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USE OF INTERTIDAL MANGROVE AND SEA WALL HABITATS BY CORAL REEF FISHES IN THE WAKATOBI MARINE PARK, INDONESIA

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ABSTRACT. **–** Intertidal mangroves and manmade structures such as sea walls (jetties) may be used as nursery areas by coral reef fishes. Fishes utilizing these intertidal habitats near the island of Kaledupa were observed by visual census on ten occasions each, to identify the species utilizing these habitats, compare the abundance and diversity at the two sites, observe the degree of site-fidelity, and attempt to locate alternate habitats utilized at low tide. Fish in the mangrove were not abundant and dominated by juveniles and adults of the orbiculate cardinalfish, *Sphaeramia orbicularis*. The vagabond butterfly fish, *Chaetodon vagabundus* was seen occasionally. One blue-lined demoiselle, *Chrysiptera caeruleolineata,* was observed repeatedly at the same location. Other fish were transient. The sea wall had a more abundant and diverse fish fauna, including many species of damselfish, two species of butterfly fishes, white-saddled cardinalfish and orbiculate cardinalfish, a moray eel, and a lionfish. Many of the fish were adults. Some species at the sea wall also showed site-fidelity, while most were transient. At low tide, they were seen congregated in deeper pools close by. This suggests that they may not utilize the coral reefs at all, but may stay by the wall all the time.

KEY WORDS. **–** mangrove, jetty, sea wall, habitat, fish, site fidelity.

INTRODUCTION

Many coral reef fishes have a territory where they may defend resources. For example, damselfish defend their territories against other grazing fishes (Thresher, 1976; Ogden & Lobel, 1978). Sites at coral reefs remain subtidal throughout all phases of the tidal cycle and are thus always available, although some fishes may undergo diurnal migrations from shelter sites to feeding sites (Hobson, 1973). Some coral reef fish are also found associated with mangrove roots and with rubble and jetties in shallow water, often as juveniles. The arching prop roots of the red mangrove *Rhizophora* spp. provide shelter and are considered to be nursery areas for some coral reef fishes (Pollard, 1984; Parrish, 1989; Robertson & Duke, 1997; Robertson & Blaber, 1992; Nagelkerken et al., 2000). Laegdsgaard & Johnson (1995) found 53 species of juvenile fish in a two-year study in mangroves in Queensland, Australia. The structural complexity of the roots provides protection against predators (Nagelkerken et al., 2000), and the more turbid water is considered to reduce foraging efficiency of predators (Robertson & Blaber, 1992). Nagelkerken & van der Velde (2002) found that non-estuarine mangroves had higher density of juvenile fishes than adjacent seagrass beds, channel, or mud flats in the Caribbean. Similarly, the density and biomass of fish collected from the mangrove prop root environment in south Florida (US) were greater than in the adjacent seagrass areas (Thayer et al., 1987). Root habitats provide abundant food for the fishes (Carr & Adams, 1973; Nagelkerken et al., 2000). In the Caribbean, mangrove nursery habitat has a strong positive influence on the community structure of fish on neighboring coral reefs (Mumby et al., 2004). Juvenile fish appear to be attracted by the structural complexity and shade provided by this habitat (Cocheret de la Moriniere et al., 2004). Many of these fish undergo ontogenetic habitat shifts to coral reefs as they grow (Heald & Odum, 1970; Rooker & Dennis, 1991), although in many cases the linkages or migrations to the nearby coral reefs have not been actually documented. The overall importance of mangroves as nurseries to reef fish populations has not been quantified and remains an active topic of research.

Some studies found mangroves to support a variety of fish but not necessarily coral reef species. Halliday & Young (1996) found atherinids, mugilids, and gerreids dominated in an Australian mangrove, while Laroche et al. (1997) found gerreids, teraponids and carangids in a Madagascar mangrove. Lin & Shao (1999) found gobiids and mugilids in Taiwanese mangroves, and Little et al. (1988) found clupeids and gobiids in mangrove forests in East Africa. Kimani et al. (1996) reported that in a Kenyan mangrove estuary, coral reef species comprised 44% of the fish.

Mangrove roots may become uncovered, and thus unavailable, at low tide. Fish may nevertheless show site-fidelity to these habitats. In this study we investigated fish use of two habitats that are exposed at low tide, forcing fish to move elsewhere: a mangrove habitat on the island of Kaledupa and a man-made sea wall (jetty) habitat on Hoga (both within the Wakatobi National Marine Park, SE Sulawesi, Indonesia – Fig. 1). We were interested in which species utilized these different habitats, the abundance and diversity of fishes at the two habitats, the fidelity of fish of a particular species to these (temporary) sites, and where the fish might go at low tide.

MATERIALS AND METHODS

The two sites selected for study are separated by 2.6 km of open water. The salinity is 34 ppt at both sites with a maximum tidal range of 1.8 m. Visual observations were made at each site by two to four individuals on ten days during the month of June, 2002. Fish were observed until all agreed on the numbers.

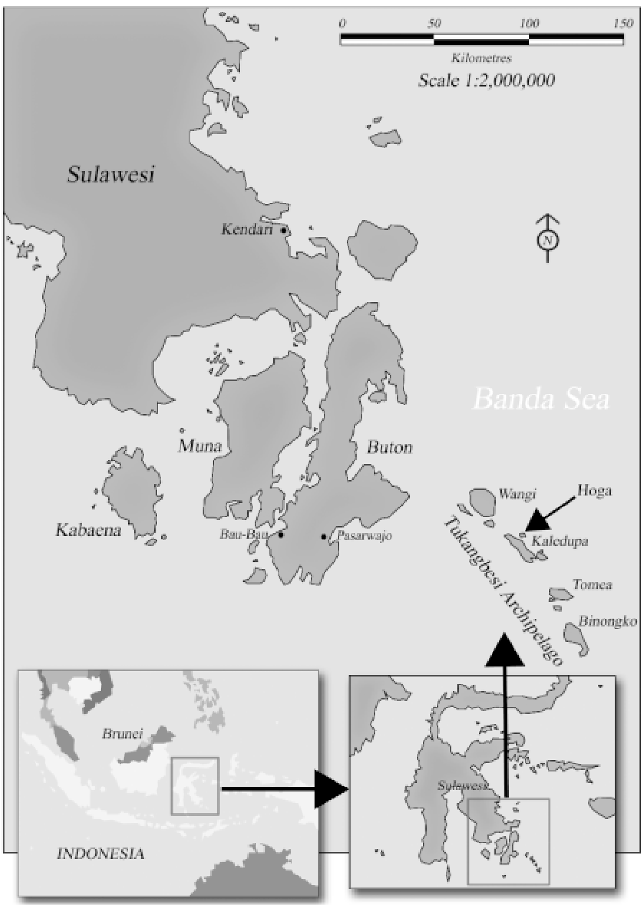

Fig. 1. Map of study sites. The arrow points to Hoga Island off the northeast coast of Kaledupa Island. The entire Tukangbesi Archipelago lies within the Wakatobi National Marine Park.

Mangrove **-** A mangrove (*Rhizophora stylosa*) habitat on small Pulau Matahari island near Kaledupa (Fig. 1) was chosen because, unlike some other mangrove locations, the depth was appropriate for snorkeling and the water clarity was adequate for visual observations. Six sites where fish were seen on the first day of observations were flagged for subsequent observations. Each site comprised approximately 2 m^2 and the distances between them were 60 m, 20 m, 10 m, 2 m, and 5 m. Nine additional visits were made at various phases of the tidal cycle (except for low tide) when the site depth, and number of fish of each species at each site were recorded.

Sea Wall or Jetty – The sea wall near the Operation Wallacea base on the island of Hoga (Fig. 1) was visited by snorkeling, and five sites that could be easily located for subsequent visits were selected. The sea wall has two inshore segments of piled up coral blocks and an outermost segment of coral blocks cemented together with a 20 cm ledge 30 cm above the sandy substrate. Occasional crumbled areas provide niches and small ledges. Gaps (3-4 m) separating the three segments allow passage of the current, and this surging through the gaps scours the sea bottom, creating pools that remain at dead low tide. The sites were: A- near the seaward end of the outer segment; B- middle of outer segment; C-inner end of the outer segment; D- near outer end of intermediate segment; and E- middle of the intermediate segment. Each site comprised about 2 m along the jetty, and the distances between them were 19 m, 17 m, 6 m (including the gap between jetty segments), and 30 m. Sites A, B, and C had the same depth profile, while D and E were 10 and 20 cm shallower, respectively. Fish were observed and recorded on 10 days during various phases of the tidal cycle (except for low tide). At three low tides, the wall was visited on foot for observations.

Total abundance and species richness were calculated each day for the combined stations at each of the two habitat types, and the means and standard deviations of the data from the ten days were calculated. For observations on the last day, Shannon-Wiener diversity indices were calculated. Site-fidelity for species was categorized as to whether fish of a given species were observed at the same site <33% of the time (low), 33-67% of the time (moderate), or >67% of the time (high).

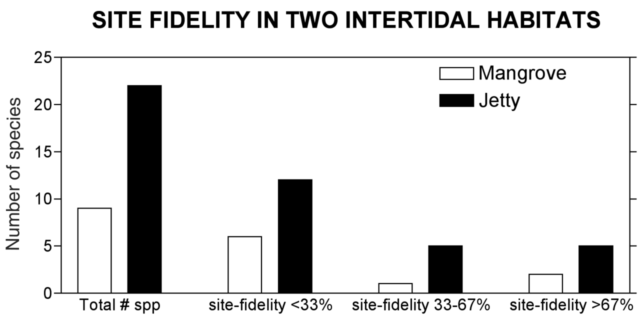

Fig. 2. Number of species seen at the two intertidal sites, and the number showing low (<33%), medium (33-67%) and high (>67%) site-fidelity

Table 1. Fish recorded at the mangrove and sea wall habitats. Percent relative abundance of each species at the two habitats, pooling data from all sites and dates (number of individuals of that species as a percentage of the total number of individuals of all species seen in that habitat).

Species	Mangrove	Sea Wall
Sphaeramia orbicularis	84	19.5
Chaetodon vagabundus	9.5	3.2
Chrysiptera caerulineatus	3.5	0
Abudefduf vaigiensis	1.5	24.2
Lutjanus russelli	1.5	0.4
Chrysiptera cyanea	0	15.4
Apogon ventrifasciatus	0	13.2
Pomacentrus chrysurus	0	12.8
Plectroglyphidodon leucozonus	0	3.0
Zanclus cornatus	0	1.6
Labroides diminiatus	0	1.6
Scorpaenopsis oxycephala	0	1.4
Thallasoma lunare	0	1
Pterois volitans	0	1
Siderea picta	0	1
Abudefduf sexfasciatus	0	0.4
Pomacanthus imperator	0	0.4

Table 2. Fish species seen at the mangrove sites, with frequencies observed (10% means that the species was seen one day out of the 10 observation days).

Species	**Site A**	**Site B**	**Site C**	**Site D**	**Site E**	**Site F**
Sphaeramia orbicularis	10%	100%	10%	100%	100%	0
Chaetodon vagabundus	30%	40%	30%	0	20%	20%
Chrysiptera caeruleolineata	0	0	0	0	0	70%
Abudefduf vaigiensis	0	10%	0	0	10%	0
Lutjanus russelli	0	10%	0	20%	10%	0

Note: Additional species were seen rarely: Blacktail sergeant (*A. sordidus*), a surgeonfish (*Acanthurus* sp.), and black patch Picasso triggerfish (*Rhinecanthus verruccosus*).

RESULTS

Mangrove – Overall, few fish were found in the mangroves, as the areas in between our sites were devoid of fish - none were seen on any of the sampling occasions. The average number of species seen at the six stations per visit was 3.6 $\pm$ 0.48 (S.E.) and the average number of individuals was 19.5 $\pm$ 2.2 in a stretch of about 100 m. The Shannon-Wiener diversity index (H') for the last day of observations was 0.703. The data on species observed at each site are seen in Tables 1 and 2, and the level of site-fidelity in Fig. 2. The most frequently observed species was the orbiculate cardinalfish, *Sphaeramia orbicularis,* which dominated the observations (Table 1) and showed great site fidelity (Table 2). Both adults and juveniles were noted. They were inconspicuous and remained motionless in the water. Vagabond butterflyfish, *Chaetodon vagabundus*, were seen sporadically. A single blue-line demoiselle (*Chrysiptera caerulineata*) was seen often at one site. Many of what appeared to be the same fish were seen repeatedly for several days at a site. (While it cannot be proved that the fish were the same individuals each day, it is likely that they were. For example, a single blue line demoiselle of the same size seen at the same site each day is likely the same individual.)

Sea Wall or Jetty – Many more fish were observed at the sea wall than in the mangrove sites, both in terms of numbers and diversity. The average number of species seen per visit was 11.3 $\pm$ 0.86 (S.E.) and the average number of individuals was 58.3 $\pm$ 8.1 in the stretch of about 10 m (five sites of two m each). These are significantly different from the numbers at the mangroves (for species, $t = 7.85$, $p < 0.0001$; for abundance, $t = 4.60$, $p < 0.0009$). The Shannon-Wiener diversity index (H') was 2.021. Here, sites were chosen because of recognizable landmarks, rather than because they were the only sites at which fish were seen. Some site-fidelity was observed. Certain species, such as the blue devil, *Chrysiptera cyanea*, the lionfish, *Pterois volitans,* and the cardinalfish, *Sphaeramia orbicularis*, were always seen at the same sites and never at other sites (Table 3). Often, when a species was seen at a site, it was there for several days in a row. Adults as well as juveniles were observed, although only *Abudefduf vaigiensis* had more juveniles than adults. Data are in Tables 1 and 3, and site fidelity in Fig. 2.

When the sea wall was visited by walking out at low tide, many fish that were normally associated with it were seen one to several meters away. Some were by rocks on the bottom in a few centimeters of water, and others in the deeper

Table 3. Fish species seen at the five sea wall sites, with frequencies observed.

Species	Site A	Site B	Site C	Site D	Site E
Abudefduf sexfasciatus	0	0	20%	10%	0
A. vaigiensis	30%	20%	90%	100%	20%
Chaetodon auruga	10%	0	0	10%	0
C. vagabundus	50%	30%	20%	0	40%
Chrysiptera cyanea	100%	0	100%	0	0
Labroides dimidiatus	50%	0	10%	0	0
Apogon ventrifasciatus	90%	30%	70%	70%	70%
Plectroglyphidodon leucozonus	0	0	0	0	60%
Pomacentrus chrysurus	60%	100%	30%	70%	30%
Pterois volitans	0	0	0	0	50%
Scorpaenopsis oxycephala	0	10%	40%	10%	0
Siderea picta	0	0	30%	0	10%
Sphaeramia orbicularis	0	0	0	10%	100%
Thallasoma lunare	10%	10%	0	10%	0
Pomacanthus imperator	20%	0	0	0	0
Zanclus cornutus	0	0	0	30%	10%

Note: Other species were seen rarely: a filefish (*Pervagor* sp.), an unidentified juvenile butterfly fish (*Chaetodon* sp.), a spot-tailed damselfish (*C. ocellicaudus*), a blueline demoiselle (*Chrysiptera caeruleolineata*), surgeons (*Acanthurus* sp.), a Russell snapper (*Lutjanus russelli*), and a bengal sergeant (*A. bengalensis*).

pools between the jetty segments where the water was about one meter deep in the middle.

DISCUSSION

Fish were scarce at the mangrove, but the one species that was abundant (orbiculate cardinalfish) showed site-fidelity. Most areas had no observable fish. We do not know where the fish go at low tide, but sea grasses nearby (~20 m away) may be their low tide refuge. Fish were far more abundant and diverse at the jetty, and the species that were found at mangroves (*S. orbicularis* and *C. vagabundus*) were also seen. Again, site-fidelity was seen with some of the species. Low tide observations suggest that these fish may not migrate to the reef at low tide, but rather stay nearby, in deeper pools. In studies on Caribbean reef fishes, Adams & Ebersole (2002) noted that certain families, including Lutjanidae, Chaetodontidae, Pomacentridae, and Labridae were found commonly at patch reef and rubble habitats as juveniles. The latter three families were represented at our sites. However, they did not find Apogonidae, and *S. orbicularis* (both juveniles and adults) were very common at both of our sites, while *A. ventrifasciatus* was very common at the sea wall. Some apogonids have been found to undergo ontogenetic habitat shifts as they mature (Vagelli, 2004), which does not appear to be the case for S. orbicularis. Adams & Ebersole (2002) suggested that rubble is a good refuge against predation, since it generally does not have holes large enough for predatory fishes. They did not mention if adults were found at their sites and stated that research is needed to determine the extent to which these juveniles actually contribute to adult populations in the nearby reefs.

It appears that some individuals of species called “coral reef” fishes may not necessarily utilize coral reefs proper, even as adults. The sea wall had filamentous algae and a large mat of brown algae, which could be a food source for herbivorous fishes. The high energy and clear water are similar to a reef, so it should provide comparable food for planktivores such as cardinalfish. *S. orbicularis*, however, dominated the mangrove and was noted in other shallow water and intertidal areas. There has not been extensive study of intertidal sea walls as habitat, although Chapman (2003) studied assemblages of animals on sea walls in Australia and noted a paucity of mobile invertebrate species in urban estuaries. Fish associating with the seawalls were not mentioned in that study.

Mangrove roots would appear to provide greater structural complexity than a sea wall as a refuge, so the low level of use of the mangrove was surprising. In contrast to mangroves studied in the western Atlantic by Ellison & Farnsworth (2001), the roots were not covered with a dense community of epibionts, which may indicate less food for fishes. Many roots were largely bare of epifauna, but had filamentous algae. Possibly the more turbid water is a deterrent to some fishes.

Other studies of mangrove fish, performed over longer periods of time, sampled fish with gillnets or fyke nets (Laroche et al., 1997; Lin & Shao, 1999) and observed some temporal differences in use. Seasonal changes have been found in density, biomass and diversity of fishes in mangrove creeks (Barletta et al., 2003), something that was not possible in our short-term study. Rooker & Dennis (1991) report that while there was a decline in species abundance at night at mangroves in Puerto Rico by visual census, no lunar cycles were seen. Boulon (1992) reports that both visual census and trapping provide useful information. Visual census is rapid and non-destructive but different observers have different accuracy (Cheal & Thompson, 1997). In the present study, two to four observers were used each time to verify observations.

Only a few studies have focused on intertidal mangroves that have to be abandoned twice a day. This type of habitat is probably less desirable than a permanent subtidal habitat. Mullin (1995) studied fish populations among intertidal mangrove roots and found that more fish species were in the open water areas than among the prop roots. Estimates of fish density showed high variability. Robertson & Duke (1990) found mangroves in northern Queensland, Australia, at high tide were important habitats for juvenile and adult fish.

There is disagreement over the importance of mangroves for coral reef fishes. Laroche et al., (1997) felt that the mangroves in Madagascar played only a limited nursery role for coral reef species. Halliday & Young (1996) report fish use of mangroves in Tin Can Bay, Australia was low. Fish communities in mangroves in Sydney Harbour were comparable to mudflats in terms of abundance and species richness, suggesting that the mangroves were not a particularly important habitat (Clynick & Chapman, 2002). Blaber & Milton (1990) concluded that Solomon Island estuaries did not play a role as nursery grounds for coral reef fishes. In Gazi Bay, Kenya, more fish were found in cleared habitats than in mangrove sites (Huxham et al., 2004). There is little documentation that the juvenile fish seen in mangroves actually move to the reefs as adults (Polunin & Roberts, 1996). Thollot (1992) observed that mangroves appear to be more important as nursery areas for coral reef fish in the Western Atlantic than in the Indo-Pacific. The previous references, as well as our data, seem to support this geographic difference.

Overfishing is another possibility at our mangrove site, which is close to a town. There is extensive fishing with fyke nets and gill nets along the shore, not far from the mangrove site. The local residents eat all sizes of fish (Duncan May, pers. comm.).

Although of very limited scope and duration, this study suggests that intertidal mangrove habitats may not necessarily be important alternate habitats for coral reef fishes in this particular area. Intertidal rocky habitat by the sea wall appears to harbor many more species and individuals than the mangrove area studied. More extensive research over longer periods of time and greater spatial areas will be needed to better understand the role of these mangrove habitats in the ecosystem and their linkages to coral reefs.

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