Report on Aerial Survey of Karumba Region for dugongs, dolphins and sea turtles for Century Zinc

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EXECUTIVE SUMMARY

- This assessment of the significance of the coastline between Gore Point (17°38'S, 139°56'E) and Point Burrows (16°58'S, 140°58'E) for dugongs, dolphins and sea turtles is based on the following:
  - an aerial survey of the region between the coast and the 3 fathom (5.5 m) contour line between -17° N and 140° W in November-December 1994 using modern aerial survey techniques.
  - nautical charts
  - published literature
  - unpublished data from five aerial surveys conducted between 1975 and 1978
  - video footage of dugong feeding trails on a seagrass bed near Karumba in 1993
  - unpublished data from surveys of seagrass beds in the Karumba region conducted by Dr Rob Coles and his staff at the Northern Fisheries Centre in Cairns in 1986 and 1995.

- The study suggests that the following species of large marine mammals and reptiles occur in the area:
  the dugong, *Dugong dugon*
  - **dolphins**: Irrawaddy River dolphin, *Orcaella brevirostris*, the bottlenose dolphin, *Tursiops truncatus*, and the Indo-Pacific hump-back dolphin, *Sousa chinesis*
  - **sea turtles**: loggerhead (*Caretta caretta*), green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*), flatback (*Natator depressus*) and olive ridley (*Lepidochelys olivacae*).

- In addition, the following oceanic species are likely to visit the area:
  - leatherback turtles (*Dermochelys coriacea*)
  - false killer whale (*Pseudorca crassidens*)
  - short-finned pilot whale (*Globicephala macrorhynchus*).

- The results of this study suggest that this region is of no greater significance to any of these species than any other region on the Queensland coast.

INTRODUCTION

The port of Karumba in the Gulf of Carpentaria is proposed as the site of the offshore loading facility for the export of lead-zinc concentrate from the Century Project (Dames and Moore 1994). The possibility of the port activities impacting on the larger marine vertebrate fauna of the area, especially dugongs, is of concern to some stakeholders.

Aerial surveys conducted in the 1970's (Table 1) suggested that the density of dugongs in the Karumba region is low relative to some other regions of the Queensland coast of the Gulf of Carpentaria, notably the Wellesley Island area and the area between the mouth of the Staaten River and Weipa. The counts of sea turtles were also much lower in the Karumba region than in the Wellesley Island area (Table 2).

These surveys used a qualitative technique in which the data recorded were simply counts of the dugongs, turtles and dolphins sighted. This technique was superseded in the mid 1980's by a quantitative technique which provided population estimates for each species group (Marsh and Sinclair 1989). In order to obtain these estimates, the counts were corrected for sampling fraction, perception bias (the proportion of animals which were visible but missed) and availability bias (the proportion of animals which were unavailable to observers because of water turbidity). This quantitative technique is now standard for dugong surveys throughout northern Australia. The Northern Territory coast of the Gulf of Carpentaria (Bayliss and Freeland 1989) and the Wellesley Islands (Marsh and Lawler 1993) have been surveyed using the new technique. Unfortunately, the results of these surveys cannot be validly compared with those for the surveys conducted in the 1970's.

This report presents the results of a survey of the Karumba region in the late dry season in 1994 using the quantitative techniques now used in the other parts of northern Australia. The results of this survey suggest that the Karumba region is of no greater significance to dugongs, dolphins or sea turtles than any other region on the Queensland coast.

METHODS

Survey Design

The area between the coast and the 3 fathom (5.5 m) contour line between -17° N and 140° W was surveyed for dugongs, dolphins and sea turtles on 30th November and 1st December 1994. Water deeper than 5.5 m was excluded from the survey area for two reasons.

(1) Seagrasses, the main food of the dugong in the Gulf of Carpentaria, do not usually occur below this depth in this region (Poiner *et al.* 1987).

(2) The quantitative aerial survey conducted in November 1991 indicated that 87% of dugongs in the Wellesley Islands area occur in waters less than 3 m deep.

The survey team consisted of a pilot, a survey leader (responsible for data recording and supervision of flight plans) and two two-person observer teams, one on each side of the aircraft (Marsh and Saalfeld 1989, Marsh and Sinclair 1989). The four observers independently counted dugongs, dolphins and sea turtles within a 0.2 km strip on either side of the Partenavia 68B aircraft while it flew at 137 m ASL at a groundspeed of 100 knots along a total of 589 km of transects. Thus the survey sampled 236 km^2 within a total area of 2715 km^2 (a sampling intensity of approximately 8.7%; Table 3, Figure 1a). Navigation was performed using a Geographic Positioning System which was mounted in the aircraft. Areas (Table 3) were estimated from 1:1,000,000 digitised topographic coverage (AUSLIG) using the Arcinfo GIS package.

Analysis

The very low numbers of sightings made it inappropriate to analyse the data to obtain a population estimate in the manner of other surveys (Marsh and Sinclair 1989a,b; Marsh and Lawler 1993). Instead, we compared the sighting rate to that obtained during the similar survey of the nearby Wellesley Island area in 1991. The rationale for this was as follows:

(1) The extreme edges of the two survey areas are less than 10km apart;

(2) Weather conditions were similar for the two surveys which were conducted at the same time of year (Table 4);

(3) The survey intensities were similar (Table 3).

RESULTS

Dugongs

Only one dugong was sighted. It was close to the coast approximately 40 km to the west of Karumba (Figure 1b). In contrast, in the Wellesley Island area, 107 dugongs were sighted in waters less than 3 m deep (Marsh and Lawler 1993). Thus the sighting rate in this depth range for the Wellesley Island area was 92 times that for the waters around Karumba (Table 5). The overall sighting rate for water of all depths in the Wellesley Island area was 42 times the rate for the Karumba area.

Turtles

There were very few sightings of turtles in the Karumba region (Figure 1b). Twelve individual turtles were sighted. In contrast, 174 were sighted in water of similar depth in the Wellesley Islands; overall 330 turtles were sighted in the Wellesley Island survey (Table 5). Thus the sighting rate of turtles in shallow water in the Wellesley Islands was 12.4 times higher than in the Karumba region. The overall sighting rate for turtles in the Wellesley Island area was 9 times that in the Karumba region.

Cetaceans

Seven dolphins were seen near Karumba (Figure 1b), compared with 12 in the Wellesley Islands in water below 3 m deep. The sighting rate in the Wellesley Island was 1.5 times that in the Karumba area though the sighting rate was low for both. In the Wellesley Islands more cetaceans were seen in water deeper than 3 m (total of 65 sighted), a habitat which was largely excluded from this survey (Table 5).

EVALUATION OF REGION FOR DUGONGS, DOLPHINS AND SEA TURTLES

Dugongs

Significance of the dugong

The dugong, the only strictly marine herbivorous mammal, has high biodiversity value. It is the only extant member of the Family Dugongidae and one of only four species in the Order Sirenia. Australian waters are considered to be the 'last bastion of the dugong in the world' and therefore Australia has special responsibility for dugong conservation especially as dugongs are of great cultural and dietary significance to coastal Aborigines and Torres Strait Islanders.

The dugong is a long-lived animal with a low rate of population increase. Adult and juvenile survivorship must be very high (>90% p.a.) for dugong numbers to be maintained. Because of the difficulties of censusing dugongs, it is impossible to evaluate trends in numbers at a local scale. Even at a regional scale, it will take at least 5 to 10 years to determine trends.

Dugongs were believed to feed opportunistically on available seagrasses (Marsh et al. 1982; Lanyon et al. 1989). Recent work by Preen (1993) suggests that dugongs select seagrasses which are lower seral or 'pioneer' species. Species of the genera *Halophila* and *Halodule* are favoured. Diet selection is correlated with the chemical and structural composition of seagrass (Lanyon 1991). The most frequently selected species are lowest in fibre, and highest in available nitrogen and presumed digestibility (Lanyon 1991). The highly specialised dietary requirements of the dugong suggest that only certain seagrass meadows may be suitable as seagrass habitat.

Significance of the Karumba region

The results of the aerial surveys conducted in the 1970's (Table 1) and in 1994 (Table 5) indicate that dugongs occur in the Karumba region, however, far fewer dugongs were seen in this area than in the Wellesley Islands and along the coast between Weipa and the mouth of the Staaten River (Tables 1 and 5). Although only one dugong was sighted on the November 1994 survey, it is likely that several dugongs are present in the Karumba region as evidenced by the feeding trails videoed by Ian Baxter in late 1993 and photographed by Coles and his co-workers in April 1995. All these feeding trails were in the intertidal seagrass beds on both sides of the mouth of the Norman River. The species present in this region *Halodule pinifolia* and *Halophila ovalis* are favoured by dugongs (Marsh et al. 1982; Preen 1993) and are widespread in intertidal areas in eastern Queensland (Lee Long et al.

1993) and in the Gulf of Carpentaria (Poiner et al. 1987).

The widespread availability of this habitat in Queensland and the counts summarised in Tables 1 and 5, suggest to me that the Karumba region is likely to be of no greater significance to dugongs than any other site on the northern Australian coast between Moreton Bay near Brisbane and Shark Bay in Western Australia. This opinion is strengthened by the findings of the seagrass surveys by Coles and his co-workers. The only area of seagrass they have confirmed in the Karumba region are the beds at the mouth of the Norman River. However, the counts of 59 dugongs between Gore Point and Karumba in April 1977 suggest that additional areas of seagrass maybe present in that region on occasions. (Intertidal seagrasses are often ephemeral in northern Australia [personal observation]).

Dolphins and small whales

Species present

Identifying cetaceans at sea is often difficult even for experienced observers, so it is not surprising that the dolphins and small whales that occur in the relatively isolated study area are poorly known. Extrapolating from other areas in tropical Australia, the dolphins and small whales occurring in the study area can be expected to fall into two categories:

- Inshore species which probably occur in the study area year round such as the Irrawaddy River dolphin, *Orcaella brevirostris*, the bottlenose dolphin, *Tursiops truncatus,* and the Indo-Pacific hump-back dolphin, *Sousa chinensis.*

and

- Oceanic species which pass through the region such as the false killer whale, *Pseudorca crassidens* and the short-finned pilot whale, *Globicephala macrorhynchus.*

I consider that the usage of the study area by oceanic species is too speculative to incorporate in the environmental impact study of the Century Project and so have concentrated on the coastal species in this report.

Irrawaddy River dolphin

The Irrawaddy dolphin occurs in tropical and sub-tropical coastal water in some major river systems of the Indo-West Pacific Region from the Bay of Bengal to the east of Australian coast between about 25° latitude north and south of the equator. There are some populations which are restricted to fresh water and it is doubtful whether Irrawaddy dolphins venture very far offshore (Marsh et al. 1989). Although animals are found long distances from the sea in several of the great rivers of Asia, there is no information to suggest that they occur in the fresh-water reaches of Australian rivers. The aerial survey data of Freeland and Bayliss (1989) suggest that Irrawaddy dolphins avoid waters less than 2.5 m and greater that 18 m deep along the Northern Territory coast.

The distribution of the Irrawaddy dolphin is poorly documented in Australia. Records suggest that it occurs at least from Broome in Western Australia to Gladstone in Queensland. I expect that *Orcaella* occurs throughout the waters in the study area and in the salt water reaches of the rivers and larger creeks.

Indo-Pacific hump-back dolphin

The hump-back dolphin typically occurs in tropical inshore waters, in estuaries and the tidal reaches of rivers. This specifies frequents mangrove zones and its distribution in the Indo-Pacific coincides fairly well with that of mangroves (Klinowska 1991). Hump-back dolphins may form mixed schools with bottlenose dolphins (Klinowska 1991). In Moreton Bay near Brisbane, *Sousa* tends to be found in waters that are both shallower and further offshore than the habitats occupied by bottlenose dolphins. This is because the hump-back dolphins are more likely to use the western side of Moreton Bay where waters remain fairly shallow for many kilometres offshore (Corkeron 1990). Corkeron documented movements of identified individuals of up to 15 km. Like *Orcaella*, I expect that *Sousa* occurs throughout the water of the study area and in the tidal reaches of the rivers and creeks.

Bottlenose dolphin

The bottlenose dolphin is found worldwide in tropical and temperate waters, both inshore and offshore (Klinowska 1991). In all areas where bottlenose dolphins have been studied, there are separate inshore and offshore ecotypes. Bottlenose dolphins exploit an impressive range of habitats. The inshore form is occasionally reported from fresh-water rivers, but I know of no evidence to suggest that they endure beyond the tidal reaches of Australian rivers. The usual inshore range includes river mouths, bays, lagoons, estuaries and shallow coastal waters out to depths of about 20 m (Klinowska 1919). Like the other two species of dolphin, I expect bottlenose dolphins to occur throughout the study area and in the tidal reaches of the rivers and larger creeks.

Conservation significance

Irrawaddy River dolphin

The Irrawaddy River dolphin, *Orcaella brevirostris*, is little known despite its essentially coastal and riverine distribution and sometimes local abundance. For example, the species was not recorded from Australia waters until 1948 when two anthropologists found the skulls of animals that had been by Aborigines in Arnhem land.

The Irrawaddy dolphin is listed by IUCN as K (a taxon which is suspected of belonging to a threatened species category, but which is insufficiently known to be formally categorised). Its status in Australia in unknown.

The species is of technical interest to dolphin specialists because of its uncertain taxonomic affinities (for a discussion see Marsh et al. 1989). In essence, scientists are uncertain whether to place the Irrawaddy dolphin in the family Delphinidae (like most other dolphins) or in the Family Monodontidae with the beluga and narwhal. Thus *O.brevirostris* is the dolphin which most overseas experts would be most interested in seeing when they visit Australia, even though it is not particularly rare.

Indo-Pacific hump-back dolphin

The Indo-Pacific hump-back dolphin is not listed in the 1990 edition of the 'IUCN List of Threatened Species'. However, the IUCN Red Data Book for Cetaceans (Klinowska 1991) gives it a K listing. Its status in Australia is unknown.

Bottlenose dolphin

Although a few inshore bottlenose dolphin populations are comparatively well studies, information is lacking for most of the inshore range and for offshore populations. Consequently, the IUCN Red Data Book for Cetaceans (Klinowska 1991) gives the species a K listing. It is not listed in the 1990 edition of the 'IUCN List of Threatened Species'. Its status in Australia is unknown.

Significance of the area

The results of the aerial surveys conducted in the 1970's and 1994 suggest that this region is not of special significance to these species of dolphins.

Sea Turtles

Species present

Loggerhead (*Caretta caretta*), green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*) and flatback (*Natator depressus*) and olive ridley (*Lepidochelys olivacae*) have been formally recorded form the southern Gulf of Carpentaria (see Limpus and Reed 1985 and Poiner et al. 1990). The leatherback (*Dermochelys coriacea*), an oceanic species, may be an occasional

visitor to the area. Most of the turtles sighted during aerial surveys are probably large green turtles.

Conservation significance

With the exception of the flatback, all the species of sea turtle that occur in the area are listed as endangered (green, hawksbill, olive ridley) or vulnerable (loggerhead) (IUCN 1990). The flatback is listed as potentially vulnerable by Kennedy (1990).

Significance of the area

The results of the aerial surveys conducted in the 1970's and in 1994 suggest that this region is not of particular significance as a feeding ground to any of these species of sea turtle. As sea turtle nesting appears largely to be confined to islands in the Gulf of Carpentaria (Limpus and Reed 1985), the Karumba area is also unlikely to contain significant nesting grounds for sea turtles. I have checked my field notes for the two surveys conducted with Heinsohn in November 1976 and April 1977 and we recorded no turtle tracks along the contrast between Gore Point and Point Burrows, even though we recorded numerous tracks in the Wellesley Islands. Poiner et al. (1990) reported that sea turtles were caught in prawn trawls in the south-eastern Gulf of Carpentaria. However, as they define this region as including the Wellesley island area, it is not possible to use their published data to assess the relative significance of the Karumba area *per se* for sea turtles. The number of turtles they reported caught per net hour in the south-eastern Gulf of Carpentaria was significantly lower than for Albatross Bay, near Weipa (Poiner et al. 1990).

4. POTENTIAL IMPACTS OF THE PORT DEVELOPMENT AT KARUMBA

The following remarks concern possible impacts of dredging and ore spillage on seagrass beds. We are not qualified to comment on specific engineering aspects regarding the Karumba port development.

Dugongs and green turtles

Habitat loss

Both dugongs and sea turtles feed on seagrass (Lanyon et al. 1989). Seagrass ecosystems are very sensitive to human impact. Deleterious human activities are reviewed by Fonseca (1987) and Shepherd et al. (1989). Seagrass beds may be destroyed directly by mining and trawling (Silas and Bastion Fernando 1985), or lost through the effects of disturbances such as dredging. These activities case an increase in sedimentation and turbidity which leads to smothering of seagrass or death due to a lack of light. However, any such threats need to be considered in the context of natural events such as cyclones and floods which can cause extensive damage to seagrass communities through severe wave action, shifting sand, adverse salinity changes and light reduction (Heinsohn and Spain 1974; Kenyon and Poiner 1987). Unless the seagrass in the Karumba region is much more extensive than indicated by Poiner et al. 1987 and the surveys conducted by Coles et al., we consider that, although dredging may have a local impact on seagrass in the vicinity of Karumba, the regional significance of

this impact on dugongs will probably be low.

Heavy metal accumulation in seagrass

Studies in the 1970's have shown that the heavy metal status of both dugongs and sea turtles reflect that of the seagrass on which they feed (Denton et al. 1980). I consider that even though the density of these species in the Karumba region is probably of only local significance, the prevention of heavy metal pollution from the products of the Century mine should be a high priority. If heavy metals accumulate in nearby seagrass beds, there is a strong probability of these metals accumulating in the tissues of local dugongs and turtles over decades. The levels of several heavy metals, including zinc, in dugongs from northern Australia, including the Wellesley Islands, were higher than have been recorded in marine mammals in other parts of the world during the 1970's (Denton et al. 1980). Local Aborigines are likely to be extremely concerned about the risk of meat of dugongs and turtles being contaminated, especially as satellite tracking studies show that dugongs in the Gulf of Carpentaria can move distances greater than that between Karumba and Mornington Island in a few days (A.R. Preen pers comm 1995). The impact of these metals on the animals *per se* is unknown.

Dolphins

Irrawaddy river dolphin

Irrawaddy dolphins have been the most common species of dolphin caught in shark nets close to the coastal cities of tropical Queensland. They are still sighted in the inshore waters in the Townsville region. This suggests that they can co-exist with industrial development, even though Klinowska (1991) states (without supporting information) that there is evidence to suggest that Irrawaddy dolphins can be excluded from previous habitats by industrial developments.

Indo-pacific hump-back dolphin

There is no species-specific information on which to assess the potential impacts of the project on *Sousa*.

Bottlenose dolphin

Claims have been made of dramatic changes in local bottlenose dolphin populations caused by human activities. However, most such claims are difficult to evaluate and definitive research has not been carried out to test the effects of chemical pollution or harassment on bottlenose dolphins (Klinowska 1991).

REFERENCES

Bayliss, P. and Freeland, W.J. 1989. Seasonal distribution and abundance of dugongs in the Gulf of Carpentaria. Aust. Wildl. Res. 16: 141-9.

Corkeron, P.J., 1990. Aspects of the behavioural ecology of inshore dolphins (*Tursiops truncatus* and *Sousa chinensis*) in Moreton Bay; Australia. Pp. 285-94 in 'The Bottlenose Dolphin' ed by S. Leatherwood and R.R. Reeves. Academic Press, San Diego, USA.

Dames and Moore 1994. The Century Project. Draft Impact Assessment Report. Century Zinc

Denton, G.R., Marsh, H., Heinsohn, G.E. and Burdon-Jones, C. 1980. The unusual heavy metal status of the dugong. Mar Biol. 57: 201-219.

Elliott, M. Distribution and status of the dugong in Northern Territory waters. Pp. 57-66 in the Dugong: Proceedings of a Seminar Workshop at James Cook University, May 1979 (ed H. Marsh). James Cook University, Townsville.

Fonseca, M.S. 1987. The management of seagrass systems. Trop. Coastal Area Manage. 2: 5-7.

Freeland, W.J. and Bayliss, P. 1989. The Irrawaddy River dolphin (*Orcaella brevirostris*) in coastal waters of the Northern Territory, Australia. Mammalia 5: 49-58.

Heinsohn, G.E. 1976. Ecology and conservation of the dugongs, *Dugong dugon*, in Australia. Unpublished report to the Australian National Parks and Wildlife Service.

Heinsohn, G.E. 1977. Ecology and conservation of the dugongs, *Dugong dugon*, in Australia. Unpublished report to the Australian National Parks and Wildlife Service.

Heinsohn, G.E. and Marsh, H. 1978. Ecology and conservation of the dugongs, *Dugong dugon*, in Australia. Unpublished report to the Australian National Parks and Wildlife Service.

Heinsohn, G.E. and Spain, A.V. (1974). Effects of a tropical cyclone on littoral and sub-littoral biotic communities and on a population of dugongs (*Dugong dugon* [Müller]). Biol. Conserv. 6:143-152.

IUCN, 1990. '1990 IUCN list of threatened animals'. International Union for the Conservation of Nature and Natural Resources, Gland, Switzerland.

Kennedy, M. (ed) 1990. 'Australia Endangered Species: the Extinction Dilemma'. Simon Schuster, Brookvale Australia.

Kenyon, R. and Poiner, I. 1987. Seagrass and cyclones in the western Gulf of Carpentaria. CSIRO Mar. Lab. Info. Sheet No. 1., Feb. 1987.

Klinowska, M. 1991. 'Dolphins, whales porpoises of the world. The IUCN Red Data Book.' International Union for the Conservation of Nature and Natural Resources, Gland Switzerland.

Lanyon, J. 1991. The nutritional ecology of the dugong (*Dugong dugon*) in tropical north Queensland. Unpublished PhD thesis, Monash University, Clayton, Victoria.

Lanyon, J., Limpus, C.J. and Marsh, H. 1989. Dugongs and turtles: graziers in the seagrass ecosystem. Pp. 610 - 634 in 'Biology of Australian Seagrasses - an Australian perspective'. (A.W.D. Larkum, A.J. McComb and S.A. Shepherd, eds.). Elsevier, Amsterdam.

Lee Long, W.J., Mellors, J.E. and Coles, R.G. 1993. Seagrasses between Cape York and Hervey Bay. Aust. J. Mar. Freshwater Res. 44: 19-31.

Ligon, S.H. 1977. A survey of dugongs (*Dugong dugon*) in Queensland. J. Mamm. 57:

580-582.

Limpus, C.J., and Reed, P.C. 1985. Green sea turtles stranded by Cyclone Kathy in the south-western Gulf of Carpentaria. Aust. Wildl. Res. 12:523-534.

Marsh, H., Channells, P.W., Heinsohn, G.E. and Morissey, J. 1982. Analysis of stomach contents of dugongs from Queensland. Aust. Wildl. Res. 9: 55-67.

Marsh, H., and Lawler, I. 1993. The Century Project. Environmental Studies. Dugongs, sea turtles and dolphins. Hollingsworth, Dames and Moore.

Marsh, H., Lloze, R., Heinsohn, G.E. and Kasuya, T. 1989. Irrawaddy dolphin. Pp. 101-118 in S.H. Ridgway and R.J. Harrison (eds). Handbook of Marine Mammals, Vol. 4, Academic Press, London.

Marsh, H. and Saalfeld, W.K. 1989. Aerial surveys of sea turtles in the northern Great Barrier Reef Marine Park. Aust. Wild. Res. 16: 239-49.

Marsh, H., and Sinclair, D.F. 1989a. An experimental evaluation of dugong and sea turtle aerial survey techniques. Aust. Wildl. Res. 16: 639-50.

Marsh, H. and Sinclair, D.F. 1989b. Correcting for visibility bias in strip transect aerial surveys of aquatic fauna. J. Wildl. Manag. 53: 1017-1024.

Poiner, I.R., Buckworth, R.C. and Harris, A.N.M., 1990. Incidental capture and mortality of sea turtles in Australia's northern prawn fishery. Aust. J. Mar. Freshwater Res. 41: 97-110.

Poiner, I.R., Staples, D.J. and Kenyon, R. 1987. Seagrass communities in the Gulf of Carpentaria, Australia. Aust. J.Mar. Freshw. Res. 38: 121-131.

Preen, A.R. 1993. 'Interactions between dugongs and seagrasses in a subtropical environment'. Unpublished PhD thesis, James Cook University, Townsville, Queensland.

Shepherd, S. McComb, A.J., Bulthius, D.A. Neverauskas, V., Steffenson, D.A. and West, R. 1989. Decline of seagrasses. In 'Biology of Australian Seagrasses -an Australian perspective'. (A.W.D. Larkum, A.J. McComb and S.A. Shepherd, eds). Elsevier, Amsterdam.

Silas, E.G. and Bastion Fernando, A. 1985. The dugong in India - is it going the way of the dodo? Paper No. 19 presented at the Symposium on Endangered Marine animals and marine Parks, Cochin, India, 12-16 Jan, 1985.

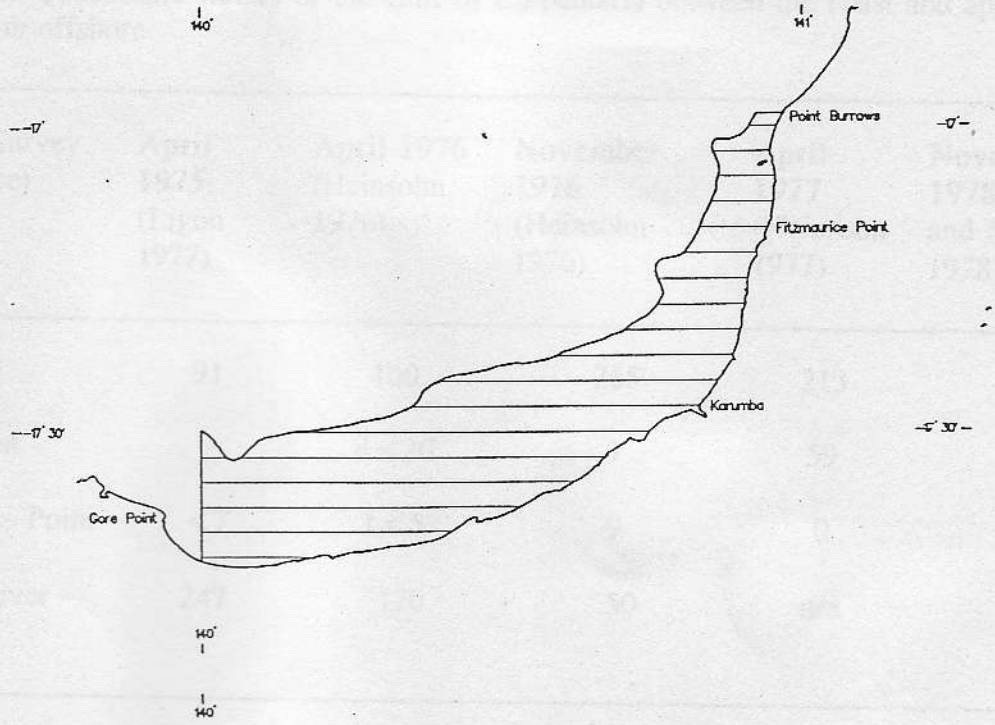

Figure 1a. The Karumba area showing the transects flown in the 1994 survey.

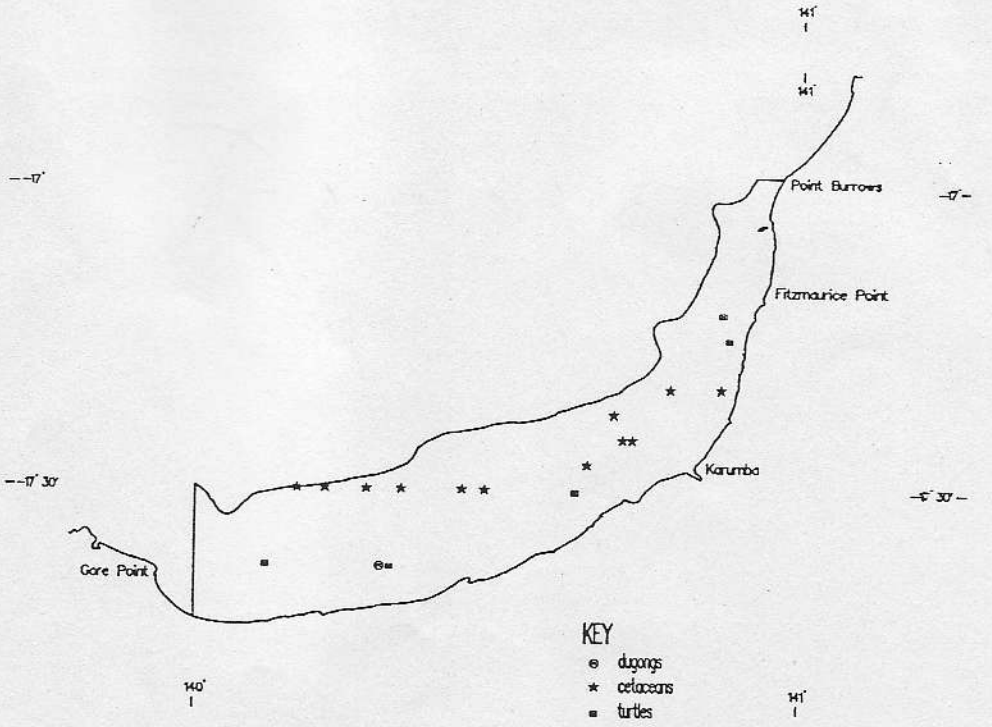

Figure 1b. The Karumba area showing the positions of the dugong, cetaceans and turtles sighted in the 1994 survey.

Table 1: Results of the qualitative aerial surveys conducted in the 1970's for dugongs over the parts of the Queensland waters of the Gulf of Carpentaria between the coast and approximately 1.6km offshore.

Date of Survey (Reference)	**April 1975** (Ligon 1977)	**April 1976** (Heinsohn 1976)	**November 1976** (Heinsohn 1976)	**April 1977** (Heinsohn 1977)	**November 1978** (Heinsohn and Marsh 1978)
Wellesley Islands	91	160	265	213	n/a
Gore Point - Karumba		$4 \leq 20$	7	59	n/a
Karumba - Point Burrows	<7	$1 \leq 5$	9	0	1
Staaten River - Weipa	247	~170	~50	n/a	96

Table 2: Numbers of dolphins and sea turtles seen during the qualitative aerial surveys for dugongs conducted by Heinsohn and Marsh in the 1970's over the parts of the Queensland waters of the Gulf of Carpentaria between the coast and approximately 1.6km offshore.

Date of Survey	November 1976		April 1977	
	Dolphins	*Sea turtles*	*Dolphins*	*Sea turtles*
Wellesley Islands	0	45	23	22
Gore Point - Karumba	0	0	1	4
Karumba - Point Burrows	0	1	0	0
Staaten River - Weipa	4	4	n/a	n/a

Table 3: Survey area and sampling intensity for the survey of the Karumba region in 1994 and the nearby Wellesley Islands in 1991.

Survey	Area (km2)	Sampling intensity (%)
Karumba	2715	8.7
Wellesley Islands - water below 3m (Block 4)	3432	8.0
Wellesley Islands - Total	8848	8.2

Table 4: Weather conditions encountered during the survey of the Karumba region in 1994 and those encountered during the 1991 survey of the nearby Wellesley Islands.

Values for Beaufort sea state and glare are the mean of the modes for each transect with range in parentheses. Glare is measured as:0, none; 1, <25% of field of view affected; 2, 25-50%; 3, > 50%.

Variable	Karumba	Wellesley Islands
Wind speed (km h-1)	<10	<10
Cloud cover (oktas)	2-4	0-7
Minimum cloud height (m)	2000	2000-8000
Beaufort sea state	2.19(1-3)	1.7(0-4)
Glare North	0.19(0-1)	1.5(0-3)
South	0.42(0-1)	2.1(0-3)
Visibility (km)	<20	<20

Table 5: Comparison of sighting rates of each taxon between the 1994 survey of the Karumba region and the survey of the nearby Wellesley Islands in 1991.

Taxon	Karumba		Wellesley Islands			
			water <3m deep		Overall	
	Number seen	sighting rate (animals /km² transect)	Number seen	sighting rate (animals /km² transect)	Number seen	sighting rate (animals /km² transect)
Dugongs	1	0.004	107	0.390	123	0.170
Turtles	12	0.051	174	0.634	330	0.455
Cetaceans	7	0.030	12	0.044	65	0.090