

## EVALUATING MANAGEMENT INITIATIVES AIMED AT REDUCING THE MORTALITY OF DUGONGS IN GILL AND MESH NETS IN THE GREAT BARRIER REEF WORLD HERITAGE AREA

A temporal series of aerial surveys (Marsh *et al.* 1996) indicated that the numbers of dugongs, *Dugong dugon*, have declined significantly along parts of the eastern coast of Queensland, Australia, since the mid 1980s. This decline has occurred over more than one thousand kilometers of coastline in the Great Barrier Reef World Heritage Area, from Innisfail to the southern border of the Area near Bundaberg (Fig. 1). Anecdotal evidence suggests that this decline has been going on for decades (Marsh *et al.* 1996). The reasons for this decrease are complex and include habitat degradation, accidental mortality in both commercial and illegal gill and mesh nets and in shark nets set for bather protection, and traditional hunting (Marsh *et al.* 1996). The relative importance of these impacts has not been quantified. However, 15 of the 30 dugong carcasses necropsied between January and September 1996 showed evidence of having been caught in a net (Marsh *et al.* 1997) suggesting that interaction with nets is a significant cause of dugong mortality.

This decline threatens the World Heritage values of the Great Barrier Reef region. An explicit justification for the region's inclusion on the World Heritage List was the fact that it "provides major feeding grounds for large populations of the endangered species, *Dugong dugon*," (GBRMPA 1981 pp. 5, 6, 14). The Australian and Queensland governments agreed to several measures aimed at arresting this decline in 1997, including a resolution not to issue permits for the indigenous hunting of dugongs in the region, south of Cooktown (Fig. 1). The most controversial measure was the establishing of a two-tiered system of Dugong Protection Areas (see Fig. 1). Foreshore and offshore set or drift nets were prohibited in seven Zone A Dugong Protection Areas in the Great Barrier Reef Region totaling 2,407 km<sup>2</sup>. River set nets were also prohibited in two of these areas (*Fisheries Regulation (No. 11) 1997 (Queensland)*). Less-restrictive modifications were introduced in eight Zone B Dugong Protection Areas totaling 2,243 km<sup>2</sup> (*Fisheries Regulation (No. 11) 1997 (Queensland)*). These modifications included net attendance requirements and

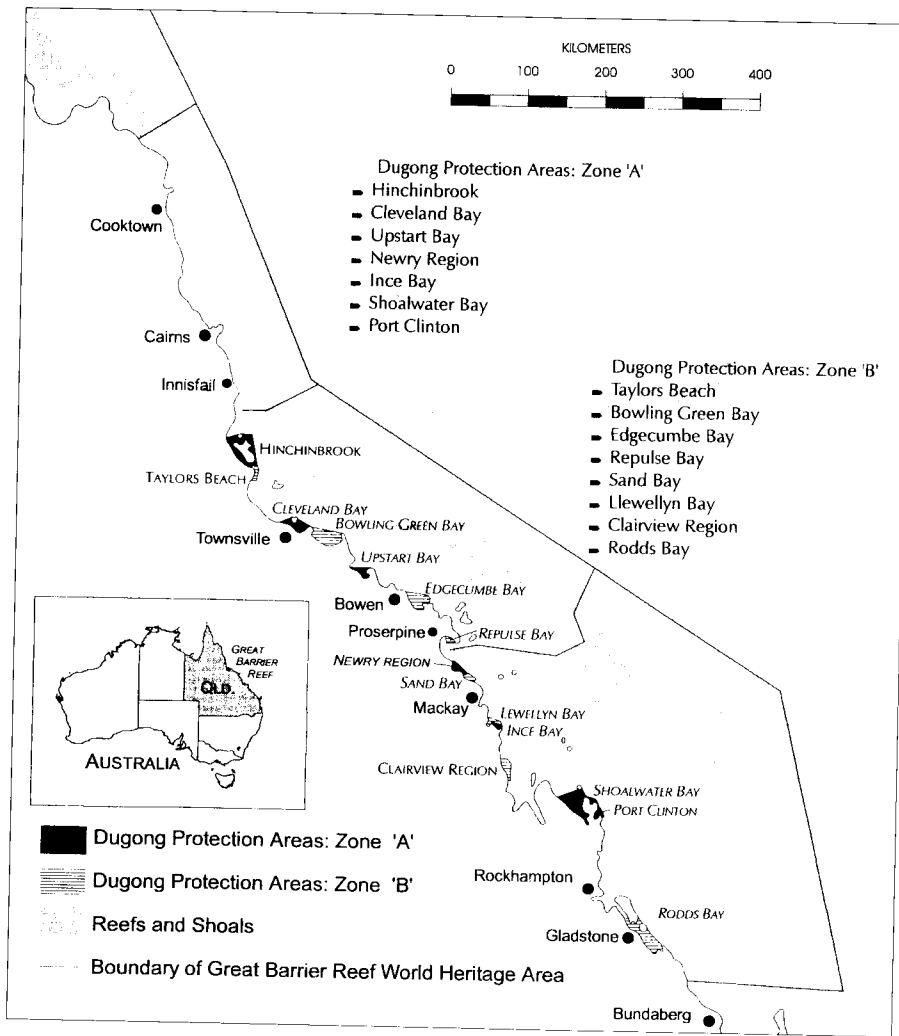


Figure 1. Map of Great Barrier Reef World Heritage Area from Innisfail to Bundaberg near southern border of Area, illustrating Dugong Protection Areas Zone A and B and place names mentioned in text. Hervey Bay-Tin Can Bay Dugong Protection Area is immediately south of region.

changes to the specifications of set and drift nets. An additional Dugong Protection Area of 1,703 km<sup>2</sup> was established in the Hervey Bay-Tin Can Bay area, immediately south of the Great Barrier Reef region. Gear modifications, net attendance rules, and local temporal and spatial closures were introduced to reduce the chances of dugongs encountering a net in the region (*Fisheries Regulation (No. 11) 1997 (Queensland)*).

The initiatives to restrict or prohibit gill and mesh netting from the Dugong Protection Areas were not supported by protagonists on either side of the controversy. The fishers considered that the social and economic impacts

of the closures were too high. Thirty-eight commercial fishing licences were cancelled as a result of a competitive licence buy-out scheme (Tisdell and Harrison 1999). Although the displaced fishers were given *ex gratia* payments, many were middle-aged, with limited education and from rural areas where unemployment is high. Media reports indicated that national (*e.g.*, Humane Society Australia), regional (*e.g.*, Queensland Conservation Council), and local (*e.g.*, North Queensland Conservation Council) conservation groups were also dissatisfied. These groups claimed that the closures were too small to be effective, specifically that they should have been large enough to contain the home ranges of individual dugongs. Satellite tracking information (Marsh and Rathbun 1990, A. R. Preen, unpublished data<sup>1</sup>) suggests that this requirement would necessitate closing most of the coastal waters in the region to gill/mesh netting. The conservationists were also concerned that there was no empirical evidence that the modifications to gill/mesh netting in the Zone B Dugong Protection Areas would reduce dugong mortality.

This paper evaluates the potential effectiveness of the Dugong Protection Areas. I conclude that, if the changes to the netting regulations are appropriate and effectively enforced, the introduction of the Zone A Dugong Protection Areas should decrease dugong mortality from commercial gill and mesh nets in the Great Barrier Reef region south of Innisfail by between about 42% and 55%. This estimate assumes that habitat quality is maintained in these areas. It is not possible to estimate the effectiveness of the Zone B Dugong Protection Areas.

Suppose the coastal waters between Innisfail and the southern border of the Great Barrier Reef World Heritage Area to approximately 20 km (Marsh and Saalfeld 1989) offshore (Fig. 1) are divided into  $n$  management areas, and that  $N_i$  is the estimated dugong population of each management area. Then the number of dugongs ( $N$ ) killed as a result of encounters with gill/mesh nets in the whole region each year can be represented by a simple model:

$$N = \sum_{i=1}^n P(M)_i \cdot N_i \quad (1)$$

where  $P(M)_i$  is the probability of a dugong being killed as a result of an encounter with a net in a year in area  $i$ . The expected absolute reduction in the number of dugongs being killed in commercial gill and mesh nets in this region can be estimated using Equation (1), by estimating the numbers of dugongs in each tier of the Dugong Protection Areas and the estimated changes in  $P(M)_i$ . The expected percentage reduction in dugong mortality from gill/mesh nets can be similarly obtained by estimating the proportion of the population of the whole area that occurs in each Dugong Protection Area.

The aerial surveys conducted in 1992 and 1994 (Marsh *et al.* 1996) provide snapshots of the recent distribution and relative abundance of dugongs in the region. The results of these surveys can be used to estimate the percentage of

<sup>1</sup> Antony Preen, School of Tropical Environmental Studies and Geography, James Cook University, Townsville, Queensland 4811, Australia, August, 1998.

Table 1. Estimated approximate proportions of dugongs between Innisfail and southern boundary of Great Barrier Reef in various Dugong Protection Areas (DPAs).

Category of DPA	Location of DPA (Area in km <sup>2</sup> )	% dugongs 1992 survey <sup>4</sup>	% dugongs 1994 survey <sup>4</sup>	Average % dugongs 1992 and 1994 surveys <sup>4</sup>
DPA:A no river set nets	Hinchinbrook (594) Shoalwater Bay-Port Clinton <sup>1</sup> (980)	38	47	42
DPA:A river set nets allowed	Cleveland Bay (410) Upstart Bay (190) <sup>2</sup> Newry region (163) Ince Bay <sup>3</sup> (70)	12	14	13
DPA:A Total	all the above (2407)	50	61	55
DPA:B Total excluding western Upstart Bay <sup>2</sup>	Taylor's Beach <sup>3</sup> (114) Bowling Green Bay (704) Edgecumbe Bay (415) Nth Repulse Bay <sup>3</sup> (32) Sand Bay <sup>3</sup> (73) Llewellyn Bay <sup>3</sup> (128) Clairview region <sup>3</sup> (263) Rodds Bay (512)	10	11	10
DPA:A and DPA:B	all the above excluding areas marked <sup>3</sup>	60	71	65

<sup>1</sup> Netting allowed in creeks in Port Clinton.

<sup>2</sup> 2 km<sup>2</sup> of western foreshore of Upstart Bay DPA Zone B.

<sup>3</sup> DPA too small to calculate estimate.

<sup>4</sup> Calculated as mean of relevant block estimate/mean of total estimate for survey rounded to nearest %.

the total number of dugongs between Innisfail and the southern boundary of the region (Fig. 1) that might be expected to occur in each tier of the Dugong Protection Areas at any point in time (Table 1). Although reasonably consistent across the two surveys, these estimates are very approximate because:

- (1) The surveys were designed to provide regional- rather than local-scale estimates of dugong distribution and abundance, and the errors associated with the local-scale estimates of abundance are large (Marsh *et al.* 1996).
- (2) The boundaries associated with the aerial survey blocks do not coincide with the boundaries of the Dugong Protection Areas, which makes it inappropriate to estimate the proportion of animals occurring in the small Dugong Protection Areas and the tidal reaches of rivers (see Fig. 1, Table 1). I estimate that this approximation makes only a trivial difference to the percentages in Table 1.
- (3) The surveys were conducted at approximately the same time of year (November-December) and provide no indication of seasonal changes in distribution. However, data on dugong distribution in the region from a

variety of sources (Preen and Morissette 1997, Preen 1999) suggest that any seasonal changes in distribution are likely to be small.

The estimates in Table 1 suggest that, in the Great Barrier Reef region south of Innisfail:

- (1) About 65% of dugongs occur in the Dugong Protection Areas.
- (2) The probability of a dugong being killed in a gill or mesh net should be reduced to zero in the areas occupied by about 42% of dugongs (those in the Hinchinbrook and Shoalwater Zone A Dugong Protection Areas) where the prohibition on set netting includes the rivers and creeks.
- (3) The probability of a dugong being drowned in a gill/mesh net should be reduced to virtually zero in the areas occupied by about 13% of dugongs (those which occur in the remaining Zone A Dugong Protection Areas). Animals using the tidal waters of the rivers flowing into these areas may still be vulnerable. I cannot estimate the risk of dugongs being caught in river set nets.
- (4) Approximately 10% of dugongs occur in the Zone B Protection Areas, where netting practices have been subject to lesser modifications. The effectiveness of these initiatives would be very difficult to measure and this has not been attempted.
- (5) About 35% of dugongs occur outside the Dugong Protection Areas.

The figures in Table 1 suggest that, if the measures introduced in the Zone A Dugong Protection Areas are effective, they should decrease the number of dugongs entangling in commercial gill or mesh nets in the Great Barrier Reef region south of Innisfail by between about 42% and 55%. This assessment is based on the following assumptions:

- (1) *That the probability of a dugong entangling in a net was not different in the Zones A from that in the remainder of the area before the closures were implemented.* In particular, that the probability of a dugong encountering a net as it moves from one Dugong Protection Area to another is not higher than for other regions outside the closures. There is no evidence to support or reject this assumption.
- (2) *That no gill and mesh netting effort was displaced by the closures.* The government scheme to buy back the licenses of displaced fishers to minimize the displacement of fishing effort from the closed areas is vital to the success of the initiative. Any displacement is likely to increase the probability of dugongs encountering nets outside the closure areas. Unfortunately, the effectiveness of this scheme appears to have been compromised by the failure to introduce regulations to prevent fishers who surrendered their licences from re-entering the fishery. Anecdotal evidence suggests that many fishers used their *ex gratia* payments to buy another licence and resume fishing.
- (3) *That there is no overall movement of dugongs from the Zone A Dugong Protection Areas to other areas after the closures.* To minimize the risks of this happening, it will be particularly important to conserve the habitat in the closure areas. If the Zone A Dugong Protection Areas are a success, the relative density of dugongs should increase in these areas relative to the remainder

of the coastal waters in the region, making habitat protection in the closure areas and adjacent dugong habitats even more crucial. It is too soon to evaluate this assumption.

- (4) *That the intended elimination of the risk to dugongs from gill and mesh nets in the Zone A Protection areas is not compromised by legal but unforeseen changes in netting practices and illegal netting.* In response to evidence that fishers were fishing in a manner contrary to the intent of the regulations designed to reduce dugong mortality, the Great Barrier Reef Ministerial Council recommended further restrictions on the use of commercial fishing nets in Dugong Protection Areas Zones A on 30 July 1999. These included a restriction in the legal mesh size of nets (other than bait nets) to between 50 mm and 115 mm and a requirement that mesh, ring, or seine nets be used only if shot and retrieved in a continuous process.

The most important dugong sanctuary in the region is clearly the 980 km<sup>2</sup> Shoalwater Bay and Port Clinton Dugong Protection Areas, which not only support more than a quarter of the dugongs in the region but are also mostly a military training area in which impacts can be tightly controlled. Compared with most areas between Cooktown and the southern boundary of the Great Barrier Reef World Heritage Area (Fig. 1), little tourism, recreational boating and commercial fishing occur in the region. In addition, the area has creeks but no coastal rivers, so impacts for upstream land uses are minimal, and there is no industry or significant settlement on the adjacent coastal lands. Satellite tracking indicates that individual dugongs often travel between Shoalwater Bay and nearby Port Clinton (A. R. Preen, unpublished data<sup>1</sup>), where limited gill and mesh netting is still allowed in the creeks. The Shoalwater Bay-Port Clinton Dugong Protection Area should be a priority for surveillance to deter fishers from netting illegally. In addition, I consider that the prohibition on gill/mesh netting in the tidal reaches of creeks should be extended to Port Clinton.

The long-term effectiveness of the Zone A Hinchinbrook Dugong Protection Area, which supports about 15% of dugongs in the region is much less certain. This is the other area where the prohibition on set gill/mesh netting includes the creeks. However, the regulations are not as restrictive as in Shoalwater Bay. Boat traffic is expected to increase in this area as a result of resort and marina developments. Vessel strikes are a major cause of mortality for Florida manatees (Wright *et al.* 1995). Although there are few records of dugong deaths due to vessel strikes in Australian waters, increasing vessel traffic increases the likelihood of strikes. Areas such as this where there are extensive shallow areas used by regionally important populations of dugongs close to recreational boating facilities are particularly at risk.

Some of the other Zone A Dugong Protection Areas in the Great Barrier Reef region are even less likely to be effective in the long-term than the Hinchinbrook Dugong Protection Area. For example, it may be difficult to maintain dugong habitat quality in Cleveland Bay, the port for Townsville (Fig. 1), the largest city in tropical Australia.

The modifications to the netting regulations in the Zones B were also de-

signed to reduce dugong mortality. However, it is impossible to estimate the effectiveness of these zones, because the effects of the changes to netting regulations in the Zone B Dugong Protection Areas on the probability of a dugong being killed in a net have not been quantified. (The difficulties of doing this are discussed below). Hence, I cannot estimate the resultant changes to dugong mortality in the region. However, it is important to appreciate that only about 10% of dugongs in the region occur in the Zone B Dugong Protection Areas.

An estimated 35% of dugongs occur outside any of the dugong sanctuaries and are effectively unprotected from fishing impacts. Fisher attendance at the net should reduce dugong mortality by facilitating: (1) removal of the net if dugongs are nearby, and/or (2) disentanglement of dugongs before drowning. Enactment of the regulation which proposes to require fishers to remain within 100 m of their net throughout the entire region may be more effective than the present fishing modifications in the Zones B Dugong Protection Areas. In practice, these effects will be impossible to measure without experimental fishing probably involving thousands of net sets (see Dawson *et al.* 1998). Such an activity is unlikely to be permitted because of the World Heritage status of the region. An additional factor to be considered in evaluating these alternatives is their relative enforcement difficulties.

There is anecdotal evidence to suggest that the probability of a dugong encountering a net is greatest in areas where tidal amplitude is greatest. In these areas the sea grass meadows on which the dugongs feed are limited to the intertidal area. Thus the dugongs and the fishers use the same very localized regions at high tide. In this regard, it is unfortunate that the spatial closures to commercial gill and mesh netting were not more extensive in the region between Repulse and Shoalwater Bays (Fig. 1), the region of greatest tidal amplitude (Maxwell 1968).

The probability of dugongs being killed is also likely to be high when nets are set in narrow movement corridors such as the tidal reaches of rivers and along rocky headlands. Satellite tracking has confirmed that dugongs use the tidal reaches of rivers and creeks (Marsh and Rathbun 1990, Preen 1999). It will be very difficult to determine whether or not corridors exist along rocky foreshores as travelling dugongs are not detectable using satellite tracking because the transmitter is pulled under the water rendering its signal unavailable to satellites (Marsh and Rathbun 1990). A precautionary approach would be to prohibit the following activities: (1) gill/mesh netting from the tidal reaches of all rivers and creeks opening into Zone A Dugong Protection Areas, and (2) rocky foreshore set nets throughout the region.

The effectiveness of all these measures will depend on parallel education and enforcement programs. It is pleasing to note that approximately 460 fishers from the region have attended an Endangered Species Awareness Course and that the Commonwealth Government has provided considerable additional funds to enforce the closures.

Several additional factors need to be considered in evaluating the likely success of the Dugong Protection Areas. The first is the spatial distribution

of different components of the dugong population. The impact of gill/mesh net mortality depends on what part of the population is most vulnerable to entanglement. Population models (Boyd *et al.* 1999) show that, as for other long-lived, slow-breeding mammals, the rate of population change in the dugong is most sensitive to changes in adult survivorship. It is not possible to quantify the influence of demography or the effectiveness of spatial closures for dugongs in the Great Barrier Reef region. There is an absence of data on either: (1) spatial segregation within the dugong population, or (2) the susceptibility of different age sex classes of dugongs to gill/mesh netting mortality.

The second potentially influential factor is whether the spacing of the Zone A Dugong Protection Areas is sufficiently close to ensure dugong gene flow between them. Mitochondrial DNA studies by Tikel (1998) suggest that the dugong's breeding pattern conforms to an "isolation by distance model," which means that an individual is more likely to breed with others in a neighboring bay than with dugongs some distance away. Based on Mitochondrial DNA, Tikel (1998) presents evidence for genetic structure within the dugongs that occur in the Great Barrier Reef region. Her studies suggest that, if dugongs disappear from an area it is unlikely to be recolonized quickly, despite the dugong's capacity for long-distance movements of hundreds of kilometers in a few days (Marsh and Rathbun 1990, Preen 1999).

Of course, it is also impossible to estimate whether these measures will be sufficient to halt the decline of the dugong in the region without the information required to estimate sustainable mortality and the relative estimates of all anthropogenic impacts. The present initiatives are an important first step in halting the decline of dugong numbers in the Great Barrier Reef region south of Cooktown. Closing the entire region to gill/mesh netting may not have been politically achievable without quantifying and addressing all the other likely causes of decline including habitat degradation, illegal netting, and illegal hunting. This approach would have delayed action for several years while dugong numbers presumably would have continued to decline.

Recovery of the dugong population in response to these management initiatives will be slow, because the estimated maximum rate of increase  $r_m$  of a dugong population is of the order of 5% per year (Marsh 1995). In addition, it is very difficult to monitor local-scale changes in population size of dugongs in a time frame useful to management (Marsh 1995; see Taylor and Gerodette 1993 for a theoretical treatment). Indeed, the results of such monitoring may be deceptive if carried out for only a limited time period. Slooten and Lad (1991) showed by simulation that, after a change in survival rates, the size of a marine mammal population tended to fluctuate for several years, until the age composition stabilized. Thus, short-term monitoring may incorrectly suggest that a population is increasing when, in the long term, it is decreasing.

Thus, managers are unlikely to be able to use changes in the size of the dugong population *per se* to evaluate the success of their initiatives to reduce mortality caused by gill/mesh nets for at least several years after the measures are introduced. Monitoring the change in the magnitude of the by-catch is

also likely to be problematic. Fishers will be reluctant to provide accurate records. An observer program would be exorbitantly expensive in this fishery, which is essentially a seasonal, artisanal fishery in which fishers operate out of small (4.2–5.2 m) boats.

It will be important to monitor spatial changes in gill/mesh netting effort over time to ensure that effort is not displaced from the closures to other areas. Displaced effort could lead to an increase in the probability of a dugong entangling a net outside the Dugong Protection Areas. This possibility is most critical in the areas adjacent to the closure areas, which are likely to be part of the home ranges of the dugongs using the closure areas. The log-book program operated by the Queensland Fisheries Management Authority provides the required data. Fishing operators are legally required to identify where they fish each day in a 30-min grid. More than 80% of fishers supply this information on a 6-min grid. Monitoring non-compliance with the changed regulations, particularly the number and spatial locations of infringements should also be priorities.

Even though it will be difficult to detect changes in the size of the dugong population, it should be more practicable to monitor changes in the spatial pattern of dugong habitat use. Surveys to determine whether the relative abundance of dugongs is stable over the various management areas should provide an indication of whether habitat quality is being maintained in the Dugong Protection Areas.

Monitoring temporal changes in the geographical distribution of dugong carcasses should provide insights into the effectiveness of Dugong Protection Areas. However, the reliability of this monitoring will be limited by the following factors:

- (1) The time series of data collected by the Queensland Parks and Wildlife Service dates only from 1996.
- (2) The probability of recovering a dugong carcass is low although is increasing. I estimate less than 20% of carcasses are recovered, largely because of the low human population density along most of the Queensland coast. However, increasing public awareness of the conservation status of the dugong and a "dugong hotline" have apparently increased the reporting of dugong carcasses.
- (3) The probability of determining the cause of death of a dugong carcass is low because of the hot climate and limited availability of trained personnel.

The chief value of the approach outlined in this paper is that it provides a method for evaluating management options in cases where action is required without waiting for the data required to estimate a sustainable yield. The only information required is: (1) knowledge of the relative abundance of the marine mammal under consideration in the various areas being considered for management action, and (2) an assessment of the likely validity of the various assumptions inherent in the approach. Management areas should be effective, even if individual animals spend only some of their time in the protected areas, provided that the areas chosen consistently support high numbers of

animals. Conservation benefits will be compromised if restrictions are introduced in areas where habitat quality cannot be maintained.

#### ACKNOWLEDGMENTS

I thank Darren Cameron, Peter Corkeron, Steve Dawson, Leanne Mackey, Lachlan Marsh, Jamie Oliver, Andy Read, Julie Robins, and Tony Stokes for their comments on an earlier draft of this manuscript and Tony Preen for stimulating me to write it.

#### LITERATURE CITED

- BOYD, I. L., C. LOCKYER AND H. MARSH. 1999. Reproduction in marine mammals. Pages 218–286 *in* J. E. Reynolds III and S. A. Rommel, eds. *Biology of marine mammals*. Smithsonian Institution Press, Washington, DC.
- DAWSON, S. M., A. READ AND E. SLOOTEN. 1998. Pingers, porpoises and power: Uncertainties with using pingers to reduce by catch of small cetaceans. *Biological Conservation* 84:141–146.
- GREAT BARRIER REEF MARINE PARK AUTHORITY. 1981. Nomination of the Great Barrier Reef by the Commonwealth of Australia for inclusion in the World Heritage List. Unpublished report to the World Heritage Committee, UNESCO. 14 pp. Available from Great Barrier Reef Park Authority, P. O. Box 1379, Townsville, Queensland 4810, Australia.
- MARSH, H. 1995. Limits of detectable change. Pages 122–130 *in* G. Grigg, P. Hale and D. Lunney, eds. *Conservation through sustainable use of wildlife*. Surrey Beatty and Sons, Chipping Norton.
- MARSH, H., AND G. RATHBUN. 1990. Development and application of conventional and satellite radio tracking techniques for studying dugong movement and habitat use. *Australian Wildlife Research* 17:83–100.
- MARSH, H., AND K. SAALFELD. 1989. Distribution and abundance of dugongs in the Northern Great Barrier Reef Marine Park. *Australian Wildlife Research* 16:429–440.
- MARSH, H., P. CORKERON, I. R. LAWLER, J. M. LANYON AND A. R. PREEN. 1996. The status of the dugong in the southern Great Barrier Reef Marine Park. GBRMPA Research Publication No 41. Available from Great Barrier Reef Marine Park Authority, P. O. Box 1379, Townsville, Queensland 4810, Australia.
- MARSH, H., P. ARNOLD, C. J. LIMPUS, A. R. BIRTLES, B. BREEN, J. ROBINS AND R. WILLIAMS. 1997. Endangered and charismatic megafauna. The Great Barrier Reef, Science Use and Management. A national conference. Proceedings volume 1:124–138. Great Barrier Reef Marine Park Authority, Townsville, Australia.
- MAXWELL, W. G. H. 1968. *Atlas of the Great Barrier Reef*. Elsevier Publishing Company, Amsterdam.
- PREEN, A. R. 1999. Dugongs, boats, dolphins and turtles in the Townsville-Carwell region and recommendations for a boat traffic management plan for the Hinchinbrook Dugong Protection Area, Report to the Great Barrier Reef Marine Park Authority, April 1999. 46 pp. + appendices. Available from Great Barrier Reef Marine Park Authority, P. O. Box 1379, Townsville, Queensland 4810, Australia.
- PREEN, A. R., AND N. MORISSETTE. 1997. A system of dugong sanctuaries for the recovery and conservation of dugong populations in the Great Barrier Reef Heritage area and adjacent southern waters. Report to the Great Barrier Reef Marine Park Authority, February 1997. 52 pp. Available from Great Barrier Reef Marine Park Authority, P. O. Box 1379, Townsville, Queensland 4810, Australia.
- SLOOTEN, E., AND F. LAD. 1991. Population biology and conservation of Hector's dolphin. *Canadian Journal of Zoology* 69:1701–1707.

- TAYLOR, B., AND T. GERODETTE. 1993. The uses of statistical power in conservation biology: The vaquita and the northern spotted owl. *Conservation Biology* 7:489–500.
- TIDSELL, C., AND S. HARRISON. 1999. Compensation for taking of natural resource interests: Principles and practices in recent Queensland cases. *Australian Journal of Environmental Management* 6:99–108.
- TIKEL, D. 1998. Using a genetic approach to optimise dugong (*Dugong dugon*) conservation management. Ph.D. thesis, James Cook University, Townsville. 277 pp. + appendices.
- WRIGHT, S. D., B. B. ACKERMAN, R. K. BONDE, C. A. BECK AND D. J. BANOWETZ. 1995. Analysis of watercraft-related mortality of Manatees in Florida, 1979–1991. Pages 259–268 in T. J. O'Shea, B. B. Ackerman and H. F. Percival, eds. Population biology of the Florida manatee, (*Trichechus manatus latirostris*). National Biological Survey Information and Technical Report 1. 289 pp.

HELENE MARSH, School of Tropical Environment Studies and Geography, James Cook University, 4811, Australia; e-mail: helene.marsh@jcu.edu.au. Received 27 July 1998. Accepted 21 October 1999.