DISCUSSION

The Shoalwater Bay area is a harsh environment for coral to live in. The tidal range during spring tides is around seven metres, currents are strong, and the water is normally turbid from stirred up silt. Mean visibility during this survey, during which we experienced mainly good weather, was just over five metres. Visibility was highest around the north-east sector reefs (seven to nine metres), which were visited during calm weather. When winds were 20 knots or more resuspended silt reduced visibility to two metres or less. The reefs were not true reefs, the corals growing on rocks or rubble banks in most cases, and only rarely extended deeper than about five metres below AHD. Dense macro algal forests were found over the entire depth range of hard substratum, even on North Ripple Island where hard substratum extended down to about 10 metres below AHD.

A comparison of coral cover on the Shoalwater Bay reefs with other areas in the Great Barrier Reef region is interesting (table 7). Hard coral cover on these reefs was generally lower than that recorded during previous fringing reef surveys from the Great Barrier Reef region, with the exception of those other reefs that, like the Shoalwater Bay reefs, lie within the area between Mackay and Port Clinton where the maximum tide range is greater than five metres. Van Woesik (1992) surveyed a large number of sites within this area and recorded coral cover values ranging from 5.3% around Percy Isles to 41% around Prudhoe Island. Most reefs in this area were algal dominated. Although the Shoalwater Bay reefs lie at the heart of this strong tide area, the coral cover we recorded was at the upper end of that recorded by van Woesik (1992) from 12 other locations within this area. The Shoalwater Bay grand mean coral cover of 38% was about twice the grand mean from van Woesik's locations of 19% cover. Coral cover from the Keppel Islands to the south of this strong tide area is comparable to that from the other fringing reefs to the north of this area (table 7). Hence, it is likely that the strong tidal currents and resulting silt movement are the major factor responsible for the low coral cover in this area, rather than lower sea temperatures.

Table 7. Summary of hard coral cover on Great Barrier Reef fringing reefs. Figures show grand mean percentage cover from groups of 20-metre line transects. [1] Ayling et al. 1997; [2] Ayling and Ayling 1991a; [3] Ayling and Ayling 1995a; [4] Kaly et al. 1993; [5] Ayling and Ayling 1995b; [6] Ayling and Ayling 1996; [7] van Woesik 1992, na = not available.

Region	Date	Latitude °S	No. sites	Hard coral cover mean	sd
Cape Flattery[1]	Feb 1996	14.9	5	**46.2**	12.2
Cape Tribulation[2]	Nov 1995	16.0	12	**60.0**	12.5
Cairns Section Nth[3]	Jan 1995	16.5	34	**81.0**	7.5
Magnetic Island[4]	Aug 1993	19.2	36	**48.4**	18.8
Middle Reef[4]	Aug 1993	19.2	5	**74.6**	3.9
Hamilton Island[5]	Mar 1995	20.3	6	**54.4**	5.7
Sir James Smith Gp.[7]	1991	20.7	56	**22.0**	na
Northumberland Is.[7]	1991	21.5	20	**11.7**	na
Shoalwater Bay[6]	Dec 1995	22.3	34	**37.8**	16.2
Keppel Islands[7]	1991	23.2	8	**54.3**	na

Biodiversity, recorded as the number of coral species encountered at each location, was also lower on the Shoalwater Bay reefs than on most other Great Barrier Reef region fringing reefs. A combined total of only 87 species were recorded over 25 hours of diving in the Shoalwater Bay region, compared with 131 species recorded during two hours of diving around Dent Island in the Whitsunday Group of Islands (Ayling and Ayling 1995b), 120 species from 30 hours of diving on 17 Cairns Section fringing reefs (Ayling and Ayling 1995a), and 143 species from 10 hours of diving around Cape Tribulation fringing reefs (Veron 1987). The number of coral species at each location was also lower than in other areas. In Shoalwater Bay the coral species

recorded at each location ranged from 23–58, compared with 35–96 from 17 locations in the Cairns Section, 131 from one location at Dent Island and 93 from one location at Hamilton Island (Ayling and Ayling 1995c). The number of coral species from Shoalwater Bay was, however, comparable to the approximately 90 species recorded from the Keppel Islands by van Woesik (1992).

The biodiversity value proposed by Done (1995) provides a measure of the uniqueness of each reef in a regional context, in this case the Great Barrier Reef region; defining the reefs value in terms of the proportion of unique or rare species that occur there. This uniqueness value was similar for most of the survey reefs because most of the regionally rare species were common throughout the Shoalwater Bay area, and hence it did not provide much guidance for managers in ranking reefs within the Shoalwater Bay area. To look at relative value among the Shoalwater Bay locations the region would need to be redefined as Shoalwater Bay and relative rareness set within this smaller region. This would defeat the purpose of the index, as one-off records of species such as *Acropora tenuis*, *A. millepora* and *Podabacia crustacea* that were rare and unimportant in the Shoalwater Bay area but extremely common on most Great Barrier Reef reefs, would have a disproportionate effect on the biodiversity value compared with common species such as *A. glauca* and *A. solitaryensis* that were very important to managers, being rare on most of the Great Barrier Reef. While the Done biodiversity value may give a ranking of relative value in a Great Barrier Reef wide context this does not necessarily help managers to rank value within a smaller area such as Shoalwater Bay.

In terms of biodiversity and species composition it is the common presence of a number of southern species that are common on fringing reefs south of the Great Barrier Reef region and on southern reefs such as Lord Howe Island, but normally rare on the Great Barrier Reef, that makes these reefs of value to managers. Similarly, the complete absence of a number of groups that are usually common on reefs in other areas is a point of value to managers; it makes these reefs unusual and unique, and suggests that representative examples should be preserved. It is interesting to compare the species composition of the Shoalwater Bay reefs with those from the Keppel Islands and the Northumberland Islands. Van Woesik (1992) records *Acropora glauca* and *A. solitaryensis* from the Keppels but not *Acanthastrea hillae* or *A. bowerbanki*. In terms of species absences he also does not list any *Echinopora*, *Pectinia*, *Merulina*, or *Oxypora* species, but he does record *Fungia* spp. and *Pavona venosa*. In the Northumberland Islands all of the species notably absent in Shoalwater Bay are recorded from at least some sites.

Done (pers. comm.) has suggested that it was his intention that the bioconstruction value be sensitive to the area covered by the various age classes, rather than just reflecting mean age. Hence the value based on proportion of individuals, that gives an approximation of mean colony age, is not a good measure of bioconstruction value. We have maintained the measure of colony age in this report, and as part of the reef ranking process, because we feel it offers another useful piece of information for reef managers.

The percentage cover based bioconstruction value proposed by Done gave a measure of bioconstruction for each reef that was positively correlated to a direct count of large coral colonies from the same reef ($r^2 = 0.31$). Within the Shoalwater Bay area two reefs (Sun and Holt) stood out as having a relatively high bioconstruction value. There were a few cases where the bioconstruction value did not seem to relate to the state of the reef. The Pearl Bay reefs, with a coral cover of only 16.5%, had a bioconstruction value well above that of all other reefs except Sun Island and Holt Island, because coral cover at this location was dominated by a few large, old colonies. While it is true that the time for replacement of such a community is high, it is hard to see the use of ranking it above reefs such as North Ripple that have over 40% coral cover, and a larger number of colonies over 100 centimetres in size, but have a low bioconstruction value because most of the corals are relatively young. Similarly, Clara Island, in spite of having only 7% coral cover and a very few colonies over 100 centimetres, had only the fifth lowest bioconstruction value. The problem here seems to be that while the time for replacement of a community with only a few old colonies is greater than one with large

numbers of young colonies the bioconstruction value of lots of small colonies may be equal to or greater than a very few large colonies, but this is not taken into account using Done's measure. However, on the whole this value did appear to provide a useful value ranking for the survey reefs.

Although our measure of mean colony age gives an underestimate due to bias in the size frequencies constructed from the line intersect data, it is clear that mean age of corals on the Shoalwater Bay reefs was low. Our biased estimate of grand mean age was only 12.4 years (excluding Pearl Bay). This suggests either that these reefs are subjected to major disturbance on a relatively short return period, or that the corals are growing very slowly as a result of high siltation rates, low water clarity and/or low temperatures. Cyclones could cause extensive damage in these shallow waters, both from wave action and from flooding and silt resuspension, and the relatively enclosed shallow waters of Shoalwater Bay are probably conducive to surface water warming and hence major bleaching events. The relative lack of exceptionally large coral colonies which are usually a feature of fringing reefs (Ayling and Ayling 1995a) also suggests that the reefs are subject to regular disturbance. Assuming normal growth rates, the oldest coral we measured in Shoalwater Bay was probably only between 100 and 200 years old. The largest massive poritid measured during this survey was only around two and a half metres diametre; heads of over five metres diametre are frequently encountered in other fringing reef areas. Acroporids over 10 metres across are also frequently encountered on fringing reefs in other areas, whereas in Shoalwater Bay we only measured 16 acroporid colonies over five metres diametre and only one of around 10 metres across. Colonies of *Goniopora* species over five metres across are also usually frequently encountered on fringing reefs, but none over two metres were measured on these survey reefs. There were many large corymbose plate and tabulate acroporids between one to five metres in diameter on the north-east sector Shoalwater Bay reefs. While large tabulate colonies are a conspicuous feature of many Central and Capricorn Section offshore reefs they are not usually so abundant on fringing reefs.

Our impression was that the Shoalwater Bay reefs were no more silty or turbid than fringing reefs in other areas we have surveyed. The occurrence of dense algal forests down to depths of about 10 metres below AHD also suggests that the water clarity in Shoalwater Bay is not unusually turbid compared with other fringing reefs; dense algal forests are rarely found below five metres depth on most fringing reefs. Corals on some extremely turbid fringing reefs, e.g. Middle Reef off Townsville, appear to grow at normal or above normal rates (Kaly et al. 1993), and it is unlikely that corals in Shoalwater Bay are growing at below normal rates for this reason. It is also unlikely that water temperatures are significantly lower in Shoalwater Bay than in the Whitsunday Island Group where fringing reef development is more 'normal'. While it is possible that these factors are slowing coral growth in the Shoalwater Bay area, it seems more likely that a high disturbance regime is responsible for the observed patterns.

The ranking of reef value within the Shoalwater Bay region was done by combining a number of reef attributes, and, at least subjectively, appeared to give a biologically meaningful and useful result. The wide range in the overall ranking value is interesting: the 18 reefs ranged from 1.83 to 4.36 on a scale of 0–5. This extreme variability has not been a feature in other surveys of fringing reefs. As an example, in the Cairns Section survey of 17 reefs, coral cover ranged from 65 to 93% (Ayling and Ayling 1995a), compared with 7–66% for this survey. Around Hamilton and Dent Islands coral cover at nine sites ranged from 32 to 71% (Ayling and Ayling 1991b), and on 12 sites in the Cape Tribulation region cover ranged from 40 to 74% (Ayling and Ayling 1991a). Similarly, aesthetic value on the Shoalwater Bay reefs ranged from 1 to 4.5 on a scale of 0-5. Although aesthetic estimates have not been made from other fringing reef surveys, my post-hoc opinion is that most would rate between three and five. This variability may result from the Shoalwater Bay area being marginal for the development of fringing reefs.

Implications for Management

The Great Barrier Reef Marine Park Authority was interested in determining the status of fringing reefs within the Shoalwater Bay and Byfield Coast area as a prerequisite for preparing a management plan for these areas. Although these reefs generally have less coral cover, lower biodiversity, and fewer large coral colonies than fringing reefs in regions of the Great Barrier Reef outside the strong tide region between Mackay and Port Clinton, they have a number of unique features, notably the abundance of a number of coral species that are rare or absent on the rest of the Great Barrier Reef (note that some of these species also occur on fringing reefs to the south of Shoalwater Bay such as around the Keppel Islands). Within the above mentioned strong tide area the Shoalwater Bay reefs appear to have a relatively high cover of corals. They are also unusual in the absence of many species that are common on most other fringing reefs. Thus although these reefs are generally not true reefs, and may be subject to high levels of disturbance, the reef type they represent is probably worthy of some protection.

It was suggested that some ranking of the reefs on values that would be meaningful for management would assist with this process. The value ranking we have provided could be used by managers in a number of ways. They might choose to protect the reefs with high or above average value, or they might choose clusters of reefs that incorporate the high value reefs along with other reefs with average or below average value.

Given that there were a number of differences in coral community composition between northern reefs (north of Collins Island) and southern reefs, it may be most appropriate to choose two clusters of reefs for protection. In the northern sector the adjacent reefs of Mumford, Ten Pin Rock, Holt and Unnamed includes one reef of above average value along with three average reefs. Note that it is reefs in this northern sector that include the greatest abundance of the unique *Acropora* species mentioned above. In the southern sector the cluster of Swan, Osborne, Sun and Clara includes the reef with the highest value, along with two average reefs and the lowest value reef.

Given the variability of the reefs in this region, and the suggestion that disturbance levels are high, the current value ranking is not likely to remain stable in the medium to long term and it may be prudent to include a variety of rankings in any protected areas.

While the Done biodiversity value gives a ranking of relative value within the larger Great Barrier Reef region, it did not appear to provide a very useful value ranking for reefs within a limited area such as Shoalwater Bay. Done's proposed bioconstruction value was more useful in this local context, although there were some cases where the calculated values seemed at variance with empirical estimates of reef value. Note that in future surveys of this type a more determined attempt should be made to collect data in a way that would make calculation of these values easier and less affected by biases. These methodological changes would almost certainly add considerably to field time on each reef but the increased value of the data may offset this. Trials would need to be made to check on the most cost effective methods to use.