



Survey 2000: bêche-de-mer and trochus populations at Ashmore Reef

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EXECUTIVE SUMMARY

Ashmore Reef is a large emergent reef system, approximately 227km² in total area, located on the edge of the continental shelf off the northwest Kimberley coastline. Ashmore Reef falls within the MOU74 Box, an area managed by the Australian Federal Government under the terms of an agreement between the Australian and Indonesian Governments. While many reefs and shoals of the MOU74 Box allow for traditional fishing by Indonesian fishers, Ashmore Reef does not. In 1983, Ashmore Reef was declared a National Nature Reserve. From 1985, Environmental Australia has funded a vessel and crew to provide on-site management at Ashmore Reef during the dry season. Since May 2000, the Australia Customs Service has provided the on-site reserve management services and their vessel the ACV Wauri has been on location year round.

In October 2000, Australian Institute of Marine Science biologists surveyed Ashmore Reef. The objectives were to determine the distribution and abundance of beche-de-mer (holothuria) and the commercial topshell, *Trochus niloticus*, instigate a monitoring program of these species and make recommendations on their subsequent management. The work was undertaken using the ACV Wauri as a base.

Current Findings

Holothurians

No specimens of *Holothuria timana* (previously named *H. aculeata*) were located during this survey. This high-value species was reported to be in significant numbers in 1988 with 11% catch by Indonesian fishers during that survey being composed of *H. timana* (Russell and Vail 1988). Furthermore, Skewes *et al.* (1999) was unable to locate this species throughout the MOU74 Box. It is possible that this species has become locally extinct from over-harvesting.

There is little doubt that the highly valued bêche-de-mer species, *Holothuria nobilis* (black teat fish) has been severely depleted at Ashmore Reef. This species is at density levels 10 times lower than heavily, bêche-de-mer fished reefs on the GBR. The large size and conspicuous nature of this shallow water species make it easily exploited.

In contrast the highly valued, deeper water species like the white teatfish (*H. fuscogilva*) and the prickly red (*Thelenota ananas*) thought to be exploited in the past are relatively abundant. It is likely that the difficulty in free diving to the depths in which

these species are found has limited fishing effort and thus provided a refuge for them from Indonesian fishers. Holothurian species found on the reef flat with low or no commercial value are still in relatively high to very high densities compared to other emergent reefs in the area.

Trochus

The topshell, *Trochus niloticus* has been severely depleted at Ashmore Reef. Extensive surveys found only 34 trochus giving a mean density of just 6.4 per hectare substantially less than would be predicted and far less than fished reefs on the GBR. The ease of collecting trochus has made it particularly vulnerable to unsustainable exploitation.

Management Recommendations

The current policy of a total ban on trochus and holothurian collection at Ashmore Reef should be maintained indefinitely. This may allow, not only the Ashmore populations to recover but provide an important source of brood stock for the broader region especially the extremely depleted stocks of Scott and Seringapatam Reefs.

The presence of a Australian Customs vessel and crew at Ashmore Reef is likely to act as a major deterrent to illegal fishing. Any recovery of depleted stocks (and protection of the non-depleted ones) is dependent on a continued Australian government presence at Ashmore Reef. This presence should be year-round since any illegal fishing in the next few years could significantly delay recovery rates of depleted stocks of bêche-de-mer and trochus.

Monitoring of trochus and bêche-de-mer populations should be carried out every two years using the methodology of this study. Repeated measure analysis of the resultant data will provide a powerful tool to assess stock recovery. Some form of stock enhancement may be required to restock Ashmore Reef if recovery is not apparent.

A better understanding on the reproductive biology is required for the MOU Box trochus and bêche-de-mer populations. Data on size and age of reproduction and growth rates are required to properly determine sustainable fishing effort (if any) and provide the basis for estimating recovery times of these exploited species.

Advice should be sought from marine research agencies, including AIMS, CSIRO and AGSO, to integrate data on ecology, oceanography and bathymetry, that will assist in understanding the full extent of habitat that may support these species in the Oceanic

Shoals bioregion. This will provide insights into connectivity between adjacent reefs that may extend beyond the boundaries of the MOU74 Box.

High-valued, shallow-water species of bêche-de-mer and trochus are heavily depleted at Ashmore Reef. However, these stocks are seriously threatened with local extinction at Scott and Seringapatam Reefs. Even the low-valued species that are relatively abundant at Ashmore Reef are being grossly over-exploited on other emergent reefs of the MOU Box.

To ensure long-term sustainability of the traditional fishery a broader marine resource management plan needs to be formulated that incorporates all the emergent reefs of the MOU Box. Given the degree of depletion of targeted species on reefs and shoals of the MOU Box the implementation of such a plan should be considered as a matter of urgency. The plan should allow for the recovery of the targeted stocks and implementation of a sustainable harvesting system for traditional Indonesian fishers. A recovered and sustainably managed fishery is likely to provide much higher returns to traditional fishers than the current heavily depleted fishery. Protected biological refuges such as Ashmore and Cartier would be a critical part of the marine resource management system playing a role in protecting biodiversity as well sustaining the fishery in regional terms.

INTRODUCTION

Ashmore Reef is large emergent reef system, approximately 227km² in total area, located on the edge of the continental shelf off the northwest Kimberley coastline (Figure 1). A conspicuous feature of the area is an extensive reef flat system, consisting of large areas of seagrass interspersed with corals and bare sandy flats. The extensive sea grass communities support a resident dugong population. Three sand cays have formed upon the reef flat zone, West, Middle and East Islands. All three are vegetated, while only two have extensive, resident bird populations.

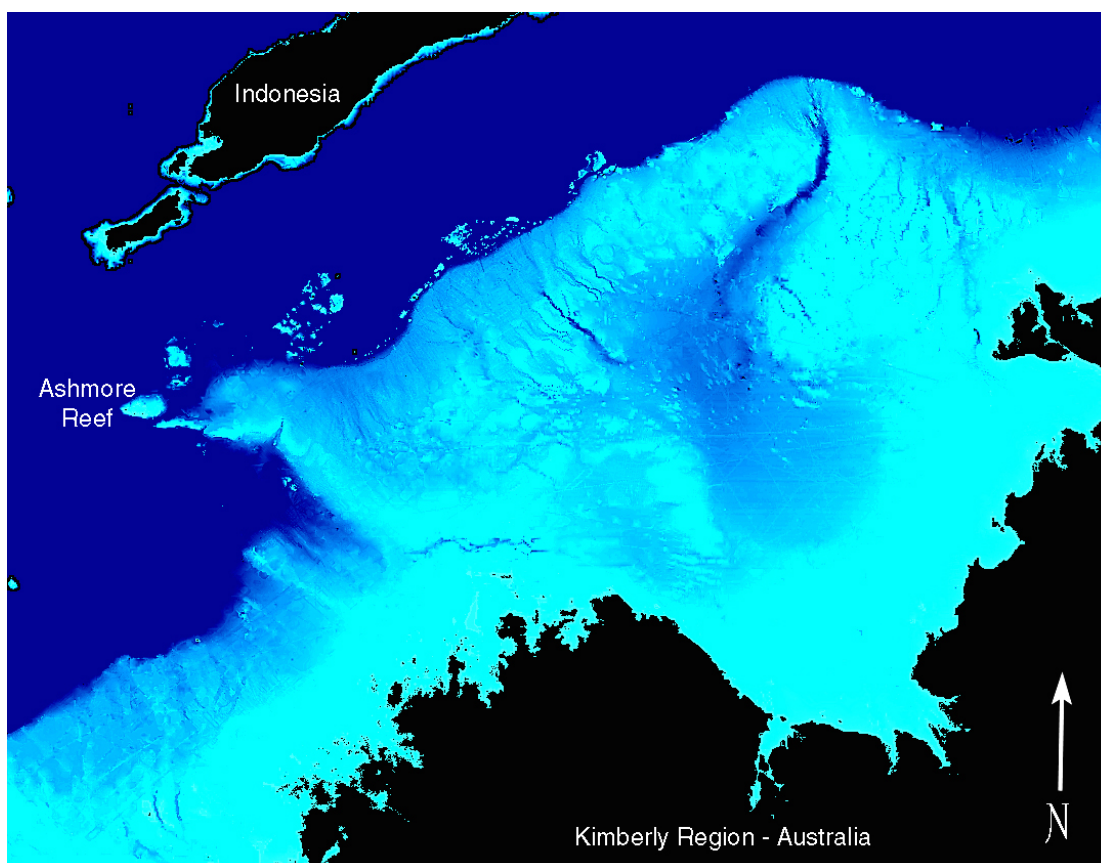


Figure 1: The far northwest continental shelf showing Ashmore Reef (original bathymetry figure from AGSO: after Heyward, Pinceratto, & Smith 1997). The majority of submerged reefs in this region are along the edge of the shelf and may support additional populations of the target animals.

The reef has two large lagoons. The western lagoon is deep ($\geq 15\text{m}$) with relatively clear water, while the eastern lagoon is shallow ($\leq 10\text{m}$ deep) with highly turbid waters. Coral communities dominate the reef crest and slope, with more than 256 scleractinian coral species found at Ashmore Reef (Veron 1993).

Ashmore Reef is part of the MOU74 Box, an area managed by the Australian Government under the terms of an agreement between the Australian and Indonesian Governments. While many reefs and shoals of the MOU74 Box allow for traditional fishing by Indonesian fishers, Ashmore Reef does not. However Indonesian fishers in traditional vessels (praus) can stop-over at Ashmore, replenish water supplies from a well on West Island and undertake subsistence fishing within West Island lagoon using a single line (Domaschenz, pers. comm.). In 1983, Ashmore Reef was declared a Marine Nature Reserve. In 1985, Environmental Australia set-up a permanent presence at Ashmore Reef during the dry season. In May 2000, the ACV Wauri was permanently based at Ashmore Reef (all year round).

Fishing of Holothurians and Trochus

Holothurians, also known as trepang, bêche-de-mer or sea cucumbers, have been fished for centuries at Ashmore Reef. Early surveys of the Kimberley Coast in the early 1800's encountered numerous Maccasans (from what is now called Sulawesi) that were fishing for bêche-de-mer (Horden 1997). After 1900 the catch likely expanded to trochus shell and shark fin (Anon. 1989). All three products have the great advantage of being well suited for preparation and storage at sea using simple methods and no refrigeration is required.

Trepang is traditionally collected by reef walking or by shallow breath-hold diving. Certain species are preferred, notably *Holothria nobilis* (black teatfish), *Holothuria fuscogilva* (white teatfish) and *Thelenota ananas* (prickly redfish). However, as populations of these species are reduced, other species are likely to be targeted. Once collected, the animals may be cleaned, boiled and then sun-dried (Cannon and Silver 1987). Trepang is a valuable catch for these fishers as it sells for up to A\$30 per kilogram in Asia (Caddy 1995). Trepang meat is high in protein; however, its value may be more related to the belief that it is an aphrodisiac.

The large marine snails in the genus *Trochus* (Figure 4) are collected in similar ways to trepang, although meat of this mollusc is of secondary importance (and probably discarded in most instances) to the lustrous shell. The mother of pearl shell is used to produce buttons, jewellery, ceramics, ornaments, cosmetics and metallic paints and sold in Asia, Europe and America.

Concern has arisen that stocks of trochus and trepang may have been drastically diminished on all reefs within the MOU74 Box. Skewes *et al.* (1999) carried out an extensive survey of both trochus and trepang and reported low to very low densities at most locations. They concluded that stocks had been severely depleted throughout

the whole area of the MOU74 Box. Ashmore Reef, even though the resident stocks had been depleted in some habitats, appeared to have the largest populations of any of the emergent reefs in the area. Illegal fishing of trochus and trepang was identified as the major threat to the biodiversity values of the reserve and it was decided to initiate a monitoring program of these stocks. Consequently the primary aims of this study were:

- ❑ To develop viable census techniques that allows for repeatable visual census of the holothurian and trochus populations of Ashmore and Cartier Reef.
- ❑ Provide information on the current status on the distribution and abundance of holothurians and trochus at Ashmore and Cartier Reef.
- ❑ To establish a benthic habitat monitoring program at Ashmore Reef.
- ❑ Recommendations on how to undertake future monitoring efforts and the management implications of the present study.

Please note that the benthic habitat monitoring was not initiated. Both weather (spring tides and a large swell) and time constraints caused this part of the project to be delayed until a latter date. It was also intended to undertake a survey of Cartier Island Marine Reserve as part of this study. Unfortunately logistics outside the control of AIMS did not permit this survey to occur. It is believed that Cartier Island has been subject to high levels of Indonesian fishing and the populations of targeted species are thought to be heavily depleted. It is recommended surveys are undertaken as soon as the opportunity allows to measure current population levels and develop strategies to support their recovery.

METHODS

Field surveys for this report relied on the vessels and infrastructure of the Australian Customs Service, in particular the ACV Wauri at Ashmore Reef. The high variability of habitat types, depths and oceanographic conditions (eg. currents and tidal conditions) required us to use a range of census techniques to determine the distribution and abundance of trepang and trochus. The census techniques were designed to become the baseline surveys for a long-term monitoring program of trochus and trepang). Counts were undertaken between the September 28th and October 10th, 2000, although some time (approximately 3 days) was lost due the Australian Customs Service undertaking patrol tasks. Surveys were undertaken in all major benthic habitats at Ashmore Reef, although weather and logistic constraints restricted the level of access to some areas (see Figures 2 and 3).

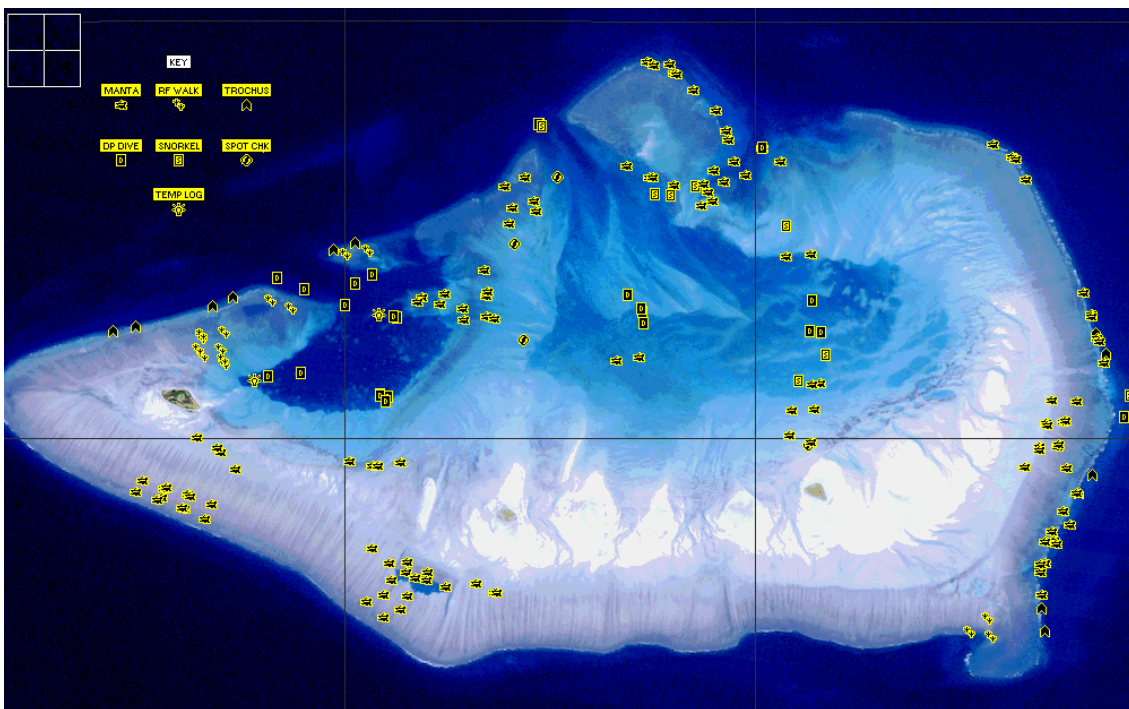


Figure 2: Map of Ashmore Reef showing the locations of the differing surveys undertaken in October 2000.

Trochus Surveys

The efficiency of surveys for *Trochus* is greatly assisted by the restricted habitat preferences of the animals. *Trochus* are almost exclusively found on hard substratum in shallow water that has a high current flow. This type of habitat is dominated by characteristic species of stony corals and crustose coralline algae, which create a complex topography providing both feeding and sheltering areas for the snails. At Ashmore Reef this habitat occurs predominantly around the reef crest and very outer reef flat (see Figure 3, Ashmore habitat map). Given the large tidal variation (approximately 5 metres during spring tides) two different census methodologies were undertaken.

REEF WALKS

Reef walks were taken at low tide to determine the distribution and abundance of *Trochus sp.* A total of 6 transects were undertaken during the October 2000 expedition. Two observers would walk down a 500-metre strip of the reef flat searching a four metre wide strip for trochus and bêche-de-mer (a two metre belt was searched by each observer). Consequently each transect covered an area of 2000m². Transects run parallel to the reef crest, with a GPS position being taken at the beginning and end of each transect (Figure 2).

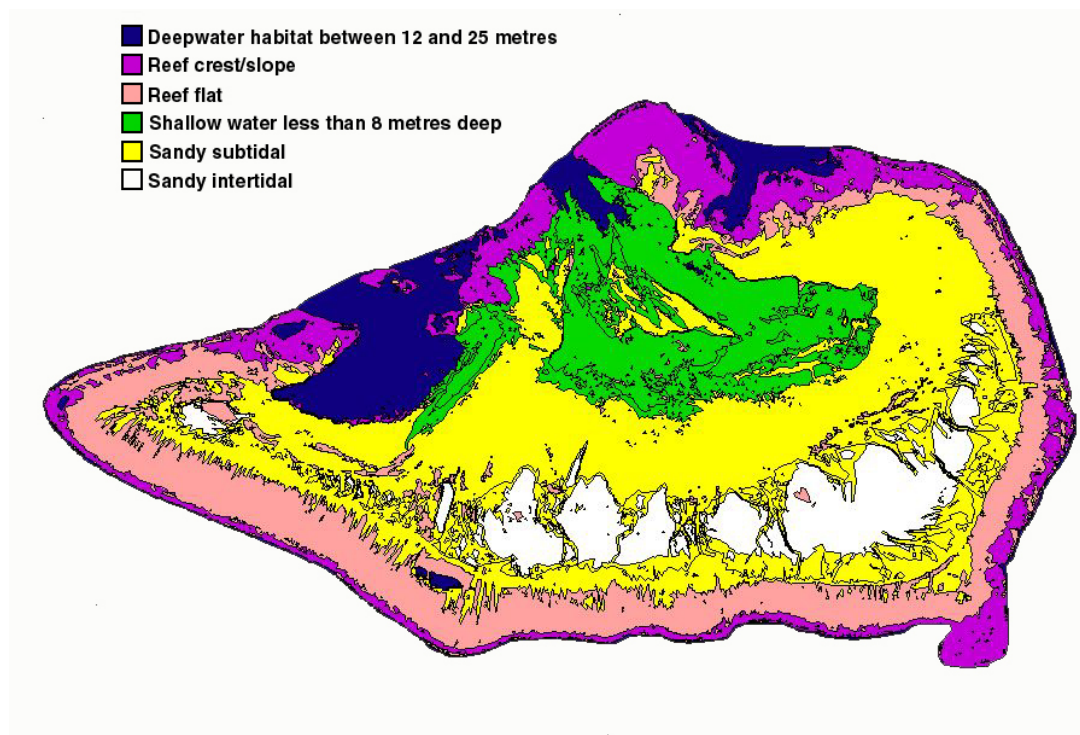


Figure 3: Habitat map of Ashmore Reef showing the six main habitats (modified after Skewes *et al.* 1999).

TROCHUS SWIM SURVEYS

Surveys over deeper, high current habitats along the outermost reef flat and upper reef crest zone required use of diving observations. Use of snorkel dive, rather than SCUBA, was selected for work in these habitats as it permitted more rapid assessment and the depths were not so great that visual survey of the benthic community was impaired. At high tide a team of three snorkel divers censused a 500m by 5m belt transect. The three observers swam in parallel along the outer part of the reef, each surveying a 5m wide strip of the habitat. The outermost diver censused the edge of the reef crest and the upper part of the reef slope. The middle and inner snorkeller censused the outer reef flat. Each snorkeller was approximately ten meters apart and censused a 5m strip of the reef. Consequently 7500m² of reef substratum was censused during each swim. The latitude and longitude of the start and end point of each transect was recorded using a GPS (see Figure 3). No snorkel surveys were possible on the southern edge of Ashmore Reef because of a very large ocean swell that created waves in excess of 3 metres along the reef edge.

Bêche-de-mer Surveys

Three different techniques were used to assess distribution and abundance of bêche-de-mer at Ashmore Reef.

REEF WALKS

Reef walks were taken at low tide to determine the distribution of sea-cucumbers. A total of 10 transects were undertaken during the October 2000 expedition. Two walkers would walk down a 500 metre strip of the reef flat searching a four metre wide strip for trochus and bêche-de-mer (two metre belt was search by each walker). Consequently each transect covered an area of 2000m². The transects run parallel to the reef crest, with a GPS position being taken at the beginning and end of each transect.

MANTA TOWS

The manta tow technique allows for the relatively rapid, broad-scale assessment of benthic organisms on shallow water substratum. The technique involves towing a snorkel diver (observer) at a constant speed behind a boat. The observer holds onto the 'manta board' attached to a small boat by a 17 metre length of rope (for methodology on manta towing see Bass and Miller 1996). This person makes a visual assessment of specific variables (depth, habitat type, dominant biota and substrate type) and counts the number and species of bêche-de-mer encountered. The counts can be written onto waterproof paper attached to the manta board. Each manta tow

was 500 metres long by 2 metres wide. The beginning and end points of each manta tow were recorded using a GPS to allow the re-survey of each tow to allow re-survey (see Appendix 2 for GPS positions). A total of 59 manta tows were undertaken during the 2000 census expedition.

TIMED SWIMS

Alternative methods were required to census bêche-de-mer that inhabit depths greater than can be effectively manta tow. Consequently timed swims were undertaken either by snorkel or SCUBA depending on depth and visibility. Each swim was 10 minutes long and was undertaken by two observers each swimming side by side. Each observer censused a two metre wide strip of substrate recording holothurian species and abundance. Measures of distances swam by observers indicate that approximately 250 metres was swam in 10 minutes. Consequently in the order of 1000 m² of habitat was censused on each swim.

RESULTS

Trochus Surveys

Extensive trochus surveys were undertaken on the northern and eastern flanks of Ashmore Reef (see Figure 2). Two species were commonly found *Trochus niloticus*, the commercial species and *Tectus pyramis*, a smaller, non-commercial species. This report focuses on *T. niloticus* data.



Figure 4: *Trochus niloticus* on the reef crest at Ashmore Reef

Only 34 trochus were found during the extensive surveys carried out in October 2000 giving a mean density of 6.4 per hectare upon the reef crest (red habitat, Figure 3). However we were only able to survey the northern and eastern flank, Skewes *et al.* (1999) found higher numbers (29.9 per ha.) on the exposed southern edge indicating we have probably underestimated *T. niloticus* densities. Interestingly, Skewes *et al.* (1999) and this study had similar densities on the sheltered reef edges (7.5 vs 6.4 per ha, respectively). However different methodologies make a comparison of the two datasets difficult.

Population age structure was determined by measuring the basal width of each trochus. All trochus found were greater than 55mm basal length, with an overall mean of 88mm (Figure 5). Consequently most individuals would have been sexually mature

adults (Castell 1997). The complete absence of smaller individuals or juveniles is not surprising since *T. niloticus* is extremely cryptic when small.

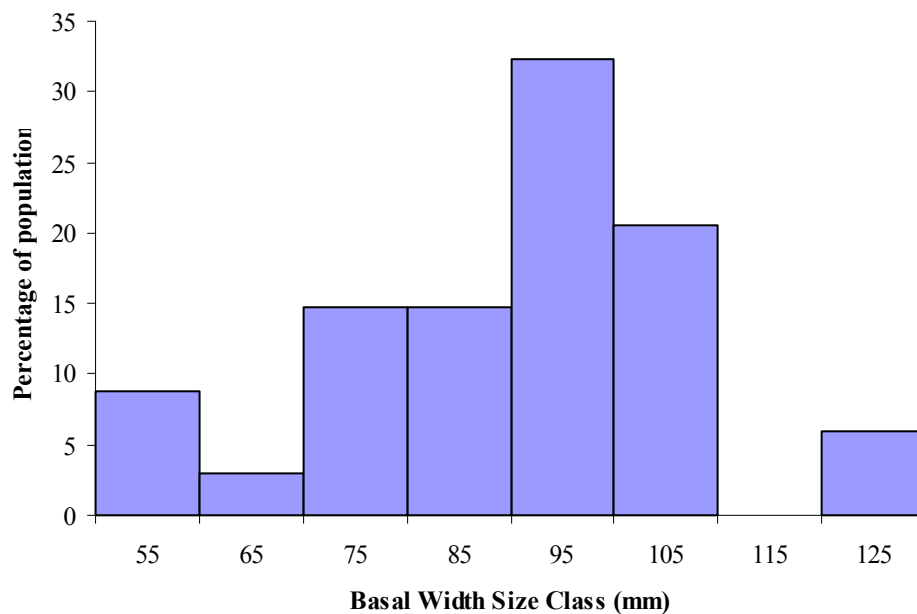


Figure 5: Mean basal width of all *Trochus niloticus* found at Ashmore Reef (n=34)

Bêche-der-mer

A total of 7013 bêche-de-mer comprising 19 species were counted during this Ashmore Reef survey. The vast majority were found upon the reef flat in less than three metres of water and were of low or no commercial value. The stratified sampling design allowed for an estimate of population numbers within each habitat (see Appendix 1). *Holothuria leucospilota* is the most abundant species (by number) at Ashmore Reef representing in excess of 5 million individuals or 83% of the all bêche-de-mer (Figure 6). In contrast the high valued commercial species (*H. nobilis*, *H. fuscogilva*, *T. ananas*) represent less than one percent of overall numbers.

Table 1: Density (number per hectare) of high valued species

	<i>Holothoria nobilis</i>	<i>Holothuria fuscogilva</i>	<i>Thelenota ananas</i>	TOTAL
Deep Lagoon	0.00	11.67	5.56	17.23
Shallow Lagoon	0.00	0.00	2.50	2.50
Intertidal Sand	0.00	0.00	0.00	0.00
Reef Flat	0.71	0.00	0.00	0.71
Reef Crest	0.59	0.00	0.00	0.59

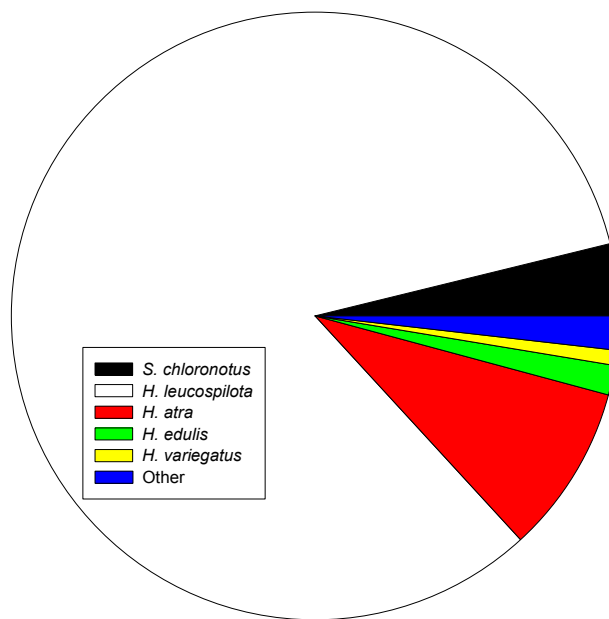


Figure 6: Estimate of the total number of bêche-de-mer at each species at Ashmore Reef . All high commercial species are included in the Other category.

HIGH VALUE COMMERCIAL BÊCHE-DER-MER SPECIES

A total of three commercial species of high value were encountered. These were *Holothuria nobilis*, *H. fuscogilva* and *Thelenota ananas* (Table 1). *Holothuria scabra* and *H. timana*, two other high-value species were not found during this survey. Skewes *et al.* (1999) also did not report finding these species in their 1998 surveys, however they were found in surveys in the 70's and 80's (Russell and Vail 1988). The density of high value commercial species was highly variable between the different habitats at Ashmore Reef. The shallow habitats of the reef crest and flat had very low densities of commercial sea cucumbers. For example, *Holothuria nobilis* the black teatfish, had extremely low densities with only three individuals found during the survey. In contrast, the deepwater habitat of the western lagoon and channel mouths,

which we surveyed on SCUBA (see Figure 3) had far higher density of the commercial species. *Holothuria fusogilva*, the white teatfish is relatively abundant in these deepwater habitats.

Table 2. Comparison of black teatfish (*H. nobilis*) densities between the Great Barrier Reef and Ashmore Reef.

Location	Density no. per hectare	Reference
GBR reefs	17.5	Hammond <i>et al.</i> (1985)
GBR unfished reefs	20.94	Uthicke and Benzie (2000)
GBR fished reefs	5.01	Uthicke and Benzie (2000)
Ashmore Reef	0.5	Russell and Vail (1988)
Ashmore Reef	1.85	Skewes <i>et al.</i> (1999)
Ashmore Reef	0.59 reef crest 0.71 reef flat	This study

LOWER VALUE COMMERCIAL BÊCHE-DE-MER SPECIES

Large numbers of lower commercial-value bêche-de-mer were found on the reef flat (Table 3). These were dominated by *Holothuria atra* (the lollyfish). The lollyfish was primarily found in areas of reef flat that were dominated by seagrass between 100 and 600 metres behind the reef crest. However, they were found in all habitats.

Holothuria edulis was found in relatively high abundance in the shallow and deeper lagoon habitats at Ashmore Reef. Interestingly, a far higher density and species richness of low value beche-der-mer was found in the deeper habitats (shallow and deeper lagoons) compared to the shallower habitats (reef flat and crest).

Table 3: Mean Density (number per hectare) of low commercially-valued species

	<i>H. atra</i>	<i>H. edulis</i>	<i>H. graffei</i>	<i>H. anax</i>	<i>H. argus</i>	TOTAL
Deep Lagoon	5.56	32.78	0.00	7.78	2.78	43.90
Shallow Lagoon	20.63	10.63	0.00	2.50	0.63	33.89
Intertidal Sand	0.00	0.00	0.00	0.00	0.00	0.00
Reef Flat	96.67	0.00	0.00	0.00	0.00	96.67
Reef Flat/ Crest	38.82	0.59	0.00	0.00	0.00	39.41

NON-COMMERCIAL BECH-DER-MER SPECIES

A single species dominated overall numbers of bech-de-mer. *Holothuria leucospilota* had a density of 1289 individuals per hectare on the reef flat, far out numbering any other species. The only other non-commercial species to be found in relatively high densities was *Stichopus chloronotus*. This species was found over all habitats except the intertidal zone.

Table 4: Mean Density (number per hectare) of non-commercial species

	<i>Holothuria leucospilota</i>	<i>Stichopus chloronotus</i>	<i>Holothuria variegatus</i>	<i>Holothuria coluber</i>
Deep Lagoon	0.00	14.44	0.00	0.00
Shallow Lagoon	2.50	28.13	0.00	0.00
Intertidal Sand	0.00	0.00	0.00	0.00
Reef Flat	1289.05	18.33	0.63	0.48
Reef Flat/ Crest	4.12	17.06	0.59	2.94

Figure 4: Bêche-de-mer of the reef flat of Ashmore Reef

Manta Tow  Manta tow snorkellor surveying holothuria population	Reef crest  Reef crest at Ashmore Reef
Reef Flat  Reef flat at Ashmore Reef	<i>H. atra</i> Lollyfish  Commonly found in shallow water on the reef flat Low commercial value
<i>Stichopus chloronotus</i> Greenfish  Found in shallow waters of the reef crest and flat Low value	<i>Bohadschia nobilis</i> Black Teatfish  Found in shallow waters of the reef crest and flat High commercial value

Holothuria leucospilota



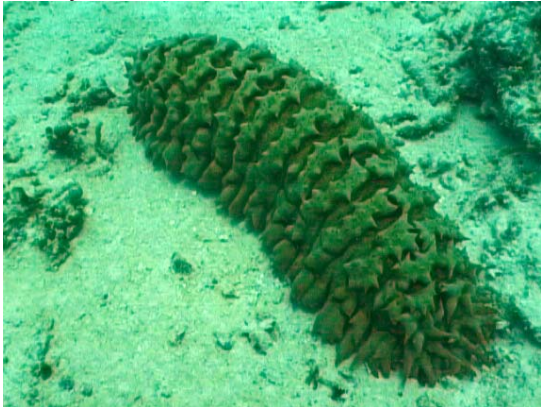
Thin, black with large tentacles
Usually found on reef flat
No commercial value

Holothuria graeffei



Common found on crest and reef slope
No commercial value

Figure 5: Bêche-de-mer of the deep lagoon of Ashmore Reef

Deepwater diver  Diver surveys deep water habitat at 19 m	<i>Holothuria fuscogilva</i> White Teatfish  Commonly found water deeper than 15m Usually covered in sediment and alga Highly commercial species
<i>H. ananas</i> Prickly Red  Orange to red in colour Commonly found in water deeper than 10m Moderate commercial species	<i>H. anax</i> Amberfish  Commonly found in water deeper than 8m Low commercial value
<i>H. fuscopunctata</i> Elephant Trunkfish  Found in water deeper than 8m	<i>Bohadschia argus</i> Leopardfish  Found over all depths from 2 to 20m

DISCUSSION

Holothurian Populations

The large size and conspicuous nature of the shallow water black teatfish (*Holothurian nobilis*) make it easily exploited. There is little doubt that this highly commercial bêche-de-mer species have been severely depleted (Skewes *et al.* 1999, this study). Our surveys covered 94000m² of reef area but we only found three black teatfish or 0.79 per hectare within its preferred habitat of the reef flat. In contrast, similar reef flats on the Great Barrier Reef (that have been fished commercially by Australian fisherman in the last ten years) have average densities of five per hectare while unfished reefs have approximately 20 per hectare (Uthicke and Benzie 2000). Presuming Ashmore Reef in the past could have supported equivalent densities there has been a severe depletion of Ashmore stocks by Indonesian fishers. Previous surveys of Ashmore Reef in 1998 (Skewes *et al.* 1999) and 1987 (Russell and Vail 1987) determined densities of *H. nobilis* at 1.28 and 0.5 per hectare. While different methodologies make direct comparison of the surveys difficult it does seem likely that initial overexploitation of *H. nobilis* occurred pre-1987. The decrease in overall density of *H. nobilis* between 1998 (1.28 ind per ha⁻¹, Skewes *et al.* 1999) and 2000 (0.79 ind per ha⁻¹, this study) could have been a result of illegal fishing, when there was no EA presence at Ashmore (between December 1999 and May 2000), natural variability or just a reflection of differing methodologies.

Low-value or non-commercial, reef flat bêche-de-mer species are still in relatively high to very high densities. In some areas, *Holothuria leucospilota*, a species of no commercial value, reached densities of 16,200 per hectare. *Holothuria atra*, a species of low commercial value also occurs in relatively high densities (Table 2). while on other emergent reefs in the MOU74 Box this species has been seriously overfished (Skewes *et al.* 1999). Major overfishing of high value species and an economic downturn in Indonesian is likely to have caused a substantial increase in the catch of low-value species in the last decade. It remains uncertain, but plausible, that the combination of the marine reserve status and an Australian presence at Ashmore Reef has contributed to the greater abundance *H. atra* (and other low value species) compared to unprotected reefs. Importantly, the high abundance of these species on Ashmore Reef could provide an important source of breeding stock for the area as a whole. However, presently little is known about the reproductive biology of these species or the potential for biological connectivity between populations in the MOU box. However populations of another echinoderm the blue starfish, *Linkia laevigata* are closely related over the extent of the MOU74 Box indicating high gene flow between

populations (Williams and Benzie 1996). Future work should undertake similar studies on commercially important beche-der-mer populations in the MOU74 Box.

The commercially valuable deeper-water holothurian species seemed to have fared far better than their shallow counter-parts. The white teatfish (*H. fuscogilva*) and the prickly red (*Thelenota ananas*) are relatively abundant in the deep western lagoon and channel mouths of Ashmore Reef in depths greater than 15 metres. It is likely that the greater difficulty in free diving to the depths in which these species are found has limited fishing effort and thus provided a refuge for them from Indonesian fishers using traditional methods. The lack of previous data (pre-1985) on Ashmore stocks makes it difficult to determine the level at which they have been fished. However there is no doubt that these deeper species have been fished in the past (see Russell and Vail 1988) but probably only in the shallower limits of their distribution.

***Trochus niloticus* Populations**

The topshell, *Trochus niloticus* has been severely depleted throughout the reefs of the MOU74 Box (Skewes *et al.* 1999). The ease of collecting trochus has made it particularly vulnerable to unsustainable exploitation. Studies of trochus stock densities on the GBR have found that 500 or more individuals per hectare to be common (Long *et al.* 1993, Castell 1997). Our data indicate that this species has been severely depleted on Ashmore Reef, with density of less than 6.4 per hectare within its limited habitat (reef crest, see red habitat, Figure 3). However, while the northern and eastern flanks of Ashmore Reef were adequately surveyed during the October 2000 survey, a large swell breaking on the southern side during the census period made visual counts there impossible. Skewes *et al.* (1999) found higher densities of *T. niloticus* on the exposed, southern edge. Consequently, it is likely that our study underestimates total trochus numbers. Future surveys should place transects along the southern side to form part of the trochus monitoring program.

Recovery Times of Depleted Stocks

Recovery times for the shallow water holothuria and trochus populations are difficult to determine. Little work has been completed to date on biology and ecology of many of these species, particularly with regard to populations in north-western Australia. While large adults are present in all depleted species, the high dilution of gametes during spawning events may prevent successful fertilisation and consequently any subsequent recruitment. The timing of spawning in these regions will also have a significant bearing on the patterns of dispersal and inter-reef connectivity. There is obviously a need to increase our basic knowledge of reproductive biology of many of these species. Furthermore there is a requirement to get a better understanding of the

gene flow between different reefs of the MOU74 Box to better understand the potential mechanisms of population recovery.

The Monitoring Program

This study was initiated to set-up a straightforward, repeatable survey program that could facilitate future monitoring of holothurian and trochus populations at Ashmore Reef. The high diversity of habitats at Ashmore Reef (in terms of depth, wave exposure and tides) meant a range of census techniques had to be employed. The initial part of the expedition was used to refine techniques and assess the differing habitats of Ashmore Reef. A stratified sampling method was used in which the extent of each habitat was determined and a number of surveys done within each of these habitats. This method allows overall numbers to be determined (Appendix 1) for each species.

Monitoring of trochus and trepang populations should be carried out every two years using the methodology of this study. Additional survey sites should be located on the southern edge for trochus and on the southeast reef flat for holothuria. These two locations are under-represented in the current monitoring program. Repeated measure analysis of the resultant data will provide a powerful tool to assess stock recovery through time.

The use of the ACV Wauri as a mother ship would provide low cost, effective logistic support for future censuses. However there are associated constraints. Not using a dedicated research vessel means there is an inability to move the vessel to the eastern side of Ashmore Reef during periods of the trip, and the ACV Wauri and crew have to complete many other tasks (eg apprehending and processing of suspected, unlawful non-citizens).

CONCLUSIONS

Though both trochus and bêche-de-mer have been exploited (some fully) at Ashmore Reef in the past, present stocks are still far healthier than other emergent reefs of the area (Skewes *et al.* 1999). Probably a combination of Marine Reserve status, with its associated fishing ban, and a government presence at Ashmore Reef in recent years have helped to partially protect both trochus and bêche-de-mer populations.

Consequently, Ashmore Reef represents a refuge for both low and high-value sedentary species at the moment. Only through a continued total ban on fishing and a constant on-site presence can this be maintained. A long-term monitoring program using the methodology and transects of this survey should be implemented to assess the recovery of exploited species and the effectiveness of the ongoing management plan. If populations fail to recovery consideration needs to be given to implementing a stock enhancement program.

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APPENDIX 1:

Estimate of total population size of each species within each habitat at Ashmore Reef. Only the 15 most abundant species shown.

SPECIES NAME	Deep Lagoon	Shallow Lagoon	Intertidal Zone	Reef Flat	Reef Crest	Grand Total
<i>Actinopyga echinites</i>	8099	0	0	940	0	9039
<i>Bohabscia argus</i>	5056	8550	0	0	0	13606
<i>Stichopus chloronotus</i>	26289	96188	0	72417	39918	234811
<i>Holothuria atra</i>	10111	70538	0	381833	90847	553329
<i>Holothuria edulis</i>	59656	36338	0	0	1376	97370
<i>Holothuria fuscogilva</i>	21233	0	0	0	0	21233
<i>Holothuria leucospilota</i>	0	8550	0	5091738	9635	5109923
<i>Holothuria nobilis</i>	0	0	0	1881	1376	3257
<i>Holothuria coluber</i>	0	0	0	1881	6882	8763
<i>Holothuria fuscopuntata</i>	0	2138	0	0	2753	4890
<i>Holothuria scabra</i>	4044	2138	0	0	0	6182
<i>Holothuria sp</i>	0	0	0	8464	0	8464
<i>Stichopus variegatus</i>	4044	42750	0	1881	0	48675
<i>Thelenota ananas</i>	10111	8550	0	0	0	18661
<i>Thelenota anax</i>	14156	2138	0	0	0	16293
					TOTAL	6155874

APPENDIX 2:

GPS positions for the sampling sites at Ashmore Reef. Legend: DP: Deep Survey, MAN: Manta Tow, RW: Reef Walk, SN: Snorkel Survey

SURVEY NO.	Start/Finish	LAT (East)	LONG (South)
DP01	S	12,13.084	122,59.182
DP02	S	12,13.218	122,59.506
DP03	F	12,13.538	123, 0.593
DP03	S	12,13.559	123, 0.640
DP04	F	12,14.507	123, 0.532
DP04	S	12,14.482	123, 0.435
DP05	F	12,14.554	123, 0.503
DP05	S	12,14.486	123, 0.433
DP06	F	12,13.488	123, 3.622
DP06	S	12,13.618	123, 3.639
DP07	S	12,13.442	123, 3.606
DP07	F	12,13.279	123, 3.444
DP08	S	12,14.740	123, 9.500
DP10	S	12,14.212	122,59.459
DP11	S	12,13.398	122,59.998
DP12	S	12,11.233	123, 2.369
DP13	S	12,11.228	123, 2.359
DP14	S	12,14.262	122,59.059
DP15	F	12,13.715	123, 5.672
DP15	S	12,13.722	123, 5.798
DP16	S	12,13.032	123, 0.326
DP17	S	12,13.145	123, 0.122
DP18	S/F	12,13.348	123, 5.689
DP19	S	12,11.518	123, 5.081
MAN001	F	12,16.483	123, 0.764
MAN001	M	12,16.611	123, 1.011
MAN001	S	12,16.780	123, 1.223
MAN002	F	12,16.705	123, 0.995
MAN002	M	12,16.667	123, 0.859
MAN002	S	12,16.602	123, 0.741
MAN003	F	12,13.303	123, 0.941
MAN003	S	12,13.268	123, 1.213
MAN004	F	12,13.393	123, 1.160
MAN004	S	12,13.357	123, 0.887
MAN005	F	12,13.443	123, 1.431
MAN005	S	12,13.392	123, 1.162
MAN006	S	12,13.543	123, 1.720
MAN006	F	12,13.580	123, 1.447
MAN007	F	12,11.860	123, 3.712
MAN007	S	12,11.725	123, 3.436
MAN008	F	12,11.960	123, 4.009
MAN008	S	12,11.873	123, 3.749
MAN009	F	12,11.311	123, 4.640
MAN009	S	12,11.066	123, 4.529

MAN010	F	12,11.675	123, 4.747
MAN010	S	12,11.415	123, 4.681
MAN011	F	12,10.481	123, 3.682
MAN011	S	12,10.508	123, 3.955
MAN012	F	12,10.622	123, 4.017
MAN012	S	12,10.527	123, 3.761
MAN013	F	12,10.816	123, 4.250
MAN013	S	12,10.638	123, 4.046
MAN014	F	12,11.617	123, 8.126
MAN014	S	12,11.466	123, 7.899
MAN015	F	12,11.888	123, 8.301
MAN015	S	12,11.647	123, 8.180
MAN016	F	12,11.915	123, 4.621
MAN016	S	12,11.842	123, 4.885
MAN017	F	12,12.148	123, 4.479
MAN017	S	12,11.915	123, 4.617
MAN018	S	12,12.047	123, 4.423
MAN018	F	12,11.789	123, 4.498
MAN019	F	12,11.941	123, 4.367
MAN019	S	12,12.209	123, 4.337
MAN020	F	12,13.499	123, 9.092
MAN020	S	12,13.243	123, 9.002
MAN021	F	12,13.792	123, 9.169
MAN021	S	12,13.532	123, 9.097
MAN022	F	12,14.091	123, 9.251
MAN022	S	12,13.829	123, 9.191
MAN023	F	12,16.216	123, 8.642
MAN023	S	12,16.027	123, 8.840
MAN024	F	12,16.490	123, 8.533
MAN024	S	12,16.255	123, 8.669
MAN025	F	12,16.866	123, 8.497
MAN025	S	12,16.598	123, 8.475
MAN026	F	12,16.237	123, 8.531
MAN026	S	12,16.505	123, 8.471
MAN027	F	12,15.868	123, 8.749
MAN027	S	12,16.111	123, 8.614
MAN028	F	12,15.651	123, 8.922
MAN028	S	12,15.862	123, 8.750
MAN029	F	12,15.100	123, 8.690
MAN029	S	12,15.349	123, 8.791
MAN030	S	12,15.063	123, 8.700
MAN030	F	12,14.801	123, 8.756
MAN031	F	12,14.546	123, 8.923
MAN031	S	12,14.776	123, 8.780
MAN032	F	12,14.806	123, 8.552
MAN032	S	12,14.543	123, 8.608
MAN033	F	12,15.094	123, 8.470
MAN033	S	12,14.839	123, 8.558
MAN034	F	12,15.340	123, 8.289

MAN034	S	12,15.128	123, 8.459
MAN035	S	12,15.969	122,58.292
MAN035	F	12,15.845	122,58.048
MAN036	F	12,15.713	122,57.772
MAN036	S	12,15.836	122,58.015
MAN037	F	12,15.644	122,57.453
MAN037	S	12,15.740	122,57.711
MAN038	F	12,15.606	122,57.796
MAN038	S	12,15.508	122,57.538
MAN039	F	12,15.677	122,58.088
MAN039	S	12,15.593	122,57.826
MAN040	F	12,15.794	122,58.373
MAN040	S	12,15.703	122,58.114
MAN041	F	12,15.165	122,58.492
MAN041	S	12,15.367	122,58.672
MAN042	S	12,15.119	122,58.439
MAN042	F	12,14.990	122,58.198
MAN045	F	12,15.331	123, 0.331
MAN045	S	12,15.272	123, 0.061
MAN046	F	12,15.295	123, 0.674
MAN046	S	12,15.331	123, 0.400
MAN047	F	12,13.299	123, 1.732
MAN047	S	12,13.559	123, 1.824
MAN048	F	12,12.979	123, 1.697
MAN048	S	12,13.246	123, 1.738
MAN049	F	12,14.062	123, 3.304
MAN049	S	12,14.022	123, 3.579
MAN060	F	12,14.962	123, 5.420
MAN060	S	12,15.045	123, 5.681
MAN061	F	12,14.651	123, 5.720
MAN061	S	12,14.659	123, 5.441
MAN062	S	12,14.335	123, 5.793
MAN062	F	12,14.343	123, 5.690
MAN063	F	12,12.794	123, 5.683
MAN063	S	12,12.814	123, 5.382
MAN064	F	12,11.518	123, 5.083
MAN064	S	12,11.672	123, 5.308
MAN069	F	12,11.983	123, 1.951
MAN069	S	12,11.861	123, 2.195
MAN070	S	12,12.238	123, 2.045
MAN070	F	12,12.149	123, 2.304
MAN071	F	12,12.426	123, 2.008
MAN071	S	12,12.270	123, 2.329
MAN072	S	12,16.895	123, 0.755
MAN072	F	12,16.698	123, 0.567
MAN073	S	12,16.497	123, 0.535
MAN073	F	12,16.320	123, 0.327
MAN074	S	12,16.874	123, 0.468
MAN074	F	12,17.048	123, 0.678

MAN075	S	12,17.147	123, 0.465
MAN075	F	12,16.963	123, 0.265
MAN076	S	12,16.846	123, 1.853
MAN076	F	12,16.736	123, 1.601
TEMP LOG inner		12,13.510	123, 0.414
TEMP LOG outer		12,14.294	122,58.904
RW01	F	12,13.933	122,58.204
RW01	S	12,14.057	122,58.519
RW02	F	12,13.724	122,58.527
RW02	S	12,13.759	122,58.252
RW03	F	12,14.013	122,58.270
RW03	S	12,14.116	122,58.527
RW04	F	12,13.933	122,58.490
RW04	S	12,13.798	122,58.247
RW05	S	12,13.351	122,59.088
RW05	F	12,13.441	122,59.347
RW06	F	12,12.816	123,00.023
RW06	S	12,12.757	123,00.278
RW07	S	12,12.746	123, 0.278
RW07	F	12,12.796	123, 0.008
RW08	F	12,17.324	123,07.604
RW08	S	12,17.374	123,07.875
RW09	F	12,17.160	123, 7.826
RW09	S	12,17.324	123, 7.604
RW10	F	12,17.324	123, 7.604
RW10	S	12,17.374	123, 7.875
SN01	S	12,11.970	123, 4.276
SN02	S	12,12.088	123, 3.973
SN03	S	12,12.076	123, 3.772
SN04	S	12,14.312	123, 5.524
SN05	S	12,13.998	123, 5.852
SN06	S	12,11.255	123, 2.405
SN07	S	12,12.445	123, 5.371
SN08	S	12,14.482	123, 9.563
TR01	S	12,12.736	122,59.862
TR01	F	12,12.654	123, 0.122
TR02	F	12,13.308	122,58.635
TR02	S	12,13.422	122,58.386
TR03	F	12,13.667	122,57.454
TR03	S	12,13.712	122,57.184
TR04	F	12,17.039	123, 8.497
TR04	S	12,17.306	123, 8.528
TR05	F	12,15.437	123, 9.115
TR05	S	12,15.656	123, 8.951
TR06	F	12,13.973	123, 9.280
TR06	S	12,13.733	123, 9.157