

RESULTS

Physical Characteristics of the Reefs

True reef development on most of the reefs appeared to be minimal; the reefs were developed on broken rocky shores, or on rubble banks. Apart from the relief provided by rock boulders in shallow water, and by the occasional large coral colony, there was little topographic complexity to these reefs. Most of the reefs were shallow, extending only a few metres below AHD (Australian Height Datum - approximately the level of the lowest spring tide), although, given the extreme tide range in the Shoalwater Bay area of from four to seven metres, depths would exceed 10 metres at high tide. The NE sector reefs were the deepest, reaching depths of between five and 10 metres below AHD in places.

The large tidal range, combined with the size of the enclosed bay, gives rise to high currents throughout this area. Although we surveyed the area through the neap tide period, tidal currents of from 1–4 knots were experienced.

Cover of Benthic Organisms

With few exceptions the reefs supported a high cover of turfing and macroalgae, with cover in the surveyed strata ranging from about 10 to 60% (figure 2, appendix 1). This cover was not restricted to a narrow fringe in shallow water, as is normal for most fringing reefs, but covered the range of depths encountered at most locations, down to at least six metres below AHD. Seagrasses occurred on many of the reefs, and were recorded in the transects at up to 18% cover from sites where regular sand patches were encountered. The grand mean cover of algae and seagrasses from all locations was about 38%, the same as the grand mean cover of hard corals.

Sponges were not an important benthic group on any of the reefs, with the highest cover recorded being only 1.6% on Blind Rock, and with a grand mean from all reefs of only 0.5% cover.

As mentioned above grand mean coral cover was very similar to total algal cover at 37.8%. There were significant differences in total coral cover between sites within each reef (table 2). Sites were between 100 and 500 metres apart and patchiness at this scale is a feature of most reefs. Hard coral cover at the locations surveyed was very variable (figure 2), with mean cover per reef ranging from a low of only 7.3% at Clara Island to a high of 66.2% at Sun Island. There were seven groupings of reefs with non-significantly different coral cover, each group covering from six to nine reefs and spanning a coral cover range of about 20% (table 3). There was no general correlation of coral cover with the position of each reef within Shoalwater Bay, although cover was on average lower around the north-west sector reefs of Collins, Five Trees, Lingham and White Rocks (figure 2).

Pocilloporid corals were not generally abundant, with a grand mean of only 1.4% cover. This group was, however, about twice as abundant on the northern reefs than on the southern reefs (figure 2). The needle coral *Seriatopora hystrix* was only recorded as occasional colonies from two of the southern reefs but was commonly found on almost all northern reefs. Acroporids were the dominant coral group on all reefs except coral-poor Clara, accounting for a mean of over 56% of total coral cover (figure 2). On the northern reefs explanate *Montipora* species covered an area about equal to the area covered by all *Acropora* species (mainly corymbose plate forms), but on all southern reefs explanate *Montipora* species were about four times as abundant as *Acropora* species (figure 3). Poritid corals were not abundant on these reefs, covering a mean of only 1.6% of the substratum, and showed no differences between northern and southern reefs. Of the other coral groups, *Turbinaria* spp. was most abundant with a grand mean cover of 6.8%, followed by faviids with 4.3% cover. Both these groups were moderately more abundant on the southern reefs, and formed a higher proportion of the total coral cover on these reefs (figure 2, appendix 1).

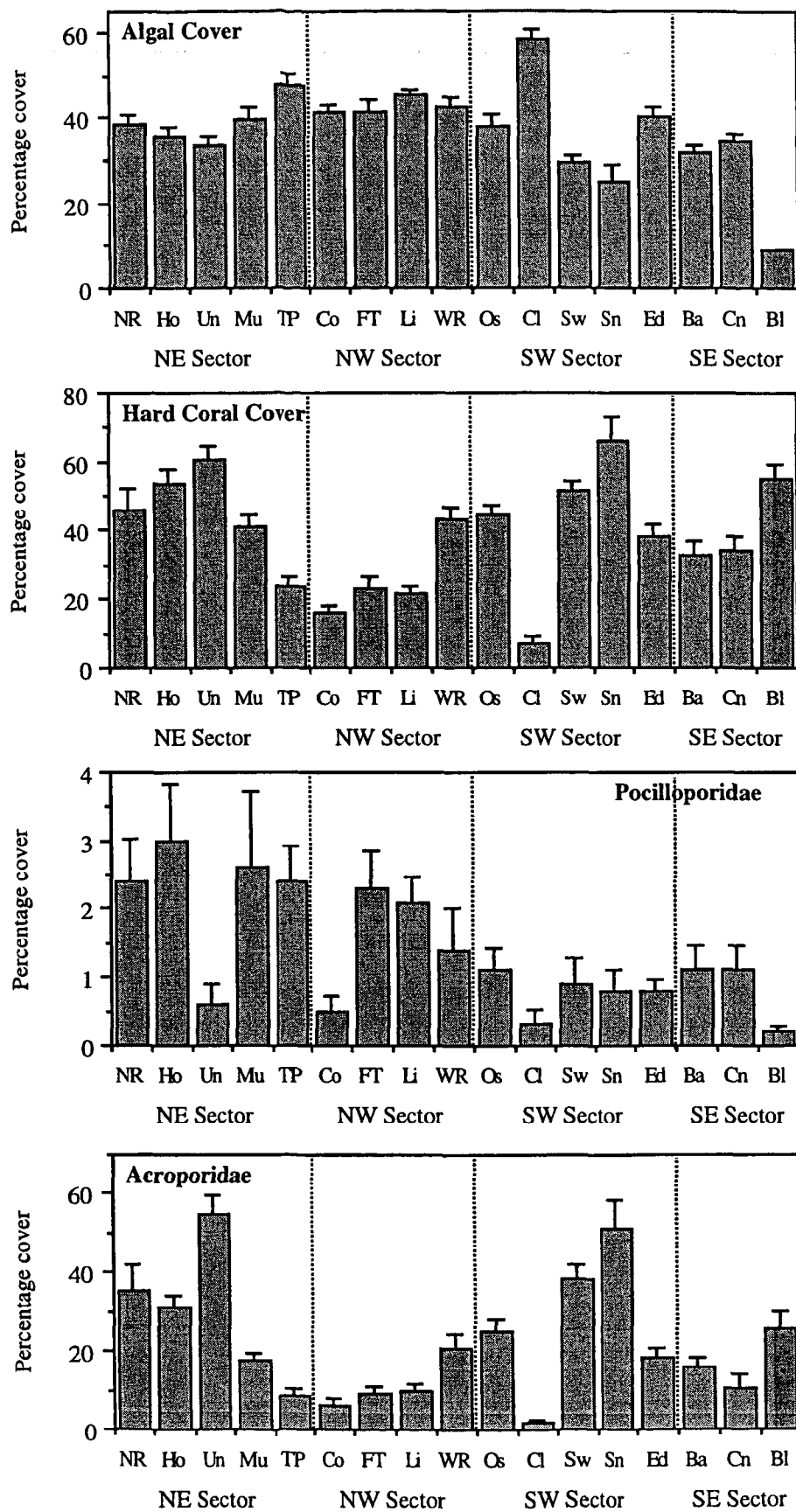


Figure 2. Abundance of benthic groups on the survey reefs. Reefs are grouped into north-east (NE), north-west (NW), south-west (SW) and south-east (SE) sectors of Shoalwater Bay. Graphs show mean percentage cover. Error bars are standard errors. Reef abbreviations as in table 1.

Figure 2. (continued)

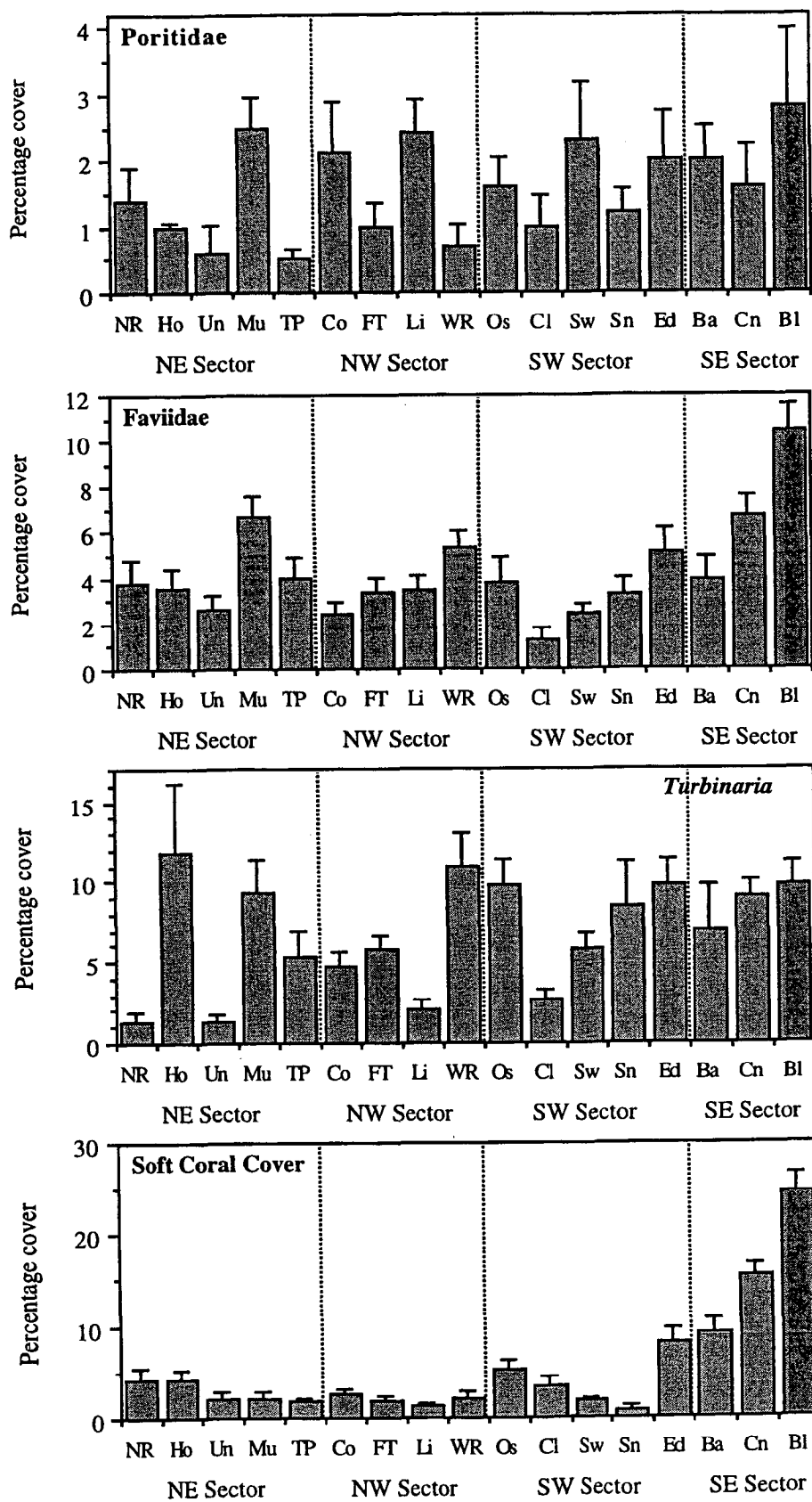


Table 2. Anova table for patterns of total coral cover among the survey reefs

Source of Variation	df	MS	Error Term	F value	p value
Reef	16	2823.5	Site (reef)	4.446	0.002
Site (reef)	17	604.816	Residual	6.956	<0.001
Residual	136	86.949			

Table 3. Groupings of reefs with similar coral cover. The significance of differences was determined using Fishers LSD tests. Abbreviations as shown in table 1. Solid lines cover reefs with non-significant coral cover differences.

Cl Co PB Li FT TP Ba Ed Mu WR Cn Os NR Sw Ho Un Sn

Lowest Highest

Soft corals were generally not common on these reefs, with the notable exception of the south-east sector reefs (figure 2). On Connor Rock soft corals covered over 15% of the substratum and on Blind Rock a variety of gorgonian and tufty low species, along with *Sinularia* and *Sarcophyton* species, accounted for almost 25% cover.

Biodiversity

The number of species recorded on each reef ranged from 23 on coral-poor Clara Island to 58 on Osborne Island, with a grand mean of 48 species (appendix 2). The number of species recorded on northern reefs (49) was similar to that on southern reefs (47). The most notable feature of the coral species from these reefs was the presence of several common species that are normally very rare on the Great Barrier Reef but are usually found on more southern fringing reefs and around Lord Howe Island and Elizabeth and Middleton Reefs. This group included *Acropora glauca*, *A. solitaryensis*, *Acanthastrea hillae* and *A. bowerbanki*, but may have included other species that were not recognised: these are all species none of the field personnel were familiar with. Two siderastreid species, *Psammocora superficialis* and *Coscinarea columna*, that are usually uncommon on fringing reefs were common on all reefs surveyed. There were also a number of notable absences of species and whole groups that are normally common on fringing reefs elsewhere on the Great Barrier Reef, including the Northumberland Islands and Percy Isles. The absences included: all *Pavona* species, all free living fungiids (*Podabacia crustacea* was recorded from three reefs), all *Pectinia* species, *Merulina ampliata*, all *Echinopora* species, *Porites cylindrica* and all *Caulastrea* species. The branching fire coral *Millepora tenella* was also not recorded from these reefs.

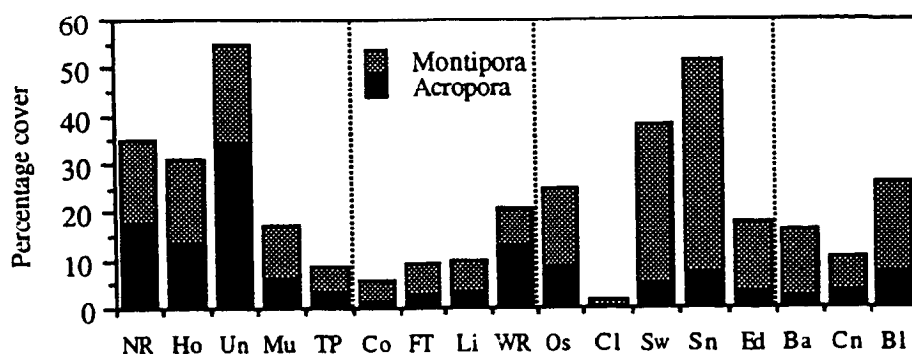


Figure 3. Distribution of *Montipora* spp. and *Acropora* spp. on the survey reefs. Mean percentage cover is shown. Reef abbreviations as per table 1.

Done's biodiversity value was calculated for each location using the species lists from appendix 1 and species abundance information from Veron (1986). Of the 87 species recorded during this survey, 13 were classed as rare in the Great Barrier Reef region by Veron (although there may be some coral species in this area that have not been previously reported from the Great Barrier Reef region, they were not recognised by the field personnel). The biodiversity values were all similar, ranging from 18.5 at Collins Island to a high of 25.7 at Clara Island (table 4). This value was converted to a rating between 0 and 5 by setting a biodiversity value of 0 as a rating of 0, and the maximum value of 25.7 as a rating of 5, and converting all intermediate values proportionally (table 4).

Table 4. Biodiversity values for the Shoalwater Bay locations. Hard coral only. Absolute values for Done's biodiversity value are shown along with a rating between 0 and 5

Location	No. coral species	No. rare species	Biodiversity value	Rating
Pearl Bay Group	41	5	21.0	4.09
North Ripple Is.	55	7	21.4	4.16
Holt Is.	55	8	23.0	4.47
Unnamed Is.	44	5	20.3	3.95
Mumford Is.	53	7	21.9	4.26
Ten Pin Rock	53	8	23.6	4.59
Five Trees Cay	37	5	22.1	4.30
Collins Is.	42	4	18.5	3.56
Lingham Is.	56	8	22.9	4.46
White Rocks	49	6	21.0	4.09
Osborne Is.	58	10	25.5	4.96
Clara Is.	23	4	25.7	5.00
Swan Is.	52	6	20.3	3.95
Sun Is.	51	5	18.8	3.66
Edward Is.	48	7	23.1	4.49
Bay Is.	56	7	21.3	4.14
Connor Rock	36	5	22.5	4.38
Blind Rock	50	8	24.4	4.75

Bioconstruction

Done's bioconstruction value calls for the use of either the 'proportion of individuals, *or* of defined area covered by individuals' (authors' italics) and the value is expressed in years. In practice using proportion of individuals gives a completely different result to using percentage area covered. Using proportion of individuals gives a value that approximates mean colony age

but using percentage cover does not. We calculated Done's bioconstruction value (V_w) for each of the reefs surveyed using both proportion of individuals and percentage cover, and converted both these to a rating between 0 and 5 in the same way as the biodiversity value (table 5). The value based on proportion of individuals may have a few problems as an indicator of reef bioconstruction, e.g. age is not necessarily related to size and a 50 year old *Acropora* colony may contribute far more to reef structure than a 200 year old faviid. We also used a direct count of the number of colonies encountered during the line transect surveys, and the search for larger colonies by the second observer on each reef, that were over 100 centimetres in diameter as a measure of relative bioconstruction value, again converted to a rating of between 0 and 5 (table 5). This sample of large colonies was obtained in a similar manner on each reef and was suitable for comparative purposes among the locations. Done's bioconstruction value based on percentage cover was positively correlated to the number of large corals counted at each location ($r = 0.552$; $p < 0.05$), suggesting that these two estimates probably provide a better measure of bioconstruction than does mean colony age.

Table 5. Bioconstruction values of the survey reefs. Three measures of bioconstruction are given: Done's bioconstruction value (V_w) based on both proportion of individuals (V_{w1}), and percentage cover (V_{w2}), and a count of the number of colonies over 100 cm recorded during the survey. Both absolute values, and ratings on a scale of 0–5, are given for these measures.

Reef	V_{w1} (age)	V_{w1} rating	V_{w2} (% cover)	V_{w2} rating	No. > 100	> 100 rating
Pearl Bay Group	27.53	5.00	28.67	3.70	31	2.46
North Ripple Is.	11.26	2.05	11.52	1.49	44	3.49
Holt Is.	11.35	2.06	28.67	3.70	52	4.13
Unnamed Is.	8.83	1.60	20.22	2.61	58	4.60
Mumford Is.	13.37	2.43	20.54	2.65	45	3.57
Ten Pin Rock	14.17	2.57	18.11	2.34	29	2.30
Five Trees Cay	11.34	2.06	16.34	2.11	16	1.27
Collins Is.	13.49	2.45	12.20	1.57	16	1.27
Lingham Is.	10.50	1.91	10.48	1.35	18	1.43
White Rocks	11.77	2.14	18.17	2.34	39	3.10
Osborne Is.	10.23	1.86	16.17	2.09	32	2.54
Clara Is.	11.62	2.11	14.36	1.85	4	0.32
Swan Is.	12.18	2.21	17.87	2.31	56	4.44
Sun Is.	16.34	2.97	38.77	5.00	63	5.00
Edward Is.	15.76	2.86	23.88	3.08	38	3.02
Bay Is.	12.49	2.27	14.69	1.90	32	2.54
Connor Rock	14.55	2.64	20.97	2.70	10	0.79
Blind Rock	11.18	2.03	14.26	1.84	23	1.83

With the exception of the Pearl Bay Group reefs our estimate of mean colony age on these reefs was low, ranging from 8.8 years on Unnamed Island to 16.3 years on Sun Island (table 5). Note that these age estimates are on the low side as the biased length frequency distributions would have underestimated colony diameter in most cases. In the Pearl Bay Group a combination of very few small corals and a few large colonies gave a mean age of 27.5 years. The bioconstruction values obtained from the count of large colonies and from the percentage cover of the different age classes were usually at variance with that derived from mean colony age (table 5). For example Pearl Bay Group and Connor Rock both rated below average in number of large colonies but were first and fourth rated respectively in mean age. At the other extreme, Unnamed Island was ranked second in number of large colonies but had the lowest mean age. Done (pers. comm.) suggests that the bioconstruction value obtained from the percentage cover data provides the most useful measure.

Rating of Overall Reef Value

Done suggests combining the criteria of biodiversity and bioconstruction values to get a five point scale for reef value (figure 4). Using this system for the Shoalwater Bay reefs confirms that they all have similar biodiversity value, in the lower half of the moderate value (3) square, and shows that they span a bigger range of bioconstruction value, from young to moderately old. All the reefs have moderate value based on this ranking.

To better rate the relative value of the reefs within Shoalwater Bay to managers we combined a number of attributes of each reef to make an overall estimate of relative reef value (table 6). The seven attributes used were: total coral cover, number of coral species recorded during the survey, biodiversity value (V_b), mean colony age (V_{a1}), bioconstruction value based on percentage cover (V_{a2}), number of large coral colonies recorded during the survey, and the subjective aesthetic rating given to each reef.

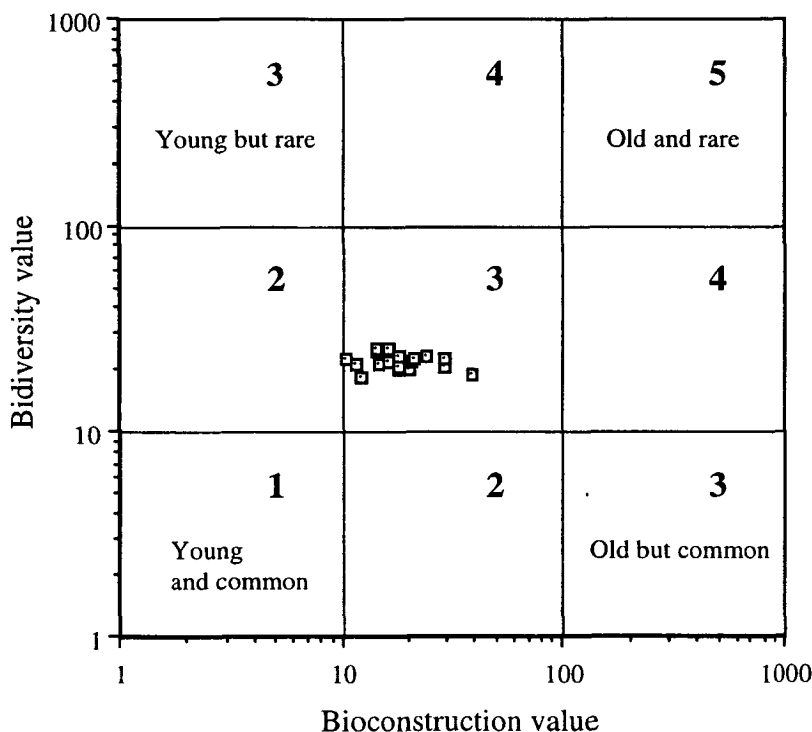


Figure 4. Suggested five point scale for reef value showing ranking of the Shoalwater Bay reefs. Done's joint criteria value is shown (1-5), combining biodiversity value with bioconstruction value based on age structure and the percent cover of the coral groups.

On the basis of these value rankings (table 6) the survey reefs can usefully be divided into three groups. Two reefs (Sun and Holt) are of above average value, three others (Five Trees, Collins, Clara) are of below average value, while the other 13 are of average value (the average range is taken as the mean \pm one standard deviation: 2.41-3.65).

It is interesting to look at the relationships among the various reef attributes. There was a strong positive correlation between coral cover and the number of large corals ($r^2 = 0.65$), but no relationship between coral cover and mean colony age ($r^2 = 0.09$), or between coral cover and the number of species ($r^2 = 0.11$). Subjective aesthetics depended strongly on both coral cover ($r^2 = 0.84$), and the number of large corals ($r^2 = 0.53$), but not on the number of species ($r^2 = 0.08$), or the mean colony age ($r^2 = 0.01$), or on underwater visibility ($r^2 = 0.01$). The lack of relationship between aesthetics and underwater visibility is interesting given that we have always suspected there would be a positive relation between these two factors.

Table 6. Relative value of the Shoalwater Bay reefs. Reef attributes on a scale of 0–5 are shown to give each attribute equal value, along with a grand mean value for each reef. V_b = biodiversity value; V_{w1} = mean colony age; V_{w2} = bioconstruction value based on percentage cover

Reef	Coral cover	No. of species	V_b	V_{w1}	V_{w2}	Corals > 100 cm	Aesthetics	Mean value
Sun Is.	5.0	4.4	3.7	3.0	5.0	5.0	4.5	4.36
Holt Is.	4.1	4.7	4.5	2.1	3.7	4.1	3.0	3.74
Unnamed Is.	4.6	3.8	4.0	1.6	2.6	4.6	4.0	3.59
Swan Is.	3.9	4.5	4.0	2.2	2.3	4.4	3.5	3.54
Edward Is.	2.9	4.1	4.5	2.9	3.1	3.0	3.0	3.35
Mumford Is.	3.1	4.6	4.3	2.4	2.7	3.6	2.5	3.30
Blind Rock	4.1	4.3	4.8	2.0	1.8	1.8	3.5	3.20
White Rocks	3.3	4.2	4.1	2.1	2.3	3.1	3.0	3.16
North Ripple Is.	3.5	4.7	4.2	2.1	1.5	3.5	2.5	3.13
Osborne Is.	3.4	5.0	5.0	1.9	2.1	2.5	2.0	3.12
Pearl Bay Gp.	1.2	3.5	4.1	5.0	3.7	2.5	1.5	3.08
Ten Pin Rock	1.8	4.6	4.6	2.6	2.3	2.3	1.5	2.81
Bay Is.	2.5	4.8	4.1	2.3	1.9	2.5	1.5	2.81
Connor Rock	2.6	3.1	4.4	2.6	2.7	0.8	3.0	2.74
Lingham Is.	1.6	4.8	4.5	1.9	1.4	1.4	1.5	2.44
Five Trees Cay	1.8	3.2	4.3	2.1	2.1	1.3	1.0	2.24
Collins Is.	1.2	3.6	3.6	2.5	1.6	1.3	1.0	2.10
Clara Is.	0.6	2.0	5.0	2.1	1.9	0.3	1.0	1.83