MARINE MANAGEMENT SUPPORT
SHARK BAY

MOVEMENTS AND COMMUNITY BASED CONSERVATION OF SHARK BAY DUGONGS

Commonwealth Project Number: 28624

Final Report to Environment Australia:

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A collaborative project between the Western Australian Department of Conservation and Land Management, Shark Bay Yadgalah Aboriginal Corporation (Inc.), Edith Cowan University and James Cook University.

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SUMMARY

This document represents the final report to Environment Australia (EA) on the completion of the project *Community Based Conservation of Shark Bay Dugongs,* funded through the Natural Heritage Trust - project number 28624. The project was a collaboration between the Western Australian Department of Conservation and Land Management (DCLM), the Shark Bay Yadgalah Aboriginal Corporation (Inc.), Edith Cowan University and James Cook University.

Through the effective combination of Indigenous and non-Indigenous involvement, the objective of the project was to acquire sufficient knowledge on dugong requirements to adequately manage the significant dugong population within the Shark Bay World Heritage Property (SBWHP). Due to the healthy status of dugongs in Shark Bay, this population has a major role to play in worldwide dugong conservation.

Building on a platform of previously established programs, the movement and habitat usage of dugongs within the SBWHP property were determined as part of this program through the use of remote location recording devices attached to individual animals. These devices were able to provide a clearer understanding of how dugongs utilise Shark Bay by illustrating the extent to which a seasonal migration pattern is undertaken. Dugongs within the bay move from preferred locations during summer, to separate preferred locations during the winter. The primary reason for this migration is attributed to changes in water temperature. Dugongs within Shark Bay are at the southern end of their global distribution range, and are therefore more susceptible to temperature change than dugongs elsewhere.

The remote recording devices determined the spatial extent of high use areas visited by dugongs throughout the year. Throughout winter high use areas it was identified that only one species of seagrass, the species *Amphibolous antarctica*, occurred here, highlighting the importance of these areas and the preservation of seagrass habitat in general within Shark Bay for dugong conservation.

The success of the project can be largely attributed to the collaboration of all the project proponents, in particular the DCLM and the Yadgalah Corporation. The importance of collaborative efforts which characterised this program cannot be underestimated when dealing with species such as dugong that have high biodiversity and cultural values. The results from this program will form a useful model for the undertaking of similar programs with Indigenous communities aimed at understanding more about the distribution and habitat usage of dugongs in other areas throughout their range.

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1 INTRODUCTION

1.1 BACKGROUND

The dugong (*Dugong dugon*) is the only herbivorous marine mammal that is strictly marine. It is listed as vulnerable to extinction at a global scale on the International Union for the Conservation of Natures '*Red List of Threatened Species*' (Hilton-Taylor, 2000). A recent document, '*A Dugong Status Report and Action Plan for Countries and Territories*', produced for the United Nations Environment Program (UNEP), details that throughout much of its range the dugong is believed to survive in relict populations that are separated by large areas which have depleted or extirpated populations (Marsh *et al*. 2002).

Whilst Australian waters contain possibly the largest remaining dugong populations in the world, there is strong evidence of significant population decline in some parts of the dugong's Australian range (Marsh, 2000). Threats to dugongs include, but are not restricted to, commercial fishing practices, hunting, habitat degradation and disturbance from other activities such as aquaculture and tourism. Effective conservation of these populations is a major requirement for the survival of the species globally.

The Shark Bay World Heritage Property (SBWHP) on the mid west coast of Western Australia is a location with a large and stable dugong population exposed to relatively limited levels of threatening activity. Effective conservation of this population requires both sound biological information and a transparent and functional community consultative process to facilitate management. The biological requirements to achieve this outcome are outlined in the *Shark Bay Marine Reserves Management Plan 1996-2006* (CALM, 1996) and include research into distribution patterns, particularly in relation to seasonal activity, and the identification of important forage resources.

1.2 GENERAL

To date, there has been minimal research into the movement patterns and habitat requirements of individual dugongs (*Dugong dugon*) within the SBWHP, an area deemed to be of international significance for this species (Preen, 1998). Previous work has focused upon determining distribution and abundance from aerial surveys (Marsh *et al*. 1994; Preen *et al*. 1997: Gales *et al*. in press.) and from observations carried out using combined aerial, vessel and land based surveys (Prince *et al*. 1981; Anderson, 1982a&b, 1986, 1994). In addition, a limited amount of work has been undertaken to determine habitat structure and forage requirements at locations where aggregations of animals have been observed (Anderson, 1986, 1994, 1998).

This project, *Movements and Community Based Conservation of Shark Bay Dugongs*, has built on a previous program that commenced in 1999 (Holley, 2002a). The aims of that program were to develop and apply a safe and reliable technique for the capture of dugongs, and to determine appropriate methods for the deployment and retrieval of remote recording devices attached to dugongs. The application of these devices, which measure dugong location on a regular basis, result in a far more accurate measure of dugong distribution and behaviour over a greater spatial and temporal scale than can be achieved by direct observation alone. This initial project sought also to develop a working relationship with a local Indigenous organisation, the Shark Bay Yadgalah Aboriginal Corporation (YAC) to carry out a research program on dugongs. To the Yadgalah, the dugong is not only an important cultural icon but also a significant food item for ceremonial occasions.

Movements and Community Based Conservation of Shark Bay Dugongs is a collaborative effort between the Western Australian Department of Conservation and Land Management (DCLM), Shark Bay Yadgalah Aboriginal Corporation Inc., Edith Cowan University and James Cook University. The involvement of the Yadgalah Aboriginal Corporation has been vital to the project's success, with the objective of ensuring genuine Indigenous representation and involvement in the development and undertaking of this program and in the development of further strategies designed to enhance dugong conservation.

2. PURPOSE

This report represents the final report to Environment Australia detailing work carried out as part of the project, *Community Based Conservation of Shark Bay Dugongs*. The objectives of the study were:

- **The collection of baseline data on the movements of Shark Bay dugongs over a wide range of spatial and temporal scales and an assessment of the most important dugong habitats and food species.**

- **The production of maps that quantify the seasonally important dugong habitat types in Shark Bay and listing of the important forage species for dugong and the depths at which they forage.**

- **The generation of improved "availability correction factors" to facilitate more accurate use of aerial survey data to estimate absolute dugong abundance.**

- **To make recommendations for conservation and management of dugongs and dugong habitat in Shark Bay, based on the project findings.**

- **The collaboration with, and participation of the project's consortium members (including the Indigenous community) and Australian scientists.**

- **Progress toward incorporating baseline information into existing and future management plans and strategies relevant to dugong conservation in this and other areas.**

3. METHODS

3.1 STUDY AREA

Shark Bay contains the western most point of the Australian coast (Figure 1) and lies between latitudes 24^0 35'S and 27^0 00'S. It is a large (13 000km^2) shallow (mainly <15m) basin with restricted oceanic exchange and high rates of evaporation (Logan *et al.* 1970). The bay is located near the northern limit of a latitudinal transition region between temperate and tropical marine flora and fauna (CALM, 1996). Seagrass meadows cover more than 4000km^2 of the bay and are reported to be the largest in the world (Walker, 1989). Of the 12 species of seagrass found in the bay, several species are of essentially southern distribution, at the northern limit of their range, and several are of tropical affinity (Walker *et al*. 1988). Dugongs within the bay are at the southern limit of their range on the WA coast with an estimated population of 11021±1357(se) individuals (Holley *et al*. in prep.).

3.2 REMOTE TRACKING

In order to carry out a remote tracking study of dugongs, animals must be caught and held in the water while tracking tags are attached. The procedure employed for the catch and restraint of dugongs was the 'rodeo' technique, as outlined in Marsh and Rathbun (1990). The use of this procedure is deemed to be the most efficient and suitable for sea conditions in Shark Bay as well as ensuring low risk of injury or mortality to the dugong.

Buoyant Satellite Platform Transmitter Terminals (PTT) tags (Telonics - Arizona, USA) and Geographical Positioning System (GPS) tags (Lotek - Newfoundland, Canada) were attached to dugongs using a padded harness that is connected around the tailstock of the dugong. The PTT transmitter or GPS engine is contained in a floating housing with antenna attached via a 3m tether to the harness (Marsh and Rathbun, 1990). Positions are recorded in a latitude and longitude format with respect to the World Geodetic System 1984 (WGS 84) datum. Fixes recorded from the GPS units are accurate to within 5m, while fixes recorded from the PTT units are variable in positional accuracy up to 1.5 km. This method of tag attachment is most appropriate for Sirenians (dugongs and manatees) as the system allows for maximum satellite uplink capability even when animals are foraging in waters <3m. However, due to this design there may be an over representation of readings in shallow water. Although dugongs have been identified as spending

72% of their time foraging in waters <5m (Chilvers *et al*. 2003) dugong distribution as recorded from the tags in deeper waters may not accurately be reflected.

3.3 HABITAT ASSESSMENT

To assess habitat structure and identify the important seagrass species that occur in the areas preferred by dugongs for foraging (as identified from GPS tags), 14 locations were sampled for seagrass composition and density. Sites were selected based upon positional information (fixes) recorded from two of the GPS tags deployed on dugongs. Sites were selected according to the successive distances travelled by the dugongs between fixes as well as the overall movement patterns of the dugongs during each deployment period.

Sites indicative of preferred dugong habitat (foraging sites) were selected from areas where the density of fixes was relatively high and concentrated over a time scale greater than 24 hours. This information indicated that the animal was moving slowly between recorded fixes and therefore suggestive of a period of foraging. Within these groupings, a single point was selected where the distance from the previous fix was <50m and the distance to the next fix was of a similar distance. In order to determine if there was a difference between high and low density areas a number of sites (travelling sites) were also sampled. These sites were indicative of habitat where dugongs were deemed to have travelled through, i.e. areas where the distances between fixes was >1km.

At each site, four 50m transects were laid out on the benthos in a north, south, east and west direction respectively. A video of the benthos was then taken along each individual transect at a constant speed and height of 50cm above the bottom. Seagrass percentage cover and composition were then later determined from the video. In addition, eight replicate $0.5m^2$ quadrats were sampled at locations selected randomly over the four transects at each site. Seagrass percentage cover was estimated within each quadrat while a shoot density count was undertaken of seagrass species within a $0.1m^2$ sectioned corner of the quadrat followed by the removal of the seagrass within that corner for above ground biomass estimation. Biomass was then measured for dry weight. These seagrass measurement methods are commonly utilised for the acquisition of baseline data for understanding the health of seagrass meadows (Kirkman, 1996).

3.4 IMPROVEMENT OF AVAILABILITY CORRECTION FACTORS AND AERIAL SURVEY

For the determination of population estimates of dugongs, the most appropriate technique is a standardised aerial survey following methods outlined in Marsh and Sinclair (1989). In these surveys, the numbers of dugongs observed from the air are corrected for observer bias, on the basis of a "perception correction factor" (PCF). Furthermore, to account for animals that could not be seen from the aircraft due to limiting water clarity and dugong diving behaviour, an "availability correction factor" (ACF) is applied. Using the correction factors in their current format is likely to produce underestimates of true population abundance (Marsh and Sinclair 1989).

In order to gain a more representative ACF to estimate numbers, a clearer understanding of dugong diving behaviour would provide data to enable the calculation of the average proportion of time dugongs spend in various zones of the water column. The collection of this data is achieved via the use of Time Depth Recorders (TDR) (Wildlife Computers, USA), which are the size of a cigarette lighter and measure the time and depth of individual dives made by the dugong. By attaching the TDR to the harness around the dugong tailstock, these measurements are obtained over a continuous period. It was anticipated that redefining the ACF based on information collected from the TDRs will increase the accuracy of aerial surveys.

The distribution of dugongs determined from an aerial survey conducted during February 2002 (prior to the improvement of the ACF) is also discussed in this report. That survey used the methods outlined in Marsh and Sinclair (1989) and Marsh *et al*. (1994). The survey was undertaken separately to this program and was funded through World Heritage funding (Holley, 2003b).

4. RESULTS

The extent to which this project has achieved its objectives is detailed below.

OBJECTIVES

The collection of baseline data on the movements of Shark Bay dugongs over a wide range of spatial and temporal scales and an assessment of the most important dugong habitats and food species.

The production of maps that quantify the seasonally important dugong habitat types in Shark Bay and listing of the important forage species for dugong and the depths at which they forage.

The generation of improved "availability correction factors" to facilitate more accurate use of aerial survey data to estimate absolute dugong abundance.

The collection of baseline data describing dugong movement patterns as part of the project *Movements and Community based Conservation of Shark Bay Dugongs*, has made an important contribution to the knowledge base on dugong ecology within the SBWHP. During the span of this project, April 2001 through to December 2002, eight dugongs were tagged with remote recording devices (Figure 2, Table 1). These deployments were carried out during the autumn and spring periods of both 2001 and 2002 at various locations (Figure 2).

The reporting of results in this document represents the combined datasets of tags from this study as well as those deployed in two previous programs in 2000, facilitated through Gordon Reid Foundation and World Heritage Funding, respectively (Holley, 2002c). The resulting movement patterns discussed in this document are thus based on the distribution of 19 individually tagged dugongs throughout the SBWHP in 2000, 2001 and 2002 (Figure 3).

4.1 SEASONAL DUGONG DISTRIBUTION IN SHARK BAY

Previous research carried out by Anderson, (1982b, 1986, 1994,1998), Prince *et al*. (1981) and Marsh (1994) suggest that dugongs undertake large-scale migration patterns within Shark Bay in response to changes in water temperature. However, these programs were unable to track

individual dugongs to identify the extent of this pattern. The resulting output from this study demonstrates that by plotting the distribution of locations obtained from remote recording devices, combined with measurements of sea surface temperatures (SST), dugongs within Shark Bay undertake an identified seasonal migration shifting between core summer and winter locations.

This identified pattern shows that animals are aggregating within the lower sections of the eastern gulf within Disappointment Reach (Figure 1) during the summer period (October-April) when SST's there are $>17^0$C. Upon decline of SST's within this region, dugongs then undertake a migration to the western gulf, particularly the areas adjacent to the eastern shoreline of Dirk Hartog Island and within South Passage (Figure 5). Dugongs remained within this region during the winter (May – September), when SSTs are relatively warm due to the influence of the Leeuwin current (CALM, 1996). As water temperatures increased, dugongs then migrated back into those areas associated with their distribution during summer. This suggests that dugongs prefer the lower reaches of the eastern gulf as suggested by Anderson (1986).

Anderson (1986) suggested that in summer dugongs also aggregate in the lower western gulf of Shark Bay within Henri Freycinet Harbour (Figure 1). No dugongs were tagged during this study at this location due to problems associated with tag attachment mechanisms and software used in the programming of tags. However, results from the aerial survey conducted during February 2002 (Holley *et al*. in prep) indicated that 25% of the overall Shark Bay dugong population estimate occurred within Henri Freycinet Harbour. This indicates that during summer the dugong population is split between the lower reaches of both the eastern and western gulfs.

Aerial surveys conducted by other researchers during the winters of 1989, 1994 and 1999 (Marsh *et al*. 1994, Preen *et al*. 1997 and Gales *et al*. in press) indicated that during the winter periods the lower reaches of both gulfs, relative to the entire bay, contained very few dugongs. In these surveys the majority of sightings occurred in the upper reach of the western gulf, particularly along the eastern shoreline of Dirk Hartog Island (Marsh *et al*. 1994, Preen *et al*. 1997 and Gales *et al*. in press). Analysis carried out on the distribution of animals and SSTs during two of the surveys, (the winter of 1999 and the summer of 2002) also confirmed that the distribution of dugongs was synchronised with the distribution of warmer waters. (Holley *et al*. in prep).

In addition to the main summer and winter aggregating areas, tag results revealed distinct zones through which dugongs tended to move between the core seasonal areas. These locations are defined as 'intermediary' sites and include the Guischenault Pt region (Figure 1), with a total of 38% of combined fixes recorded during spring (July –October in 2000, 2001 and 2002) occurring within this area.

4.2 SEASONAL HABITAT USAGE

Results from the habitat surveys indicated that the preferred habitat for tagged dugongs during winter are those seagrass beds where there was 30-80% coverage of the species *Amphibolous antarctica* with an estimated above ground biomass of 110-360g m^{-2} in waters <5m (Table 2). Observations made at these locations also showed that they were immediately adjacent to channels and other areas of deeper water. Sites that were surveyed as low use or 'travelling' sites were either deeper (>10m) and with no seagrass present, or shallow (<5m) with a sparse coverage (<10%) of the seagrass species *Posidonia australis* (not recorded as part of dugong diet) mixed throughout sand and/or rubble.

Due to time and resource constraints, summer habitat surveys were not within the scope of this study. Hence, it is not possible to make comparisons between summer and winter dugong habitat preferences. However, research conducted prior to this study by Anderson (1982b, 1986) and Masini *et al.* (2001), describe a number of locations within the lower eastern gulf that coincide with the relatively dense summer aggregations based on a number of tagged dugongs. They describe the seagrass habitat at these locations being comprised of the species *Halodule uninervis* and *Halophila ovalis*, with mean above and below ground biomass of 69.8gm^{-2}. Both of these species of seagrass have previously been identified as among the preferred forage species for dugongs throughout their global range (Marsh *et al.* 1999).

4.3 DISTANCES TRAVELLED AND INDIVIDUAL MOVEMENTS OF SHARK BAY DUGONGS

From the calculation of distances between recorded fixes and the analysis of movements made by individual dugongs from all deployments, it was determined that dugongs are capable of undertaking extensive movements throughout the bay. These movements describe travel in addition to the migrational paths traversed between core seasonal locations (Figure 6).

Preliminary investigation suggests that these movements were exploratory, with animals travelling long distances and but spending short periods in any one location, before returning to the previous aggregation site. An example of this movement pattern is exemplified through locations obtained from a dugong tagged with the unit 0702 (Figure 2). This animal, a female (Table 1), undertook a journey of 316km in 11 days from her winter range into the previously identified summer range before returning. Possible reasons for this, and similar movements by other animals, may be linked to these animals searching for warmer waters in those regions containing the preferred seagrass species such as *H. uninervis* and *H. ovalis.* A summary of distances and average speeds of dugongs tagged in 2000 and 2001 is shown in table 3.

In addition to exploratory movements, analysis of distances travelled between recorded fixes by each animal over the entire deployment program indicated that immediately post capture dugongs travelled a considerable distance away from the capture site. Most of the tagged animals were recorded as travelling distances up to 80km away from the catch location in the two days succeeding tagging. The dugongs remained away from these locations for a number of days before returning. Although as previously identified dugongs are capable of extended movements, the consistency of these post capture movements indicates that the animals suffered acute levels of disturbance during the chase, catch and handling procedures. Dugongs are not capable of sustained high-speed swimming and rapidly become exhausted during pursuit. Monitoring of the animals during the handling procedure revealed that the animals were suffering from acute stress due to increased respiratory rates and vocalisation (chirps and squeaks). The susceptibility to stress-induced mortality to dugongs from this form of activity is unknown.

4.4 DISTRIBUTION OF DUGONGS OUTSIDE THE SHARK BAY MARINE PARK

Location data from tagged animals indicated that dugongs are utilising waters outside of the existing Shark Bay Marine Park boundary. The distribution of dugongs outside of this boundary has previously been identified by Preen (1997) where approximately 50% of sightings of dugongs during two winter aerial surveys were found to occur outside of the reserve structure. Although the majority of locations and defined critical habitats from this study fell within the existing reserves (Figure 5), a number of recorded locations (3% of total recorded fixes from all deployments) occurred outside (Figure 3). In addition, the travel paths of a number of tagged dugongs (5% of total movements from all deployments) crossed this boundary, with the majority

of these movements occurring when dugongs were travelling to and from identified seasonally important locations (Figure 6).

4.5 PRODUCTION OF MAPS SHOWING SEASONALLY IMPORTANT DUGONG HOME RANGES, FORAGE SPECIES AND DEPTH.

For the production of maps to determine seasonally important locations, the use of the "fixed kernel home range technique"(Silverman, 1986) was employed on the combined location information from the remote recording devices. The kernel technique is a statistical method for estimating probability densities. The density at any location is an estimate of the amount of time spent there by an animal and this information forms the basis for investigations into habitat use and preference (Seaman and Powell, 1996). The most important resulting output from this analysis is the 95% probability contour, with the area within the contour seen as the most important for dugong usage (Figure 5).

4.6 IMPROVEMENT OF AVAILABILITY CORRECTION FACTORS

Researchers from the School of Tropical Environment Studies and Geography (TESAG) at James Cook University, Queensland, undertook this component of the study due to the historical role of this university in the conduct of aerial surveys for determination of dugong abundance. Dive profiles from TDRs attached to the satellite and GPS tags deployed on dugongs as part of this program were combined with dive profiles from other tagged animals in Queensland (Chilvers *et al*. 2003). Average dive times and depths were used in the creation of the new ACF. The new ACF, along with the original approach of Marsh and Sinclair (1989), was then used to recalculate total dugong abundance estimates obtained from two previous aerial surveys in the Torres Strait and Northern Great Barrier Reef (NGBR) regions. The results from these recalculations showed only a slight difference in the new abundance estimates, (NGBR 9,966 for the new estimate vs. 9,193 and Torres Strait 14,029 for the new estimate vs. 14,106) (Pollock *et al*. in press). The minimal differences between these results indicate that the estimates obtained from previous aerial surveys conducted with the old ACF are valid, and should still be regarded as important for monitoring of dugong populations.

5. DISCUSSION AND RECOMMENDATIONS

OBJECTIVES

Recommendations for conservation and management of dugongs and dugong habitat in Shark Bay, given the project findings.

The results from this project combined with data obtained from previous deployments during 2000 (Holley, 2002c) have increased our understanding of the movement patterns and habitat usage of the dugong population within Shark Bay. A number of key findings have been generated which will provide a basis for future management decisions aimed at maintaining a high level of conservation for the dugong and its habitat within the SBWHP. The key findings from this project and recommendations for management are discussed below.

5.1 SEASONAL MOVEMENTS

The defined seasonal migration pattern identified in this study illustrates the importance of the entire SBWHP for the continued conservation of this large and relatively stable population of dugongs. The establishment of education programs highlighting this seasonal movement pattern and the dugong's utilisation of distinct areas throughout the year would effectively facilitate the conservation of this population. By providing general education programs based on the identified dugong distribution pattern, the local community and general publics appreciation and awareness of dugong ecology within the bay would be increased. These programs should also serve the purpose of providing recreational boaters and other users of the marine park with knowledge on dugong movements and locations throughout the year. This knowledge is important as it highlights those areas where caution should be exercised in respect of disturbance to flora and fauna, such as dugongs and their important seagrass habitats.

RECOMMENDATION

The major seasonal dugong migration pattern within Shark Bay should be used as a platform for education and interpretation programs focusing on dugongs and dugong habitat within the SBWHP.

5.2 DEFINED CRITICAL HABITAT AREAS

While the core areas of activity (Figure 5) were defined on the basis of tracking data from a small proportion of the Shark Bay dugong population, there was significant overlap of usage of areas amongst even this small sample of animals (Holley *et al*. in prep). Anecdotal information from a number of sources also confirms that these core areas of activity regularly contain large numbers of dugongs. By defining these areas as important dugong conservation zones, greater protection can be afforded to dugongs by ensuring that activities, which are likely to impact directly on animals or indirectly through habitat disturbance, are minimised.

RECOMMENDATION

Use the identified core areas of activity as the basis of defining special dugong conservation zones within the SBWHP.

5.3 WINTER HABITAT RESOURCES

The habitat surveys demonstrate that during the winter distribution pattern the only forage available for dugongs is the seagrass species *Amphibolis antarctica* (Table 2). It has been suggested that dugongs may also forage upon another species of seagrass, *Halophila spinulosa,* during the winter in Shark Bay (Anderson, 1994). However, no presence of *Halophila spinulosa* was recorded during investigations carried out in this study, highlighting the significance of *A.antarctica* for dugong forage requirements in Shark Bay.

The habitat surveys also determined that dugongs not only foraged solely on *A.antarctica*, but that there were a number of similar habitat characteristics defining the high use sites. The fact that the dugongs tracked in this study seemed to prefer to forage on *A.antarctica* which had a mean cover between 30% and 70% and which were in waters less than four metres deep (Table 2) indicates that dugongs aggregate and selectively forage in these areas, as opposed to foraging randomly. To facilitate effective conservation of this population, dugongs they must continue to have access to forage areas identified within this study as well as similar habitats throughout the bay. Hence, the recognition and protection of *A.antarctica* beds throughout the entire bay, particularly those that share similar characteristics to high use sites as outlined here, is essential.

RECOMMENDATION

Assign protective measures as appropriate for *Amphibolous antarctica* meadows within the dugongs winter range, in particular those areas which share similar characteristics to high use sites as determined from this study.

5.4 DUGONG DISTRIBUTION OUTSIDE OF THE SHARK BAY MARINE RESERVE

The movement data from this study indicates that significant numbers of dugongs move through areas outside of the marine reserve boundaries. The Shark Bay Marine Park is an effective conservation mechanism for dugongs and habitat within its boundaries. Although dugongs are subject to the same level of protection both on and off-reserve under the Wildlife Conservation Act 1950, certain activities can occur outside of the existing marine park structure which may indirectly impact on dugongs.

The major threats to dugongs in Shark Bay outside of the marine reserves are likely to derive from activities such as trawling, through the disturbance of seagrass habitat, and seismic exploration with the generation of excessive noise levels to which dugongs may react adversely. In addition, shipping movements and dredging activities are also likely to impact indirectly upon dugongs outside of the reserve through the generation of noise and habitat modification. The main application of the results of this study in terms of revealing the wide ranging movement patterns of dugongs in the bay, is to illustrate that appropriate conservation of this population requires protection measures that reflect the dugongs entire spatial distribution, and not just that which occurs within the marine reserve boundaries.

RECOMMENDATION

Further considerations need to be given to the extension of the existing Shark Bay Marine Park boundary to adequately encompass all dugong distribution and migration movements.

5.5 FUTURE INTENSIVE DUGONG RESEARCH PROGRAMS

The capture and deployment procedure employed in tagging dugongs for this program, as well as previous programs within Shark Bay, followed strict protocols (Lawler *et al.* 2000; Gales and Holley, in prep.) to ensure the potential of injury or death to the dugong was minimised. The chase and catch procedure employed during this program is believed to represent the safest option for dugong capture (Lawler *et al.* 2000). Nevertheless, it can be reasoned that the disturbance created by this activity is probably acute based on the immediate movement of a number of animals to locations up to 80km away. Although no dugong mortality events are known to have occurred from the tagging procedures during this or previous programs in Shark Bay, very little is known about the susceptibility of dugongs to mortality after capture.

Aside from the direct impact upon dugongs that were tagged, there were likely to be other animals in the vicinity that may have been disturbed by this activity. The combined disturbances created from the catch process on non-target as well as target animals, particularly at identified catch locations over an extended period, may increase this populations susceptibility to mortality. Considered opinion amongst researchers involved in this project, as well as similar projects elsewhere within the dugongs range, is that the number of dugongs captured within discrete populations should be minimised to reflect the size of the population.

RECOMMENDATION

Restrict the conduct of future research programs involving the chase and capture and handling of dugongs within Shark Bay.

6. COLLABORATION

OBJECTIVE

The collaboration with, and participation of the project's consortium members (including the indigenous community) and Australian scientists.

The conduct of this project has relied heavily upon the collaboration and participation of the project's other consortium members, the Shark Bay Yadgalah Aboriginal Corporation Inc., Edith Cowan University and James Cook University. The level of involvement of each of these members is outlined below.

6.1 SHARK BAY YADGALAH ABORIGINAL CORPORATION INC.

Members of the Yadgalah Aboriginal Corporation (YAC) have been involved throughout the program, from initial discussions on project objectives and project direction through to the project's conclusion. The YAC has identified this project as important at both a community level and in a broader Indigenous context. The YAC see the project as a vehicle for increasing the involvement of Indigenous communities in similar research programs that have broad conservation and management objectives, particularly involving species such as dugongs that have both high biodiversity and cultural values.

During this project up to three YAC members were involved in each deployment of remote recording devices. Members were the prime observers for locating target animals, and also the main catchers and assistant boat operators when undertaking deployments. Members have also been actively involved in planning deployment programs by identifying areas where dugongs were likely to be located at various times of the year. YAC have also contributed in the production of popular articles, such as a feature article in Landscope Magazine (Holley and Capewell, 2002) and an article in Australian Geographic (Mitchell, 2003) and provided assistance with film crews accompanying the deployment teams.

Upon completion of each deployment program a social BBQ was held where many members of the YAC along with local DCLM staff attended. These events served as important social gatherings, particularly for the YAC elders and those members not actively involved in the

program. During a deployment of tags on dugongs in March 2002 the majority of the Yadgalah members, including elders, accompanied local DCLM staff aboard a chartered vessel to witness dugongs being captured and tags attached by the deployment team. This activity provided those YAc elders and members not involved in the deployment program with an insight into the field techniques employed in the capture and tagging of dugongs.

Upon completion of the project a further boat cruise was undertaken during December 2002 as a thank you gesture to the YAC members. A final BBQ was held following this boat cruise where the community was thanked and presented with maps showing the distribution of all tagged dugongs since the onset of the initial program in 1999. In addition, representatives from the Indigenous communities 'Ngarluma Yindjibarndi' and 'Kurama Mardudhunera' in the Pilbara region of WA were invited to attend the boat cruise and BBQ as guests of Yadgalah and DCLM. This represented an opportunity for the YAC and DCLM to provide an overview and highlight the success of the jointly run program to other Indigenous groups.

6.2 EDITH COWAN UNIVERSITY

The role of the Centre for Ecosystem Management at Edith Cowan University in this project has been to provide scientific assistance and expertise in habitat assessments at those locations deemed to be of importance as forage areas to dugongs. Seagrass survey techniques developed at the Centre were utilised to characterise seagrass habitat structure. The Centre will continue to maintain a role in research into dugong habitat requirements in Shark Bay through a PhD student undertaking a study to identify the nutritional content of various seagrass species for dugongs over two seasons at the core seasonal locations identified from the tags deployed during this study. This PhD project will continue to involve members from Yadgalah.

6.3 JAMES COOK UNIVERSITY

Researchers from the School of Tropical Environment Studies and Geography at James Cook University have been involved in the project through the provision of tags for deployment on dugongs as well as through providing operational assistance in the development of tag attachment and retrieval mechanisms. The school has also been responsible for the analysis of dive data obtained from Time Depth Recorders (TDRs) attached to the tag harnesses. The information from

this project and from similar programs in Queensland has been combined, and a related article describing dugong dive behaviour has recently been submitted to the Canadian Journal of Zoology (Chilvers *et al*. in press). As mentioned previously, (Section 4.6) the School has also been responsible for the generation of improved "availability correction factors", with this work submitted to the Journal of Wildlife Management (Pollock *et al*. in press).

7. MANAGEMENT STRATEGIES.

OBJECTIVE

Progress toward incorporating baseline information into existing and future management plans and strategies relevant to dugong conservation in this and other areas.

7.1 SHARK BAY

The existing Shark Bay Marine Reserves Management Plan (CALM, 1996) is due for the required 10-year review in 2006. The review process will determine to what level management objectives as set out in the plan have been achieved, with any new information that may affect management activities assessed. In line with this process, results from this project, *Community Based Conservation of Shark Bay Dugongs*, will be assessed and incorporated into the review. In addition, information gained from this study has been and will continue to be used in the assessment of proposed development activities such as aquaculture applications.

The strategies, in order of priority, as listed in the current plan (CALM, 1996) are to:

1. Control activities which may adversely impact on dugongs;
2. Encourage further research on dugong distribution, abundance, biology and behaviour in the reserves;
3. Implement a long term monitoring program for dugongs;
4. Investigate and report on any observed cases of dugong breeding or calving in the reserves; and
5. Encourage the wise management of important dugong habitats outside the reserves.

The outcomes from this study and the previous deployments have made significant progress to achieving a number of the strategies as outlined above. By determining distribution patterns, core areas of activity and habitat composition at areas significant to dugongs, a comprehensive knowledge base now exists with which to make more informed decisions regarding strategies 1 and 5. The undertaking of this program has been driven by strategy 2 and the findings generated have and will continue to generate further applied research that will provide ongoing effective conservation of the Shark Bay dugong population.

7.2 OTHER AREAS OF SIGNIFICANCE TO DUGONGS

The *Status Report for Countries and Territories* (Marsh *et al*. 2002) identifies the Kimberley region of Western Australia as an area in which little is known about dugong distribution and abundance and the impact of anthropogenic activities, such as traditional hunting upon these populations. The report states that detailed studies, carried out in conjunction with local Indigenous communities, on the extent and range of dugong movements should be undertaken as a high priority within this region. The results achieved and relationships established as part of the current project would form an ideal foundation with which to develop a similar project within the Kimberley.

8. SUMMARY OF RECOMMENDATIONS

The project *Community Based Conservation of Shark Bay Dugongs* has made a significant contribution to the understanding of fundamental requirements for the effective conservation of this internationally significant dugong population. Listed below is a summary of the recommendations, as outlined within section 5.

i. **The major seasonal dugong migration pattern within Shark Bay should be used as a platform for education and interpretation programs focusing on dugongs and dugong habitat within the SBWHP.**

i. **Use the identified core areas of activity as the basis of defining special dugong conservation zones within the SBWHP.**

ii. **Assign protective measures as appropriate for *Amphibolous antarctica* meadows within the dugongs winter range, in particular those areas which share similar characteristics to high use sites as illustrated within this study.**

iii. **Further considerations to be given to the extension of the existing Shark Bay Marine Park boundary to adequately encompass all dugong distribution and migration movements.**

iv. **Restrict the conduct of future research programs involving the chase and capture and handling of dugongs within Shark Bay.**

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TABLES

Table 1. Biological and location data of dugongs caught during 2001 & 2002.

DUGONG TAG Id.	1311	7301	7001	0303	0803	0702	0606	0602
SEX	M	F	M	M	M	F	M	M
LENGTH (M)	-	2.5	2.8	2.1	2.4	2.6	2.8	2.7
GIRTH (M)	-	1.6	1.6	1.9	1.6	1.8	1.9	-
DEPLOYMENT DATE	16/5/01	18/9/01	20/9/01	19/3/02	21/3/02	17/6/02	18/6/02	20/6/02
RETREIVAL DATE	1/7/01	28/9/01	28/9/01	27/3/02	11/5/02	25/7/02	9/8/02	2/7/02
DEPLOYMENT PERIOD	40	8	9	9	52	39	52	13
TAG TYPE	PTT	GPS	GPS	GPS	GPS	GPS	GPS	GPS
NUMBER OF LOCATIONS	56	89	77	134	627	1735	1481	130

Table 2. Important forage species and habitat characteristics at survey locations.

LOCATION	SITE NAME	HABITAT TYPE	SEAGRASS SPECIES	MEAN COVER (%)	MEAN BIOMAS (gms/0.1m^2)	MEAN SHOOT DENSITY (0.1m^2)	DEPTH (m)
South Passage	SP1	Travelling	Sand/Rubble	-	-	-	6
South Passage	SP2	Foraging	*A.antarctica*	40.82	18.55	30	4
Bellefin Flats	BF1	Foraging	*A.antarctica*	69.04	21.20	32	1.5
Bellefin Flats	BF2	Foraging	*A.antarctica*	36.67	36.03	31	2.4
Bellefin Flats	BF3	Travelling	Sand	-	-	-	12
Dirk Hartog	DH1	Foraging	*A.antarctica*	70.48	11.34	51	2.5
Dirk Hartog	DH2	Travelling	*P.australis*	11.98	1.31	20	3
Dirk Hartog	DH3	Travelling	Sand	-	-	-	12
Dirk Hartog	DH4	Foraging	*A.antarctica*	68.09	11.63	79	3.5
Dirk Hartog	DH5	Foraging	*A.antarctica*	53.71	17.30	130	1.5
Guischenault Pt.	GP1	Foraging	*A.antarctica*	40.12	26.86	59	2
Guischenault Pt.	GP2	Foraging	*A.antarctica*	36.15	14.44	59	3
Guischenault Pt.	GP3	Travelling	*A.antarctica* *P.australis*	86.4	27.83	76	1.5
Guischenault Pt.	GP4	Travelling	*A.antarctica*	15.94	10.74	20	1.5

Table 3. Summary table of speeds and distances travelled by dugongs tagged during 2001& 2002.

DUGONG	SUM (km)	COUNT (Locations)	MEAN (km)	RANGE (m)	S.E. (m)	DURATION (Days)	AVERAGE SPEED (Km/h)
1311	218.340	56	3.899	0.0 - 31002	837.4	40	0.227
7301	116.351	90	1.293	0.0 -54893	849.2	8	0.537
7001	68.124	71	0.959	1.3 - 52846	747.4	9	0.315
0303	155.319	134	1.159	0.0 - 12187	176.7	9	0.718
0803	143.931	627	0.230	0.0 - 7794	30.14	52	0.115
0702	676.461	1735	0.390	0.2 - 47895	57.2	39	0.723
0606	739.432	1481	0.499	0.0 - 52755	79.2	52	0.592
0602	187.772	130	1.444	5.35 - 39178	379.4	12	0.649

FIGURES

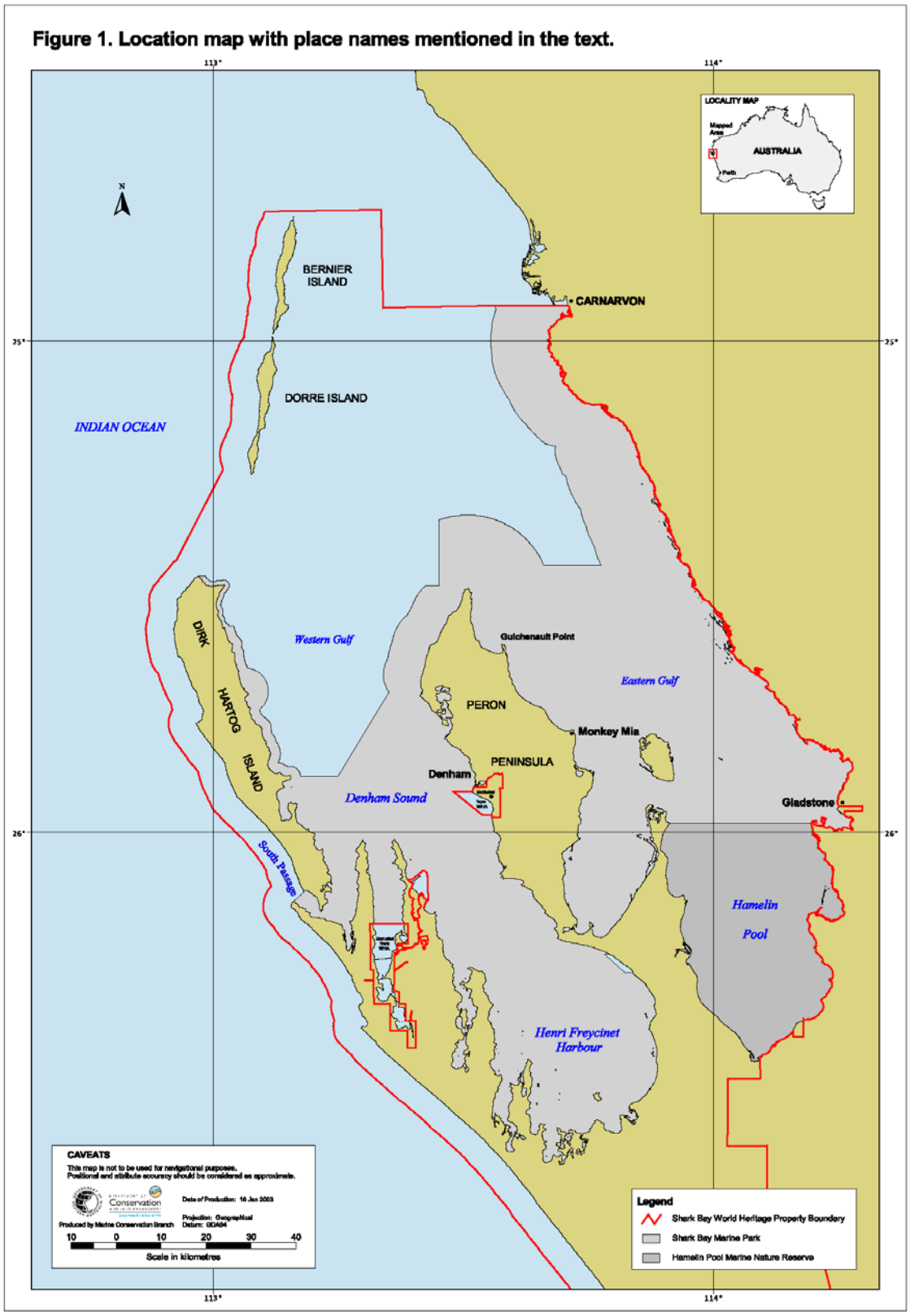

Figure 1. Location map with place names mentioned in the text.

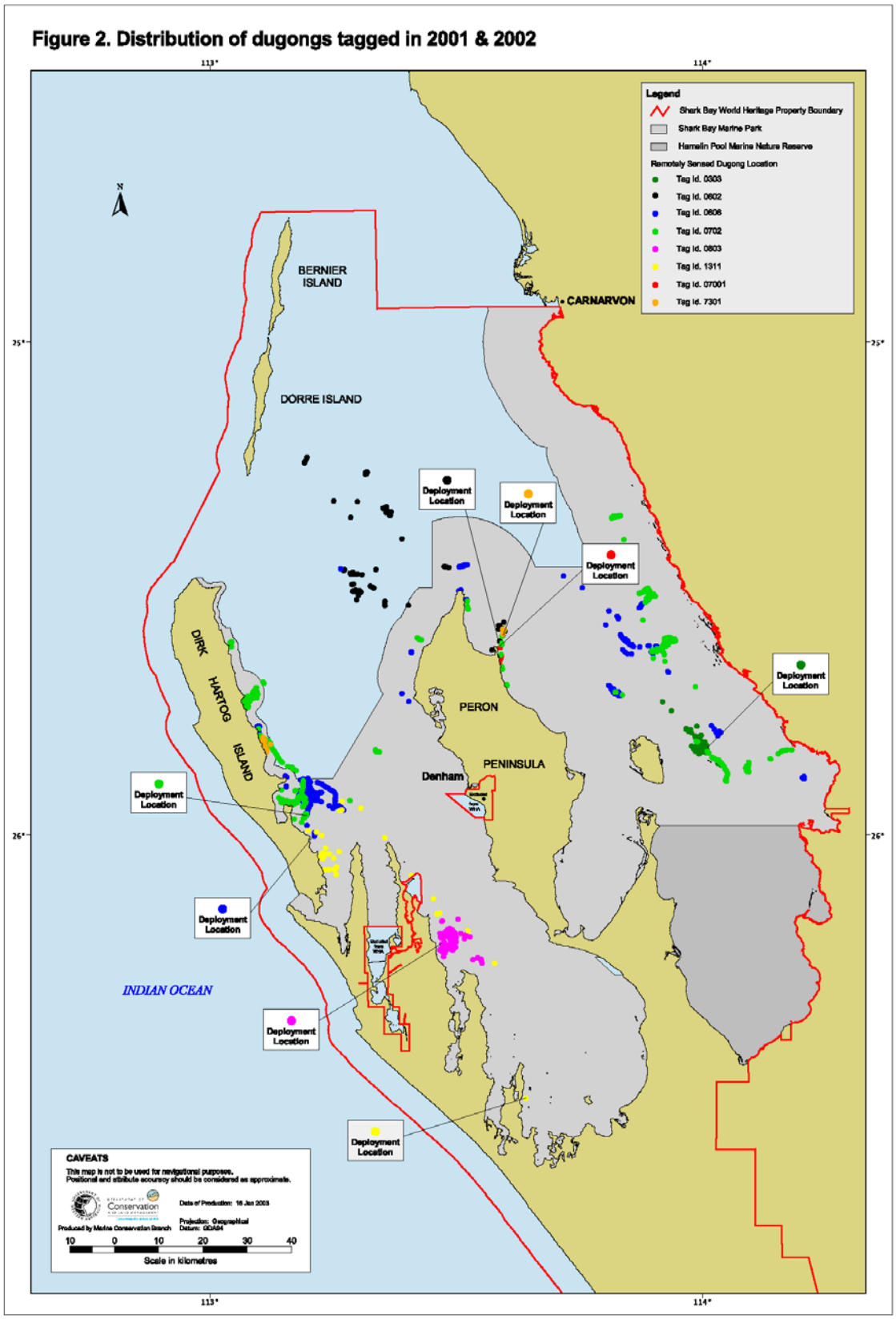

Figure 2. Distribution of dugongs tagged in 2001 and 2002.

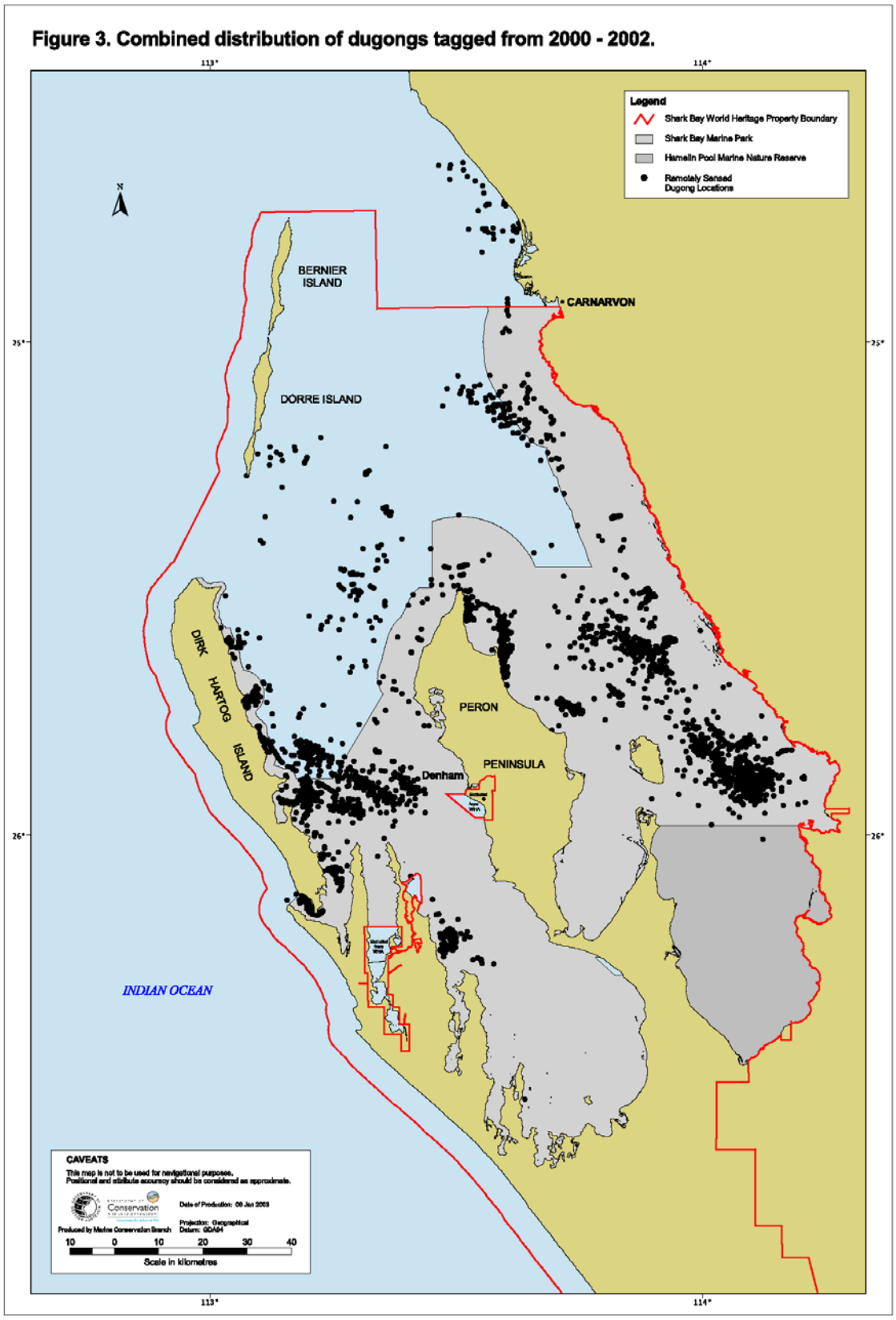

Figure 3. Combined distribution of dugongs tagged from 2000 – 2002.

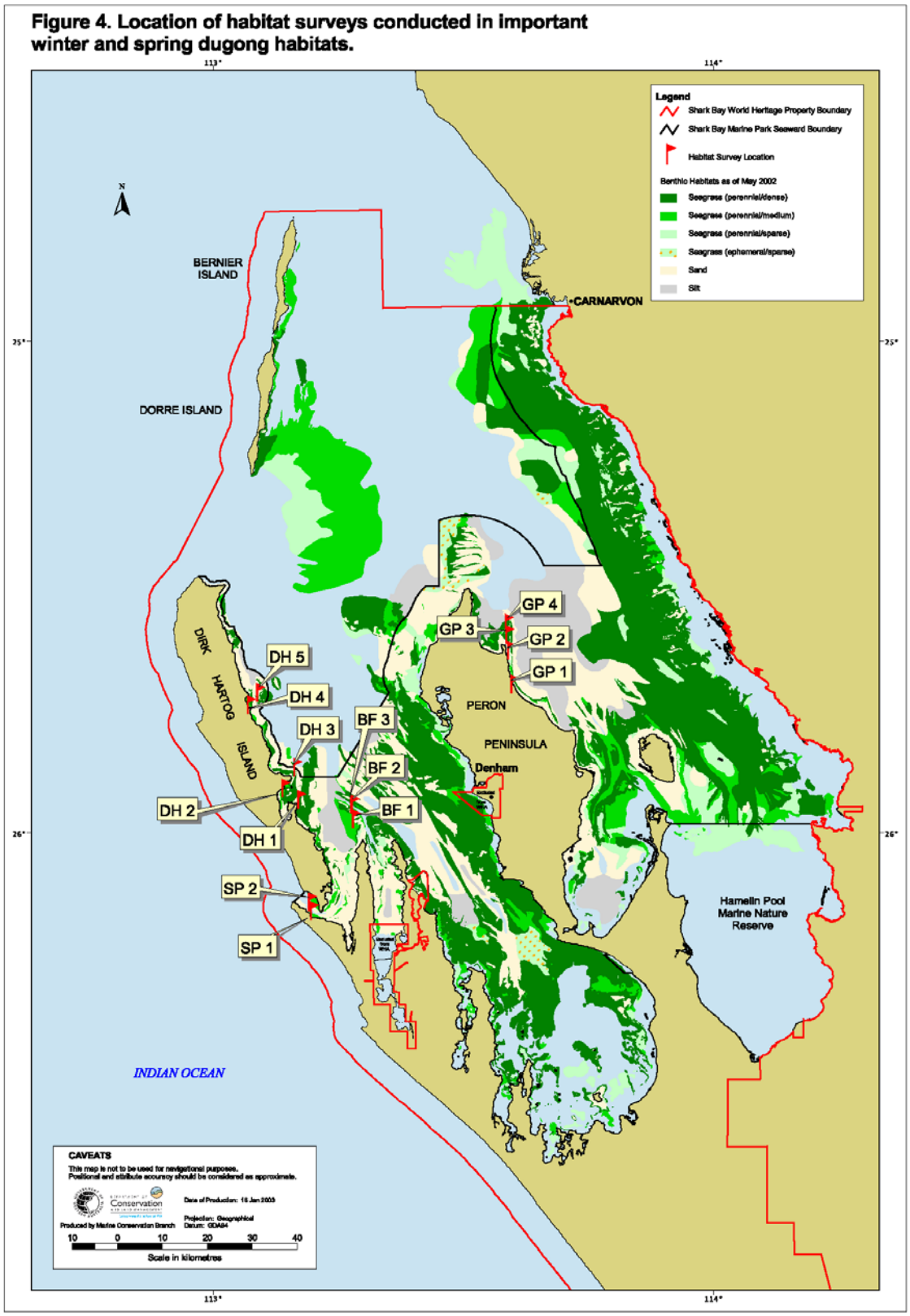

Figure 4. Location of habitat surveys conducted in important winter and spring dugong habitats.

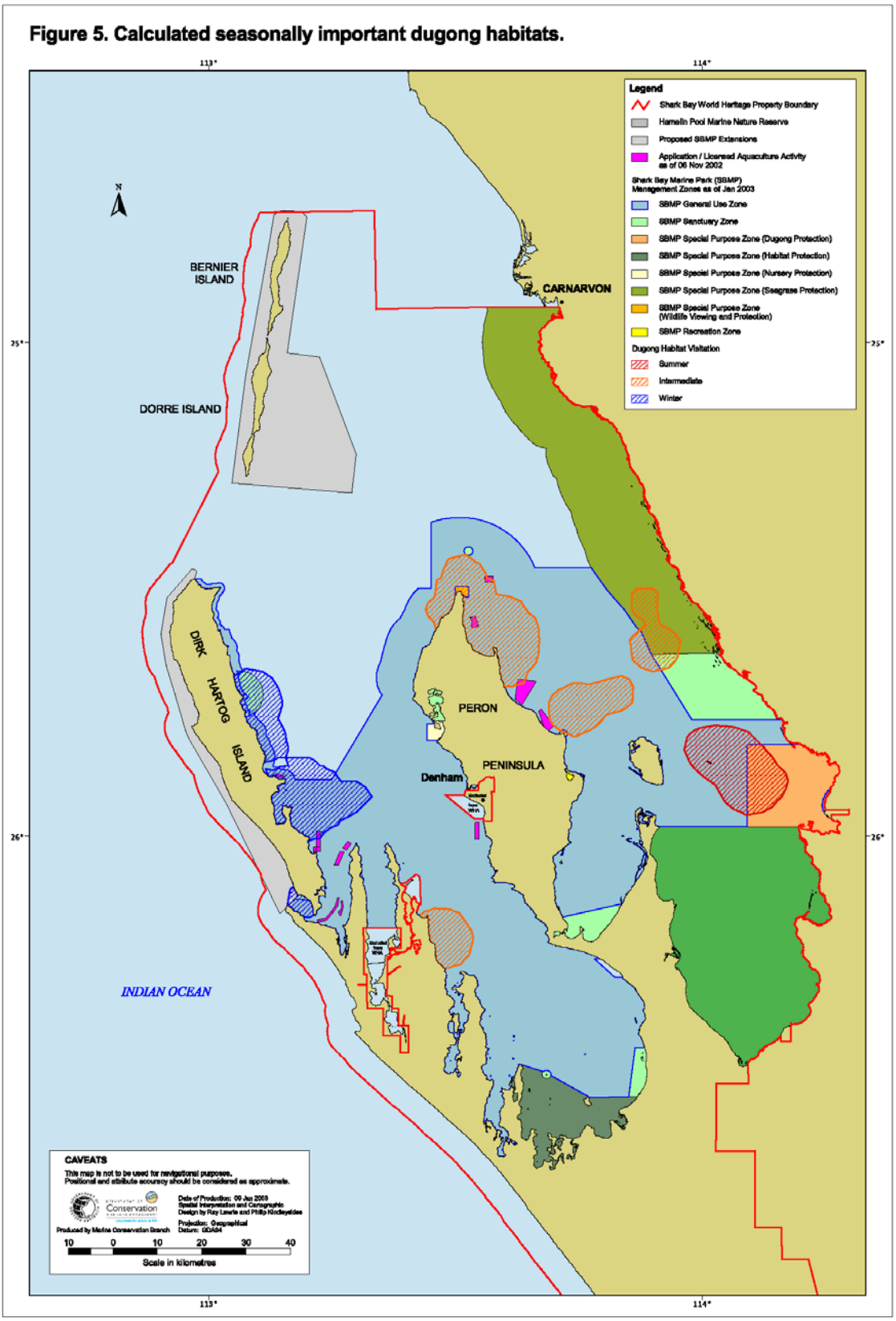

Figure 5. Calculated seasonally important dugong habitats.

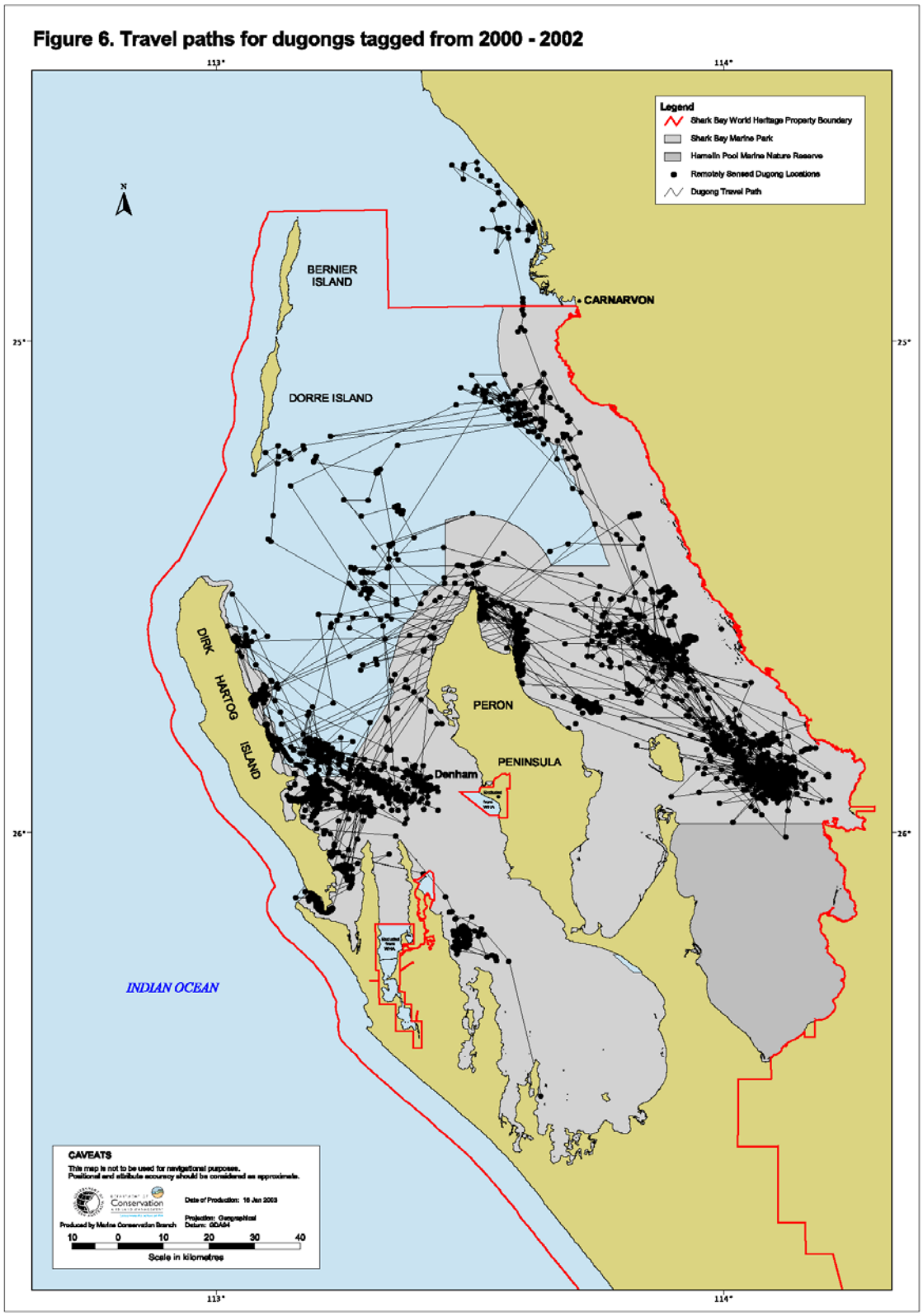

Figure 6. Travel paths for dugongs tagged from 2000 – 2002.

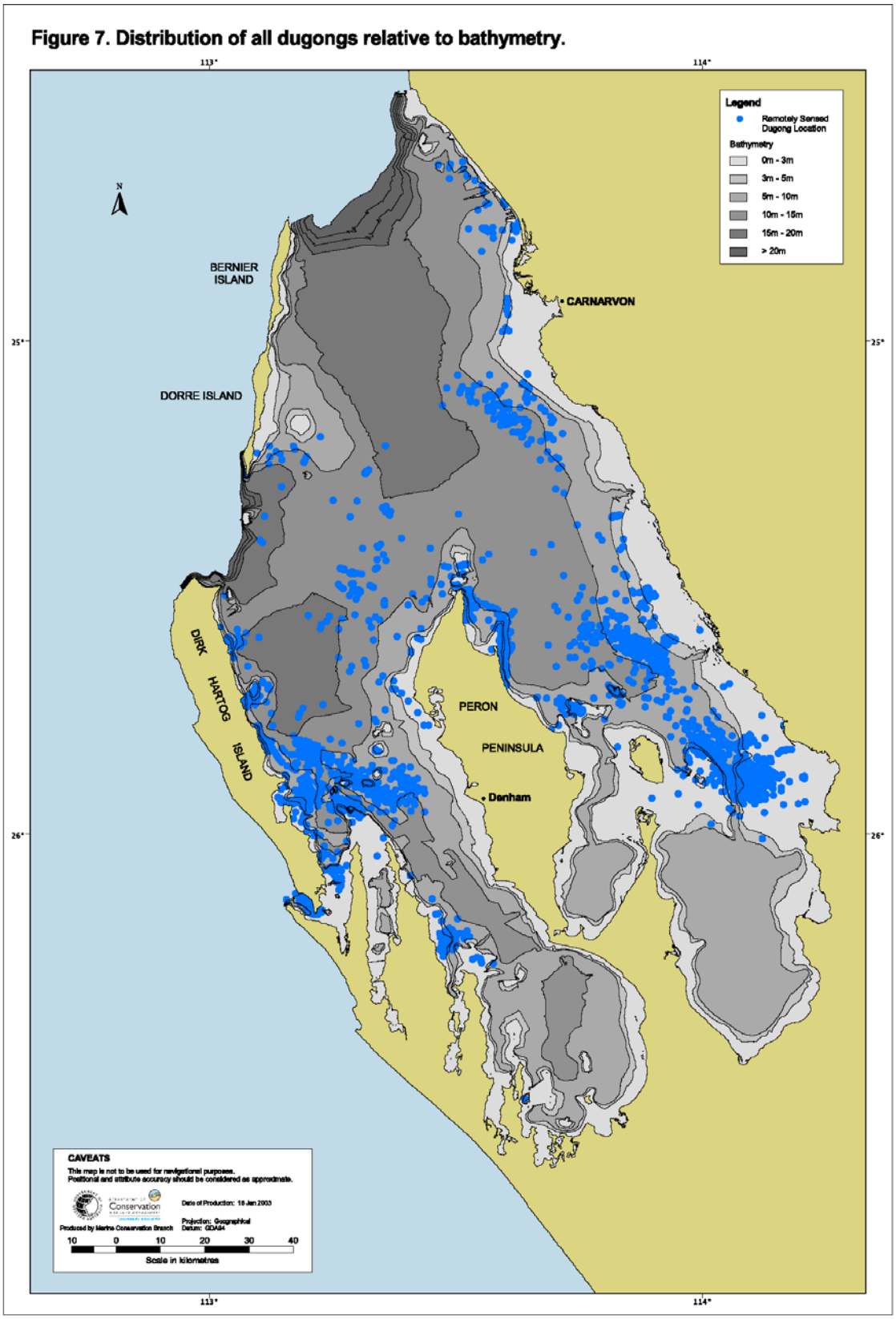

Figure 7. Distribution of all dugongs relative to bathymetry.