DISCUSSION

The importance of the Hinchinbrook area as dugong habitat has been recognised since the 1970s (Heinsohn & Marsh 1980). The particular importance of the area for the conservation of dugongs along the populated coast of Queensland was recognised only when the decline in dugong numbers was quantified (Marsh et al. 1996). In 1987, dugongs in the Townsville-Hinchinbrook region represented approximately 19% of all dugongs in the Great Barrier Reef region south of Cooktown. Due to the decline of dugongs elsewhere, this had increased to 32% by 1992, and to 49% by 1994 (Marsh et al. 1996).

This study has provided the first detailed, year-round picture of dugong distribution and habitat use in the Townsville-Hinchinbrook area. The previous aerial surveys of the region lacked either temporal or spatial coverage. Marsh's transect surveys have all been conducted in the same month (Marsh et al. 1996), while Heinsohn's shoreline surveys did not cover significant areas of dugong habitat, especially in Missionary Bay. This study has combined year-round aerial surveys with long-term tracking, and has been supplemented by sightings from the public and Heinsohn's data from the 1970s.

The aerial surveys showed that the most important dugong habitat in the Townsville-Cardwell region occurs in Missionary/Shepherd Bay in the Hinchinbrook area and in eastern Cleveland Bay in the Townsville area (figures 6b, 6c). Areas of less intense use, based on the aerial surveys, are Hinchinbrook Channel and the area between Magnetic Island and Bluewater Creek (figures 6b, 6a, 6c). A different, and independent, measure of habitat use in the Townsville-Cardwell region was provided by the tracking. While confirming the broad results of the aerial surveys, the tracking identified substantial use of Hinchinbrook Channel by dugongs (figures 4b, 5a). It also highlighted the use of the Lucinda coast and Bowling Green Bay (figures 4b, 5b). The sightings reported by the public, although inevitably biased by the distribution of search effort, provided useful supplementary information on the distribution of marine mammals in areas of high visitation. The public sightings demonstrated the presence of dugongs in all areas of Hinchinbrook Channel, particularly the southern half (figure 12a, table 12), where few aerial survey or tracking records occurred. The public sightings, and the tracking, also highlighted the presence of dugongs along the Cardwell foreshore (figures 12a, 4b). The importance of this area as a dugong feeding area was confirmed by the survey of feeding trails (figure 13). The results of Heinsohn's shoreline surveys of the 1970s are consistent with the current distribution of dugongs, although dugongs appear to have been more common in Hinchinbrook Channel at the time of Heinsohn's surveys.

The relative abundance of dugongs in Hinchinbrook Channel was one of the main discrepancies between the aerial survey and tracking data. Dugongs in the channel were difficult to see from the air because of the often turbid water, the presence of shadows from clouds formed along the spine of Hinchinbrook Island, and because some of the dugongs used relatively deep water. On four aerial surveys we flew directly over a discrete area of the channel that was occupied, on each occasion, by one of the tagged dugongs, but he was never seen. Other areas where the tracking data highlighted a sightability bias in the aerial surveys were off Lucinda, and along the northern coast of Hinchinbrook Island in Missionary Bay. Few dugongs were seen in these areas (figure 6b) where the water was typically very turbid, yet the tracking data shows substantial use by dugongs (figure 4b). In areas of deep water, both the tracking and aerial survey data are biased. In such areas neither the dugongs, nor their transmitters spend much time near the surface. One such area is northern Missionary Bay, where boat based observations indicate greater use by dugongs than suggested by the tracking and survey data. Spot dives in the area identified a patchy cover of the seagrass *H. decipiens* to a depth of 11 m. Although recent seagrass maps of the area indicate no seagrass in this area, this particular area was not surveyed (Lee Long et al. 1998, map 1).

Missionary Bay and eastern Cleveland Bay have been confirmed as the most important areas for dugongs in this region, however, the tracking has shown that the effectiveness of dissecting out such areas for localised protection is questionable. In the Hinchinbrook area, greater Missionary Bay (including Shepherd Bay), is not divisible from the northern half of Hinchinbrook Channel (including the area off Cardwell), nor separable from the area off Lucinda. All are part of the one habitat from the

dugongs' perspective and all are linked by regular movements of dugongs. In the Townsville area, Cleveland Bay and Bowling Green Bay form the one dugong habitat. At the regional scale, the Hinchinbrook and Townsville areas are also linked by the flux of dugongs between them.

The estimates of dugong numbers in the Hinchinbrook and Cleveland Bay survey blocks are similar to those resulting from the standard dugong surveys conducted in previous years (table 17). Although the coverage of each set of surveys was similar, a statistical comparison of these estimates is not possible as the survey designs were different. Marsh's survey of Hinchinbrook extended as far north as Dunk Island, but excluded Shepherd Bay, and the density of transects on the current study was substantially greater than on Marsh's surveys. Despite the variation in the estimates, these data suggest that there has been no decline in dugong numbers in this region since 1987.

Table 17. Estimates of dugong populations in the Cleveland Bay and Hinchinbrook survey blocks. The size and shape of survey blocks was not identical for the surveys by Marsh and those of the current study.

	Population estimate +/- se		
Survey Date	Cleveland Bay	Hinchinbrook	Reference
Nov. 1987	360 +/- 92	284 +/- 131	Marsh et al. 1996
Nov. 1992	106 +/- 56	227 +/- 114	Marsh et al. 1996
Nov. 1994	183 +/- 29	484 +/- 170	Marsh et al. 1996
1997/8	266 +/- 81[1]	523 +/- 230[2]	This study

[1] Average of seven surveys [2] Average of eight surveys

During the current study dugong numbers were estimated from seven surveys of Cleveland Bay and eight surveys of Hinchinbrook. Population estimates varied considerably. In Cleveland Bay, estimates ranged from 176 (se 60) to 400 (se 97), and in the Hinchinbrook block they ranged from 306 (se 108) to 1186 (se 458; table 6). The statistical comparison of surveys was complicated by the changes to some transects instigated about halfway through the surveys. However, most comparisons resulted in significant differences in population estimates (table 3, appendix 2). The significant variations in population estimates may be the result of:

- substantial movements of dugongs occurring within the survey area - hence population estimates of Cleveland Bay or Hinchinbrook vary because of movement of dugongs between these blocks
- substantial movement of dugongs between the survey blocks and adjoining areas to the north or south - hence the significant difference in population estimates when both survey blocks were surveyed together
- substantial variation in sightability of dugongs between surveys that was not adequately described by the environmental covariates.

It is likely that all three factors were occurring. The tracking demonstrated movement of a substantial proportion of tagged dugongs between survey blocks and between the survey areas and surrounding areas. Importantly, the tracking indicated that there was no large-scale movement or migration out of the survey area (only one of 13 dugongs left the region during the tracking period).

Comparison of the results of these surveys with the results of surveys from other areas using very similar methods suggests that the density of dugongs in Cleveland Bay and Hinchinbrook is quite high (table 18). Such a comparison must be done with caution as most other surveys covered much greater areas and included areas of good and poor dugong habitat. The most comparable surveys are those of Shoalwater Bay/Port Clinton and Exmouth Gulf. Both these surveys primarily covered a relatively small inshore area that was known to be important dugong and turtle habitat. The density of dugongs was substantially higher in Cleveland Bay/Hinchinbrook than in these other areas. In Ningaloo Reef the water was particularly clear, making dugongs much more easily sighted than most other areas. Hence the very high density of dugongs observed in this area.

Table 18. Density of dugongs estimated by aerial surveys of different areas.

Location	Date	Area (km^2)	Density dugongs/km^2 +/- se	Reference
Cleveland Bay & Hinchinbrook	1997/8	888	0.75 +/- 0.20*	This study
Shoalwater Bay/Port Clinton	1997	1185	0.40 +/- 0.08	Preen 1999
Exmouth Gulf	1989	3180	0.33 +/- 0.10	Preen et al. 1997
	1994	3180	0.32 +/- 0.16	Preen et al. 1997
Ningaloo Reef	1989	555	1.14 +/- 0.23	Preen et al. 1997
	1994	869	1.11 +/- 0.37	Preen et al. 1997
Qld Gulf of Carpentaria	1997	33 026	0.12 +/- 0.02	Marsh et al. 1998
GBR south of Cape Bedford	1986–7	39 183	0.09 +/- 0.01	Marsh et al. 1994
	1992	39 183	0.05 +/- 0.01	Marsh et al. 1994
GBR north of Cape Bedford	1985	31 288	0.26 +/- 0.0	Marsh & Saalfeld 1989a
	1990	31 288	0.33 +/- 0.0	Marsh et al. 1993
Torres Strait	1987	30 533	0.41 +/- 0.0	Marsh & Saalfeld 1991
	1991	30 560	0.79 +/- 0.1	Marsh et al. 1997
Shark Bay	1989	14 906	0.71 +/- 0.12	Marsh et al. 1994
	1994	14 906	0.71 +/-0.10	Preen et al. 1997

* Average of five surveys.

The distribution of dugongs, dolphins, turtles, manta rays and gill nets in the Townsville-Cardwell region was similar in the 1970s (when Heinsohn conducted 26 shoreline surveys of the area), and in 1997–98 (when I conducted nine surveys). The important difference between the two groups of surveys was the lower sighting rate of dugongs during the recent surveys. This difference is not easily dismissed as an artefact of different survey methods as they were similar for each set of surveys. Heinsohn's surveys were flown at a higher altitude and surveyed a wider strip. Heinsohn flew at mostly at 900' (274 m) and surveyed a strip estimated to be 800 m wide (Heinsohn et al. 1979), while we flew at 550' (167 m) and used a marked strip width of 250 m. The probability of detecting a dugong decreases the further the dugong is from the flight line (see Buckland et al. 1993), so it is very likely that Heinsohn's *effective* strip width was substantially narrower than 800 m. We used a narrower strip width to avoid the problem of missing animals at greater distances. However, we did scan beyond the marked outer edge of our transects in Hinchinbrook Channel, and recorded the dugongs and dolphins (but not turtles) seen as a separate category. Consequently, the effective strip width searched during Heinsohn's and our surveys was not as different as the nominal strip widths suggest. The sighting rates of most species and gill nets were higher during the recent surveys, than during the 1970s (table 11). Assuming that all these groups have not increased in abundance, these results suggest that the closer view afforded by the lower survey altitude of the recent surveys more than compensates for the wider view afforded by Heinsohn's higher surveys.

Although dolphins, turtles, manta rays and gill nets were seen more frequently during the 1997–98 surveys than during the surveys of the 1970s, dugongs showed the opposite trend. Dugongs were seen 4.15 times more frequently in Hinchinbrook Channel in the 1970s than during the recent surveys (table 11). Assuming that dolphins, turtles and manta rays have not all increased in abundance since the 1970s, the most plausible explanation for the different trend shown by dugongs is that the number of dugongs in the region has declined since the 1970s.

Strip-transect aerial surveys indicate that there has not been a decline in dugong numbers in the

Townsville-Cardwell region since 1987 (table 17). In this regard, this region is unique to the southern Great Barrier Reef region (Marsh et al. 1996). Data on the decline in dugong deaths in shark nets, and other anecdotal information suggest that the decline in dugong numbers south of Cooktown (measured as 50% between 1987 and 1994) may have commenced in the 1960s (Marsh et al. 1996). Hence, it is plausible that there was a decline in dugong numbers in the Townsville-Cardwell region between Heinsohn's surveys and the first strip-transect survey in 1987.

The apparent decline in dugong numbers in Hinchinbrook Channel (table 11), like the decline of dugongs along most of the populated coast of Queensland, may have many causes (Marsh et al. 1996). Possible factors include gill net mortality, seagrass loss (especially around the Herbert River distributaries), and disturbance by boat traffic.

Mesh net mortality has been addressed by prohibiting the use of nets likely to catch dugongs within the Hinchinbrook Dugong Protection Area. Although this DPA would provide better protection for dugongs if its boundaries were adjusted to incorporate the Lucinda area used by dugongs (as originally proposed by Preen and Morissette 1997), mesh netting is now banned from most dugong habitat in the Hinchinbrook area. The extent of seagrass loss is unknown, although there was apparently no detected decline in seagrass abundance in the southern channel between 1987 and 1996 (Lee Long et al. 1998). Habitat deterioration due to upstream practices is a difficult issue to manage, but Landcare and Integrated Catchment Management are likely to have long-term benefits for coastal habitats. Boat traffic is an increasing problem.

The great majority of boats used in the Hinchinbrook area are powerboats. Data from the boat-paths study indicate that 80% of all boat movements in the northern Hinchinbrook area are made by small to large speedboats. The data from the aerial surveys, which included additional areas south of Hinchinbrook Island, where trawlers were common (figure 9b), suggest that 66% of boats used in the Hinchinbrook area are small to large speedboats (table 19).

Table 19. Percentage of different categories of boats recorded in the Hinchinbrook area.

Boat type	Percentage of boat types	
	Northern Hinchinbrook (from observation of boat paths)	Hinchinbrook (from aerial surveys)
Small to medium speedboat	65.2	61.5
Large speedboat	14.2	4.9
Sailing boat	11.1	13.9
Displacement hull/trawler	4.2	17.8
House boat	3.9	1.9
Cruise ship	1.4	0
n	431	309

The distribution of dugongs (based on tracking and aerial surveys) and the distribution of boats (based on aerial surveys) suggests that there may be a relationship between the two (figure 15). Within both Missionary Bay and Cleveland Bay, the greatest density of dugong sightings occurs within the area where there were few boat sightings. This inverse relationship is particularly strong in Cleveland Bay, where there is a lot of boat activity around the seagrass beds to the northeast and southwest of the area used by the dugongs. If this apparent relationship is evidence of displacement of dugongs by boat traffic, it may partly explain some of the differences between Heinsohn's surveys of the 1970s and the recent surveys. In particular, Heinsohn recorded dugongs over a much larger area of eastern Cleveland Bay (specifically on the areas of seagrass now little used by dugongs to the northeast and southwest; figure 11a) and in the southern and western areas of Hinchinbrook Channel (figure 11a).

Boat traffic in the Townsville-Hinchinbrook area has probably increased greatly since the 1970s, when George Heinsohn's surveys were flown. In the 11 years between 1984 and 1995, boat registrations in the Ingham district increased by 24% (Gilbert & Benzaken 1996). With recent developments in Hinchinbrook Channel, boat traffic in that area is likely to increase significantly. The two proposed marinas in the initial stages of being established at Oyster Point and Dungeness will attract more boats to the region. Anecdotal evidence indicates that the new boat ramp at Oyster Point has already increased boat traffic in the northern channel. Up to 70 boat trailers have been counted at this boat ramp on weekends (Whiteman 1998), which is approximately a four-fold increase compared with prior use of other tide-limited boat ramps at Cardwell (personal observation). One hundred and twenty boat trailers were counted at the Oyster Point boat ramp on Easter Saturday 1998 (Williams 1998). The greater boating activity is probably a result of the capacity to launch boats under rough and windy conditions. During such conditions it is likely that most boating will be restricted to the protected channel, thus increasing the use of this area.

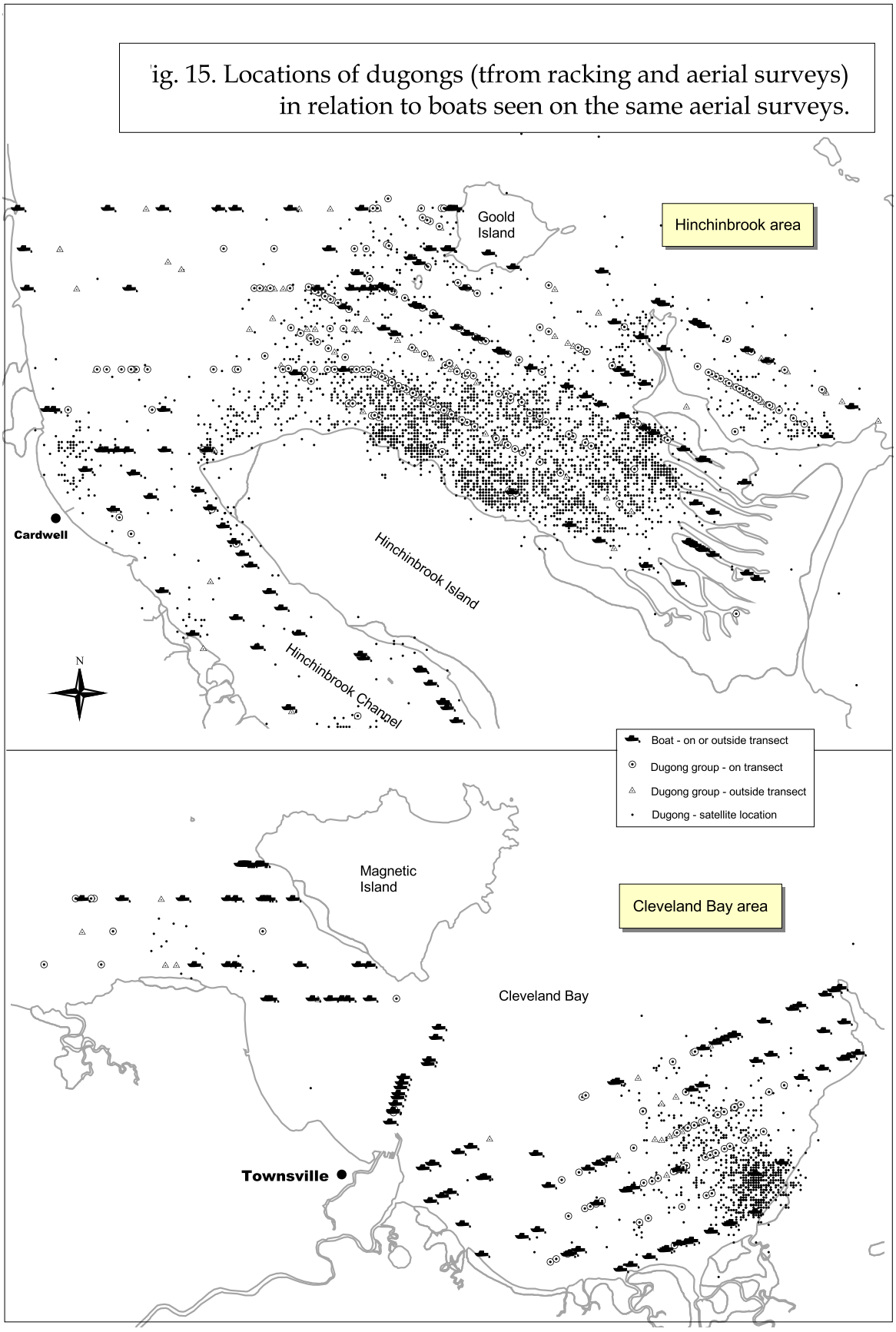
The establishment of a marina-based resort at Oyster Point will also change the nature of boating activity in the northern channel. A study of boat use in southern Moreton Bay found that the use of recreational boats is very pulsed, with 83% of usage occurring on the weekend (Curgenven & Shanco 1982). As a result there is relatively little boat traffic for five days/week. The pattern of boat usage at a marina resort is likely to be very different. Fishing dinghy hire, jet ski hire, para sailing, water skiing, sight seeing cruises, ferry services to Hinchinbrook Island and fast-cat trips to the reef can be expected to occur with the same frequency seven days/week. Consequently, not only is overall boat activity likely to increase, but so too will the average daily intensity of boat traffic.

Boat strike of dugongs is known to occur in the northern Hinchinbrook area under the current intensity of boat traffic (Illidge 1996). In Florida there has been a tight correlation between the increase in boat traffic and the increase in manatee deaths caused by boat strike (Wright et al. 1995). The predicted increase in boat traffic in the Hinchinbrook area can be expected to result in an increase in boat strikes, and an increase in other effects of boat disturbance such as habitat alienation and restricted access to intertidal seagrasses. For these reasons it is important to establish control of boat traffic, by regulation and education, before the increase occurs. This will help prevent the gradual decline of the quality of the dugongs' habitat.

Dolphins

This report presents the first reliable data on the species composition of dolphins in the Townsville-Cardwell area, and indeed for most of the Queensland coast. Unfortunately, the number of each species seen on most surveys was inadequate to calculate meaningful population estimates.

The breakdown of dolphin species in Missionary Bay and Cleveland Bay, as determined by aerial survey, was broadly similar to the species composition of dolphins identified in the Hinchinbrook area by members of the public (table 20). In both cases Humpback dolphins were the most commonly seen species (based on number of groups, not number of individuals), while similar proportions of Irrawaddy and Bottlenose dolphins were seen.



ig. 15. Locations of dugongs (tfrom racking and aerial surveys) in relation to boats seen on the same aerial surveys.

Humpback dolphins were common at both ends of Hinchinbrook Channel, in Missionary Bay and in Cleveland Bay (figures 9a and 12b). Irrawaddy dolphins were most common in Hinchinbrook Channel and in the southern part of Halifax Bay (figure 9b). By contrast, Bottlenose dolphins were most common in offshore areas of Halifax Bay (table 10, figure 9c). The apparent preference of Humpback

and Irrawaddy dolphins for protected, nearshore waters, and Bottlenose dolphins for offshore waters is consistent with what is known of these species (Corkeron et al. 1997; Klinowska 1991; Stacy & Leatherwood 1997). Humpback and Irrawaddy dolphins are listed as Rare under Queensland legislation (*Nature Conservation Act 1992*).

Table 20. Percentage of dolphin species recorded by the public, and on aerial surveys.

	Percentage of dolphin groups recorded	
	Public sightings - Hinchinbrook area	Aerial surveys - Hinchinbrook & Cleveland Bay
Humpback dolphin	40	51
Irrawaddy dolphin	35	18.4
Bottlenose dolphin	20	24.5
other	5	6.1
n	20	49

Turtles

The distribution of turtles in the Townsville-Cardwell region closely follows the known distribution of seagrasses in the area (Lee Long et al. 1998). Consequently, turtles were most frequently seen in greater Missionary Bay and in the eastern half of Cleveland Bay (figure 7). Estimates of turtle numbers varied significantly amongst surveys (table 3). These differences may reflect movement of turtles between survey blocks between surveys, or movements between survey blocks and adjacent areas that were not surveyed. They may also be due to variable sightability as a result of weather and water clarity differences amongst surveys, or to different diving and surfacing behaviour of turtles on different surveys.

Table 21 shows the density of turtles estimated in a variety of areas, in comparison to the Townsville and Hinchinbrook area. It is difficult, however, to compare the density of turtles in Cleveland Bay and the Hinchinbrook area with surveys of other areas, as most other surveys have covered much greater areas, including a greater diversity of habitats (e.g. nearshore embayments to offshore reefs). The surveys of Shoalwater Bay/Port Clinton and Exmouth Gulf are the most comparable surveys. The survey of Ningaloo reef is not strictly comparable because of the different habitat and the very clear water. The density of turtles in Cleveland Bay/Hinchinbrook is similar to that in Exmouth Gulf but only about half that of Shoalwater Bay/Port Clinton (table 21). The latter area, which experiences very low levels of visitation and boat traffic is known to support exceptionally high numbers of turtles.

Table 21. Density of turtles estimated by aerial surveys of different areas.

Location	Date	Area (km^2)	Density turtles/km^2 +/- se	Reference
Cleveland Bay & Hinchinbrook	1997–98	888	1.13 +/- 0.20*	This study
Shoalwater Bay/Port Clinton	1997	1185	2.03 +/- 0.31	Preen 1999
Exmouth Gulf	1989	3180	1.42 +/- 0.28	Preen et al. 1997
	1994	3180	1.02 +/- 0.22	Preen et al. 1997
Ningaloo Reef	1989	555	4.51 +/- 0.47	Preen et al. 1997
	1994	869	4.9 +/- 0.83	Preen et al. 1997
Qld Gulf of Carpentaria	1997	33 026	0.48 +/- 0.04	Marsh et al. 1998
GBR south of Cape Bedford	1986–87	39 183	0.64 +/- 0.04	Marsh et al. 1994
	1992	39 183	0.85 +/- 0.13	Marsh et al. 1994
GBR north of Cape Bedford	1985	31 288	1.03 +/- 0.08	Marsh & Saalfeld 1989b
	1990	31 288	1.46 +/- 0.11	Marsh et al. 1993
Torres Strait	1987	30 533	1.43 +/- 0.16	Marsh & Saalfeld 1991
Shark Bay	1989	14 906	0.43 +/- 0.05	Preen et al. 1997
	1994	14 906	0.57 +/-0.05	Preen et al. 1997

* Average of five surveys.