sp.*	1.8	15	0.5	+	+
Haemulidae	Painted Sweetlips	*Diagramma labiosum*	5.5	10	0.3	+	+
Haemulidae	Brown Sweetlips	*Plectorhinchus gibbosus*	4.2	7	0.2	+	+
Haemulidae	Blotched Javelin	*Pomadasys maculatus*	0.6	1	0.03	+	**+**
Lethrinidae	**Swallowtail Seabream**	***Gymnocranius elongatus***	**10.9**	20	0.7	+	**No**
Lethrinidae	Grass Emperor	*Lethrinus laticaudis*	4.8	12	0.4	+	+
Lethrinidae	**Spangled Emperor**	***Lethrinus nebulosus***	**11.5**	29	0.9	+	+
Lethrinidae	Yellowtail emperor	*Lethrinus atkinsoni*	7.9	23	0.7	+	**No**
Mullidae	Opalescent Goatfish	*Parupeneus heptacanthus*	0.6	1	0.03	+	**No**
Mullidae	Bartail Goatfish	*Upeneus tragula*	6.1	19	0.6	+	+
Chaetodontidae	Philippine Butterflyfish	*Chaetodon adiergastos*	0.6	1	0.03	+	+
Chaetodontidae	Goldstripe Butterflyfish	*Chaetodon aureofasciatus*	3.6	17	0.6	+	+
Chaetodontidae	Margined Coralfish	*Chelmon marginalis*	3.0	7	0.2	+	+
Chaetodontidae	**Müller's Coralfish**	***Chelmon müelleri***	**24.8**	71	2.3	+	+
Pomacanthidae	**Scribbled Angelfish**	***Chaetodontoplus duboulayi***	**27.3**	76	2.5	+	+
Pomacanthidae	Sixband Angelfish	*Pomacanthus sexstriatus*	3.0	7	0.2	+	+
Pomacentridae	Sergeant	*Abudefduf sp.*	2.4	4	0.1	+	+
Pomacentridae	Australian Anemonefish	*Amphiprion rubrocinctus*	0.6	1	0.03	+	+
Pomacentridae	Banded Damsel	*Dischistodus darwiniensis*	0.6	1	0.03	+	+
Pomacentridae	Black Damsel	*Neoglyphidodon melas*	0.6	1	0.03	+	+
Ephippidae	**Shortfin Batfish**	***Zabidius novemaculeatus***	**12.7**	103	3.3	+	+
Sphyraenidae	Pickhandled Barracuda	*Sphyraena jello*	4.8	10	0.3	+	**No**
Sphyraenidae	Striped Barracuda	*Sphyraena obtusata*	1.2	2	0.1	+	**No**

Sphyraenidae	Barracuda	*Sphyraena sp.*	0.6	1	0.03	+	+
Labridae	**Purple Tuskfish**	***Choerodon cephalotes***	**10.9**	24	0.8	+	+
Labridae	**Blue Tuskfish**	***Choerodon cyanodus***	**35.2**	97	3.2	+	+
Labridae	Blackspot Tuskfish	*Choerodon schoenleinii*	0.6	3	0.1	+	+
Labridae	Tuskfish	*Choerodon sp.*	3.0	5	0.2	+	+
Labridae	**Redstripe Tuskfish**	***Choerodon vitta***	**13.9**	33	1.1	+	+
Scaridae	Bluebarred Parrotfish	*Scarus ghobban*	0.6	2	0.1	+	**No**
Blenniidae	Yellow Fangblenny	*Meiacanthus luteus*	0.6	1	0.03	+	**+**
Gobiidae	Shrimpgoby	*Amblyeleotris sp.*	0.6	1	0.03	+	**No**
Gobiidae	Unknown Goby		2.4	4	0.1	+	+
Acanthuridae	Inshore Surgeonfish	*Acanthurus grammoptilus*	7.9	53	1.7	+	+
Siganidae	Black Rabbitfish	*Siganus fuscescens*	1.2	5	0.2	+	+
Scombridae	School Mackerel	*Scomberomorus queenslandicus*	2.4	5	0.2	+	+
Scombridae	**Mackerel**	***Scomberomorus sp.***	**25.5**	58	1.9	+	+
Bothidae	Flounder	*Pseudorhombus sp.*	3.0	5	0.2	+	+
Soleidae	Unidentified Sole/Flounder	*Flounder*	6.1	11	0.4	+	+
Monocanthidae	Bearded Leatherjacket	*Anacanthus barbatus*	0.6	1	0.03	+	+
Monocanthidae	Fanbelly Leatherjacket	*Monacanthus chinensis*	5.5	9	0.3	+	+
Monocanthidae	Pigface Leatherjacket	*Paramonacanthus choirocephalus*	8.5	17	0.6	+	+
Monocanthidae	Threadfin Leatherjacket	*Paramonacanthus filicauda*	1.2	2	0.1	+	**No**
Monocanthidae	Leatherjacket	*Paramonacanthus sp.*	2.4	7	0.2	+	+
Tetraodontidae	Narrowlined Puffer	*Arothron manilensis*	0.6	1	0.03	+	+
Tetraodontidae	Rough Golden Toadfish	*Lagocephalus lunaris*	0.6	1	0.03	+	+
Tetraodontidae	Ferocious Puffer	*Feroxodon multistriatus*	0.6	1	0.03		+
Tetraodontidae	Silver Toadfish	*Lagocephalus sceleratus*	2.4	7	0.2	+	**No**
Tetraodontidae	Toadfish	*Lagocephalus sp.*	0.6	2	0.1	+	+

*According to database of Atlas of Living Australia as for 1/03/2012 and Museum and Art Gallery of the Northern Territory as for 21/05/2012

Table 3. Presence-absence of different fish species and mean number of species recorded at 22 surveyed sites in Darwin Harbour in BRUVS survey in May-September 2011. Stations are presented in order "from Harbour entrance to mid estuary".

Specieso	SS-1BW	SS 2BW	SS-3BW	SS-1RM	SS-2RM	SS-3RM	6 Rock	8 Rock	DSAC Barge	5 Rock	Obstruction Rock	USPEAR	John Holland Barge	2 Rock	British Motorist	Lucky Dip	Cor 12	South Shell Island	Channel Island	North Channel Bank 1	4 Rock North Channel Island	North Channel Bank 2
Mean species number at site	11.2	13.5	11.7	9.0	10.5	14.4	**5.9**	9.1	8.8	4.3	5.3	4.0	0.8	5.3	8.0	2.8	1.7	**7.1**	3.0	**4.5**	3.7	**6.2**
Hemiscyllium trispeculare	0	0	0	0	0	0	**Y**	0	0	0	0	0	0	0	0	0	0	**Y**	0	**0**	0	**Y**
Chiloscyllium punctatum	0	**Y**	0	0	0	0	0	0	**Y**	0	0	0	0	0	0	**Y**	0	0	**Y**	**Y**	0	**Y**
Nebrius ferrugineus	0	0	0	0	0	0	0	0	0	0	0	**Y**	0	0	0	0	0	0	0	0	0	0
Carcharhinus melanopterus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**Y**	0	0	0	0	0	0
Carcharhinus sorrah	0	0	**Y**	0	0	0	0	0	0	0	0	0	0	0	**Y**	0	0	0	0	0	0	0
Carcharhinus dussumieri	0	**Y**	**Y**	0	0	**Y**	**Y**	0	**Y**	0	0	**Y**	0	0	0	0	0	0	**Y**	0	0	0
Carcharhinus sp.	0	**Y**	0	0	**Y**	0	0	0	0	0	0	0	0	0	0	0	0	**Y**	0	0	0	0
Galeocerdo cuvier	0	0	0	0	0	0	0	0	0	**Y**	0	0	0	0	0	0	0	0	0	0	0	0
Sphyrna lewini	0	0	0	0	**Y**	**Y**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhynchobatus djiddensis	0	0	0	0	0	0	0	0	0	**Y**	0	0	0	0	0	0	**Y**	**Y**	**Y**	0	0	0
Neotrygon kuhlii	0	0	0	0	**Y**	**Y**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**Y**
Himantura uarnak	0	0	0	0	**Y**	**Y**	0	0	**Y**	0	0	0	0	0	0	0	0	**Y**	**Y**	0	0	0
Himantura sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**Y**	0	0	0
Pastinachus sephen	0	0	0	0	0	0	0	0	**Y**	0	0	0	0	**Y**	0	0	0	0	**Y**	0	0	0
Gymnothorax sp.	0	0	0	0	0	**Y**	0	0	0	0	0	0	0	0	0	0	0	0	**Y**	0	0	0
Herklotsichthys lippa	0	0	0	**Y**	**Y**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Netuma thalassina	0	0	0	0	0	0	**Y**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Paraplotosus butleri	0	0	0	0	0	0	0	0	0	0	**Y**	0	0	0	0	0	0	**Y**	0	0	0	**Y**

Platycephalus endrachtensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Y	0	0	0
Psammoperca waigiensis	Y	0	0	0	0	0	0	Y	0	0	0	0	0	0	0	0	0	0	Y	0	0	0
Ambassis sp.	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cephalopholis boenak	Y	0	0	0	0	0	Y	Y	0	0	0	0	0	0	0	0	0	Y	Y	0	0	Y
Cephalopholis sonnerati	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Y	0	0	0	0
Cephalopholis sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	Y	0	0	0	Y	0	0	0	0
Epinephelus coioides	0	0	0	Y	Y	0	Y	Y	0	Y	Y	Y	Y	Y	Y	0	0	Y	Y	Y	Y	Y
Epinephelus lanceolatus	Y	0	0	0	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plectropomus laevis	0	0	0	0	0	0	Y	0	0	0	0	0	0	Y	0	0	0	0	0	0	0	0
Plectropomus maculatus	0	0	0	0	0	0	0	Y	0	0	0	0	0	Y	0	0	0	Y	0	0	0	0
Diploprion bifasciatum	0	0	0	0	0	0	0	0	0	0	Y	0	0	0	0	0	0	0	0	0	0	0
Pseudochromis wilsoni	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Y
Pelates quadrilineatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Y	0	0	0	0	0	0	0
Terapon theraps	0	0	0	Y	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sphaeramia orbicularis	0	0	0	0	0	0	0	0	Y	0	0	Y	0	0	Y	0	0	Y	Y	0	Y	Y
Sillago sihama	0	0	Y	Y	Y	0	0	0	0	0	0	0	0	0	Y	0	0	Y	Y	0	0	0
Echeneis naucrates	Y	0	0	0	Y	Y	0	0	0	0	0	0	0	0	0	0	Y	Y	Y	0	0	0
Alectis ciliaris	0	Y	Y	Y	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carangoides sp.	0	0	Y	Y	Y	Y	Y	0	Y	0	Y	0	0	0	0	0	Y	Y	Y	0	0	0
Carangoides coeruleopinnatus	0	0	0	0	0	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Caranx bucculentus	Y	0	Y	Y	Y	0	0	0	0	0	0	Y	0	0	0	0	0	Y	Y	Y	0	Y
Gnathanodon speciosus	Y	0	Y	0	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pantolabus radiatus	Y	Y	Y	Y	Y	Y	0	0	Y	0	0	0	0	0	Y	0	0	Y	Y	0	0	Y
Scomberoides commersonianus	0	0	0	0	0	0	0	0	Y	0	0	0	0	0	0	0	0	0	0	0	0	0
Selaroides leptolepis	Y	Y	Y	Y	Y	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Seriolina nigrofasciata	0	0	Y	0	Y	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leiognathus longispinis	Y	Y	Y	Y	Y	Y	0	0	Y	Y	Y	Y	Y	Y	Y	0	0	Y	Y	0	Y	0
Leiognathus equulus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Y	0	0	0	0	0	0	0
Leiognathus sp.	0	0	0	0	0	0	0	0	Y	0	Y	0	0	Y	0	0	0	Y	Y	0	Y	0
Lutjanus carponotatus	Y	0	0	0	0	Y	Y	Y	0	0	Y	0	0	Y	0	0	0	Y	Y	Y	0	Y

Lutjanus erythropterus	0	0	0	0	**Y**	0	0	0	0	0	0	0	0	0	**Y**	0	**Y**	0	**Y**	0	0	0
Lutjanus fulvus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	0	**Y**
Lutjanus gibbus	0	0	0	0	0	**Y**	0	0	0	0	**Y**	0	0	0	0	0	0	0	0	**Y**	0	**Y**
Lutjanus johnii	0	0	0	0	0	0	**Y**	0	**Y**	0	0	0	0	0	0	0	0	0	0	0	0	0
Lutjanus malabaricus	0	0	0	**Y**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lutjanus russelli	**Y**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lutjanus vitta	0	0	0	0	0	0	0	**Y**	**Y**	0	0	0	0	**Y**	0	0	0	**Y**	0	0	0	0
Nemipterus hexadon	0	**Y**	**Y**	0	0	0	0	0	0	0	0	0	0	0	**Y**	0	0	0	0	0	0	0
Nemipterus nematopus	0	0	0	0	0	**Y**	0	0	0	**Y**	0	0	0	0	0	0	0	0	0	0	0	0
Nemipterus sp.	0	**Y**	0	**Y**	**Y**	**Y**	**Y**	0	**Y**	**Y**	**Y**	0	**Y**	0	0	0	0	0	0	**0**	0	**Y**
Pentapodus porosus	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	0	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	0	**Y**	**Y**	0	**Y**	0
Scolopsis sp.	0	0	0	0	0	**Y**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diagramma labiosum	0	0	0	**Y**	**Y**	0	0	**Y**	0	0	**Y**	0	0	**Y**	0	0	0	**Y**	**Y**	0	0	0
Plectorhinchus gibbosus	0	0	0	0	0	0	0	**Y**	0	0	0	0	0	0	0	0	0	0	0	**Y**	0	**Y**
Pomadasys maculatus	0	0	0	0	**Y**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gymnocranius elongatus	0	**Y**	**Y**	0	**Y**	**Y**	0	0	**Y**	0	**Y**	0	0	0	**Y**	0	0	**Y**	0	0	0	0
Lethrinus laticaudis	0	0	0	0	0	0	0	0	**Y**	0	0	0	0	0	**Y**	**Y**	0	0	0	0	0	0
Lethrinus nebulosus	0	0	0	0	0	**Y**	**Y**	**Y**	0	**Y**	0	0	0	**Y**	0	0	0	**Y**	**Y**	0	0	0
Lethrinus sp.	0	**Y**	**Y**	**Y**	**Y**	**Y**	0	0	0	0	0	0	0	0	0	0	0	0	**Y**	0	0	0
Parupeneus heptacanthus	0	0	0	0	0	**Y**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upeneus tragula	**Y**	0	0	**Y**	**Y**	**Y**	0	0	0	0	0	0	0	0	0	0	0	0	**Y**	0	0	0
Chaetodon adiergastos	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**Y**	0	0	0	0
Chaetodon aureofasciatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**Y**	**Y**	0	0	0
Chelmon marginalis	0	0	0	0	0	0	0	0	0	0	0	0	0	**Y**	0	0	0	**Y**	**Y**	0	0	0
Chelmon muelleri	**Y**	0	0	0	0	**Y**	**Y**	**Y**	0	**Y**	**Y**	0	0	0	0	0	0	**Y**	**Y**	0	**Y**	**Y**
Chaetodontoplus duboulayi	**Y**	0	0	**Y**	0	0	**Y**	**Y**	0	**Y**	0	0	0	**Y**	0	0	0	**Y**	**Y**	**Y**	**Y**	**Y**
Pomacanthus sexstriatus	0	0	0	0	0	0	**Y**	**Y**	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Abudefduf sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**Y**	0	0	0	0
Amphiprion rubrocinctus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**Y**	0	0	0	0
Dischistodus darwiniensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**Y**	0	0	0

Neoglyphidodon melas	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Y	0	0	0	0
Zabidius novemaculeatus	Y	0	Y	Y	Y	0	0	Y	0	0	0	0	0	Y	0	0	0	0	Y	0	0	Y
Sphyraena jello	0	0	0	Y	Y	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sphyraena obtusata	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Y	0	0	0
Sphyraena sp.	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Choerodon cephalotes	Y	0	0	0	Y	Y	0	0	Y	0	0	0	0	0	0	0	0	Y	0	Y	0	Y
Choerodon cyanodus	Y	0	0	0	Y	Y	Y	Y	Y	Y	Y	0	Y	Y	0	Y	0	Y	Y	Y	Y	Y
Choerodon schoenleinii	0	0	0	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Choerodon sp.	0	0	0	Y	Y	0	0	0	0	0	0	0	0	0	0	Y	0	0	0	0	0	0
Choerodon vitta	Y	0	0	Y	0	0	Y	Y	0	Y	Y	0	0	Y	0	Y	0	0	0	0	0	0
Scarus ghobban	0	0	0	0	0	0	0	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aspidontus dussumieri	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Y	0	0	0
Amblyeleotris sp.	0	0	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Goby	0	Y	Y	0	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acanthurus grammoptilus	0	0	0	0	0	0	Y	Y	0	0	0	0	0	Y	0	0	0	Y	Y	0	0	0
Siganus sp.	0	0	0	0	0	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scomberomorus queenslandicus	0	0	Y	0	Y	0	0	0	0	0	0	0	0	0	Y	0	0	0	0	0	0	0
Scomberomorus sp.	Y	Y	0	Y	Y	Y	Y	0	Y	Y	0	Y	0	Y	Y	0	0	Y	Y	0	0	0
Pseudorhombus sp.	Y	0	0	Y	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Flounder	0	Y	Y	Y	Y	Y	0	0	0	0	0	0	0	0	Y	0	0	0	Y	0	0	0
Anacanthus barbatus	0	0	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Monacanthus chinensis	Y	0	0	0	0	Y	0	0	Y	0	0	0	0	0	0	0	0	0	0	0	0	0
Paramonacanthus choirocephalus	0	0	Y	0	0	Y	0	0	Y	0	0	0	0	Y	Y	0	0	Y	Y	0	0	0
Paramonacanthus filicauda	0	Y	0	0	0	0	0	0	Y	0	0	0	0	0	0	0	0	0	0	0	0	0
Paramonacanthus sp.	0	0	0	0	0	0	0	0	0	0	0	Y	0	0	Y	0	0	Y	0	0	0	0
Arothron manilensis	0	0	0	0	0	0	0	0	0	0	0	0	0	Y	0	0	0	0	0	0	0	0
Lagocephalus lunaris	0	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lagocephalus sceleratus	0	Y	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lagocephalus sp.	0	0	0	0	0	0	0	0	Y	0	0	0	0	0	0	0	0	0	0	0	0	0

3.1.1 Fish abundance and species number (fish biodiversity).

There was a substantial variation in both species diversity and fish abundance (based on average Margalef species richness index and MaxN) among surveyed sites in Darwin Harbour, Fig. 4. The highest values were recorded at six sites offshore of Lee Point and at sites at the Harbour entrance, East Point, Talc Head, South Shell Island and the south – west side of Channel Island (Table 1, Fig. 1). Statistically significant differences were detected in Margalef index of species diversity (Margalef 1957) among surveyed sites (df = 21; F = 7.933; P < 0.001, one-way ANOVA) and fish abundance (Lg10 (n+1) transformed data, df = 21; F = 5.573; P < 0.001 one-way ANOVA). Results of Tukey's HSD test indicating the level of significance are given in Tables 7 and 8. While fish abundance varied significantly among the number of stations, species richness values were similar.

Analysis of mean fish abundance and species richness was repeated using only fish species targeted by recreational fishers. Sometimes no such species were recorded at the site, sometimes when there was only one species at the site and the Margalef species richness index value was zero. Such sites were excluded from the analysis and therefore not represented at Fig. 6. The distribution of the targeted fishes abundance was similar to distribution of all species: abundance values were higher at sites off Lee Point and at the Harbour entrance, Fig. 4 and Fig. 5, Table 9; ANOVA revealed significant differences between stations (df = 20; F = 4.202; P < 0.001 of Lg10 (MaxN+1)). At South Shell Island and at sites to the south-west off Channel Island recreational fish species richness appear to be similar to sites off Lee Point and at the Harbour entrance, Fig. 6. Differences in species richness (Margalef species richness index) of fish species targeted by recreational fishers recorded at each site were statistically significant at high significance level for species richness (one-way ANOVA, df = 20 F= 2.736 p = 0.001). However, these differences were

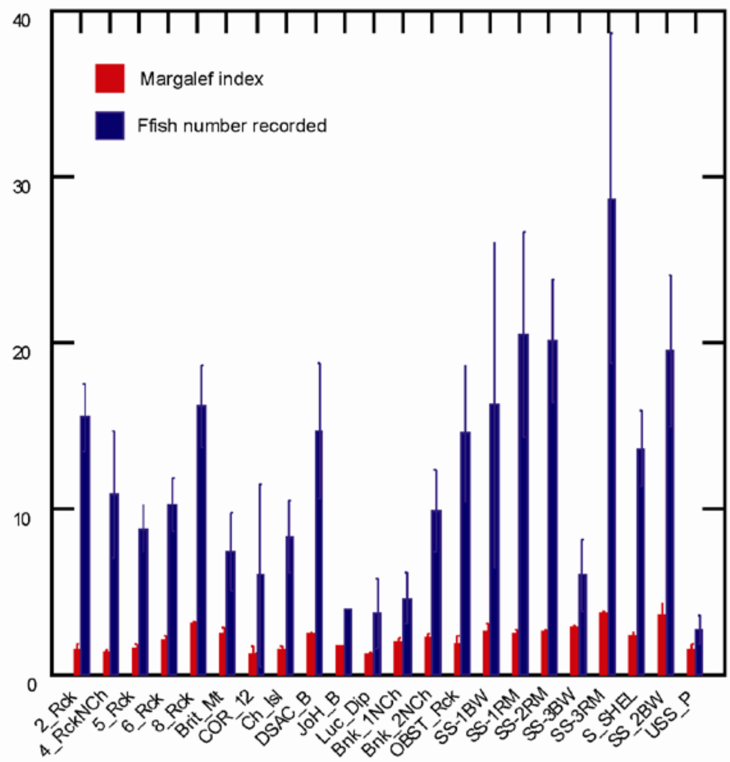

Figure 4. Mean fish number in one 60-minutes video sample and Margalef species richness index of all fishes recorded at each of 22 analysed sites during BRUVS survey in Darwin Harbour in May-September 2011.

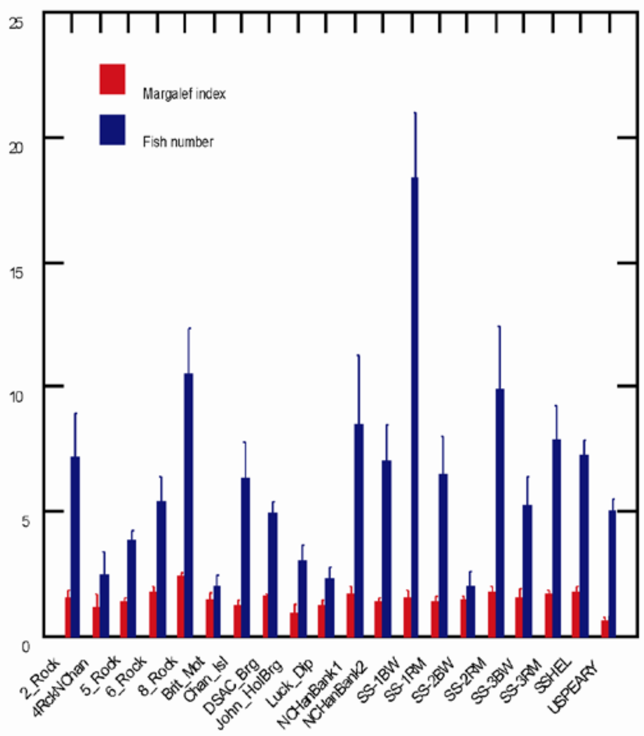

Figure 5. Mean number of individuals in one 60-minutes video sample and Margalef index in fish species targeted by recreational fishers in BRUVS survey of Darwin Harbour in May-September 2011.

3.1.2 Fish abundance and species diversity in different habitats

Four main types of habitat were identified within the area of study in Darwin Harbour:

• "Lower littoral. Coral" habitat (areas of the bottom with the depth ≤6 m and live hard coral growth). This type of habitat inside was recorded at 9.4% of BRUVS stations inside the Harbour, Fig. 6.

• "Lower littoral. No coral" habitat (depth ≤6 m with a variety of bottom cover (and absence of bottom cover), but without live hard corals). A proportion of this type of the habitat registered in our samples was 17.3%, Fig. 7.

• "Deep filter feeders" habitat (sponges, sea whips, gorgonians, hydroids with some algae at the depth 6-16 m and deeper. This bottom habitat was the most common in our fish video samples contributing 45.7%, Fig. 8.

• "Deep no cover" habitat (areas of bare gravel, pebbles, silted sand or silt at the depth 6-16 m and deeper).This was the second common type of bottom habitat encountered during our survey in the Harbour, 27.6%, Fig. 9.

The highest mean species richness expressed as Margalef index and fish number were recorded in coral habitat, the lowest – in "Lower littoral. No coral" habitat, Fig. 10 (df = 3; F = 12.429; P < 0.001, df = 3; F = 14.835; P < 0.01, respectively, one way ANOVA, fish number data was Lg10 (MaxN+1) transformed). Statistically significant differences in species diversity per site were found for "Deep, filter feeders" vs. "Lower littoral. No coral", "Deep no cover" vs. "Lower littoral. Coral" and "Lower littoral. No coral" vs. "Lower littoral. Coral" habitats, Table .Statistically significant differences in fish number were found between "Deep, filter feeders" vs. "Lower littoral. No coral cover" habitats; "Deep, filter feeders" vs. "Lower littoral. Coral"; "Deep no cover" vs. "Lower littoral. Coral" and "Lower littoral. No coral" vs. "Lower littoral. Coral" habitats, Tables 11, 12.

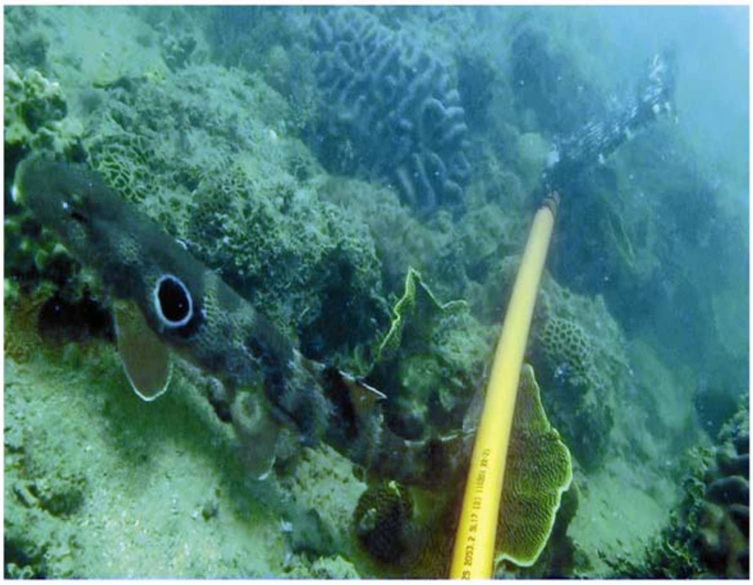

Figure 6. Speckled Carpetshark *Hemiscyllium trispeculare* in "Lower littoral, Coral" habitat in Darwin Harbour. Image from footage taken at South Shell Island during BRUVS fish of Darwin Harbour in May-September 2011.

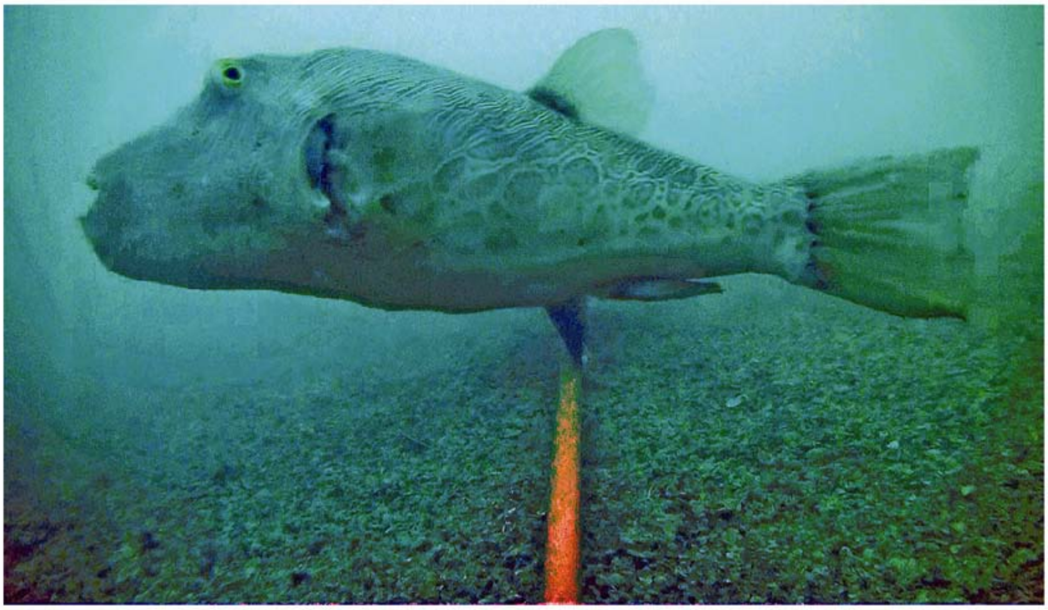

Figure 7. Ferrocious Pufferfish, *Feroxodon multistriatus* in “Lower littoral, no coral”. Image from footage taken during BRUVS fish survey in Darwin Harbour in May-September 2011.

Figure 8. Scribbled Angelfish, *Chaetodontoplus duboulayi* and Müller's Coralfish, *Chelmon mülleri* in "Deep filter feeders" habitat. Image from footage taken during BRUVS fish survey in Darwin Harbour in May-September 2011.

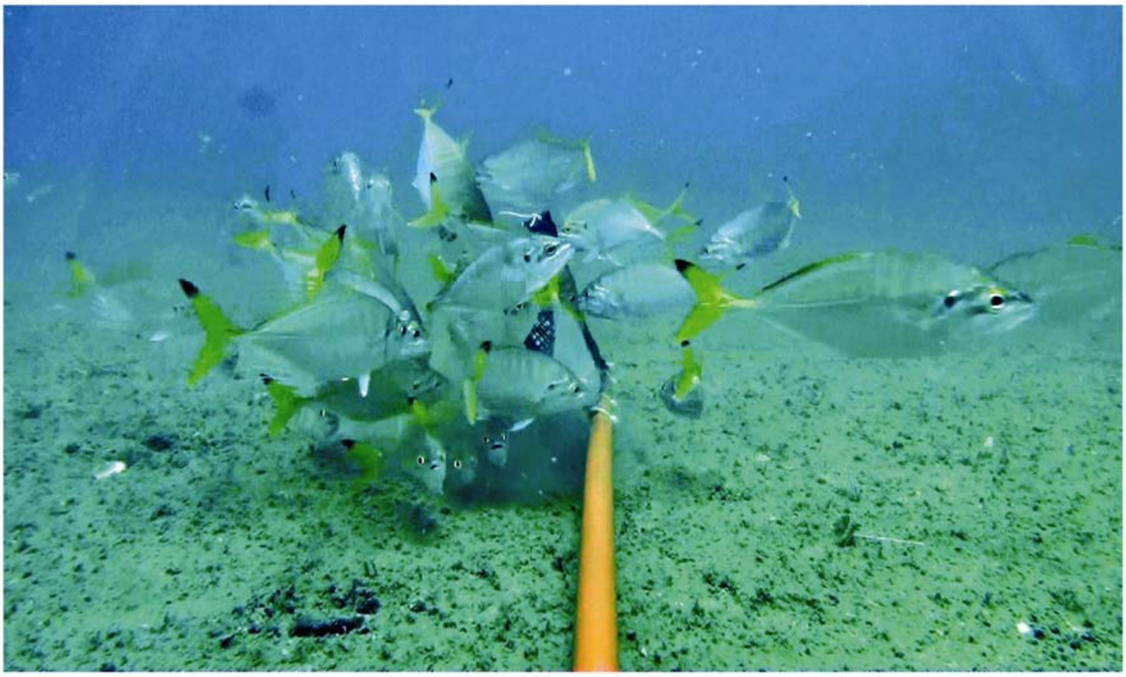

Figure 9. Fringefin Trevally *Pantolabus radiatus* in "Deep no cover" habitat in Darwin Harbour. Image from footage taken during BRUVS fish survey in Darwin Harbour in May-September 2011.

Table 4. Fish species contributed 90% to all fish abundance recorded during BRUVS survey in Darwin Harbour in May-September 2011.

Common name	Scientific Name	% Contribution
Fringefin Trevally	*Pantolabus radiatus*	15.3
Yellowstripe Scad	*Selaroides leptolepis*	13.2
Northwest Threadfin Bream	*Pentapodus porosus*	11.9
Whipfin Ponyfish	*Equulites leuciscus*	7.2
Shortfin Batfish	*Zabidius novemaculeatus*	3.3
Stripey Snapper	*Lutjanus carponotatus*	3.2
Blue Tuskfish	*Choerodon cyanodus*	3.2
Ponyfish	*Leiognathus sp.*	2.8
Scribbled Angelfish	*Chaetodontoplus duboulayi*	2.5
Threadfin Bream	*Nemipterus sp.*	2.4
Muller's Coralfish	*Chelmon muelleri*	2.3
Bluespotted Trevally	*Caranx bucculentus*	2
Mackerel	*Scomberomorus sp.*	1.9
Largescale Grunter	*Terapon theraps*	1.8
Inshore Surgeonfish	*Acanthurus grammoptilus*	1.7
Goldspotted Rockcod	*Epinephelus coioides*	1.5
Trevally	*Carangoides sp.*	1.2
Crimson Snapper	*Lutjanus erythropterus*	1.1
Redstripe Tuskfish	*Choerodon vitta*	1.1
White Cheek Shark	*Carcharhinus dussumieri*	0.9
Sharksucker	*Echeneis naucrates*	0.9
Spangled Emperor	*Lethrinus nebulosus*	0.9
Perchelet	*Ambassis sp.*	0.8
Purple Tuskfish	*Choerodon cephalotes*	0.8
Brownbarred Rockcod	*Cephalopholis boenak*	0.7
Orbicular Cardinalfish	*Sphaeramia orbicularis*	0.7
Swallowtail Seabream	*Gymnocranius elongatus*	0.7
Emperor	*Lethrinus sp.*	0.7
Northern Whiting	*Sillago sihama*	0.6
Bartail Goatfish	*Upeneus tragula*	0.6
Goldstripe Butterflyfish	*Chaetodon aureofasciatus*	0.6
Pigface Leatherjacket	*Paramonacanthus choirocephalus*	0.6
Monocle Bream	*Scolopsis sp.*	0.5
Pennantfish	*Alectis ciliaris*	0.4
TOTAL		**90%**

Table 5. List of fish species with the highest occurrence over 165 video station during BRUVS survey in Darwin Harbour in May-September 2011.

Common Name	Scientific name	%Occurence
Northwest Threadfin Bream	*Pentapodus porosus*	49.7
Blue Tuskfish	*Choerodon cyanodus*	35.2
Whipfin Ponyfish	*Equulites leuciscus*	32.1
Stripey Snapper	*Lutjanus carponotatus*	27.3
Scribbled Angelfish	*Chaetodontoplus duboulayi*	27.3
Fringefin Trevally	*Pantolabus radiatus*	26.7
Mackerel	*Scomberomorus sp.*	25.5
Muller's Coralfish	*Chelmon muelleri*	24.8

Table 6. Total number of fish targeted by amateur fishers recorded during Baited Remote Underwater Video System survey in Darwin Harbour in May-September 2011. Species list is ranked according to the fish abundance and given in descending order.

Common name	Scientific name	Number of fish recorded
Shortfin Batfish	*Zabidius novemaculeatus*	103
Stripey Snapper	*Lutjanus carponotatus*	98
Blue Tuskfish	*Choerodon cyanodus*	97
Bluespotted Trevally	*Carnax bucculentus*	60
Queenfish	*Scomberomorus sp.*	56
Goldspotted Rockcod	*Epinephelus coioides*	46
Trevally	*Carangoides sp.*	37
Redstripe Tuskfish	*Choerodon vitta*	36
Crimson Snapper	*Lutjanus erythropterus*	34
Spangled Emperor	*Lethrinus nebulosus*	29
Purple Tuskfish	*Choerodon cephalotes*	24
Brownbarred Rockcod	*Cephalopholis boenak*	23
Emperor	*Lethrinus sp.*	23
Grass Emperor	*Lethrinus laticaudis*	13
Golden Trevally	*Gnathanodon speciosus*	11
Barcheek Coral Trout	*Plectropomus maculatus*	10
Blackbanded Amberjack	*Seriolina nigrofasciata*	10
Brownstripe Snapper	*Lutjanus vitta*	10
Painted Sweetlips	*Diagramma labiosum*	10
Pickhandled Barracuda	*Sphyraena jello*	10
Rockcod	*Cephalopholis sp.*	7
Brown Sweetlips	*Plectorhinchus gibbosus*	7
Paddletail	*Lutjanus gibbus*	6
Golden Snapper	*Lutjanus johnii*	5
Wrasse	*Choerodon sp.*	5
Giant Queenfish	*Scomberomorus queenslandicus*	5
Onion Trevally	*Carangoides coeruleopinnatus*	4
Saddletail Snapper	*Lutjanus malabaricus*	4
Queensland Groper	*Epinephelus lanceolatus*	3
Bluespotted Coral Trout	*Plectropomus laevis*	3
Blackspot Tuskfish	*Choerodon schoenleinii*	3
Tomato Rockcod	*Cephalopholis sonnerati*	2
Moses' Snapper	*Lutjanus russelli*	2
Striped Barracuda	*Sphyraena obtusata*	2
Giant Sea Catfish	*Arius thalassinus*	1
Yellowtail Flathead	*Platycephalus arenarius*	1
Giant Queenfish	*Scomberoides commersonianus*	1
Blacktail Snapper	*Lutjanus fulvus*	1
Blotched Javelin	*Pomadasys maculatus*	1

Table 7. Tukey's HSD test of Margalef's species richness index at different sites in Darwin Harbour during BRUVS survey in May-September 2011. Using model MSE of 0.491 with 123 df. Only significant differences (p ≤ 0.05) are listed.

SITES	SITES	Difference	p-Value	95% Confidence Interval Lower	Upper
2_Rck	8_Rck	-1.533	0.013	-2.922	-0.144
2_Rck	SS-3RM	-2.160	0.000	-3.494	-0.825
2_Rck	SS-2BW	-2.034	0.041	-4.035	-0.032
4RckNCh	8_Rck	-1.677	0.006	-3.118	-0.236
4RckNCh	SS-3RM	-2.304	0.000	-3.693	-0.915
4RckNCh	SS-2BW	-2.178	0.021	-4.216	-0.139
5_Rck	8_Rck	-1.444	0.010	-2.733	-0.155
5_Rck	SS-2BW	-1.945	0.047	-3.879	-0.011
6_Rck	SS-3RM	-1.553	0.002	-2.812	-0.295
8_Rck	Ch_Isl	1.481	0.001	0.319	2.643
8_Rck	Luc_Dip	1.795	0.011	0.183	3.406
Ch_Isl	SS-2RM	-1.001	0.021	-1.939	-0.064
Ch_Isl	SS-3RM	-2.108	0.000	-3.205	-1.012
Ch_Isl	SS-2BW	-1.982	0.021	-3.834	-0.131
Luc_Dip	SS-3RM	-2.422	0.000	-3.986	-0.857
Luc_Dip	SS-2BW	-2.296	0.023	-4.458	-0.134
Bnk_1NCh	SS-3RM	-1.642	0.010	-3.104	-0.180
Bnk_2NCh	SS-3RM	-1.472	0.024	-2.861	-0.083
OBST_Rck	SS-3RM	-1.747	0.001	-3.136	-0.358
SS-3RM	S_Shell	1.324	0.009	0.153	2.494
SS-3RM	USS_P	2.185	0.001	0.462	3.908

Site abbreviated names explained in Table 1.

Table 8. Tukey's HSD test differences in mean fish abundance (MaxN) at the station at different sites in Darwin Harbour during BRUVS survey in May-September 2011. Using model MSE of 0.096 with 141 df. Only significant differences (p ≤ 0.05) are listed.

SITES	SITES	Difference	p-Value	95% Confidence Interval	
				Lower	Upper
2_Rck	Ch_Isl	0.530	0.007	0.068	0.991
5_Rck	SS-2RM	-0.662	0.000	-1.129	-0.194
5_Rck	SS-3RM	-0.658	0.002	-1.187	-0.128
6_Rck	SS-2RM	-0.617	0.003	-1.127	-0.108
6_Rck	SS-3RM	-0.613	0.018	-1.181	-0.046
COR_12	SS-1RM	-0.769	0.022	-1.490	-0.048
COR_12	SS-2BW	-1.019	0.040	-2.019	-0.019
COR_12	SS-2RM	-0.989	0.000	-1.703	-0.276
COR_12	SS-3BW	-0.957	0.008	-1.794	-0.120
COR_12	SS-3RM	-0.985	0.001	-1.741	-0.229
Ch_Isl	DSAC_B	-0.461	0.000	-0.809	-0.112
Ch_Isl	SS-1BW	-0.731	0.002	-1.316	-0.147
Ch_Isl	SS-1RM	-0.666	0.000	-1.068	-0.264
Ch_Isl	SS-2BW	-0.916	0.008	-1.717	-0.115
Ch_Isl	SS-2RM	-0.887	0.000	-1.275	-0.499
Ch_Isl	SS-3BW	-0.855	0.000	-1.439	-0.270
Ch_Isl	SS-3RM	-0.883	0.000	-1.344	-0.421
Luc_Dip	SS-1RM	-0.618	0.035	-1.218	-0.018
Luc_Dip	SS-2RM	-0.839	0.000	-1.430	-0.248
Luc_Dip	SS-3BW	-0.807	0.015	-1.542	-0.072
Luc_Dip	SS-3RM	-0.835	0.001	-1.476	-0.193
Bnk_1NCh	SS-1RM	-0.633	0.011	-1.199	-0.068
Bnk_1NCh	SS-2RM	-0.854	0.000	-1.410	-0.298
Bnk_1NCh	SS-3BW	-0.822	0.006	-1.529	-0.115
Bnk_1NCh	SS-3RM	-0.850	0.000	-1.459	-0.240
SS-3RM	S_Shell	0.520	0.043	0.006	1.034

Table 9. Tukey's HSD test of differences in fish abundance (MaxN) for fish species targeted by recreational fishers at different sites in Darwin Harbour. Using model MSE of 0.038 with 85 df. The data was Lg10 (MaxN +1) transformed.

SITE	SITE	Difference	p-Value	95% Confidence Interval	
				Lower	Upper
4RckNCh	SS-1BW	-0.765	0.003	-1.380	-0.150
6_Rck	SS-1BW	-0.534	0.003	-0.969	-0.099
8_Rck	Luc_Dip	0.622	0.003	0.120	1.124
Ch_Isl	SS-1BW	-0.659	0.000	-1.118	-0.201
DSAC_B	SS-1BW	-0.550	0.001	-0.960	-0.140
JoH_B	SS-1BW	-0.828	0.032	-1.622	-0.034
Luc_Dip	SS-1BW	-0.887	0.000	-1.429	-0.344
Luc_Dip	SS-2BW	-0.860	0.029	-1.680	-0.040
Luc_Dip	SS-2RM	-0.574	0.003	-1.041	-0.106
Luc_Dip	SSHEL	-0.494	0.046	-0.984	-0.003
SS-1BW	SS-1RM	0.553	0.001	0.133	0.974
SS-1BW	SS-3BW	0.642	0.002	0.140	1.144
SS-1BW	USS_P	1.004	0.002	0.210	1.798

Table 10 Tukey's HSD test of Margalef's species richness index for fish species targeted by recreational fishers at different sites in Darwin Harbour. Using model MSE of 0.224 with 86 df.

SITE	SITE	Difference	p-Value	95% Confidence Interval	
				Lower	Upper
8_Rck	Ch_Isl	1.000	0.005	0.160	1.841
8_Rck	SS-1RM	0.846	0.015	0.083	1.608

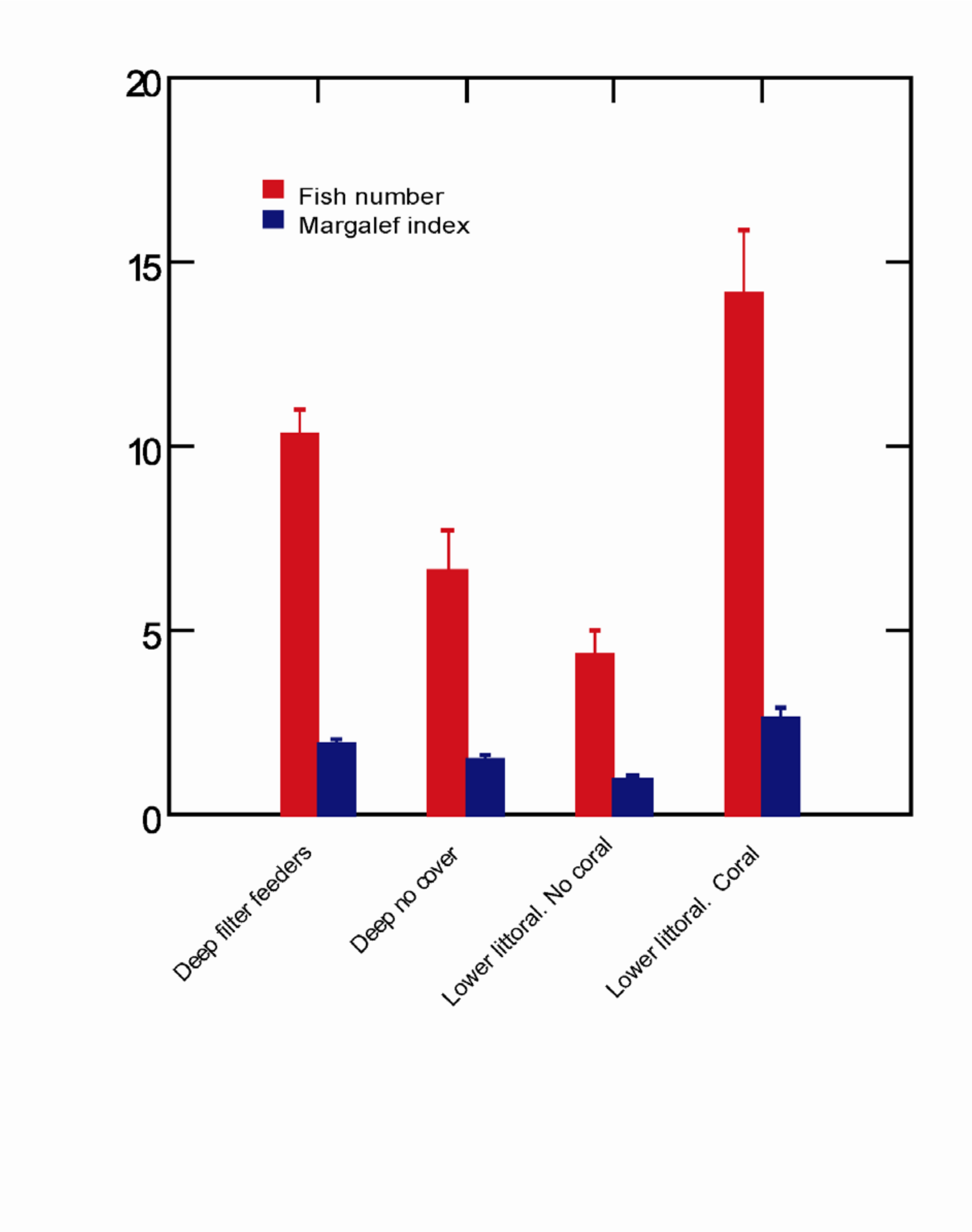

Figure 10. Number of fish individuals recorded in one 60-minutes video sample and Margalef index in different bottom habitat types during BRUVS Darwin Harbour surveyin May-September 2011.

Table 11. Tukey's HSD test of Margalef's species richness index for each sample at four different habitats in Darwin Harbour during BRUVS survey in May - September 2011. Using model MSE of 0.589 with 108 df.

Habitat	Habitat	Difference	p-Value	95% Confidence Interval	
				Lower	Upper
Deep_Filtercover	Deep_nocover	0.234	0.543	-0.224	0.692
Deep_Filtercover	ShallowNcor_Cover	0.679	**0.015**	0.097	1.261
Deep_Filtercover	Shallow_coral	-0.601	0.072	-1.238	0.036
Deep_nocover	ShallowNcor_Cover	0.445	0.269	-0.192	1.081
Deep_nocover	Shallow_coral	-0.835	**0.011**	-1.522	-0.148
ShallowNcor_Cover	Shallow_coral	-1.280	**0.000**	-2.055	-0.504

Table 12. Tukey's HSD test of mean fish number at station for four main identified habitats in Darwin Harbour during BRUVS survey in May-September 2011. Using model MSE of 92.769 with 88 df.

Habitat	Habitat	Difference	p-Value	95% Confidence Interval	
				Lower	Upper
Deep_Filtercover	Deep_nocover	0.025	0.981	-0.146	0.197
Deep_Filtercover	ShallowNcor_Cover	0.258	**0.014**	0.040	0.475
Deep_Filtercover	Shallow_coral	-0.084	0.797	-0.322	0.155
Deep_nocover	ShallowNcor_Cover	0.232	0.058	-0.005	0.470
Deep_nocover	Shallow_coral	-0.109	0.687	-0.365	0.148
ShallowNcor_Cover	Shallow_coral	-0.341	**0.014**	-0.631	-0.052

3.1.3 Species assemblages and associations within different sites and habitats in the Harbour

Multi-variate analysis (SIMPER) identified several specific fish assemblages related to each of four identified bottom habitat at different depth. It should be noted, that the bottom habitat of Darwin Harbour is often highly mosaic and in shallow (less than 10 m) a relatively small area (200-300 m^2) can contain coral community, rocky reef, bare silted sand and silty habitat with filter feeders epifauna.

Coral habitat fish communities and fish assemblages associated with non-coral lower littoral habitats have high Bray-Curtis dissimilarity value, 92.1%. Both species composition and fish abundance differ (Table 13) and non-coral lower littoral habitat has lesser number of fish comparing to hard coral communities. None of the fishes found in both habitats has similar abundance values (Table 13). Coral habitat was populated by fish species, associated with coral and rocky reef: Surgeonfishes, Butterflyfishes, Rockcods, Wrasses and School Srevallies that occur in many habitats. Only one species - Goldstripe Butterflyfish, Chaetodon aureofasciatus is typical coral dwelling fish depending on corals as food source and shelter (Gomelyuk 2011). None of the species found in non-coral lower littoral were unique and typical for this habitat. Fish assemblage consisted of species that can be found in a large variety of habitats and depths. Average fish abundance was smallest comparing to all surveyed habitats, Table 13.

Fish assemblage from coral habitat differs from “Deep, filter feeders” fish community as well, Bray-Curtis dissimilarity: 84.90%. Species that were common and abundant in coral habitat were either absent or extremely rare in deeper areas with filter feeding animals, Table 14. Only a few species - Blue Tuskfish, Scribbled Angelfish, Goldspotted Rockcod, some trevallies, White Cheek Shark and Brownstripe Snapper were sharing both these bottom communities, Table 14.

Differences between fish assemblage from coral habitat and deep bare bottom areas were even higher: only White Cheek Shark has similar abundance in both habitats, Table 15. School trevallies and Northwest Threadfin Bream, inhabiting almost all types of habitat in deeper areas dominated in silty, silted sandy and sandy bottom.

Bray-Curtis dissimilarity between fish assemblages from “Deep no cover” and “Deep, filter feeders” was rather high – 91.6%, Table .15. While the average fish abundance in both habitats was similar, fish composition was different. Demersal Northwest Threadfin Bream and school, inhabiting water column Ponyfish *Equulites leuciscus* were common and relatively abundant in both habitats. Contrary to "Deep, filter feeders" habitat fish community where the fraction of "reef species" were relatively high, Table 16, school mid-water species such ponyfishes and trevallies dominated in "Deep no cover" habitat. Still, this habitat is important nursery for important amateur and commercially targeted snapper *Lutjanus erythropterus*, Fig. 11) and other species targeted by amateur fishers, Table16.

Comparison of "Deep bare" and "Lower littoral, no coral" habitats showed that both fish assemblages composition and average fish abundance in these habitats were different, Table 17. As it was already mentioned above, "Lower littoral, no coral" in Darwin Harbor has the lowest fish abundance and biodiversity.

The non-metric multi-dimensional scaling (MDS) showed a clear separation between samples from different bottom habitats (Fig. 12). Stress level 0.17 indicates a potentially useful 2-dimensional ordination. "Lower littoral, coral habitat" samples have formed more separately, although still a loose group, while other bottom habitat samples groupings are very loose, wide overlapping each other.

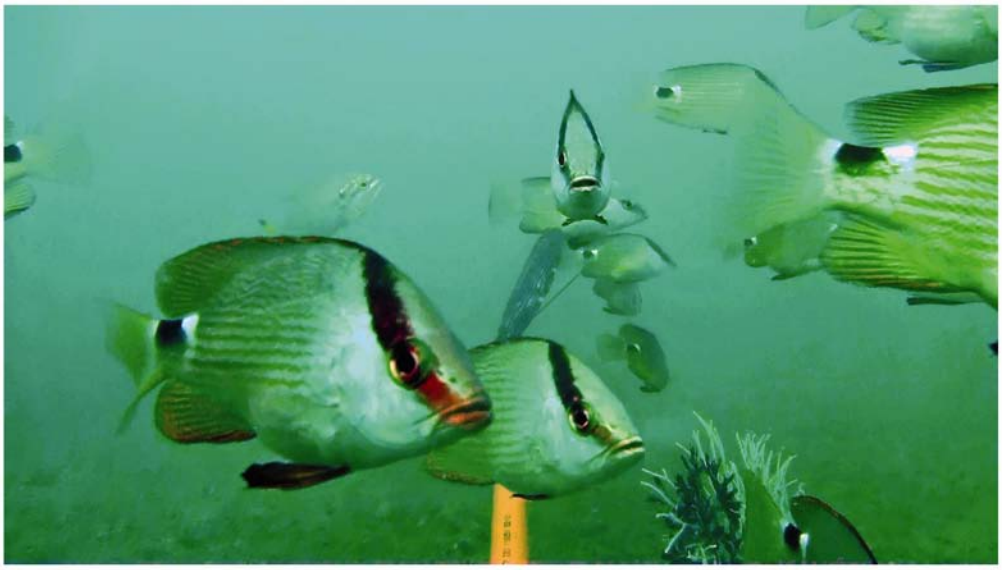

Figure 11. Crimson Snapper Lutjanus erythropterus juveniles at 'British Motorist" wreck in Darwin Harbour.

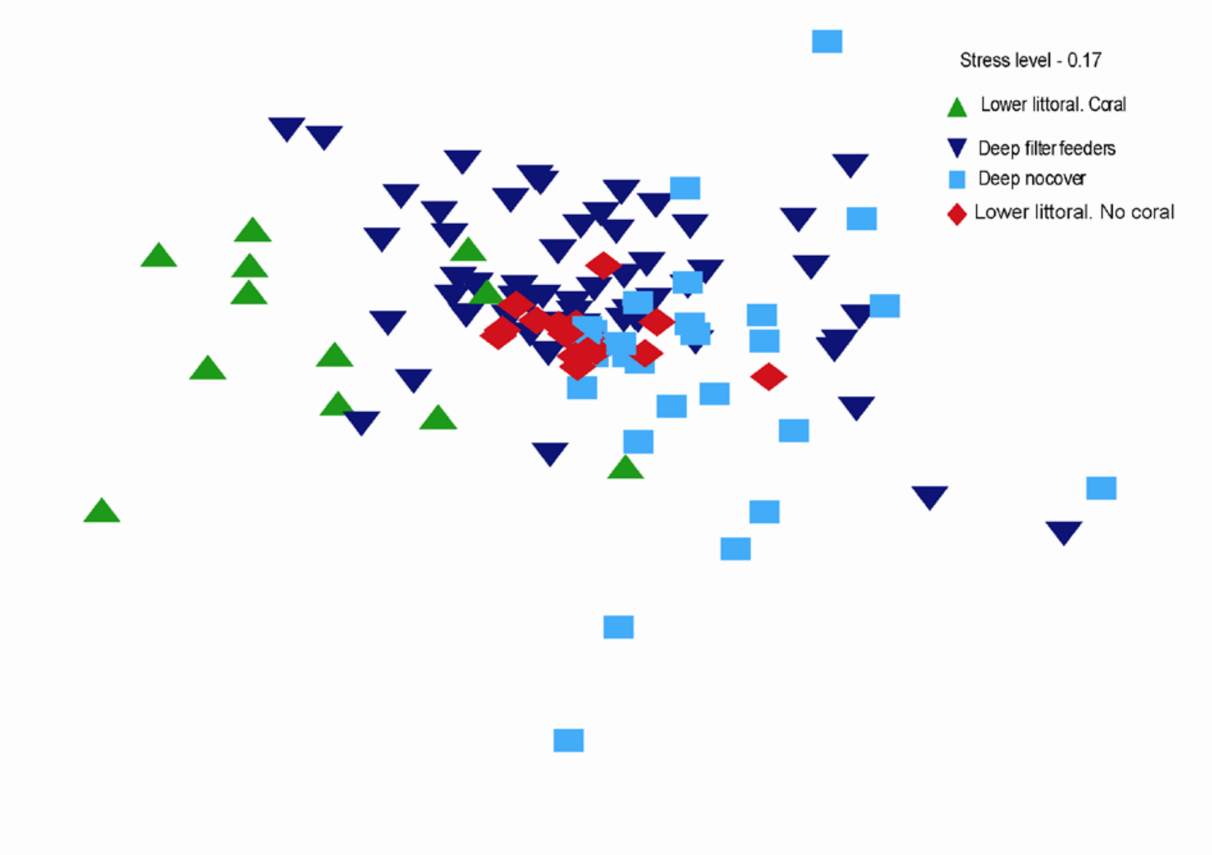

Figure 12. Non-metric 2-D scaling (nMDS) of fish assemblages from four identified bottom habitats in Darwin Harbour.

4 Discussion

In spite of poor water quality and strong tidal currents typical of the Harbour, the use of baited underwater video (BRUVS) method was successful. A relatively high percent of sampled species (26% of all previously recorded) and a substantial number of new species records for Darwin Harbour demonstrate the advantages of BRUVS technique. It is important to note that this BRUVS technique works well with species targeted by recreational fishers: 803 individuals of the total 3075 fishes recorded during this survey or 26.1% and 39 species of total 108 recorded or 36.1% are recreational fishers. Distribution of targeted fishes (biodiversity and abundance) along surveyed part of Darwin Harbour follows similar patterns as distribution non-targeted species (Fig. 4 and 5). In addition, it can be used in habitats where traditional ichthyological nets, trawls and traps sampling gear cannot work effectively or are overly selective. Finally, the BRUVS method is now commonly used elsewhere in tropical northern Australia (Cappo et al. 2011) and therefore more data on tropical Australian waters became available for comparision.

4.1 Darwin Harbour fish assemblages comparison with other areas surveyed with BRUVS

A “snapshot” of the fish habitat association in the vicinity of James Price Point (northern Western Australia) was obtained by Australian Institiute of Marine Science (AIMS) in 2009 when BRUVS were deployed in coastal waters for the survey. A total of 7085 individuals from 116 species of bone fishes, sharks and rays were recorded from 154 one-hour BRUVS stations =samples (Cappo et al. 2011). Both biodiversity and fish abundance at James Price Point were higher when collected from equivalent positions in the Great Barrier Reef lagoon. The medians differed significantly by factor of 2 for richness and 2.8 for fish abundance (Cappo et al. 2011). Unfortunately, because of the lack of the data we cannot perform appropriate statistical comparison of GBR lagoon, James Price Point and Darwin Harbour. However, similar numbers of BRUVS samples (154 at WA and 165 in Darwin Harbour) brought different results. The fish abundance is higher at James Price Point comparing to Darwin Harbour (7085 individuals against 3075, Table 1).The number of fish species recorded in WA area was 114, while in our study in Darwin Harbour 108 fish species. The values of median species number and fish number in one sample in WA indicated in (Cappo et al. 2011) are higher when in Darwin Harbour, 10 against 6.5 and 34.2 against 13, subsequently). It is still important to note that area of study at James Price Point was ~420 km2, while our area of study in Darwin Harbour ~150km2, by a factor of 2.8 smaller. Interestingly, according to the data for Great Barrier Reef lagoon, provided in Cappo et al. (2011), both species richness and fish abundance was higher in Darwin Harbour: 5 against 6.5 and 9.5 against 13, subsequently (Fig. 14. 15).

Statistical analysis was performed to compare the data collected in the BRUVS study in Port Essington, Cobourg Marine Park in 2005 (Gomelyuk 2009) and Darwin Harbour data. The data on number of species, number of fish (MaxN) and Margalef index in one 60-minutes sample were compared. Thirty-eight samples available for Cobourg were compared with 38 randomly obtained samples from Darwin Harbour data. Port Essington at Cobourg has higher mean species number in a sample than Darwin Harbour, x = 8.58 vs. x = 6.94, difference was statistically significant in one –tail comparison and not significant in two-tail comparison (t-test: two-sample assuming unequal variances, respectively: t = 1.68, P(T<=t) one-tail = 0.048; t-critical one-tail 1.66; P(T<=t) two-tail = 0.096, t-critical-two tail = 1.99, Fig. 14. Differences between Port Essington and Darwin Harbour in Margalef index were not statistically significant (t-test: two-sample assuming unequal variances: t = 0.856; P(T<=t) one-tail = 0.19. The number of fish in one video sample was higher at Port Essington, x = 29.3 vs x = 18.0, differences highly significant (t-test: two-sample assuming unequal variances: t = 2.92; P(T<=t) two-tail = 0.004; t-critical two-tail = 1.992, Fig. 15.

Total number of BRUVS video samples taken in Port Essington was 38 and they have been taken from three sites within the area of ~35 km^2 (Gomelyuk 2009). Total number of samples used for analysis in Darwin Harbour is 165 and they have been taken from 24 sites within the area of ~150 km^2. Total 1115 individuals from 64 fish species were recorded in Port Essington. Total number of 3075 individuals from 108 species was recorded in Darwin Harbour. Indeed, the relationship between the samples number and the number of recorded species is not linear and is described by saturation curve (Ludwig & Reynolds 1988). Still, total recorded individuals number in Darwin Harbour is lower than it can be expected from larger number of samples collected (by a factor of 4.3, comparing to Port Essington). The number of in individuals recorded in one video sample in Darwin Harbour was lower than at Port Essington, Fig. 15.

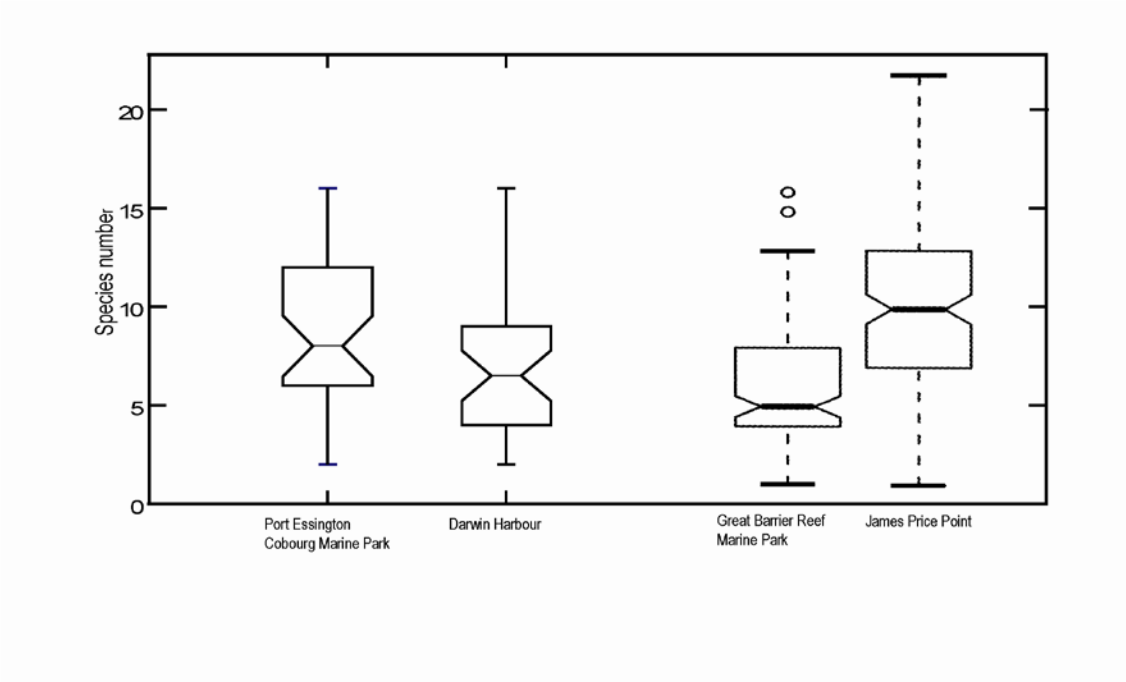

Figure 13. Comparison of the median species richness in one 60-minutes BRUVS sample in Port Essington, Cobourg Marine Park (Gomelyuk 2009) and Darwin Harbour (this survey) compared to data for Great Barrier Reef Marine Park lagoon and James Price Point, Western Australia (from Cappo et al. 2011). The notches show the median and 95% Confidence Intervals. If the notches do not overlap, this is strong evidence that two medians differ (Chambers et al. 1983).

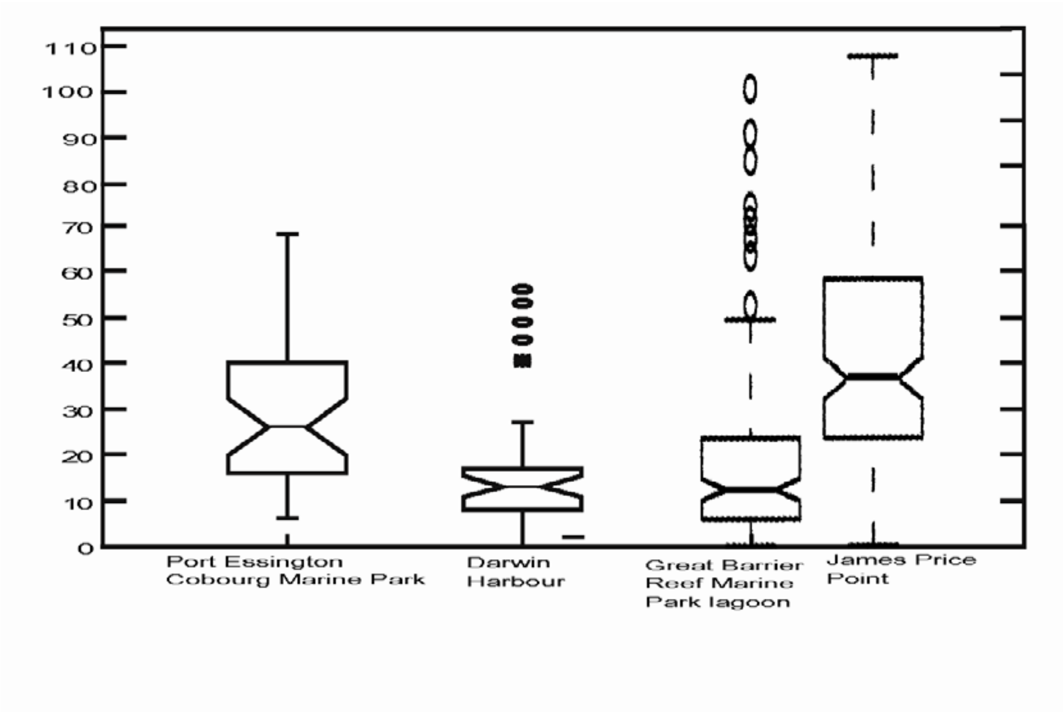

Figure 14. Comparison of the median fish number recorded in one 60-minutes BRUVS sample in Port Essington, Cobourg Marine Park, Darwin Harbour compared to data for Great Barrier Reef Marine Park lagoon and James Price Point, Western Australia, see caption for Fig. 14.

4.2 Fish assemblages properties in Darwin Harbour

The majority of the fish (more than 50%) in our samples were relatively small carnivorous trevallies, threadfin breams and ponyfishes. Trevallies and ponyfishes are feeding on zooplankton and nekton in water columns; Threadfin Breams are demersal and feeding on benthos. A fraction of fish species targeted by recreational fishers (Table 6.) to all fish recorded during the survey was only 26.2%, Table 2. Therefore, the lower fish abundance in the Harbour comparing to Port Essington in Cobourg Marine Park and James Price Point in northern Western Australia is not related to overfishing.

It is possible that lower fish abundance in Darwin Harbor may be a result of the fact that standing stock of nutrients in the Harbour is low and nutrient concentrations are low in the main body of the Harbour (0.05-2.0 milligrams per litre of nitrogen and 0.01-0.04 milligrams per litre of phosphorus) with slight seasonal variations due to river runoff during the wet season (Water Monitoring Branch 2005, Budford et al. 2008). The majority of nutrients that enter the harbour are imported from the ocean and are typically in the particulate or organic form (Burford et al 2008) that is not bioavailable for photosynthesising plants.

At Dampier Archipelago, Western Australia, where the concentrations in inorganic nutrients were considered to be generally low (as found by Rochford, 1980), but the mean concentration of nitrogen were 5.6-9.8 milligrams per litre (8.6 times higher then the Darwin Harbour). The mean concentration of phosphorus at Dampier Archipelago waters were 4.63 – 12.36 milligram per litre -340 times higher than in Darwin Harbour.

4.3 Future monitoring of fish assemblages in Darwin Harbour

Results from this study show that baited underwater video stations are an effective methodology for monitoring fish assemblages in Darwin Harbour. Nonetheless, the relatively murky water in Darwin Harbour poses challenges for monitoring fish using BRUVS. The suitable period for visual survey inside the Harbour is restricted to the dry season (May to September) when rivers flow in the Harbour and water turbidity are lower. The “window of opportunity” of water visibility of 4-5 m is only 4-5 days a month for most of non-estuarine part of the Harbour. Permanently high water turbidity precludes the use of BRUVS method in estuarine area of the Harbour (down to the south-east from South Shell Island-Wickham Point in Elizabeth River and down to the south-east from Channel Island).

Based on the results of this study, three areas in Darwin Harbour with the highest fish biodiversity and abundance and appropriate underwater visibility conditions for video survey are perspective for fish biodiversity monitoring: Lee Point where artificial reefs “Rick Mills” and “Bottle Washer”; East Point; and south-west from Channel Island (Figure 16).

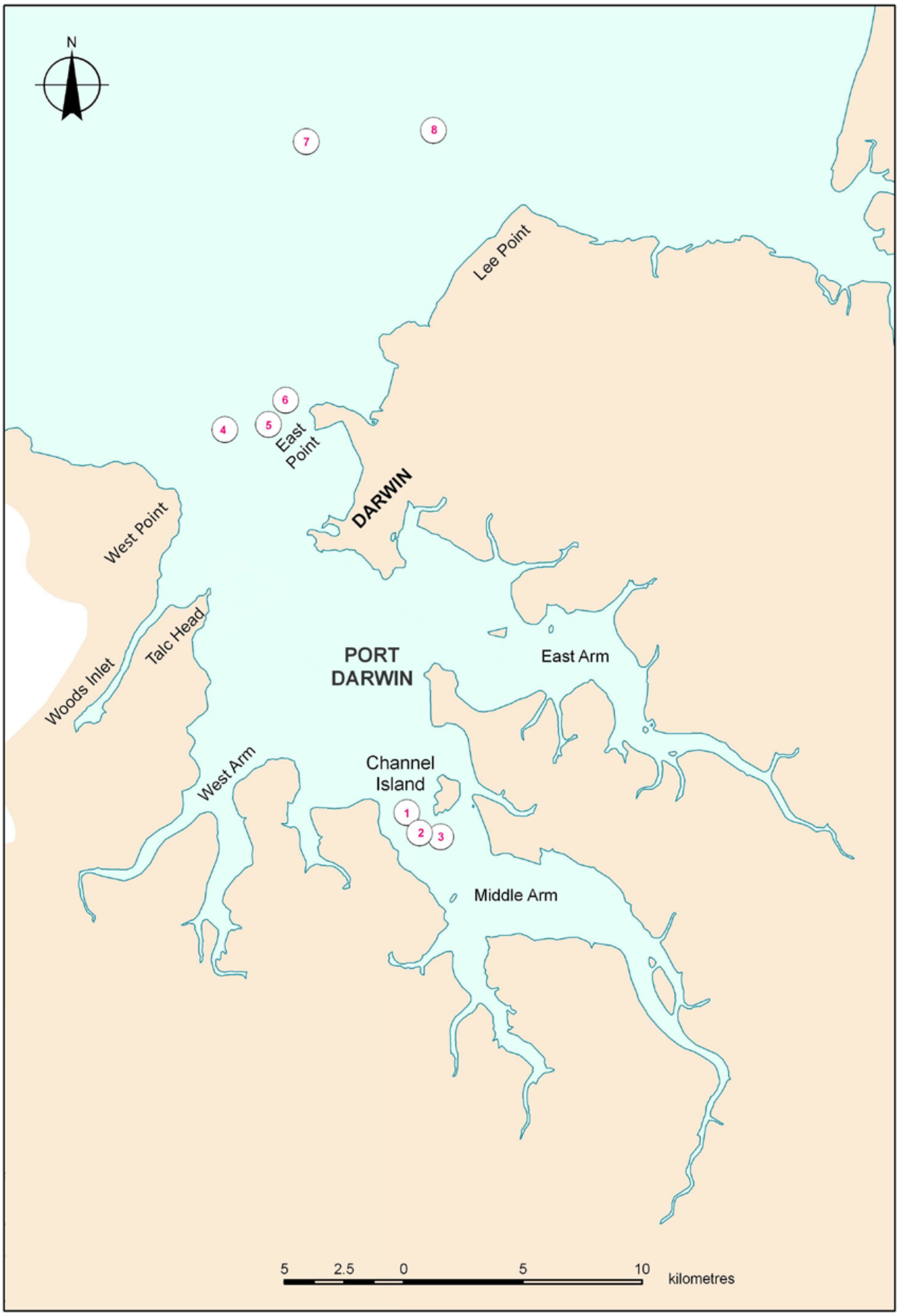

Figure 15. Perspective areas and sites for fish assemblages monitoring in Darwin Harbour.

5 Acknowledgments

Many people contributed to making this study possible. Katie Elsley, Martina Ripcke, Nina Trikojus, Sarah Wright and Ray Chatto participated in a boat trips as volunteers and have helped with all their effort and enthusiasm. Department of Resources – Fisheries provided the boat. Wayne Baldwin and Poncie Kurnoth from Department of Resources – Fisheries were boat skippers and their contribution was invaluable for safe marine operation and data collection. Project completion will be impossible without extensive contribution from Daniel Low Choy in logistic support, participations in BRUVS survey, video images interrogation and very helpful comments on the report draft. Gavin Dally provided his help with cross referencing species known as Harbour inhabitants and already held in Museum and Art Gallery of the Northern Territory collection. Tony Griffiths provided extensive editions and comments to the draft.

6. References

Brotz L., Cheung W.W.L., Kleisner K., Pakhomov E. and D.Pauly 2012. Increasing jellyfish populations: trends in Large Marine Ecosystems. Hydrobiologia 2012, DOI: 10.1007/s10750-012-1039.

Buckworth, R. C., Newman, S. J., Ovenden, J. R., Lester, R. J. G., and McPherson, G. R. 2007. The Stock Structure of Northern and Western Australian Spanish Mackerel. Final Report, FRDC Project 1998/159. Department of Primary Industry, Fisheries and Mines Fishery Report 88.

Burford M.A., Alongi D.M., McKinnon A.D. & Trott L.A. 2008. Primary production and nutrients in a tropical macrotidal estuary, Darwin Harbour, Australia. Estuarine, Coastal and Shelf Science, 79: 440–448.

Byrne T 1988. Darwin Harbour – hydrodynamics and coastal processes. In: H.K. Larson et al. (eds) Proceedings of the Workshop on Research and Management in Darwin Harbour. Australian National University North Australia Research Unit. Mangrove Monograph No. 4.

Coleman, A. P. M. 2004. The National Recreational Fishing Survey: The Northern Territory. Department of Business, Industry and Resource Development Fishery Report 72.

Cappo M., Harvey E., Malcolm H. and Speare P. 2003 Potential of video techniques to monitor diversity, abundance and size of fish in studies of marine protected areas. In Beumer J.P., Grant A. And Smith D.C. (eds) Aquatic protected areas: what works best and how do we know? World Congress on Aquatic Protected Areas Cairns, Australia. Sydney: Australian Society for Fish Biology: 455–464.

Cappo M., Speare P. and De'Ath G. 2004 Comparison of baited remote underwater video stations BRUVS and prawn shrimp trawls for assessments of fish biodiversity in inter-reefal areas of the Great Barrier Reef Marine Park. Journal of Experimental Marine Biology and Ecology, 302: 123–152.

Cappo M., Harvey E. and Shortis E.M. 2007 Counting and measuring fish with baited video techniques—an overview. In Lyle J.M., Furlani D.M. and Buxton C.D. (eds) Proceedings of the 2006 Australian Society for Fish Biology Conference and Workshop Cutting-edge technologies in fish and fisheries science, Hobart, August 2006. Hobart:ASFB, pp. 101–114.

Cappo M., Stowar M., Syms C., Johansson C. & Cooper T. 2011. Fish-habitat associations in the region offshore from James Price Point – a rapid assessment using Baited Remote Underwater Video Stations (BRUVS). Journal of the Royal Society of Western Australia, 94: 303–321.

Clarke K.R. and Warwick R.M. 2001 Change in marine communities: an approach to statistical analysis and interpretations. Plymouth: Plymouth Marine Laboratory and Natural Environment Research Council.

da Silva, J.F., Duck, R.W. & Catarino, J.B. 2004, "Seagrasses and sediment response to changing physical forcing in a coastal lagoon", Hydrology and Earth System Sciences, 8, 2: 151-159.

DeMartini, E. E. & Roberts, D. 1982. An empirical test of biases in the rapid visual technique for species-time censuses of reef fish assemblages. Marine Biology, 70, 129-134.

Fortune J. and Drewry J. 2009. Darwin Harbour region report cards 2009. Aquatic Health Unit, Department of Natural Resources, Environment, The Arts and Sport. Palmerston NT 0831, P. 62.

Gomelyuk V. 2008. Fish assemblages composition and structure in three shallow habitats in north Australian tropical bay, Garig Gunak Barlu National Park, Northern Territory, Australia. Journal of the Marine Biological Association of the United Kingdom, 89, 3: 449–460.

Harvey, E., Fletcher, D. & Shortis, M. 2001a. A comparison of the precision and accuracy of estimates of reef-fish lengths determined visually by divers with estimates produced by a stereo-video system. Fisheries Bulletin, 99, 63-71.

Harvey, E., Fletcher, D. & Shortis, M. 2001b. Improving the statistical power of length estimates of reef fish: a comparison of estimates determined visually by divers with estimates produced by a stereo-video system. Fisheries Bulletin, 99, 72-80.

Harvey, E., Shortis, M., Stadler, M. & Cappo, M. 2002. A comparison of the accuracy and precision of measurements from single and stereo-video systems. Marine Technology Society, 36, 38-49.

International Code of Zoological Nomenclature (1999). International code of zoological nomenclature adopted by the International Union of Biological Resources International Commission on Zoological Nomenclature. 4th edn. London : International Trust for Zoological Nomenclature.

Larson, H.K. 1988. The fishes of Darwin Harbour. In: Larson, H.K., Michie, M., and J.R. Hanley (eds). Darwin Harbour. N.A .R. U. Mangrove Monograph Number 4: 153-164.

Larson H.K. and Williams R.S. 1997 Darwin harbour fishes: a survey and annotated checklist. In Hanley J.R., Caswell G., Megirian D. And Larson H.K. (eds) Proceedings of the Sixth International Marine Biological Workshop. The Marine flora and fauna of Darwin harbour, Northern Territory, Australia. Darwin, 1997. Darwin: Museum and Art Galleries of the Northern Territory and the Australian Marine Sciences Association, pp. 339–380.

Leinster S., Knights D., McAuley A. 2007. EDAW 2007 "Water Sensitive Urban Design Objectives For Darwin - Discussion Paper" for the Northern Territory Department of Planning and Infrastructure.

Lynam C.P., Gibbons M.J., Axelsen B.E., Conrad A. J., Sparks C.A.J., Coetzee J., Benjamin G. Heywood B.G. 2006. Jellyfish overtake fish in a heavily fished ecosystem. Current Biology 16,13: 1976.

Lohrer, A.M. & Wetz, J.J. 2003, Dredging-induced nutrient release from sediments to the water column in a southeastern saltmarsh tidal creek, Marine Pollution Bulletin, 46, 9: 1156-1163.

Manteifel B.P. (1970) Biologicheskie osobennosti upravlenija povedeniem ryb. Moscow: Nauka.

Margalef R. 1958. Information theory in ecology. International Journal of General Systems., 3: 36-71.

Martin, J. M. 2005. The distribution, abundance and trophic ecology of the fishes of Darwin Harbour mangrove habitats. PhD Thesis, Charles Darwin University.

Newman, S. J., Steckis, R.A., Edmonds, J. S. and Lloyd, J. 2000. Stock structure of the gold-band snapper (*Pristipomoides multidens*) (Pisces: Lutjanidae) from the waters of northern and western Australia by stable isotope ratio analysis of sagital otolith carbonate. Marine Ecology Progress Series 198: 239-247.

Ovenden, J. R., Lloyd, J., Newman, S. J., Keenan, C. P. and Slatter, L. S. 2002. Spatial genetic subdivision between northern Australia and South-East Asian populations of *Pristipomoides multidens*: a tropical marine reef fish species. Fisheries Research 59: 57-69.

Padovan, A.V. 2003. Darwin Harbour Water and Sediment Quality. In: Proceedings: Darwin Harbour Region: Current knowledge and future needs'. (Ed. Working Group for the Darwin Harbour Advisory Committee) pp. 5-18 (Department of Infrastructure. Planning and Environment, Darwin.

Priede I.G, Merrett N.R (1996) Estimation of abundance of abyssal demersal fishes; a comparison of data from trawls and baited cameras. J Fish Biol 49 (Suppl A):207–216.

Walters, C. J., and Buckworth, R. C. 1997. Shark and Spanish mackerel Stocks assessed. Northern Territory Fishing Industry Council Newsletter, July 1997. 8(2), 14-15.

Water Monitoring Branch, 2005. The Health of the Aquatic Environment in the Darwin Harbour Region. Natural Resource Management Division, Department of Natural Resources, Environment and the Arts, Darwin. Report 5/2005D.

Willis TJ, Babcock RC (2000) A baited underwater video system for the determination of relative density of carnivorous reef fish. Mar Freshw Res 51:755–763.