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The abundance, biomass and size of macrograzers on reefs in Moreton Bay, Queensland

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ABSTRACT

Reef systems in subtropical Moreton Bay were surveyed using underwater visual census techniques to assess the structure of macrograzer assemblages relative to tropical reefs. The community was dominated by acanthurids, pomacentrids, and siganids, with relatively few scarids, blennies and didemnid urchins. Biomass of fish grazers on Moreton Bay reefs at Amity rock-wall and Myora was not significantly different from other Pacific reefs indicating that even at high latitudes fish grazing might be an important structuring influence on coral communities. □ *keystone species, epilithic algal community, coral reef, fishes, urchins, reef health.*

The health of tropical coral reefs is sustained in part by the grazing activity of fishes that remove the algal competitors of corals, link a highly productive source of primary production with other members of the coral reef food web (Choat 1991; Polunin & Klumpp 1992), and influence the structure of benthic communities (Ogden & Lobel 1978; Hatcher 1981; Horn 1989; Carpenter 1990; Petraitis 1990). Their role is of such significance in Indo-Pacific reef systems that they are considered a keystone guild (Choat 1991). Herbivorous and omnivorous members of the Pomacentridae, Scaridae, Siganidae and Acanthuridae are widely recognized as the main families involved. More recently the tribe Salariini of the family Blenniidae has been added to the guild (Townsend & Tibbetts 2000, 2004). Invertebrate grazers are also recognized to play a role in maintaining the balance between coral and algae (Ogden & Lobel 1978; Klumpp *et al.* 1988). However, the role of grazing fishes and invertebrates in the health of coral reefs outside of the tropics is less well understood. Many of the families important in tropical reef systems are

represented in subtropical communities but there is little information on whether their role is of the same pivotal importance (Horn 1989).

Moreton Bay is a major embayment on the eastern coast of Australia. It is a marine park and supports a diversity of marine habitats that include significant coral reef outcrops. Lying just outside the bay, but within the marine park, is Flinders reef, for which 119 species of corals have been recorded (Harrison *et al.* 1998). Within the bay the communities are less diverse (64 species) yet substantial outcrops lie adjacent to bay islands (Mud, Green, St Helena and Peel), near Dunwich on the western side of North Stradbroke Island, and along the south western shores of Moreton Bay between Point Halloran and Wellington Point (Flood 1978; Johnson & Neil 1998; Wallace *et al.* 2009). These subtropical coral communities are chiefly dominated by faviid corals; however, in the eastern bay acroporids are locally abundant (Johnson & Neil 1998; Harrison *et al.* 1998).

Herbivory as a community structuring agent is generally considered to be less important outside

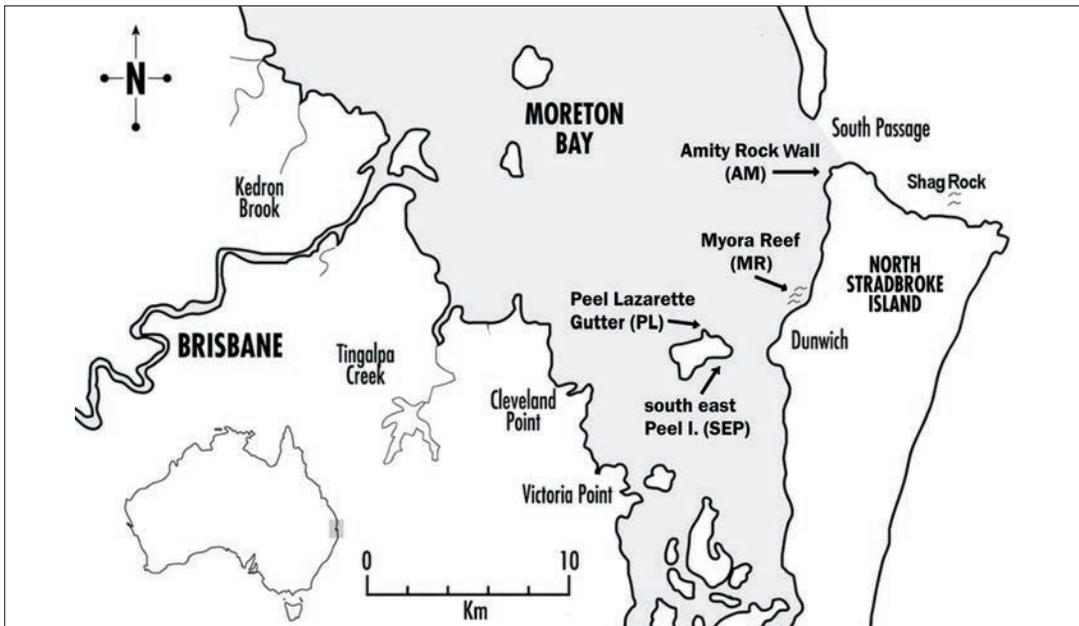


FIG. 1. Map of study locations in Moreton Bay, where AM = Amity Rock Wall, MY = Myora Reef, PL = Peel Lazarette Gutter, and SEP = south east Peel Island.

of the tropics (Ogden & Lobel 1978). Herbivores tend to comprise a smaller proportion of the overall abundance of reef fish; however, they can make up a substantial proportion of the biomass (Russell 1977). Thus the role of fish herbivory in coral reefs at high latitudes may have been underestimated (Russell 1983). Indeed Russell (1983) suggested that subtidal algal turfs in New Zealand were partially maintained by fish grazing, and blennies are important grazers in temperate rocky reef systems (Ojeda & Munoz 1999). To assess the role of fishes and larger invertebrates in the health of subtropical reef systems of Moreton Bay we surveyed and compared the abundance and biomass of herbivorous and omnivorous macrograzers on reef outcrops within Moreton Bay, southeast Queensland.

MATERIALS AND METHODS

Grazer biomass was estimated at four sites in central eastern Moreton Bay (Fig. 1): Lazarette Gutter, Peel Island ($27^{\circ}28'52''\text{S}$, $153^{\circ}21'16''\text{E}$) comprising high cover of principally faviid corals with soft corals; south east Peel Island ($27^{\circ}30'07''\text{S}$, $153^{\circ}22'21''\text{E}$) comprising lateritized sandstone outcrops and scattered faviid coral colonies;

Myora ($27^{\circ}28'21''\text{S}$, $153^{\circ}24'36''\text{E}$) comprising high cover of acroporid corals; and, Amity Point Rock Wall ($27^{\circ}24'02''\text{S}$, $153^{\circ}26'13''\text{E}$), a retaining sea wall with scattered coral colonies of *Acropora*, *Pocillopora* and faviids. At the time the surveys were conducted, the Amity Rock Wall site was heavily fished by anglers targeting bream, whiting and pelagic species. The recreational catch of grazing fish is dominated by siganids with occasional scarids landed from the jetty (pers. obs.). Spear fishing occurs at this site, with parrot and surgeon fishing being regularly targeted (N. VanDyke pers. com). Recreational line fishing activity at other reef areas in the bay was intense, and while grazers are not targeted it is likely that some are caught. Discussions with local spear fishermen indicate that parrot and surgeon fish are commonly targeted, as they are relatively easy to catch, their habitat is easily accessible for shore divers and the flesh is valued for consumption, while siganids are actively avoided due to their venomous spines (N. VanDyke pers. com). A commercial fishery existed for siganids on reefs around Peel, but its intensity has declined with protection of the area and a drop in demand (Tibbetts & Connolly 1998).

Table 1. Constants used to estimate biomass (M) from length (L_T) for major families of grazing fish $M=aL_T^b$.

| Family | Species | a | b | Source |
|---------------|------------------------------|--------|-------|---------------------------------|
| Acanthuridae | <i>Acanthurus fuscus</i> | 0.0089 | 3.278 | Letourneur (1998) |
| Blenniidae | <i>Blennius ocellaris</i> | 0.0140 | 2.963 | Pereda & Villamor (1991) |
| Kyphosidae | <i>Kyphosus bigibbus</i> | 0.0275 | 2.860 | Froese (1998) |
| Pomacentridae | <i>Pomacentrus coelestis</i> | 0.370 | 2.630 | Kochzius (1997) |
| Scaridae | <i>Scarus ghobban</i> | 0.0233 | 2.919 | Murty (2002) |
| Siganidae | <i>Siganus fuscescens</i> | 0.0162 | 3.010 | Letourneur <i>et al.</i> (1998) |

Four to six underwater visual censuses were completed at each site by divers on SCUBA using a measuring tape to centre a 50 x 4 m belt transect. The identity and length (± 10 mm) of individuals from families of grazing fishes and the grazing urchin, *Diadema* sp. were recorded in February (late summer) 2005. Fish biomass was estimated using equations relating length estimates to mass (Table 1). Average size of fish in each transect was computed by dividing the total biomass by the total number of fishes in a transect. This measure was used to examine whether grazing is being done by smaller or larger fishes at different sites.

Values of biomass.200 m⁻² were compared graphically both among sites in Moreton Bay, and between Moreton Bay and data sets collected by the senior author from: Heron Island reef slope and reef crest, Great Barrier Reef (23°26'S, 151°55'E); Solomon Islands sites – Mbili Marine Protected Area in outer Marovo Lagoon; Tengamo patch reefs in mid lagoon with low level protection by the family living on Tengamo Island; and two inner lagoon patch reef sites subject to terrestrial runoff and situated close to villages Koreke and MerusaA, Marovo Lagoon (8°39'S, 158°08'E); and lastly Gaulin reefs, San Salvador, Bahamas (24°02'N, 74°30'W). Four replicates were taken at each location. While having suffered some coral bleaching in recent episodes Heron reef might be considered a healthy functional reef as it is remote from land-based nutrient sources and closed to fishing. The two sites in San Salvador are oligotrophic, moribund reef systems in which non-herbivorous fishes are heavily exploited but herbivores appear not to be taken for food (pers. obs.). The Marovo Lagoon sites represent a gradient of health from the oceanic influenced Mbili MPA to the inner sites at Merusu.

Non-parametric multidimensional scaling (MDS) of similarity (Bray Curtis) matrices derived from square root transformed abundance and biomass data were used to assess general patterns among sites (Primer V5.2.4, Plymouth Marine Laboratories, Clark & Warwick 1994). Means were tested using one-way Analysis of Variance on data that if necessary to satisfy assumptions inherent in ANOVA had been $\log(x+1)$ transformed. Due to unequal numbers of replicates post hoc comparisons of means were conducted using Tukey's HSD for unequal N ($\alpha = 0.05$).

RESULTS

Twenty four species of herbivorous and omnivorous grazing fishes were identified from reef sites in Moreton Bay. Most species belonged to the Pomacentridae (11 species), followed by the Acanthuridae (5 species), and Kyphosidae (2 species), with the Siganidae, Blenniidae and Scaridae each represented by a single species (Table 2). Four families of grazers were found at Peel Lazarette and all seven families were found at both Myora Reef and Amity Rock Wall. No grazers were observed in transects at the southeast Peel site, so it was ignored in further analyses.

The biomass and abundance of the grazing families surveyed were highly variable across the sites at which grazers were observed (Figs 2A, B). There were no significant differences in mean overall abundance of grazers (5 ± 4.7 at Peel Lazarette, 14 ± 12.1 at Myora, and 15.5 ± 21.1 individuals.200 m⁻² at Amity Point), mean abundance of *Diadema* between the two sites at which they were found, Myora and Amity Point (2.5 individuals.200 m⁻²), and mean biomass of grazers between Amity Point (374 ± 305.7 g.200 m⁻²) and Myora Reef (576 ± 828.4 g.200 m⁻²).

A multidimensional scaling plot of reef sites based on mean estimated biomass by family of

Table 2. List of grazing fishes and urchins observed in transects on reef areas in Moreton Bay. Trophic groupings are H = herbivore, O = omnivore, ? unknown.

| Name & authority | Common name | Trophic Grouping |
|--|------------------------|------------------|
| Acanthuridae | | |
| <i>Acanthurus dussumieri</i> Valenciennes, 1835 | Eyestripe surgeonfish | H |
| <i>Acanthurus grammoptilus</i> Richardson, 1843 | Finelined surgeonfish | H |
| <i>Acanthurus nigrofuscus</i> (Forsskål, 1775) | Brown surgeonfish | H |
| <i>Ctenochaetus binotatus</i> Randall, 1955 | Twospot surgeonfish | H |
| <i>Prionurus microlepidotus</i> Lacepede, 1804 | Sixplate sawtail | H |
| Blenniidae | | |
| <i>Omobranchus punctatus</i> (Valenciennes, 1836) | Muzzled blenny | O |
| Blenniidae unid | | ? |
| Kyphosidae | | |
| <i>Kyphosus sydneyanus</i> (Günther, 1886) | Silver drummer | H |
| <i>Microcanthus strigatus</i> (Cuvier, 1831) | Stripey | O |
| Pomacentridae | | |
| <i>Abudefduf bengalensis</i> (Bloch, 1787) | Bengal sergeant | O |
| <i>Dascyllus melanurus</i> Bleeker, 1854 | Blacktail humbug | O |
| <i>Parma oligolepis</i> Whitley, 1929 | Big-scale parma | H |
| <i>Plectroglyphidodon leucozonus</i> (Bleeker, 1859) | Singlebar devil | H |
| <i>Pomacentrus australis</i> Allen & Robertson, 1974 | Australian damsel | H |
| <i>Pomacentrus chrysurus</i> Cuvier, 1830 | Whitetail damsel | H |
| <i>Pomacentrus moluccensis</i> Bleeker, 1853 | Lemon damsel | O |
| <i>Pomacentrus wardi</i> Whitley, 1927 | Ward's damsel | H |
| <i>Stegastes gascoynei</i> (Whitley, 1964) | Coral sea gregory | H |
| Scaridae | | |
| Scaridae unid juvenile | | |
| <i>Scarus ghobban</i> Forsskål, 1775 | Blue-barred parrotfish | H |
| Siganidae | | |
| <i>Siganus fuscescens</i> (Houttuyn, 1782) | Mottled spinefoot | H |
| Invertebrates | | |
| <i>Diadema setosum</i> | Long spined searchin | H |
| <i>Diadema</i> (white) | | |

grazing fishes revealed that Moreton Bay did not form a separate grouping, rather the sites intergraded with the tropical sites studied (Fig. 3). The first dimension (X axis) appeared to separate on biomass, whereas the second dimension (Y axis) was driven more by the number of families. Amity and Myora sites were not markedly dissimilar to communities surveyed at Heron Island, Solomon Islands and Bahamas. However, Peel Lazarette was very clearly distinguished from other sites in having very low grazer biomass.

Mean abundance of grazing fishes did not differ significantly among the Moreton Bay sites (Fig. 4A, Table 3A). However the abundances of grazers at Moreton Bay sites were significantly lower than at Heron reef crest and reef slope, Koreke and Mbili MPA in the Solomon Islands and the two Bahamian sites. Grazer biomass was significantly lower at Peel Lazarette Gutter than at Amity and Myora reefs, which in turn were only significantly different from the two Bahamian reefs of the other sites studied (Fig. 4B,

Macrograzers of Moreton Bay reefs

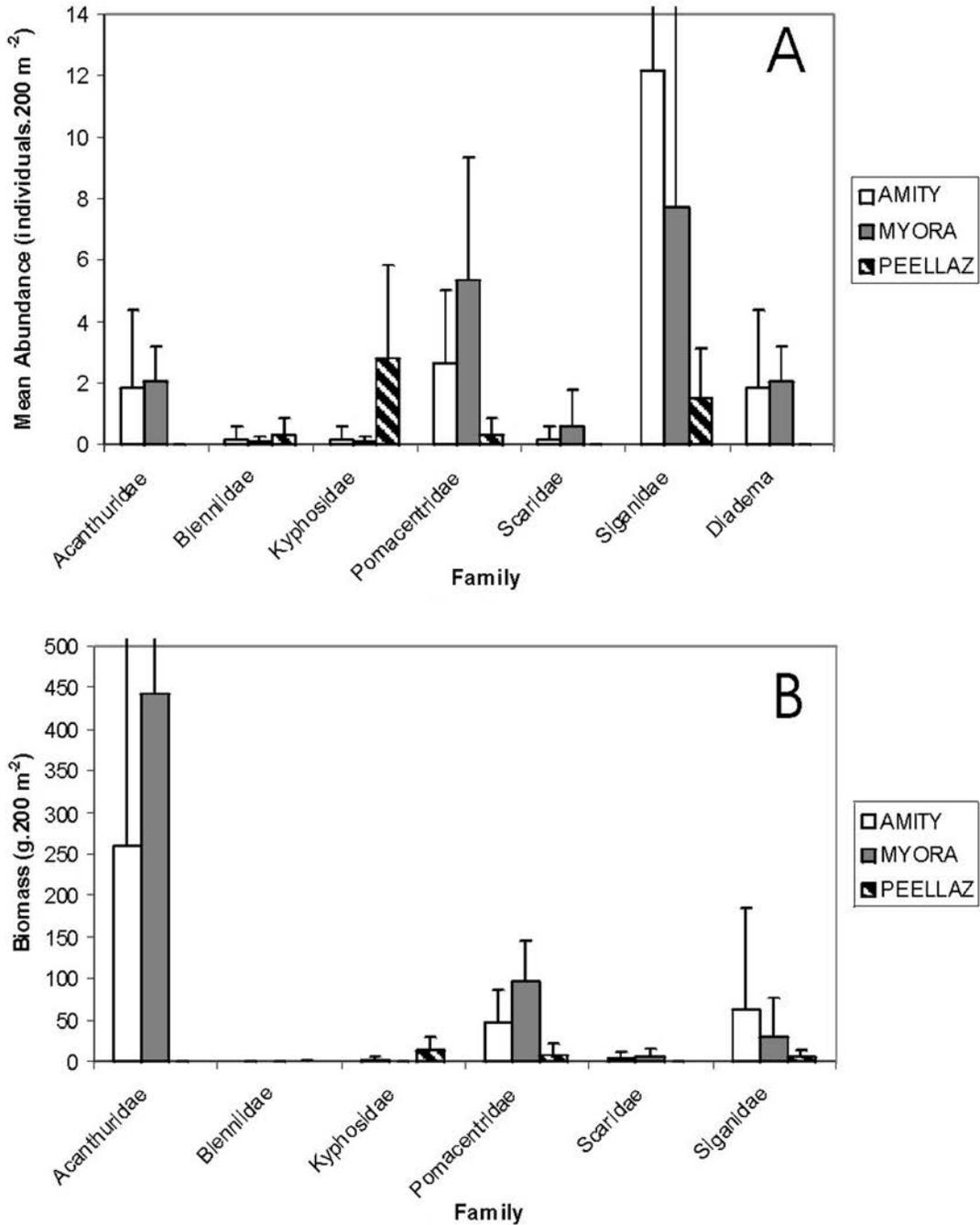


FIG. 2. **A**, Mean biomass of grazing fishes (g.200 m⁻²) and **B**, mean numerical abundance (for grazing fishes and grazing fish families and the urchin *Diadema*) (individuals.200 m⁻²) of grazing fish families at three reef sites in Moreton Bay. Error bars = SD (Note for A, SD values for Amity and Myora were 311.2 and 870.9, respectively; and for B, SD values for Amity and Myora were 21.3 and 8.8, respectively. **Note:** reef at SE Peel Island was surveyed but no grazers were recorded in transects. AMITY, Amity Point; MYORA, Myora Reef; PEELLAZ, Lazarette Gutter, Peel Island.

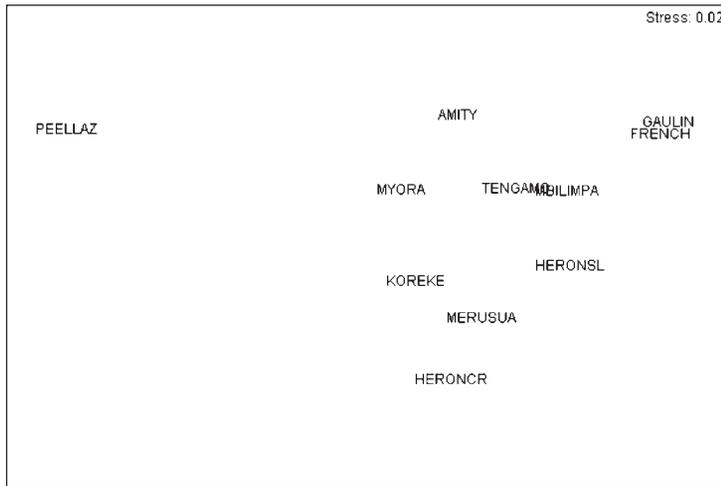


FIG. 3. Multidimensional scaling plot of reef sites based on mean estimated biomass by family of grazing fishes. Sites within Moreton Bay are AMITY = Amity Point Rock Wall, MYORA = Myora Reef, PEELLAZ = Lazarette Gutter, Peel Island; sites on Heron Island, Great Barrier Reef are HERONCR = Heron reef crest, HERONSL = Heron reef slope; sites in Marovo Lagoon Solomon Islands include the managed open lagoon sites of TENGAMO = reefs near Tengamo Island, MBILIMPA = Mbili Village Marine Protected Area, and the non-managed, terrestrial runoff sites dominated by massive corals of KOREKE = near Koreke Village and MERUSUA = near Merusu Village; and sites in the lagoon of San Salvador Island, Bahamas, GAULIN = Gaulin Reef, Graham's Harbour and FRENCH = French Reef, French Bay. Stress 0.02.

Table 3B). Peel Lazarette had a significantly smaller mean size of grazing fishes than the other sites (Fig. 4C, Table 3C).

DISCUSSION

The subtropical coral reefs of Moreton Bay support grazing fish communities dominated by acanthurids, pomacentrids and siganids, and while scarids and kyphosids were observed, they were relatively unimportant in terms of either abundance or biomass. Blennies are important grazers in tropical reef systems (Townsend & Tibbetts 2000, 2004), and on high latitude reefs in the Atlantic (Ojeda & Munoz 1999), however they did not feature in grazing assemblages of Moreton Bay reefs, despite the authors' experience with identifying and counting these cryptic fishes. However, grazing blennies are a generally a feature of rocky intertidal communities in south-east Queensland (Tibbetts *et al.* 1998), and at Flinders Reef, a diverse coral assemblage (Harrison *et al.* 1998) lying just outside of Moreton Bay, but within the Moreton Bay Marine Park (pers. obs.). Only a single specimen of the omnivorous genus *Omobranchus* (Tibbetts *et al.* 1998) was recorded.

The absence of grazing fishes and urchins from transects conducted on the site to the southeast of Peel Island is unusual. Siganids were observed outside of transects but no other macrograzers were seen during the observation period. This might be an effect of low habitat complexity (see Hixon & Beets 1993). At south east Peel faviid corals occur on rocky ledges offering little cover to fish. Similarly the faviid-dominated reef at Peel Lazarette Gutter offers relatively few refugia for small fish. Interestingly the venomous, planktivorous blenny *Meiacanthus lineatus* (De Vis, 1884) was relatively common at Peel Lazarette Gutter, but this may result from a combination of its venomous nature and its diet of plankton, with space occupied by algal turfs required for grazers being particularly limited at this site. In contrast the rock wall at Amity Point and the acroporid-dominated reef at Myora provide algal turf substrates and excellent cover for fishes, which may well have contributed to the high diversity and abundance of grazers at these sites.

Amity Rock Wall and the reef at Myora had populations of didemnid sea urchins. *Diadema* were absent from the Lazarette Gutter, Peel Island. The dense field of massive corals at Peel would

Macrograzers of Moreton Bay reefs

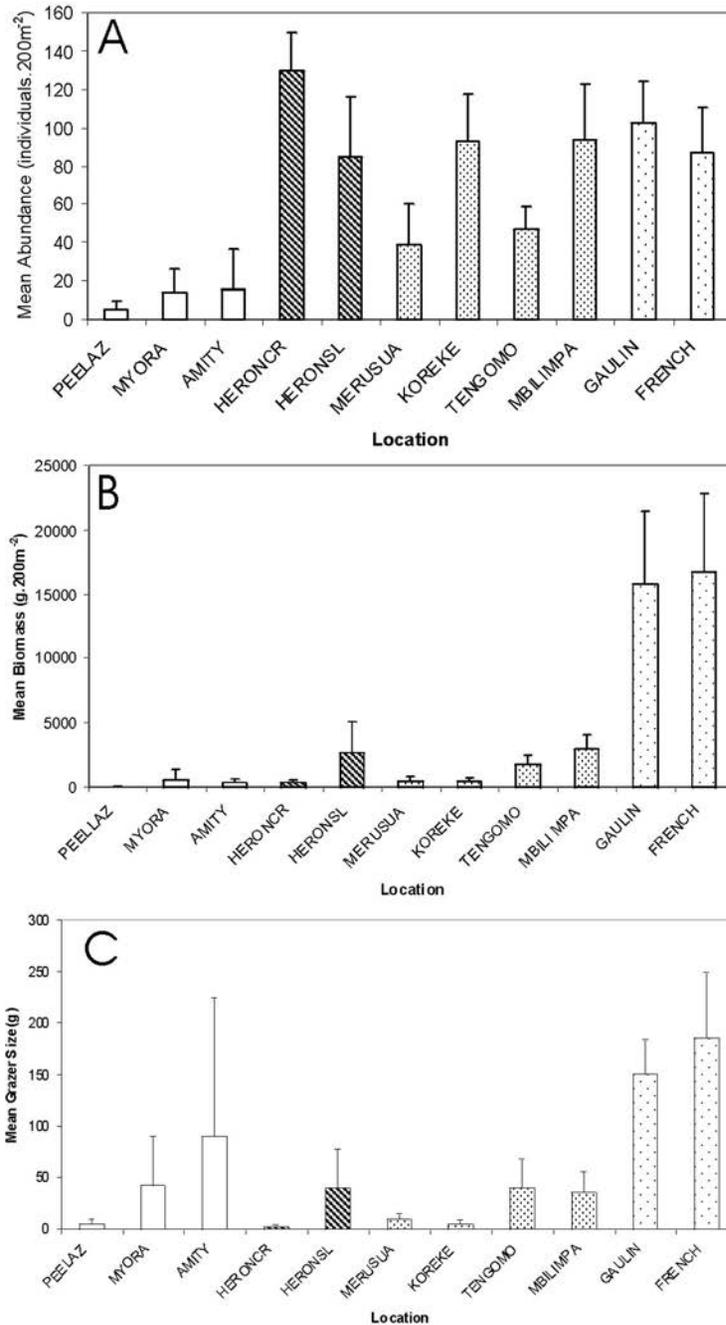


FIG. 4. Mean abundance (A), biomass (B) and mean grazer size (C) for reefal areas in Moreton Bay compared with Heron reef crest (HERONCR) and slope (HERONSL); Merusu Site A (MERUSUA), Koreke (KOREKE), Tengamo (TENGAMO) and Mbili Marine Park Area (MBILIMPA), Marovo Lagoon, Solomon Islands; and Gaulin (GAULIN) and French Bay (FRENCH) Reefs, San Salvador, Bahamas). Values for graph A were derived from means of the ratios of total biomass to total numerical abundance for all grazing fishes among replicate 50 x 4 m belt transects. Error bars = SD.

Table 3. Post hoc comparisons of means using Tukey's HSD for unequal N for one way Analysis of Variance on A) Abundance, B) Log (X+1) Biomass and C) Log (X+1) Size for sites within Moreton Bay are AMITY = Amity Point rock wall, MYORA = Myora Reef, PEELAZ = Lazarette Gutter, Peel Island; sites on Heron Island, Great Barrier Reef are HERONCR = Heron reef crest, HERONSL = Heron reef slope; sites in Marovo Lagoon Solomon Islands include the managed open lagoon sites of TENGAMO = reefs near Tengamo Island, MBILIMPA = Mbili Village Marine Protected Area, and the non-managed, terrestrial runoff sites dominated by massive corals of KOREKE = near Koreke Village and Merusu A = near Merusu Village; and sites in the lagoon of San Salvador Island, Bahamas, GAULIN = Gaulin Reef, Graham's Harbour and FRENCH = French Reef, French Bay. Values in bold highlight significant differences between pairs of sites ($\alpha = 0.05$).

| A | | | | | | | | | | | | |
|-------------------------|--------|--------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|--|
| Mean Abundance Location | 15.50 | 14.00 | 5.00 | 129.25 | 84.50 | 38.75 | 93.25 | 47.25 | 93.5 | 102.75 | 87.00 | |
| | AMITY | MYORA | PEEL | HERONCR | HERONSL | MERUSUA | KOREKE | TENGOMO | MBILIMPA | GAULIN | FRENCH | |
| AMITY | | 1.0000 | 0.9983 | 0.0002 | 0.0019 | 0.8856 | 0.0005 | 0.5577 | 0.0004 | 0.0002 | 0.0012 | |
| MYORA | | | 0.9999 | 0.0002 | 0.0015 | 0.8413 | 0.0004 | 0.4918 | 0.0004 | 0.0002 | 0.0009 | |
| PEEL | | | | 0.0002 | 0.0004 | 0.4702 | 0.0002 | 0.1797 | 0.0002 | 0.0002 | 0.0003 | |
| HERONCR | | | | | 0.1272 | 0.0002 | 0.3777 | 0.0003 | 0.3876 | 0.7800 | 0.1797 | |
| HERONSL | | | | | | 0.1100 | 0.9999 | 0.3306 | 0.9999 | 0.9745 | 1.0000 | |
| MERUSUA | | | | | | | 0.0270 | 1.0000 | 0.0258 | 0.0049 | 0.0754 | |
| KOREKE | | | | | | | | 0.1061 | 1.0000 | 0.9999 | 1.0000 | |
| TENGOMO | | | | | | | | | 0.1022 | 0.0227 | 0.2473 | |
| MBILIMPA | | | | | | | | | | 0.9999 | 1.0000 | |
| GAULIN | | | | | | | | | | | 0.9912 | |
| FRENCH | | | | | | | | | | | | |
| B | | | | | | | | | | | | |
| Mean Biomass Location | 2.4084 | 2.4195 | 1.0946 | 2.5367 | 3.1977 | 2.5008 | 2.5882 | 3.2069 | 3.444 | 4.2017 | 4.1792 | |
| | AMITY | MYORA | PEEL | HERONCR | HERONSL | MERUSUA | KOREKE | TENGOMO | MBILIMPA | GAULIN | FRENCH | |
| AMITY | | 1.0000 | 0.0010 | 1.0000 | 0.3897 | 1.0000 | 1.0000 | 0.3733 | 0.0936 | 0.0003 | 0.0003 | |
| MYORA | | | 0.0103 | 1.0000 | 0.4098 | 1.0000 | 1.0000 | 0.3930 | 0.1009 | 0.0003 | 0.0004 | |
| PEEL | | | | 0.0039 | 0.0002 | 0.0052 | 0.0025 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | |
| HERONCR | | | | | 0.6399 | 1.0000 | 1.0000 | 0.6215 | 0.2106 | 0.0007 | 0.0008 | |
| HERONSL | | | | | | 0.5680 | 0.7385 | 1.0000 | 0.9995 | 0.1157 | 0.1340 | |
| MERUSUA | | | | | | | 1.0000 | 0.5495 | 0.1702 | 0.0005 | 0.0006 | |
| KOREKE | | | | | | | | 0.7214 | 0.2803 | 0.0010 | 0.0011 | |
| TENGOMO | | | | | | | | | 0.9996 | 0.1229 | 0.1421 | |
| MBILIMPA | | | | | | | | | | 0.4484 | 0.4918 | |
| GAULIN | | | | | | | | | | | 1.0000 | |
| FRENCH | | | | | | | | | | | | |

TABLE 3. Continued ...

| Mean Size | 1.5006 | 1.4667 | 0.5807 | 0.5727 | 1.3406 | 1.0156 | 0.7297 | 1.5559 | 1.5033 | 2.1997 | 2.2535 |
|-----------|--------|--------|--------|---------|---------|---------|--------|---------|---------|--------|--------|
| Location | AMITY | MYORA | PEEL | HERONCR | HERONSL | MERUSUA | KOREKE | TENGOMO | MBILMPA | GAULIN | FRENCH |
| AMITY | | 1.0000 | 0.0158 | 0.0859 | 1.0000 | 0.8404 | 0.2586 | 1.0000 | 1.0000 | 0.3890 | 0.2885 |
| MYORA | | | 0.1182 | 0.1113 | 1.0000 | 0.8911 | 0.3164 | 1.0000 | 1.0000 | 0.3234 | 0.2341 |
| PEEL | | | | 1.0000 | 0.2765 | 0.9112 | 1.0000 | 0.0589 | 0.0895 | 0.0003 | 0.0002 |
| HERONCR | | | | | 0.2635 | 0.9015 | 1.0000 | 0.0552 | 0.0841 | 0.0003 | 0.0002 |
| HERONSL | | | | | | 0.9870 | 0.5819 | 0.9996 | 1.0000 | 0.1437 | 0.0965 |
| MERUSUA | | | | | | | 0.9951 | 0.7370 | 0.8359 | 0.0093 | 0.0056 |
| KOREKE | | | | | | | | 0.1808 | 0.2543 | 0.0007 | 0.0004 |
| TENGOMO | | | | | | | | | 1.0000 | 0.5074 | 0.3921 |
| MBILMPA | | | | | | | | | | 0.3945 | 0.2931 |
| GAULIN | | | | | | | | | | | 1.0000 |
| FRENCH | | | | | | | | | | | |

not seem conducive to the provision of either shelter or feeding opportunities for didemnids. The distribution of urchins was patchy, and appeared not to be related to the biomass of grazing fishes. We infer from this that grazing at sites with low biomass of grazing fishes is not compensated by urchins. Either grazing on Moreton Bay reefs is being carried out by other invertebrates that were not seen by us (e.g., crustaceans, Shaw & Tibbetts 2004) or that grazing is not required to limit algal growth. It is possible that bottom up control of algal growth is an important regulating factor in the oligotrophic waters of eastern Moreton Bay (see Albert *et al.* 2009).

Macroalgal cover at the sites studied varied from 5% at Amity Point to 20% at Peel Island (Dennison & Abal 1999), while macroalgal diversity was highest at Peel Island (23 species) and lowest at Amity Point (1 species), with nine species recorded for Myora (Phillips 1998). The extent to which grazers are responsible for this trend in macroalgal abundance and diversity must be resolved empirically; however, it broadly matches the trend in grazer biomass across these sites, suggesting that such experiments might be productive. With the exception of Harrison *et al.* (1998) data for Myora Reef, there are no data available for Moreton Bay concerning cover of epilithic algae, which are a principal focus of the grazing activities of fishes and invertebrates, and comprise microalgae, the early life developmental stages of macroalgae, sediment, detritus, phytoplankton and meiofauna (Wilson & Bellwood 1997). Such data would be very useful, not only for grazing studies but also in simple monitoring for trends in the health of Moreton Bay reefs.

The grazing assemblage of Moreton Bay reefs were not distinct from comparison reefs but instead community analysis suggested that they tend to intergrade with the tropical sites studied, supporting the notion that grazers might be important structuring agents on high latitude reefs (Russell 1983). The two sites in Moreton Bay with the highest abundance of grazing fish had lower grazer abundances than sites at Heron Reef, some Solomon Islands reefs and Bahamian reefs. However, in terms of both biomass and mean grazer size these Moreton Bay sites were not significantly different from the other Pacific reefs studied,

although we feel this is partly attributable to high variation in the data and the low power of the parametric tests applied. It is clear from our data that grazer biomass on coral outcrops within Moreton Bay is very low ($0.025\text{--}0.078\text{ g m}^{-2}$) compared with reefs worldwide; $7.5\text{--}44\text{ g m}^{-2}$ in the Great Barrier Reef (Russ 2003), $2.7\text{--}15.4\text{ g m}^{-2}$ in the Caribbean (Williams & Polunin 2001), $25\text{--}160\text{ g m}^{-2}$ in Hawaii (Friedlander & DeMartini 2002).

Pandolfi *et al.* (2003) suggested that the health of reefs is directly indexed to the level of human impact on reef systems, and that as a consequence reefs worldwide are threatened by the cumulative effects of over fishing and pollution. They emphasized that the removal of grazers by over fishing can lead to a phase shift in the coral reef community from a coral dominated substrate in which grazers restrict the growth of algal communities to a low turf, to a community dominated by foliose algae that overgrow, shade and lead to the death of corals. Following European settlement the reefs of Moreton Bay have become degraded in terms of species richness, coral cover, and health (Lybolt *et al.* 2010), yet the biomass of grazing fishes at some sites is comparable to some tropical reefs. The population of grazing fishes is low in most areas and the function of grazing appears not to have been visibly replaced by other groups of grazers. *Diadema* have the potential to fulfill this role in the grazing guild, but they are neither abundant nor ubiquitous. Edmunds & Carpenter (2001) in a Caribbean reef found mean densities of *Diadema antillarum* of 5 m^{-2} in habitats in which they effectively control algal growth to the benefit of corals. In the present study the highest density observed was two orders of magnitude lower, indicating that their role is likely to be neither pivotal nor compensatory.

As far as we are aware anglers seldom either target or capture grazing fishes (with the exception of siganids) in Moreton Bay. However, spearfishers actively target larger herbivorous species in the bay due to their ease of access and value as a food fish. Of greater concern is that experienced spearfishers target parrotfish at dawn and dusk, when they are settled into their protective mucous cocoons within crevices (N. VanDyke, pers. com). This also occurs in Marovo Lagoon, where locals participate in night spearfishing known as 'tope ipu' in the Marovo language.

Thus spearfishing potentially explains the low abundance and size of parrotfish in both Moreton Bay and Marovo Lagoon. Indeed, during our surveys in both Marovo and Moreton Bay larger parrotfish seemed inordinately nervous and rapidly fled from us suggesting that they might indeed be targeted, but also that their biomass might have been underestimated under such conditions. Interestingly the Bahamian reefs are relatively remote, heavily line fished but seldom speared, which has perhaps resulted in unusually large parrotfishes dominating these reef assemblages and not fleeing at the approach of snorkelers and SCUBA divers. While on a numerical basis there is little to distinguish the Atlantic and Pacific reefs, these larger and more approachable parrotfish on the Bahamian reefs confer the biomass dominance by the Atlantic reefs investigated by us. It will be interesting to see whether parrotfish populations and average fish size in Moreton Bay increase following the recent (1 March 2009) closure of extensive reefal areas in the bay with the refinement of the Moreton Bay Marine Park provisions (<http://www.legislation.qld.gov.au/LEGISLTN/SLS/2008/08SL343.pdf>).

The main canopy forming macroalgae in Moreton Bay are the fucoids *Sargassum natans* (Linnaeus) Gaillon and *Cystoseira trinodis* (Forsk.) C. Ag. (pers obs). Periodically these grow on faviid corals and form extensive canopies; an event that is apparently survived by the corals. These canopy algal-coral assemblages appear to be associated with shore areas (e.g. close to Goat Island and Polka Point, pers. obs.) and may well be supported by nutrients from local runoff. There is no apparent limitation on the initiation of these events by grazing fishes or any apparent control of the canopies by browsing fishes once they are formed. The relatively mobile schools of kyphosids and siganids we observed might offer a counter to these blooms, but we have observed no browsing activity and, interestingly, little apparent damage to the coral hosts of these algae.

More recently the potential role of Moreton Bay as a coral refuge from the effects climate change has been discussed. Supporters point to the extensive reef communities that occupied the bay pre-European settlement, while opponents suggest that even with considerable improve-

ments in water quality Moreton Bay has only held coral for 50% of the past 7000 years (Lybolt *et al.* 2010). Should tropical corals either naturally find a home in Moreton Bay, or be transplanted there, they will be welcomed by only a modest diversity of grazing fishes and urchins; however, high grazer abundance may not be essential to control algae in the oligotrophic waters of eastern Moreton Bay (Albert *et al.* 2008; Brown 2010). Moreover, the other important positive effects of grazing such as the opening up of sites for coral settlement will still occur while the negative effects of grazer removal of coral spat will be less than in more grazer-replete systems (Christiansen *et al.* 2009). Notwithstanding, in the potential face of oblivion a 50% chance is better than none, and we feel that efforts should be directed toward improving our understanding of the biology and dynamics of Moreton Bay's grazing fishes in the event that they may support a refuge for Indo-Pacific coral reef diversity.

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LITERATURE CITED

- Albert, S., Udy, J. & Tibbetts, I.R. 2008. Responses of algal communities to gradients in herbivore biomass and water quality in Marovo Lagoon, Solomon Islands. *Coral Reefs* 27(1): 73–82.
- Brown, J. 2010. Top-down and bottom-up regulation of the Epilithic Algal Community (EAC) on two declared Fish Habitat Areas (FHA's) within Moreton Bay. Honours thesis, The University of Queensland.
- Carpenter R.C. 1990. Mass mortality of *Diadema antillarum*. I. Long-term effects on sea urchin population-dynamics and coral reef algal communities. *Marine Biology* 104: 67–77.
- Choat, J.H. 1991. The biology of herbivorous fishes on coral reefs. Pp. 120–155. In, Sale, P.F. (Ed.), *The Ecology of Fishes on Coral Reefs*. (Academic Press: San Diego, CA).
- Christiansen, N.A., Ward, S., Harii S. & Tibbetts I.R. 2009. Grazing by a small fish affects the early stages of a post-settlement stony coral. *Coral Reefs* 28: 47–51.
- Clark, K.R. & Warwick, R.M. 1994. *Change in Marine Communities: an Approach to Statistical Analysis and Interpretation*. (Plymouth Marine Lab.: Plymouth).
- Dennison, W.C. & Abal, E.G. (Eds) 1999. Macroalgae on rocks, mangroves and seagrass. P. 166. In, *Moreton Bay Study, A Scientific Basis for the Healthy Waterways Campaign*. (SEQRWMST: Brisbane).
- Edmunds P.J. & Carpenter R.C. 2001. Recovery of *Diadema antillarum* reduces macroalgal cover and increases abundance of juvenile corals on a Caribbean reef. *Proceedings of the National Academy of Sciences of the United States of America* 98(9): 5067–5071.
- Flood, P.G. 1978. The significance of two contrasting sedimentary environments (the fringing coral reef and the tidal mud flat) presently in juxtaposition along the southwestern shore of Moreton Bay, Queensland. *Papers, Department of Geology, University of Queensland* 8(2): 44–63.
- Friedlander, A.M. & DeMartini, E.E. 2002. Contrasts in density, size, and biomass of reef fishes between the northwestern and the main Hawaiian islands: the effects of fishing down apex predators. *Marine Ecology Progress Series* 230: 253–264.
- Froese, R. 1998. Length-weight relationships for 18 less-studied fish species. *Journal of Applied Ichthyology* 14: 117–118.
- Harrison, P.L., Harriott, V.J., Banks, S.A. & Holmes N.J. 1998. The coral communities of Flinders Reef and Myora Reef in the Moreton Bay Marine Park, Queensland, Australia. Pp. 525–536. In, Tibbetts, I.R., Hall, N.J. & Dennison, W.C. (Eds), *Moreton Bay and Catchment*. (School of Marine Science: Brisbane).
- Hatcher, B.G. 1981. The interaction between grazing organisms and the epilithic algal community of a coral reef: a quantitative assessment. *Proceedings of the 4th International Coral Reef Symposium (Manila)* 2: 515–524.
- Hixon, M.A. & Beets, J.P., 1993. Predation, prey refuges, and the structure of coral-reef fish assemblages. *Ecological Monographs* 63(1): 77–101.

- Horn, M.H. 1989. Biology of marine herbivorous fishes. *Oceanography and Marine Biology: An Annual Review* **27**: 167–272.
- Johnson, P.R. & Neil, D.T. 1998. The corals of Moreton Bay: living with extremes. Pp. 503–524. *In*, Tibbetts, I.R., Hall, N.J. & Dennison, W.C. (Eds), *Moreton Bay and Catchment*. (School of Marine Science: Brisbane).
- Klumpp, D.W., McKinnon, A.D. & Mundy, C.N. 1988. Motile cryptozoa of a coral reef: abundance, distribution and trophic potential. *Marine Ecology Progress Series* **45**: 95–108.
- Kochzius, M. 1997. Length-weight relationship of fishes from a seagrass meadow in Negros Oriental, Philippines. *Naga ICLARM Q.* **20**(3/4): 64–65.
- Letourneur, Y. 1998. First length-weight relationships of some marine fish species of Réunion Island, SW Indian Ocean. *Naga ICLARM Q.* **21**(4):37–39.
- Letourneur, Y., Kulbicki, M. & Labrosse, P. 1998. Length-weight relationships of fish from coral reefs and lagoons of New Caledonia, southwestern Pacific Ocean: an update. *Naga ICLARM Q.* **21**(4): 39–46.
- Lybolt, M., Neil D., Zhao, J., Feng, Y., Yu, K. & Pandolfi, J. 2010. Instability in a marginal coral reef: the shift from natural variability to a human-dominated seascape. *Frontiers in Ecology and Environment*. [doi:10.1890/090176]
- Murty, V.S. 2002. Marine ornamental fish resources of Lakshadweep. CMFRI Special Publication No. 72. 384 p.
- Ogden, J.C. & Lobel, P.S. 1978. The role of herbivorous fishes and urchins in coral reef communities. *Environmental Biology of Fishes* **3**: 49–63.
- Ojeda, P.F. & Munoz, A.A. 1999. Feeding selectivity of the herbivorous fish *Scartichthys viridis*: effects on macroalgal community structure in a temperate rocky intertidal coastal zone. *Marine Ecology Progress Series* **184**: 219–229.
- Pandolfi, J.M., Jackson, J.B.C., Baron, N., Bradbury, R.H., Guzman, H.M., Hughes, T.P., Kappel, C.V., Micheli, F., Orden, J.C., Possingham, H.P. & Sala, E. 2004. Are U.S. coral reefs on the slippery slope to slime? *Science* **307**(5716): 1725–1726.
- Pereda, P. & Villamor, B. 1991. Relaciones biometricas en peces de la plataforma Cantabrica. Informes Técnicos Instituto Espanol de Oceanografia. No. 92, 39 pp.
- Petratits, P.S. 1990. Direct and indirect effects of predation, herbivory and surface rugosity on mussel recruitment. *Oecologia* **83**: 405–413.
- Phillips J. 1998. Macroalgae of Moreton Bay: species diversity, habitat specificity and biogeography. Pp. 279–290. *In*, Tibbetts, I.R., Hall, N.J. & Dennison, W.C. (Eds), *Moreton Bay and Catchment*. (School of Marine Science: Brisbane).
- Polunin, N.V.C. & Klumpp, D.W. 1992. A trophodynamic model of fish production on a windward reef tract. Pp. 213–233. *In*, John, D.M., Hawkins, S.J. & Price, J.H. (Eds), *Plant-animal Interactions in the Marine Benthos*. (Clarendon Press: Oxford).
- Russ, G.R. 2003. Grazer biomass correlates more strongly with production than with biomass of algal turfs on a coral reef. *Coral Reefs* **22**: 63–67.
- Russell, B.C. 1977. Population and standing crop estimates for rocky reef fishes of north-eastern New Zealand. *New Zealand Journal of Marine and Freshwater Research* **11**: 23–36.
- Russell, B.C. 1983. The food and feeding habits of rocky reef fish of north-eastern New Zealand. *New Zealand Journal of Marine and Freshwater Research* **17**: 121–145.
- Shaw, M. & Tibbetts, I.R. 2004. Grazing by *Metopograpsus frontalis* (Decapoda: Grapsidae) on intertidal rock walls of Moreton Bay. *Proceedings of the Royal Society of Queensland*. **111**: 95–101.
- Tibbetts, I.R. & Connolly, R.M. 1998. The nekton of Moreton Bay. Pp. 395–420. *In*, Tibbetts, I.R., Hall, N.J. & Dennison, W.C. (Eds), *Moreton Bay and Catchment*. (School of Marine Science: Brisbane).
- Tibbetts, I.R., Kim, J.W. & Carseldine, L. 1998. Intertidal fish communities of rocky shores in south-east Queensland. Pp. 451–466. *In*, Tibbetts, I.R., Hall, N.J. & Dennison, W.C. (Eds), *Moreton Bay and Catchment*. (School of Marine Science: Brisbane).
- Townsend, K.A. & Tibbetts, I.R. 2000. Biomass and distribution of herbivorous blennies in the southern Great Barrier Reef. *Journal of Fish Biology* **56**: 774–791.
2004. The ecological significance of the combtoothed blenny, *Salaria fasciatus*, in a coral reef ecosystem. *Journal of Fish Biology* **65**: 77–90.
- Wallace, C.C., Fellegara, I., Muir, P.R. & Harrison, P.L. 2009. The scleractinian corals of Moreton Bay, Queensland, Australia: high latitude, marginal assemblages with increasing species richness. *In*, Davie, P.J.F. & Phillips, J.A. (Eds), *Proceedings of the Thirteenth International Marine Biological Workshop, The Marine Fauna and Flora of Moreton Bay, Queensland*. *Memoirs of the Queensland Museum – Nature* **54**(2): 1–118.
- Williams, I. & Polunin, N. 2001. Large-scale associations between macroalgal cover and grazer biomass on mid-depth reefs in the Caribbean. *Coral Reefs* **19**: 358–366.
- Wilson, S.K. & Bellwood D.W. 1997. Cryptic dietary components of territorial damselfishes (Pomacentridae, Labroidae). *Marine Ecology Progress Series* **153**: 299–310.