SHARK BAY MARINE RESERVES MONITORING PROGRAM

BASELINE STUDIES AND MONITORING OF VISITOR SITES IN THE SHARK BAY MARINE PARK SHARK BAY, WORLD HERITAGE AREA AND HAMELIN POOL MARINE NATURE RESERVE

FINAL REPORT: MMSP/MW/SBMP-4/1997

A collaborative project between CALM Marine Conservation Branch, Geraldton Regional Office and Gascoyne District Office

Project No. 151/95 - National Ecotourism Program
Commonwealth Department of Tourism

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Report to
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Cary J L (1997). Shark Bay Marine Reserves Monitoring Program. Final Report. Baseline studies and monitoring of visitor sites in the Shark Bay Marine Park, Shark Bay World Heritage Area and Hamelin Pool Marine Nature Reserve. MMSP/MW/SBMP-4/1997 (Marine Conservation Branch, Department of Conservation and Land Management, 47 Henry St., Fremantle, Western Australia, 6160). Unpublished report.

Field notes and general documentation relating to the Shark Bay Marine Reserves Monitoring Program (SBMRMP) are archived in the following Marine Conservation Branch files:

MMSP/MW/BIO/1997/1
MMSP/MW/SOC/1997/1
MMSP/MW/GEN/1997/1
MW/SB/MRMP0496/OCN

Copies of this report are available at:

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EXECUTIVE SUMMARY

Funding to the Department of Conservation and Land Management through the National Ecotourism Program, administered by the Office of National Tourism, has enabled the establishment of a comprehensive baseline monitoring program of ecologically important benthic communities (ie seagrass meadows and coral reefs) of the Shark Bay Marine Park, Shark Bay World Heritage Area and Hamelin Pool Marine Nature Reserve. The primary objective of the Shark Bay Marine Reserves Monitoring Program (SBMRMP) is to ensure that recreation and tourism activities in this area are ecologically sustainable. Monitoring stations have been established at key sites to provide quantitative data on key benthic habitats. Over time, the SBMRMP will facilitate the detection of human induced changes to these communities before unacceptable or irreversible impacts occur.

This report summarises data collected from three field surveys undertaken in the Shark Bay Marine Park, Shark Bay World Heritage Area and Hamelin Pool Marine Nature Reserve during 1996 and 1997. A total of 77 monitoring sites, including 56 permanently-marked 'transect' sites and 21 'non-transect' sites, were established throughout the area and the benthic communities were described, visible impacts recorded and a permanent photographic record taken using underwater video cameras.

Evidence of human activity including litter and physical damage to coral and seagrass communities, presumably from anchor damage and propeller scour respectively, was found at 13 of the 77 sites. Damage to coral communities was found at two sites, scours in seagrass meadows at three sites and litter at 10 sites. Overall the results suggest that current impacts of human activity on the benthic communities in the Shark Bay Marine Park, Shark Bay World Heritage Area and Hamelin Pool Marine Nature Reserve are localised and ecologically insignificant and that the major benthic primary producer communities (ie seagrass meadows and coral reefs) are in excellent condition.

Two of the impacted sites that were established in August 1996, were resurveyed in April 1997. These sites showed no significant change in the selected monitoring parameters (ie live coral cover and seagrass cover). These data are provided to demonstrate the type of results this program will produce.

A 'piggy-back' survey of the shrimp fauna at 22 sites in the Shark Bay World Heritage Area recorded a total of 61 species of Caridean shrimps from 24 genera. Two of these species have not been recorded in Australia and three species are 'new' to science. The shrimp fauna in the waters adjacent to Dirk Hartog, Bernier and Dorre islands had a higher diversity than any other region in Shark Bay (see Appendix III).

Recommendations with respect to additional monitoring sites, monitoring frequency and usage are made.

Companion reports associated with this project and already forwarded to the Office of National Tourism include:

D'Adamo N and Pobar G J (1996). Shark Bay Marine Reserves Monitoring Program. Field Program Report SBMRMP-01/96. Preliminary Field Survey: 15-22 April 1996.

D'Adamo N, Colman J G and Pobar G J (1996a). Shark Bay Marine Reserves Monitoring Program. Data Report SBMRMP-02/96. Preliminary Field Survey: 15-22 April 1996.

D'Adamo N, Colman J G and Pobar G J (1996b). Shark Bay Marine Reserves Monitoring Program. Initialisation of long-term monitoring sites: August 1996. Field Program Report SBMRMP-03/96.

Cary J L and Pobar G J (1997). Shark Bay Marine Reserves Monitoring Program. Initialisation of long-term monitoring sites: August 1996. Data Report MMSP/MW/SBMP-1/1997.

Cary J L (1997). Shark Bay Marine Reserves Monitoring Program. Initialisation and re-sampling of long-term monitoring sites and further ground-truthing of habitat map: April 1997. Field Program Report MMSP/MW/SBMP-2/1997.

Cary J L and Daly T W (1997). Shark Bay Marine Reserves Monitoring Program. Initialisation and re-sampling of long-term monitoring sites: April 1997. Data Report MMSP/MW/SBMP-3/1997.

Media contact in relation to the Shark Bay Marine Reserves Monitoring Program, included 10 newspaper articles, six radio interviews and two television interviews.

RECOMMENDATIONS

***Recommendation:* A representative sub-set of the 'control' sites, established during the SBMRMP should be monitored annually to determine the natural variability of these key benthic communities.**

***Recommendation:* A comprehensive database of human usage in the Shark Bay region should be developed, as a matter of priority, and regularly updated to identify the current level, nature and trends of human threats to the environmental values of the Shark Bay Marine Park, Shark Bay World Heritage Area and Hamelin Pool Marine Nature Reserve.**

***Recommendation:* Sites SB5, SB6, SB103, SB53 and SB80 should be established as permanent 'transect' sites as a matter of priority.**

***Recommendation:* Sites identified as having a 'high' level of risk from recreational activities should be monitored every three years or sooner if there are significant increases in the level of human usage in the area.**

***Recommendation:* Fish populations targeted by recreational fishers, particularly site-attached species, should be monitored in the Shark Bay Marine Park and Shark Bay World Heritage Area to establish quantitative baselines for future reference.**

***Recommendation:* Other key marine habitats, such as stromatolite, mangrove and soft-sediment communities, as well as key marine faunal groups, such as mammals, reptiles and birds, should be progressively incorporated into the SBMRMP.**

***Recommendation:* A poster display should be produced for use at shows and exhibitions to inform the community of the rationale, objectives and outcomes of the Shark Bay Marine Reserves Monitoring Program.**

***Recommendation:* An educational program should be produced to assist the management of the Shark Bay Marine Park, Shark Bay World Heritage Area and Hamelin Pool Marine Nature Reserve, particularly in regard to reducing the level of impact from human activities such as anchor damage, propeller scars and litter. Target audiences would be charter boat operators, recreational boat users and fishers.**

1. INTRODUCTION

Shark Bay is located in Western Australia, 700 kilometres north of Perth (Figure 1). The Shark Bay region is a popular destination for both domestic and international tourists with in excess of 100 000 visitors per annum. Most visitors consider Shark Bay's natural attributes as the most important features, in particular, the human/dolphin interaction at Monkey Mia, the vast undeveloped and unspoilt natural environment and the diverse flora and fauna are regarded as special values (CALM, 1994a). Hamelin Pool contains the most pristine and abundant examples of stromatolites found anywhere in the world. The region's dugong population, estimated at 10 000, is the second largest in the world. Dolphins, whales, whale sharks, manta rays and turtles are also important fauna in the region. Line fishing is considered the most popular water based activity, followed by swimming, power boating, net fishing and snorkelling and to a lesser extent SCUBA diving and spearfishing (CALM, 1994a).

The Hamelin Pool Marine Nature Reserve and the Shark Bay Marine Park were gazetted in May 1990 and November 1990 respectively. The Shark Bay Marine Reserves Management Plan 1996-2006 was released in February 1997 (CALM, 1996). Shark Bay was inscribed on the World Heritage list in December 1991 on the basis of its natural values. The waters adjacent to Bernier and Dorre Islands and west side of Dirk Hartog Island, located within the World Heritage Area, are also considered worthy of marine reserve status (CALM, 1994b).

In 1994, the Office of National Tourism provided financial assistance ($50 000) to the Department of Conservation and Land Management (CALM), the statutory managers of the Shark Bay Marine Park and Hamelin Pool Marine Nature Reserve and lead agency for the Shark Bay World Heritage Area, to establish an ongoing monitoring program to ensure that recreation and tourism activities are ecologically sustainable. This was in accordance with a recommended strategy of the Shark Bay Marine Reserves Management Plan (CALM, 1996) to '*ensure that recreation developments and activities do not detract from or adversely impact on the conservation values of the reserves'*.

The successful management of the marine environment is contingent upon comprehensive long-term monitoring programs that provide information on natural variability and long-term trends in key biological communities, determine the status of important natural attributes at regular intervals and identify undesirable trends resulting from human activities in time for remedial management action to be implemented effectively. Monitoring programs generally comprise one or more of the following complementary objectives: (i) local scale impact and/or *compliance monitoring* that examines the effects of human activities in a localised area(s); (ii) temporally-constrained, broadscale *surveillance monitoring* to assess the impact of episodic regional physical and biological processes (eg the effect of cyclones and predators) and (iii) spatially-constrained, long-term monitoring of key biological parameters to determine the extent and cause of *natural variation* (eg seasonal and inter-annual variability) of key ecosystem attributes.

This report summarises the activities and results of the Shark Bay Marine Rerserves Monitoring Program (SBMRMP). Although the SBMRMP primarily addresses objective (i) it will also provide, in time, information related to objectives (ii) and (iii).

The primary operational objective of this program was to establish re-locatable, long-term monitoring sites to provide baseline ecological data from which impacts from recreational usage could be monitored and managed. This report summarises data from each of the field surveys in April 1996, August 1996 and April 1997.

Data collected as part of the SBMRMP were also used to improve the biological accuracy of the existing GIS map of the major benthic habitats of the Shark Bay Marine Park (Cary, Daly and McQuillan, 1997),

developed collaboratively by CALM and the Geography Department of the University of Western Australia (Bruce, 1996).

Figure 1. Location map of Shark Bay.

An opportunity arose to 'piggy-back' a shrimp fauna survey to provide a better understanding of shrimp fauna diversity in selected habitats of Shark Bay. A photographic survey was also undertaken as part of the SBMRMP to provide high quality transparencies of key biological communities to use in community awareness programs.

2. PROJECT BRIEF

The following workplan was outlined in the project specification:

Action 1: Undertake field investigation to establish the location of monitoring sites and controls (March 1995).

Action 2: Undertake field surveys to establish baseline data on the marine biota, its condition, diversity and distribution (June 1995).

Action 3: Undertake field and other surveys to establish levels of visitor use on the sites (June, 1995).

Action 4: Undertake an annual field monitoring survey to monitor visitation and the condition of the sites to establish whether there are any changes to the ecosystem and to establish the cause of these changes (June 1996).

Action 5: Incorporate relevant information into management (ongoing).

3. EVALUATION OF PROJECT BRIEF

The Marine Conservation Branch (MCB) of CALM, which was not officially formed until March 1996, was handed primary carriage of the SBMRMP. The Branch consists of marine scientists with extensive experience in the marine environment. To this end it was considered worthwhile and opportune to evaluate the original program objectives and actions in order to ensure maximum benefit was gained from this project. The following section outlines the modifications and rationale that were made to the original workplan.

3.1 Time-line

The dates referred to in the work plan above were delayed by about one calender year, initially because of the delays in the transfer of professional staff from the Department of Environmental Protection to CALM and then because of the necessity to conduct the field surveys during appropriate climatic conditions. The Office of National Tourism, in a letter of 5 June 1996, approved an extension of the contract to 30 June 1997.

3.2 Project Brief Action Items

Action 1: There were no changes to Action 1. Action 1 was completed and comprised a preliminary field survey undertaken in April 1996 and two reports; D'Adamo and Pobar (1996) and D'Adamo, Colman and Pobar (1996a).

Action 2: There were no changes to Action 2. Action 2 was completed and comprised of two field surveys undertaken in August 1996 and April 1997. Two reports were produced for the August 1996 field survey; D'Adamo, Colman and Pobar (1996b) and Cary

and Pobar (1997) and two for the April 1997 field survey; Cary (1997) and Cary and Daly (1997).

Action 3: The collection of quantitative visitor usage data in the Shark Bay area since 1993, when the last semi-quantitative survey was undertaken, has largely been confined to the Monkey Mia area. The absence of broadscale usage data prevented any meaningful quantitative estimates of usage numbers and patterns at individual sites. Furthermore, a one-off survey of usage, in an area as large as Shark Bay, was considered unlikely to deliver meaningful results and, additionally, not be cost-effective within the overall context of this project. An alternative approach to action Item 3 was therefore adopted. This approach involved an assessment of the temporal trends in the Monkey Mia (ie the most popular destination for tourists in Shark Bay) visitor records as an index of changes to the overall visitor numbers to the Shark Bay area, combined with a qualitative assessment of changes to spatial usage patterns since 1993 by local CALM staff. The review of visitation to Monkey Mia, indicated that yearly numbers were relatively static between 1993 and 1996. Similarly the limited anecdotal information available suggested that usage patterns over the Shark Bay area were similar to those recorded in 1993. On this basis, it was considered that there would be little to be gained from undertaking Action Item 3 as outlined in the Project Specifications. However, the above analysis upholds the spirit of this Action Item and, perhaps as importantly, has further emphasised the need to establish usage databases as a priority management tool for marine reserve management in Western Australia.

Action 4: Two of the most highly 'impacted' sites established in the August 1996 field survey were re-surveyed in the April 1997 and the results are presented here to demonstrate the type of results this program will deliver at each site over the long-term and also to indicate the indicative level of precision of the methodology used. No significant changes in the measured parameters were recorded at these sites. Considering that these two sites were the most heavily 'impacted' of all the sites, and that at most of the other sites there were no signs of human activity, it was considered to be unnecessary, and of limited value to resurvey, the remaining sites. Rather, it was considered that the emphasis of the SBMRMP should be to incorporate a greater spatial coverage in areas of relatively high existing and potential user activity, with primary emphasis remaining on recreational/tourism sites. In addition, it was considered important to increase the spatial coverage of 'control' sites. The re-alignment of this objective provided the opportunity to increase the spatial extent of the monitoring grid to incorporate key habitats around Bernier and Dorre islands, as this area has been recommended to be included in the Shark Bay Marine Park (CALM, 1994b), and the Wooramel Bank area which is a major seagrass meadow and an important feeding area for dugong (Figure 4).

Action 5: There were no changes to Action 5. Action 5 deals with the incorporation of relevant information into management (ongoing) and this objective is addressed in this report (section 6.2).

4. METHODS

4.1 Site selection

A preliminary field survey, which visited 78 sites, was conducted in April 1996 (D'Adamo, Colman and Pobar, 1996a) and was undertaken to gain familiarity of the ecological and cultural attributes of the Shark Bay area to facilitate the selection of long-term monitoring sites (Figure 2). Site selection was also assisted

by discussions with CALM rangers and managers, local tourist operators, recreational divers and fishers and the results of the 1993 visitor survey (CALM, 1994a).

Long-term monitoring sites were established throughout the Shark Bay Marine Park, Shark Bay World Heritage Area and Hamelin Pool Marine Nature Reserve in areas of *relatively* high current usage, where usage may be high in the near future and in comparable 'control' areas where current and predicted usage is low and likely to remain low. Sites were classified according to a 'risk' assessment based on two criteria;

Figure 2. Sites visited during the April 1996 survey (from D'Adamo, Colman and Pobar, 1996).

the level of existing and projected short-term human usage determined from the 1993 visitor survey (CALM, 1994a) and *in-situ* evidence of human activity (eg anchor damage, propeller scars, litter). Three levels of risk have been used: 'high', 'medium' and 'low'. Sites with a 'high' level of risk have a relatively high level of current human usage and show obvious visual signs of human activity. Sites with a 'medium' risk have a moderate level of human usage and show no signs of human activity. Sites with a 'low' risk have a low level of human usage and show no signs of human activity. These 'low' risk sites are considered as 'control' sites. Some 'control' sites were also placed in some of the sanctuary zones within the Shark Bay Marine Park and in the Hamelin Pool Marine Nature Reserve.

4.2 Establishment of 'transect' sites

At each 'transect' site, three 50 m transects were permanently-marked at each end by driving 'star' pickets into the seabed, their location determined using a differential GPS (DGPS) and the benthic communities along each transect were photographed using a video camera (Sony Hi-8) in an underwater housing. A total of 56 permanent 'transect' sites, including areas of high usage and 'control' sites, were established. Forty-one 'transect' sites were established in the August 1996 survey (Table 1 and Figure 3) and 15 'transect' sites in the April 1997 survey (Table 2 and Figure 4). Details of the methods used to select the sites and establish the permanent transects and descriptions of the video sampling technique and methodologies used to describe and record the benthic communities are given in Cary and Pobar (1997) and Cary and Daly (1997).

The benthic video transect technique used here was developed by the Australian Institute of Marine Science (AIMS) to monitor the status of coral-dominated benthic communities by detecting and quantifying major spatial and temporal changes in the percentage cover of sessile benthos (Christie *et al.*, 1996). As well as being a non-destructive technique, essential for repetitive long-term monitoring at 'fixed' locations, it also provides a permanent record of benthic habitats, including seagrass meadows, which can be later analysed in a variety of ways. This method is designed to identify changes in benthic communities and, as such, it can be used to identify impacts that result from recreational and commercial usage. The technique can also be used to quantify natural variability of the benthos if monitored on a regular basis over appropriate temporal scales. The technique generally allows significant changes to key ecological parameters (eg live coral cover) to less than 5% accuracy to be identified.

4.3 Establishment of 'non-transect' sites

'Non-transect' sites were generally established in areas that were, at the time of the surveys, unsuitable (eg exposed to heavy swell) for establishing permanently-marked transects or where the degree of environmental risk, as determined within the risk assessment framework discussed in section 4.1, was determined to be between 'medium' and 'low'. It was considered that this latter category did not warrant the additional effort to establish permanently-marked transects. The location at 'non-transect' sites was determined by DGPS and the surrounding (within 50 m radius) benthic communities were described and photographed by underwater video camera.

A total of 21 permanent 'non-transect' sites were established. Five sites were established in April 1996 (SB5, SB6, SB103, SB40, SB80), 11 (including SB53) in August 1996 (Table 1 and Figure 3) and five in April 1997 (Table 2 and Figure 4). Sites SB5, SB6, SB103, SB53 and SB80 are 'high' risk sites and should be established as 'transect' sites as a matter of priority (see recommendations in section 6.2). These sites were either unsafe for diving or could not be visited for logistical reasons at the time of the August 1996 and April 1997 surveys.

4.4 Re-surveyed sites

'Transect' sites SB105 and SB20, which had evidence of human activity when first established in August 1996 (see Table 3), were re-surveyed in April 1997 (Figure 4). These sites are representative of two of the major marine communities of the Shark Bay area: coral reef areas and perennial seagrass meadows and

data from these sites were used to demonstrate how time-series plots will eventually be constructed for each site and the indicative accuracy of the methods used.

Figure 3. Locations of long-term monitoring sites established during the August 1996 survey (from Cary and Pobar, 1997).

Figure 4. Locations of long-term monitoring sites established during the April 1997 survey (from Cary and Daly, 1997).

Table 1. 'Transect' and ' non-transect' sites established in August 1996.

Site number	Site name	Dominant factor in site selection	Habitat	Level of risk	Video Footage
'Transect' sites					
SB10	Surf Point	Recreation site	Coral	Medium	Yes
SB15	Sea Cages	Aquaculture site	Sand	Medium	Yes
SB65	Homestead Bay	Recreation/Landing site	Seagrass	Medium	Yes
SB66	Saunters Patch	Control site	Coral	Low	Yes
SB67	Egg Is.	Recreation site	Coral	Medium	Yes
SB75	Sandy Point Reef	Recreation site, sanctuary zone	Coral	Medium	Yes
SB22	Bellefin Flats	Control site	Seagrass	Low	Yes
SB20	Herrisson Flats	Recreation site	Seagrass	High	yes
SB36	Fork Flats	Control site	Seagrass	Low	Yes
SB38	White Island	Recreation site	Seagrass	Low	Yes
SB45	Three Bay Island	Recreation site	Seagrass	Medium	Yes
SB57	Pearl Beds	Aquaculture site	Pearl beds in seagrass	HIgh	Yes
SB55	Kangaroo Island	Recreation site	Seagrass	Medium	Yes
SB31	Slope Island-nth platform	Industrial/recreation	coral/seagrass	High	Yes
SB32	Slope Island -nth seagrass	Industrial/recreation	Seagrass	Medium	Yes
SB27	Useless Inlet North	Recreation site	Seagrass	Low	Yes
SB60	Lefebre Island	Recreation site	Seagrass/coral	High	Yes
SB50	Double Island	Recreation site	Seagrass	Low	Yes
SB54	Boat Haven	Recreation site	Seagrass	Low	Yes
SB28	Useless Inlet South	Industrial/recreation	Seagrass	Medium	Yes
SB95	Aquaculture site A	Proposed aquaculture site	Seagrass	Low	Yes
SB104	Outer Big Lagoon	Control site	Seagrass	Low	Yes
SB105	Broadhurst Reef South	Recreation site	Coral	High	Yes
SB127	East Peron flats	Control site	Seagrass	Low	Yes
SB121	Guichenault Point	Recreation site	Seagrass	Medium	Yes
SB125	Pearl Farm	Aquaculture/Rec-reation site	Seagrass	Medium	Yes
SB128	Pearl Farm Control	Control site	Seagrass	Low	Yes
SB131	Monkey Mia	Recreation site	Seagrass	High	Yes
SB132	Monkey Mia Offshore	Control site	Seagrass	Low	Yes
SB98	Inshore Denham	Control site	Seagrass	Medium	Yes
SB120	80 Acres	Recreation site	Limestone pavement/coral	High	Yes
SB141	Herald Gut	Control site	Seagrass	Low	Yes
SB195	Lharidon Bight	Control site	Seagrass	Low	Yes
SB180	Herald Loop	Control site	Seagrass	Low	Yes
SB182	Faure Bank East	Control site	Seagrass	Low	Yes
SB184	Faure Bank West	Control site	Seagrass	Low	Yes
SB186	Hamelin Pool East	Control site	Seagrass	Low	Yes
SB190	Hamelin Pool West	Control site	Seagrass	Low	Yes

SB139	Gladstone Bay	Recreation	Seagrass	Medium	Yes
SB147	Gladstone Jetty	Recreation	Seagrass	Medium	Yes
SB148	Gladstone marker	Control site	Seagrass	Low	Yes

Table 1 cont. 'Transect' and 'non-transect' sites established in August 1996 field survey.

Site number	Site name	Dominant factor in site selection	Habitat	Level of risk	Video footage
'Non-transect' sites					
SB112	Cape Peron Flats East	Proposed aquaculture site	Sand	Low	No
SB110	Gudrun wreck	Recreation/historic interest	Wreck habitat	Medium	Yes
SB14	Sunday Is.	Recreation site	Limestone pavement	Medium/low	Yes
SB300	Bent Stick	Recreation site	Sand/coral patches	Medium/low	No
SB19	'001'	Recreation site	Coral	Medium/low	Yes
SB29	Useless Inlet Reef	Recreation site	Coral	Low	No
SB39	White Island Flats	Recreation site	Limestone pavement	Medium/low	Yes
SB48	Baudin Island	Control	Seagrass	Low	No
SB36A	Fork Flats Reef	Recreation site	Limestone pavement/coral	Medium/low	Yes
SB53	Kangaroo Is-southern fringe	Recreation site	Seagrass	High	Yes
SB99	Six Mile Flats	Recreation site	Coral	Medium/low	No

4.5 Community awareness

Interviews were undertaken with the electronic and print media to raise the awareness of the SBMRMP. These included 10 newspaper articles in regional and state newspapers (an example is presented as Appendix I), six radio interviews on ABC regional radio and two television interviews which were shown on local outlets of the state-wide television station GWN during prime-time.

A professional photographer took part in the April 1997 field survey at no additional cost to the project. Approximately 150 high quality transparencies from the April 1997 field survey have been catalogued at the Marine Conservation Branch of CALM. These transparencies are of coral reefs, seagrass meadows, invertebrates, fish and mammal species and recreational and commercial activities. Photographs taken during this field trip will be used by CALM for community education and awareness programs.

4.6 Oceanographic data

Salinity and temperature data were collected opportunistically at no extra cost to the project. The data will be used to further develop an understanding of circulation patterns in the Shark Bay area as part of a separate project. An understanding of the oceanography of the region is an essential component of the technical information base required for effective management. The oceanographic data is not presented in this summary report.

4.7 Crustacea data

A visiting Swedish zoologist took part in the April 1997 field survey, at no extra cost to this project. Shrimp samples were collected at 22 of the SBMRMP sites (Appendix II). These data provide a better understanding of shrimp fauna diversity in selected habitats of Shark Bay.

Table 2. 'Transect' and 'non-transect' sites established in April 1997

Site number	Site name	Dominant factor in site selection	Habitat	Level of risk	Video Footage
'Transect' sites established April 1997					
SB21	Bar Flats	Recreation site	Coral	Medium	Yes
SB70	Louisa Bay	Recreation site	Coral	Medium	Yes
SB90	Turtle Bay	Recreation site	Coral	High	Yes
SB149	Gladstone	Control site	Seagrass	Medium	Yes
SB150	Disappointment Reach Sanct. Zone	Control site	Seagrass	Low	Yes
SB151	Disappointment Reach-North	Control site	Seagrass	Low	Yes
SB152	Grey Point-West	Control site	Seagrass	Low	Yes
SB153	Carnarvon-South	Control site	Seagrass	Medium	Yes
SB200	Uranie Bank	Control site	Seagrass	Low	Yes
SB201	Cape St Cricq-North	Control site	Coral	Low	Yes
SB202	Castle Point	Control site	Coral	Low	Yes
SB204	Cleft Rock	Recreation site	Coral	Low	Yes
SB205	East Koks Island	Recreation site	Coral	Low	Yes
SB213	Red Cliff Point-South	Control site	Coral	Low	Yes
SB214	Hospital Bay	Recreation site/ Anchorage	Coral reef	Low	Yes
'Non-transect' sites established in April 1997					
SB199	Dirk Hartog-West	Recreation site	Coral	Low	Yes
SB207	Cape Couture-West	Control site	Lagoon/intertidal Coral	Low	Yes
SB208	Cape Ronsard-West	Control site	Coral	Low	Yes
SB210	Dampier Reef	Control site	Coral	Low	Drop down video
SB212	Disaster Cove	Recreation site	Small sandy bay/ Coral	Medium/low	Yes

5. RESULTS

5.1 Site data

Of the 56 permanent 'transect' sites and 21 'non-transect' sites that were established (Figures 3 and 4), evidence of human activity, such as isolated overturned living coral colonies (presumed to be caused by anchors), scours in shallow seagrass beds (presumed to be caused by propellers) and litter, was found at only 13 of the sites (Table 3). These 13 sites are considered as 'high' risk sites. Although these impacts were ecologically insignificant, some of the sites are popular diving sites (eg Monkey Rock; SB5) and the presence of litter and physical damage to the benthos detract from their value.

Table 3. Sites with evidence of human activity in the Shark Bay Marine Park and World Heritage Area

Site	Name	Visual Impact	Level of risk
SB 5	Monkey Rock	overturned corals (presumed anchor damage)	high
SB 6	Steep Point	litter	high
SB 60	Lefebre Island	damaged corals and litter (ie bottles)	high
SB 80	Whithnell Point	fishing line	high
SB 90	Turtle Bay	fishing line and litter (ie beer cans)	high
SB 103	Gregory's	fishing line and hooks	high
SB 105	Broadhurst Reef	anchor damage to coral, discarded fish traps	high
SB 120	80 Acres	fishing line, hooks and sinkers	high
SB 20	Herisson Flats	scour in seagrass (presumed propeller scars), litter (ie beer cans)	high
SB 57	Pearl Beds	scour in seagrass (presumed propeller scars)	high
SB 31	Slope Island, North Platform	litter (ie bottles, ring pulls, mooring rope)	high
SB 131	Inner Bank Monkey Mia	propeller scars on seagrass	high
SB 53	Kangaroo Island , south fringe	litter (ie fishing line)	high

5.1.1 'Transect' sites

The characteristics of the 'transect' sites are summarised in Tables 1 and 2. Specific site details can be found in the companion data reports of Cary & Pobar, 1997 and Cary & Daly, 1997. A total of 56 sites were

established including thirty-nine sites in seagrass meadows, 16 in coral reef habitats and one near an existing aquaculture site. The low levels of current and projected usage and the absence of any visual evidence of human activity allowed 21 sites in the seagrass meadow habitat and four sites in the coral reef habitat to be classified as having a 'low' level of risk and therefore can be considered as *defacto* 'control' sites (Tables 1 and 2). Recreational activities are known to occur at 24 of the 'transect' sites and, at a further seven sites, recreational activities overlap with commercial activities. Some 'transect' sites were established close to commercial activities, such as aquaculture and the salt works, as the infrastructure associated with these activities appears to attract marine life and therefore recreational users. Monitoring of these sites has a double effect of providing information on the effects of both commercial and recreational activities.

The *Amphibolis antarctica* seagrass meadow at sites SB147 and SB151, on the Wooramel Bank (Figures 3 and 4), all had characteristic scour marks of uprooted plants or stems stripped of leaves, up to three metres in diameter. These may be dugong feeding scars. Another Wooramel Bank site (ie SB149) also had what appeared to be dugong feeding scars, of approximately 0.1 m in diameter, in the sediment of the surrounding *Halodule uninervis* meadows.

Site SB201, at Cape St Cricq off the southern end of Dorre Island, had small areas of up to 30 m^2 of dead branching coral (*Acropora* sp.).

Compared with most other similar areas surveyed, two sites (ie SB202, SB201) on the eastern side of Dorre Island and a site (ie SB213) on the south-eastern side of Bernier Island, had a relatively high abundance of large coral trout (*Plectropomus leopardus*) and cod (*Epinephelus* sp). Site SB202 also had a high abundance of juvenile coral trout.

5.1.2 'Non-transect' sites

A total of 21 'non-transect' sites were established. The characteristics of these sites are summarised in Tables 1 and 2. Specific site details can be found in the companion data reports of Cary & Pobar, 1997 and Cary & Daly, 1997. Although sites SB5, SB6, SB103 and SB80 were established as 'non-transect' sites in April 1996, these sites are classified as 'high' risk sites (Table 3). Similarly, site SB40 which is classified as a 'medium' risk site.

Two sites were established in seagrass meadows, 13 in coral reef habitats, four on limestone reef habitat, one at a proposed aquaculture site and one near a ship-wreck. There are 16 sites that are used for recreation activities, one site used for aquaculture and four 'control' sites.

5.2 Re-surveyed sites

Detailed data from sites SB105 and SB20, initially surveyed in August 1996 and re-surveyed in April 1997, are presented in Appendix III. At site SB105, percentage live hard coral cover is used as the key ecological parameter of interest and was approximately 8% in both surveys (Figure 5a). Similarly, at site SB20, a seagrass meadow dominated by *Amphibolis antarctica*, the key ecological parameter used is the 76-100% cover category. The percentage cover of seagrass in this category was similar in both surveys (Figure 5b).

5.3 Crustacea data

A total of 61 species of Caridean shrimps from 24 genera were found in the Shark Bay World Heritage Area (Appendix II). Over 800 specimens of shrimps were collected from 22 sites. The majority of these specimens were associated with other invertebrates, such as ascidians and sponges. Two species recorded have never been found previously in Australia and three species are 'new' to science. Sites SB20, SB90, SB199 and SB214 had the highest species richness with more than nine species found at each site. The shrimp fauna of the waters adjacent to the Dirk Hartog, Bernier and Dorre islands had a higher diversity than any other region sampled in Shark Bay.

6. DISCUSSION

6.1 The impact of human activities

Seventy-seven long-term monitoring sites, approximately half in areas of known recreational/commercial usage and half as *defacto* 'control' sites, were established throughout the Shark Bay Marine Park, Shark Bay World Heritage Area and Hamelin Pool Marine Nature Reserve. The locations of the sites gave particular emphasis to the ecologically important perennial seagrass meadow and coral reef habitats. Descriptions of the benthic habitats, visual evidence of human activity and a video photographic record of the benthic communities were recorded at each site. A general description of fish communities was also recorded at some sites. Three permanently-marked, relocatable transects were established at 56 of the sites (ie 'transect' monitoring sites) and provide quantitative baseline data on the benthic communities which, in time, will enable detrimental changes to key conservation attributes (eg live coral cover) to be detected before unacceptable or irreversible impacts occur. Twenty-one 'non-transect' monitoring sites were also established in areas of less concern or where logistical difficulties prevented the establishment of 'transect' sites.

The results of the surveys conducted during the SBMRMP suggest that the impact of human activity on the seagrass and coral reef communities in the Shark Bay Marine Park, Shark Bay World Heritage Area and Hamelin Pool Marine Nature Reserve is minimal with less than 20 % of the sites showing visual signs of human activity. Where this did occur, it was generally ecologically insignificant impacts such as physical damage to isolated coral colonies, presumably caused by anchors, scours in shallow seagrass beds, presumably caused by propellers and litter (Table 3). The areas of highest impact were found in the waters around Steep Point, Useless Loop, Cararang Peninsula, the north-eastern tip of Dirk Hartog Island, Monkey Mia and the northern tip of the Peron Peninsula. These areas correlate well with the areas identified in the 1993 visitor survey as being the most popular marine sites to visit in the Shark Bay area (CALM, 1994a).

The most severe impacts recorded were physical damage and over-turning of corals at Monkey Rock (SB5) and Broadhurst Reef (SB105), presumably from boat anchors, and scours through seagrass meadows at Herisson Flats (SB20), Pearl Beds (SB57) and Inner Bank, Monkey Mia (SB131), presumably from boat propellers. The other common impact observed was litter, such as cans, bottles and fishing gear (Table 3). These impacts were generally very localised and, as such, ecologically insignificant. However, physical damage to benthic communities, such as corals, and litter do detract from the recreational and aesthetic qualities of these sites. Despite these minor impacts, the results of the SBMRMP suggest that the seagrass meadows and coral reef habitats in the Shark Bay Marine Park, Shark Bay World Heritage Area and Hamelin Pool Marine Nature Reserve are in excellent condition.

This conclusion is not surprising considering the relatively low number of tourist resorts and charter vessels operating in such a large region. The Shark Bay World Heritage Area covers 2.2 million hectares, of which 71% is marine, and it has only two main tourist centres, Denham and Monkey Mia. Monkey Mia is the most popular tourist destination in Shark Bay (CALM, 1994a) and has approximately 80,000 visitors per year. Nanga and Tamala stations have approximately 15,000 and 1400 visitors per year, respectively. Visitor numbers for Dirk Hartog Island are not available. The town of Carnarvon lies immediately to the north also provides accommodation for tourists visiting the Shark Bay Marine Park and World Heritage Area.

Line fishing is a popular water-based activity in Shark Bay, as is swimming, power boating, net fishing, snorkelling and to a lesser extent SCUBA diving and spearfishing (CALM, 1994a). Denham, Monkey Mia and Carnarvon have the largest anchorages and boat launching areas for charter operators and recreational fishers in this region. Four charter boats operate out of Denham all year round, however, there can be up to six boats operating in the tourist season. Two of these charter boats are for sightseeing, with one of these vessels operating tours to a pearl farm. The other two vessels are used for diving and fishing trips. Up to 50 recreational boat trailers can be found at the Denham boat ramp during the height of the tourist season (B. Barton, personal communication). At Monkey Mia there are three charter boats which operate sightseeing tours and up to 50 recreational boat trailers can be found at the boat ramp during the height of the tourist season (B. Barton, personal communication). Up to nine boats and 60 campers can be found at Steep Point at one time (R. Shepherd, personal communication). Approximately 466 boats per year (up to 7 m in size), enter Tamala Station (K. King, personal communication) and a large number of tourists entering Nanga Station Tourist Complex have small boats (M. Sears, personal communication). No figures are available for Carnarvon. Most of the vessels operating out of Carnarvon visit the northern end of the World Heritage Area, including Bernier Island. Limited anecdotal information is available for Cape Peron, Gladstone and Bush Bay, the other small boat launching areas.

6.2 Management implications and recommendations

6.2.1 Benthic primary producers as an index of ecosystem health

The SBMRMP established a quantitative baseline data set of the major subtidal benthic primary producer communities (eg perennial seagrass meadows and coral reefs) in the Shark Bay Marine Park, Shark Bay World Heritage Area and Hamelin Pool Marine Nature Reserve because of their obvious ecological significance (ie pelagic productivity is low in Shark Bay) to the local marine environment. These communities are, by definition, highly productive and usually contain a high diversity of plants and animals. In the absence of significant direct and indirect deleterious human activities (such physical damage and pollution respectively) on the seagrass and reefal communities of the Shark Bay area, the 'health' of these key benthic habitats is likely to be largely indicative of the 'health' of their associated faunal communities. The results of this program suggest that the perennial seagrass meadows and the coral reefs of this area are generally in excellent condition with little evidence of serious human disturbance. It follows that the same conclusion can be reached about the associated faunal communities. However this does not necessarily apply to species which are subjected to extractive activities. Specific

monitoring programs may be required for these species before any such meaningful conclusions can be reached (see recommendation in section 6.2.5).

6.2.2 Accuracy of monitoring methodology

The two sites surveyed initially in August 1996, and resurveyed in April 1997, showed no significant changes in the indicative parameters that were measured (see Figure 5). This was not unexpected given the relatively minor nature of the impacts determined from earlier surveys and the short time period between the surveys. These results were included to provide an example of the outputs the SBMRMP will deliver over the long-term and also as an indication of the accuracy of the methodology, in this case likely to be less than 5 %.

6.2.3 Monitoring natural variability

Until the natural variability of the selected monitoring parameters of the benthic communities is established, it will be difficult to distinguish whether changes are due to natural processes or anthropogenic activities. This highlights the critical need to determine the cause and extent of the natural variability of key monitoring parameters if the Shark Bay Marine Park, Shark Bay World Heritage Area and Hamelin Pool Marine Nature Reserve are to be managed effectively. This can be achieved, in part, by annual monitoring of a representative sub-set of the 'control' sites of the SBMRMP.

Recommendation: **A representative sub-set of the 'control' sites, established during the SBMRMP should be monitored annually to determine the natural variability of these key benthic communities.**

6.2.4 Monitoring of human activities

Sites identified as having a relatively 'high' level of risk from human activities (Table 3) should be monitored every three years or sooner if there are significant increases in the level of human usage in the area. To this end a comprehensive database of human usage is required, as a high priority, to identify the current level, nature and trends of human 'threats' to the environmental values of the Shark Bay Marine Park, Shark Bay World Heritage Area and Hamelin Pool Marine Nature Reserve.

Recommendation: **A comprehensive database of human usage in the Shark Bay region should be developed, as a priority, and regularly updated to identify the current level, nature and trends of human threats to the environmental values of the Shark Bay Marine Park, Shark Bay World Heritage Area and Hamelin Pool Marine Nature Reserve.**

Recommendation: **Sites SB5, SB6, SB103, SB53 and SB80 should be established as permanent 'transect' sites as a matter of priority.**

Recommendation: **Sites identified as having a 'high' level of risk from recreational activities (see Table 3) should be monitored every three years or sooner if there are significant increases in the level of human usage in the area.**

6.2.5 Further monitoring

Fish abundance

Fishing is a popular recreational and commercial activity in the region (CALM, 1994a). Field observations (see section 5.1.1) suggest that there are significant differences in the relative abundance of key target fish species (eg particularly site-attached species such as coral trout and cod) in some parts of the Shark Bay World Heritage Area. Interestingly, the sites with relatively high abundances of these large fish are, coincidentally, among the least accessible locations in the region. Monitoring of fish populations, particularly of site-attached species that are targeted by recreational fishers, should be initiated to establish quantitative baselines for future reference.

Recommendation: **Fish populations targeted by recreational fishers, particularly site-attached species, should be monitored in the Shark Bay Marine Park and Shark Bay World Heritage Area to establish quantitative baselines for future reference.**

Key Habitats
Other key marine habitats of the Shark Bay Marine Park, Shark Bay World Heritage Area and Hamelin Pool Marine Nature Reserve, such as mangrove and soft-sediment communities, as well as key faunal groups such as mammals, reptiles and birds, should be progressively included into the SBMRMP.

Recommendation: **Other key marine habitats, such as stromatolite, mangrove and soft-sediment communities, as well as key marine faunal groups, such as mammals, reptiles and birds, should be progressively incorporated into the SBMRMP.**

6.2.6 Community awareness and education

The television and radio interviews and newspaper articles (see example in Appendix I) provided excellent opportunities to improve community awareness of the SBMRMP, however it is believed that further educational material is required to further promote this program. To this end, it is recommended a poster be produced which informs the community of the reasons why monitoring programs are needed to manage the Shark Bay Marine Park, Shark Bay World Heritage Area and Hamelin Pool Marine Nature Reserve, the objectives of the program, the results and management implications.

The photographs taken during the field surveys of the SBMRMP could be used for the poster and the poster could be displayed at key centres in the Shark Bay region and at other marine conservation and tourism exhibitions in Western Australia. Talks could also be given to the Shark Bay community, Shark Bay Tourist Committee, Shark Bay Recreational Fishing Committee, Denham Fisheries Association and the Shire of Shark Bay on the implications of this study for the management of the marine environment in the Shark Bay region.

Recommendation: **A poster display should be produced for use at shows and exhibitions to inform the community of the rationale, objectives and outcomes of the Shark Bay Marine Reserves Monitoring Program.**

Recommendation: **An educational program should be produced to assist the management of the Shark Bay Marine Park, Shark Bay World Heritage Area and Hamelin Pool Marine Nature Reserve, particularly in regard to reducing the level of impact from human activities such as anchor damage, propeller scars and litter. Target audiences would be charter boat operators, recreational boat users and fishers.**

7. AUDITORS FINANCIAL STATEMENT

The total cost of the Shark Bay Marine Reserves Monitoring Program was approximately $147,500. Appendix IV presents the financial statement of the three field surveys.

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Dr Chris Simpson, Nick D'Adamo and Dr Jeremy Colman from the MCB and Ron Shepherd from the CALM Midwest reviewed drafts of the manuscript.

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APPENDIX I

Article from the Sunday Times newspaper, 11 August, 1996

APPENDIX 11

Shrimp fauna of Shark Bay, Western Australia

The shrimp fauna in Shark Bay, Western Australia

Matz Berggren

Introduction

The hypersaline environments of Shark Bay provide variation in habitat along the 12 500 km of western coastline of Western Australian which is noted for its paucity of embayments. It is a very diverse area in respect to habitats, as has previously been reported for fish, molluscs, echinoderms and corals (Western Australian Museum, 1995). The bay is partially sealed from the ocean by a rim of islands (Dirk Hartog, Dorre and Bernier Islands) with shallow connections in between. This means that two markedly different sets of conditions are available for colonisation about the islands, with the seaward habitats being swept by oceanic water but those on the Shark Bay side experiencing elevated nutrients and extreme water temperature and salinities. An important source of recruitment into the Bay is undoubtedly by invertebrate larvae carried southwards in the Leeuwin Current from tropical areas and swept into the Bay in association with the occasional meandering gyres and temporary countercurrents which break away from the main current. The larvae of temperate species can probably recruit into Shark Bay *via* the closer-to-shore cooler counter-current.

Earlier investigations of the shrimps of Shark Bay concentrated on the inner parts of the bay, and based on the species found, sampling was probably done using dredges. A list of the shrimps that have been found in the area prior to 1990 is provided by Jones (1990).

Methods

Sampling was undertaken at 22 SBMRMP sites, including seagrass meadows and coral habitats using SCUBA and snorkelling. Sampling methods included delicate 'picking' and collection of possible host invertebrates in reef areas and using a hand-net in seagrass areas. The samples were stored in separate, labelled plastic bags or vials and site specific data such as depth and habitat/host characteristics recorded on a plastic sheet.

Results

A total of 62 species of Caridean shrimps were recorded during this survey (Table 1) with the dominant groups being the Pontoniinae (33 species), the Alpheidae (16 species) and Hippolytidae (9 species) from 24 different genera collected from different habitats within Shark Bay. More than 800 specimens were collected from the 22 sites, with the vast majority being associated with other invertebrates. Since sampling was conducted only by using SCUBA and snorkelling, the results must show some bias since bottom dwellers (in burrows or in coral rubble) were not sampled for by dredging or digging.

The species numbers found implies a very diverse caridean shrimp fauna resident in Shark Bay, particularly given that bottom-dwelling species will be underestimated in this survey. Two species appear to be new for Australia, *Hippolyte commensalis* Kemp, 1925 and *Platypontonia hyotis* Hipeau-Jacquotte, 1971 and three are new to science. For Western Australia alone, 22 are new to the area and when looking only at the south-western part of W.A. (south of North-West Cape), 37 are new in that area.

In order to interpret readily the distributional significance of the fauna recorded during this survey and taking into account distributional information recorded in the literature, it is relevant to divide the coast of west and northern Australia into four areas, as follows:

- sw W.A.= from the south coast to about Carnarvon (including Shark Bay),
- nw W.A.= from south of North-West Cape to the border to the Northern Territory,
- N.T.=Northern Territory,

- Qld=Queensland.

Since the field trip there has been a limited amount of time available for laboratory-based work and this has prevented conclusive identification of species marked as *aff.* in Table 1. These species did not fit easily into the given descriptions available and indeed they might prove to be con-specific with a species already named in the list, or to a species already described but not listed in Table 1 or to an entirely new species. This process of identification is ongoing. Forms that undoubtedly represent new species are marked as n.s. in the Table 1. A final description of all the shrimps found with restricted synonomy, detailed morphological information, distributional information, ecological remarks and discussions about the findings will be presented in a relevant international journal.

Table 1. Coral reef shrimps (and other shrimp-like crustaceans) from Kimberley. New for Shark Bay (S.B. new). Previous distribution according to earlier results in W.A. (south-west=sw and north-west=nw), N.T. and Qld.

Infra	Genera -order Caridea	Species	Auktor	S.B. new	WA sw	WA nw	NT	Qld	Found at Shark Bay station no
Fam.	**Alpheidae**								
1	Alpheus	bicostatus	De Man, 1908	n	y	n	y	y	207
2	Alpheus	deutropus	Hilgendorf, 1879	y	y	y	n	y	202
3	Alpheus	edwardsi	Audouin, 1827	n	y	y	y	y	105
4	Alpheus	lottini	Guérin, 1829	n	y	y	y	y	201
5	Alpheus	paralcyone	Coutière, 1905	n	y	y	y	y	208
6	Alpheus	spongiarum	Coutiére, 1897	n	y	y	y	y	201
7	Athanas	areteformis	Coutière, 1903	n	y	n	n	y	207
8	Athanas	aff. indicus	(Coutière, 1903)	y	y	n	n	y	90,199,202,205,207
9	Synalpheus	coutièrei	Banner, 1953	y	n	y	y	y	152,153
10	Synalpheus	aff. harpagatrus	Banner & Banner, 1975	y	y	y	n	n	150,214
11	Synalpheus	hastilicrassus	Coutière, 1905	y	n	y	n	n	120
12	Synalpheus	neomeris	(De Man, 1897)	n	y	y	y	y	204,214
13	Synalpheus	neptunus	Banner & Banner, 1975	y	y	n	n	n	199,214
14	Synalpheus	sciro	Banner & Banner, 1975	y	y	y	n	n	21
15	Synalpheus	stimpsonii	(De Man, 1888)	n	y	y	y	y	90,199,204,213
16	Synalpheus	streptodactylus	Coutière, 1905	n	y	y	y	y	21,214
Fam.	**Hippolytidae**								
17	Hippolyte	caradina	Holthuis, 1947	y	n	n	n	y	20,150,151,152,153
18	Hippolyte	aff. commensalis	Kemp, 1925	y	n	n	n	n	90
19	Latreutes	aff. compressus	Stimpson, 1860	y	n	n	n	n	200
20	Latreutes	aff. mucronatus	Stimpson, 1860	y	n	n	n	y	20,153
21	Latreutes	pygmaeus	Nobili, 1904	y	n	n	n	y	20,150,151,152,153,20
22	Lysmata	amboinensis	(De Man, 1888)	y	n	n	n	y	90
23	Saron	marmoratus	(Oliver, 1811)	n	y	y	y	y	201
24	Thor	amboinensis	(De Man, 1888)	n	y	y	y	y	204
25	Thor	paschalis	(Heller, 1861)	y	n	y	y	y	21,204,207
Fam.	**Palaemonidae**								
Sub.-	**fam. Palaemoninae**								
26	Leander	n.s.		y					20
27	Urocaridella	n.s.		y					90
Sub.-	**fam. Pontoniinae**								

28	Anchistus	custos	(Forskål, 1775)	n	y	y	y	y	20,90,213,253
29	Anchistus	miersi	(De Man, 1888)	y	n	y	n	y	105,202
30	Conchodytes	maculatus	Bruce,1989	y	n	y	n	n	213,214
31	Conchodytes	monodactylus	Holthuis, 1952	y	n	n	y	y	90,202
32	Coralliocaris	graminea	Dana, 1852	n	y	y	y	y	207
33	Coralliocaris	viridis	Bruce, 1974	y	n	n	y	y	204
34	Dasella	ansoni	Bruce, 1983	y	n	n	y	n	208,213
35	Hamopontonia	aff. corallicola	Bruce, 1970	y	n	y	y	y	21,105,202,213
36	Harpiliopsis	beaupresii	(Audouin, 1826)	n	y	y	y	y	201
37	Notopontonia	platycheles	Bruce, 1991	y	n	n	n	n	208,213,214
38	Palaemonella	pottsi	(Borradaile, 1915)	y	n	y	y	y	90,105,199
39	Palaemonella	rotumana	(Borradaile, 1898)	n	y	y	y	y	20,105,150,153,202
40	Parapontonia	nudirostris	Bruce, 1968	y	n	n	n	y	90
41	Periclimenaeus	arabicus	(Calman, 1939)	y	n	n	y	y	214
42	Periclimenaeus	bidentaus	Bruce, 1970	y	n	n	n	y	150
43	Periclimenaeus	pachydentatus	Bruce, 1969	y	n	n	n	y	199,204
44	Periclimenaeus	rastifer	Bruce, 1980	y	n	n	n	y	214
45	Periclimenaeus	stylirostris	Bruce, 1969	y	n	n	y	y	152,153,199,214
46	Periclimenes	aff. cobourgi	Bruce & Coombes,	y	n	n	y	n	20,151
47	Periclimenes	amymone	De Man, 1902	n	y	y	y	y	21,207
48	Periclimenes	anacanthus	Bruce, 1988	y	n	n	y	y	20,150,151,153
49	Periclimenes	brevicarpalis	(Schenkel, 1902)	y	n	y	y	y	90
50	Periclimenes	commensalis	Borradaile, 1915	y	n	y	y	y	105,199,201,204,213
51	Periclimenes	grandis	(Stimpson, 1860)	y	n	y	y	y	21,205
52	Periclimenes	holthuisi	Bruce,1969	y	n	n	y	y	20,21,120,202
53	Periclimenes	incertus	Borradaile, 1915	y	n	y	y	y	202,214
54	Periclimenes	kempi	Bruce, 1969	y	n	y	y	y	90,205
55	Periclimenes	n.s.							90
56	Periclimenes	psamate	(De Man, 1902)	y	n	y	n	y	214
57	Periclimenes	seychelliensis	Borradaile, 1915	y	n	y	y	y	20,152
58	Periclimenes	sonor	Nobili, 1904	y	n	n	y	y	90
59	Platypontonia	hyotis	Hipeau-Jacquotte, 1971	y	n	n	n	n	199,204
60	Thaumastocaris	streptopus	Kemp, 1922	y	n	y	n	y	214
Fam.	**Rhynchocinetidae**								
61	Rhynchocinetes	brucei	Okuno, 1994	y	n	n	n	y	90
62	Rhynchocinetes	durbanensis	Gordon, 1936	y	n	n	n	n	90,199
Infra	**-order Stenopodidea**								
Fam.	**Stenopodidae**								
63	Stenopus	hispidus	(Oliver, 1811)	n	y	y	y	y	90
Infra	**-order Dendrobranchiata**								
Fam.	**Peaneidae**								
64	Penaeus	marginatus	Randall, 1840	n	y	y	n	y	149
64=	Total no of species		New to Shark Bay =	45					

Additional species found in Shark Bay reported from other sources:

- Jones, 1990: 35 (mainly not associated shrimps)
- Identified from photos taken by C. Bryce: 1 (*Hymenocera picta* Dana, 1852, not reported before from Shark Bay).

The addition of 36 species from previous surveys not found this time, to the list of shrimps from this survey makes the total number of Caridean and Stenopodidean shrimps at Shark Bay: 99 species in 28 genera.

Discussion

Shark Bay is a shallow enclosed bay with extreme water temperatures and salinities in its inner parts (Marsh, 1990). Furthermore, large amounts of sediment are suspended and moved within the bay by both tidal currents and river discharge. These factors appear to be affecting the abundance of the free-living shrimps in the seagrass areas (Table 2). Shrimp abundance at SB152 is probably low because sampling was limited to snorkelling (due to the lack of air for SCUBA) and the depth was 10 m.

Otherwise there is a clear gradient in species diversity from SB149, in the south-east of the bay to SB153 in the north-east of Shark Bay (see Table 2 in this report and Figure 4 in main report). The low number of shrimp species from Uraine Bank (SB200) is surprising given its apparently favourable position in the outer part of Shark Bay and cannot be explained at the moment. The highest numbers of shrimps (both species and genera) were recorded from Site SB20 on the western side of Shark Bay, an area with good water movement.

Table 2. Number of specimens and species of free-living shrimps from the sampling stations in seagrass meadows.

Station	Total no of individuals	Individuals per sample	Total no of species	Species per sample	Depth-Visibility
SB20	71	35,5	7	6,5	2 - 8 m
SB149	0	0	0	0	3 - 2 m
SB150	13	6,5	3	2	4 - 6 m
SB151	18	18	4	4	4 - 5 m
SB152	5	5	3	3	10 - 10 m
SB153	23	23	5	5	4 - 10 m
SB200	5	5	2	2	6 - 10 m

Compared to other seagrass areas I have visited on the same latitude (see Inhaca Island below), a much lower number of specimens are obtained in Shark Bay using the same methods. This is also an indication that the environment is very severe for the year-round resident species.

This is in contrast to the western part of the bay, especially off the islands. The majority of the cryptic shrimp fauna were found on the eastern side of the islands (Dirk Hartog, Dorre and Bernier islands). There is a high diversity of habitats for shrimps around the islands and particularly for the different species of invertebrates that serve as hosts for shrimps.

Previously, I have studied the shrimp fauna of Inhaca Island, off the southern coast of Mozambique, where some of the southernmost coral reefs in the world are found. There are a number of similarities between Shark Bay and Inhaca Island. Inhaca Island, at 26°S, is situated at a similar latitude to Shark Bay. Also, a warm southwards moving current (Mozambique current) flows outside the coast and a close-to-shore cooler counter-current sweeps northwards closer inshore. Maputo Bay, with Inhaca Island as an outer barrier towards the Indian Ocean, is very shallow (average depth 10m) and has a higher temperature than the open sea outside the island. The shrimp fauna of the coral reefs and seagrass meadows is very diverse with 37 genera with 98 species of Caridean and Stenopodidean shrimps. Maputo Bay has been interpreted

as a tropical enclave in a subtropical/temperate area (Berggren 1993). This can be used as a valuable comparison with Shark Bay as it is located at a similar latitude albeit on the opposite side of the Indian ocean. The number of species at Shark Bay is about the same, but the number of genera is lower, 28 in Shark Bay compared with 37 at Inhaca Island.

This is probably due to comparatively more extreme conditions inside Shark Bay, but tropical eastern Africa is also a faunistically richer source area than is northern Australia.

Prior to this survey species such as *Platypontonia hyotis* Hipeau-Jacquotte 1971, *Parapontonia nudirostris* Bruce 1968, *Periclimenaeus bidentaus* Bruce 1970, *Periclimenaeus pachydentatus* Bruce 1969, *Periclimenaeus rastifer* Bruce 1980, *Periclimenes psamate* (De Man, 1902) and *Rhynchocinetes brucei* Okuno, 1994 were only found outside Australia or in tropical Queensland waters. This indicates. that Shark Bay functions as a tropical enclave in a subtropical/temperate area. This same tropical/temperate overlap was found at Maputo Bay in Mozambique. This is further supported by the fact that about seven species in the area are either new to science or being geographical subspecies, probably endemic.

The taxonomically four most species-rich stations were SB20, SB90, SB199, SB214. SB20 was an important study site, a seagrass station where the sample comprised free-living shrimps. This compares with the structurally more diverse reef-areas of other stations and where the majority of the catch comprised different species of associated/cryptic shrimps (shrimps that lives on or inside other invertebrates). The most outstanding area is the northern end of Dirk Hartog Island, with 17 species of shrimps found at two sites, SB90 and SB199. More sampling within this area would probably have increased the species number considerably. The most outstanding site was SB214 (Wedge Rock at Hospital Bay on Bernier Is.) and this was probably due to the high coral diversity. Sampling was only carried out in one small area and if the sampling regime had been extended further then it is highly likely that this would have dramatically increased the number of shrimp species. There is a striking difference in species abundance between the outer part of the bay (*e.g.* the islands) which had 50 species, compared to the inner part of the bay where there were only 25 species. At both the outer and inner parts of the bay the three main habitat types, seagrass meadow, coral, rock/limestone, were sampled.

Table 3. Summary of the taxonomic result for each station. Stations that shrimps were obtained from sponges are marked since in some occasions the number of individuals from sponges can be very large.

Station	Family/Sub-	Genera	Species	Individuals	Comment
SB149	0	0	0	0	
SB200	1	1	2	5	
SB120	2	2	2	7	
SB205	2	2	3	5	
SB208	2	3	3	5	
SB151	2	3	4	19	
SB152	3	5	5	18	*
SB105	2	5	6	32	
SB201	3	5	6	16	*
SB150	3	6	6	21	*
SB207	3	4	7	13	
SB204	3	6	7	13	
SB202	2	7	7	34	*
SB213	2	7	7	12	
SB21	3	4	8	71	
SB153	3	7	8	61	*

SB199	4	8	9	92	*!
SB20	3	6	10	81	
SB214	2	5	14	347	*!
SB90	6	12	16	35	
			Total:	887	*=sponges

Conclusion

The shrimp fauna around Dirk Hartog, Bernier and Dorre islands are unique and therefore should be given some form of protection. This conclusion supports the one made by the Western Australian Museum (1995) based on fish, mollusc, echinoderm and coral studies.

Two shrimp species recorded have never been found previously in Australia and three species are new to science.

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APPENDIX 111

Percentage cover of the benthic groups for sites SB105 and SB20
in August 1996 and April 1997

(a) SB105, August 1996

Id Code			% Cover					
Benthic	**Taxonomic**	**Specific OTU**	**T1**	**T2**	**T3**	**Mean**	**Std dev**	**Std error**
Hard Coral			T1	T2	T3			
	Acroporiidae	Acropora spp.	0.4	0	0.8	0.40	0.40	0.20
		Favites spp.	0	4	7.2	3.73	3.61	1.80
		Montipora spp.	0.8	0	0	0.27	0.46	0.23
	Dendrophyllidae	Turbinaria spp.	8.8	0	0	2.93	5.08	2.54
	Pocilloporiidae	Pocillopora spp.	0.4	0.8	0	0.40	0.40	0.20
Hard Coral			10.4	4.8	8	7.73	2.81	1.40
	Alcyoniidae	Sarcophyton spp.	31.6	24	33.6	29.7	5.06	2.53
	Demospongidae	Sponge spp.	0	0	0.4	0.13	0.23	0.12
			31.6	24	34	29.8	5.22	2.61
Other								
	Other	Rock	23.2	8	16	15.7	7.60	3.80
	Other	Rubble	22	50.8	20.4	31.0	17.11	8.55
	Other	Sand	12.8	12.4	21.6	15.6	5.20	2.60
Other			58	71.2	58	62.4	7.62	3.81

(b) SB105 April 1997

Id Code			% Cover					
Benthic	**Taxonomic**	**Specific OTU**	**T1**	**T2**	**T3**	**Mean**	**std dev**	**std error**
Hard Coral			T1	T2	T3			
	Acroporiidae	Acropora spp.	3.6	0	9.6	4.40	4.85	2.42
		Favites spp.	0	2.4	0	0.80	1.39	0.69
		Montipora spp.	0	0	0	0.00	0.00	0.00
	Dendrophyllidae	Turbinaria spp.	6.8	0.4	0	2.40	3.82	1.91
	Pocilloporiidae	Pocillopora spp.	2		0	1.00	1.41	0.71
Hard Coral			12.4	2.8	9.6	8.27	4.94	2.47
	Alcyoniidae	Sarcophyton spp.	13.6	17.2	28.8	19.	7.94	3.97
	Demospongidae	Sponge spp.	0	0.4	1.2	0.5	0.61	0.31
			13.6	17.6	30	20.4	8.55	4.28
Other								
	Other	Rock	19.6	10	6	11.	6.99	3.49
	Other	Rubble	46	67.2	42	51.7	13.5	6.77
	Other	Sand	8.4	2.4	12.4	7.73	5.03	2.52
Other			74	79.6	60.4	71.3	9.87	4.94

SB20, August 1996 and April 1997

Id Code			% Cover					
Benthic	**Taxonomic**	**Specific OTU**	**T1**	**T2**	**T3**	**Mean**	**Std dev**	**std error**
August 1996								
Seagrass			T1	T2	T3			
	Amphibolis antarctica	50-75% coverage	3	5	-	2.7	2.5	1.4
		75-100% coverage	90	90	88	89.3	1.2	0.7
	Posidonia australis	75-100% coverage	7	5	12	8.0	3.6	2.1
Seagrass			100	100	100	100	0	0
Epiphytes	algae	high medium low	high	high	high	high		
Epiphytes			high	high	high	high		
April 1997								
Seagrass			T1	T2	T3			
	Amphibolis antarctica	50-75%	5	5	-	3.3	2.8	1.6
		75-100%	90	90	89	89.7	0.6	0.4
	Posidonia australis	75-100%	5	5	11	7.7	3.5	2.0
Seagrass			100	100	100	100	0	0
Epiphytes	algae	high	high	high	high	high		
Ephipytes			high	high	high			

APPENDIX IV

Auditors Financial Statement

Table 3. 'Non-transect' sites established in April 1996

Site number	Site name	Dominant factor in site selection	Habitat	Level of risk	Video Footage
'Non-transect' sites					
SB5	Monkey Rock	Recreation site	Limestone pavement/coral	High	Yes
SB6	Steep Point	Recreation site	Limestone pavement/coral	High	No
SB103	Gregory's	Recreation site	Limestone pavement/coral	High	No
SB40	Mary Ann	Recreation site	Limestone pavement/coral	Medium	Yes
SB80	Whithnell Point	Recreation site	Limestone pavement/coral	High	Yes