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Spatio-temporal patterns of juvenile and adult abundance and biomass of reef fishes in the Sulu Sea, Philippines

M.R. Deocadez[1], E.P. Moleño[2], H.O. Arceo[3], J.P. Cabansag[4], J.L. Apurado[5], S.S. Mamauag[1], C.L. Villanoy[1] and P.M. Aliño[1]

1) Marine Science Institute, University of the Philippines, Diliman, Quezon City
2) Mindanao State University @ Naawan, Naawan, Misamis Oriental, Philippines
3) DAI USAID Philippine Environmental Governance 2 Project, Philippines
4) University of the Philippines-Tacloban, Tacloban City, Philippines
5) San Carlos University, Cebu City, Philippines

Abstract: Underwater fish visual census was undertaken to determine juvenile and adult abundance and biomass of commonly occurring reef fish taxa/species at several sites along the major marine corridors in the Sulu Sea. Presence/absence, abundance, and biomass of taxa/species in both stages showed varying patterns within and among sites. Variation in adult abundance and biomass of some species suggests decreasing similarities with increasing distance at some sites while other species showed contrasting patterns with distant sites exhibiting similarities. For juvenile abundance, patterns were similar with those of the adults. Significant correlation between juvenile and adult abundance was observed at some sites. The match and mismatch of spatial patterns of distribution of adults and juveniles of reef-associated fishes are influenced by two major factors. Local water circulation patterns at the different corridors, which potentially disperse egg and larvae within and between corridors shows changing connectivity potential of fish populations. Relatively high species diversity of juvenile and adult fish was observed in areas of high entrainment. On the other hand, disturbance and stresses such as over-fishing and habitat degradation will increase mortality in fish populations at varying stages of their life history and, therefore, reduces the connectivity potential in a range of spatial scales in the Sulu Seascape.

Keywords: reef fish abundance and biomass, entrainment and habitat degradation, spatial and temporal patterns

Introduction

The marine corridors in the Sulu Sea have been proposed to be strategic marine priority conservation areas that help provide the resiliency in the Sulu Sea (Ong et al. 2002). These areas are found at the heart of the Coral Triangle, which has been recognized as the center of highest marine biodiversity (Carpenter and Springer 2005). Regular monitoring of adult and juvenile reef fish abundances serve as crucial proxies to reef conditions and help understand the major determinants of the population structure of coral reef fishes (Booth and Beretta, 2004).

Observations of the changes in reef benthos and community structure of associated fish dovetail with other factors such as hydrography (Cowen 2002) and larval biology (Leis and McCormick 2002) to fully understand the connectivity of reef populations (Cowen et al. 2006). This study presents the dynamics of the reef fish community structure in the marine corridors of the Sulu Sea.

Materials and Methods

A total of 44 transects from five municipality sites covering the three marine corridors in the Sulu Sea were sampled (Mabini and Verde in the Verde Island Passage; Balabac in the Balabac Strait; Cagayancillo and Tubbataha reefs in the Cagayan Ridge) (Fig.1). Survey months were made during the transition periods of the Northeast monsoon (October 2006) and Southwest monsoon (April-May 2006 and 2007). Fish Visual Census (FVC) was used to determine fish assemblages and abundance of adults and juveniles (English et al. 1997). Fish were identified if possible at the species level, their numbers and sizes estimated within an area of 500m^2 (adult) and 50m^2 (juvenile) per transect.

Multivariate analyses of spatial pattern of adult and juvenile fish correlation with forcing factors were performed using the ordination technique, non-metric Multidimensional Scaling (nMDS). In addition, Analysis of Similarities (ANOSIM) was carried out to determine significance of generated patterns (PRIMER 6 ver. 6.1.6). This approach examines factors that influence the spatial and temporal patterns of the reef associated fish communities. From the patterns we can infer insights that will facilitate marine biodiversity conservation measures to reduce the threats on reef health and help in the design of MPA networks.

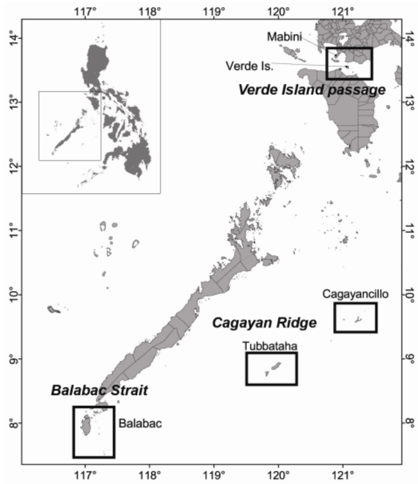

Figure 1. Map of study sites within the three major marine corridors (i.e., *Verde Island Passage, Balabac Strait and Cagayan Ridge* includes Tubbataha and Cagayancillo.

Results

Adult abundance and biomass

Presence/absence, abundance and biomass of taxa/species at adult stages showed varying patterns within and among the municipality sites in the three corridors. Non-metric MDS analysis for abundance showed clear patterns only in between-site category (Fig. 2a). For biomass, ordination analysis provided similar patterns as with abundance. Analysis of Similarity (ANOSIM) of abundance and biomass revealed that factor Site (municipality) was more important than Time (season) (Table 1) suggesting that site-specific attributes are more important forcing factors upon the fish community structure.

Pair-wise comparison for differences in abundance and biomass between municipalities showed large variation between Balabac and Tubbataha (Table 2) especially for the abundances of families Apogonidae, Pomacentridae, Caesionidae Labridae, Lutjanidae, Anthiinae and Acanthuridae. There were more apogonids and labrids (Cheilininae) at Balabac than at Tubbataha but more caesionids, pomacentrids, acanthurids, and lutjanids at the latter than at the former. Between Tubbataha and Mabini/Verde sites, there were more caesionids, acanthurids, lutjanids and serranids at Tubbataha than at Mabini/Verde. Some sites showed increasing similarities with decreasing distance (e.g. adjacent sites Cagayancillo-Tubbataha versus distant sites Cagayancillo-Mabini/Verde) based on the abundances of dominant taxa such as caesionids, acanthurids, lutjanids and serranids. However, distant sites such as Balabac and Mabini/Verde also showed similarities based on the abundances of pomacentrids (*Acanthochromis polyacanthus*) and anthiinids (*Pseudanthias huchtii*). Following Tubbataha in reef fish biomass is Cagayancillo, Mabini, Verde and Balabac. Consistent peaks were observed for Tubbataha for the three intermonsoon seasons, while Mabini was observed to be highest in October. Palawan sites were recorded with highest biomass in the April-May transition periods. In addition, its relatively isolated location in the Sulu Sea (island mass effect; Hammer and Hairy 1981, AMERCO and Andrews 1989) affords the Cagayancillo reefs the high abundance observed.

Temporal pattern in abundance did not differ (April-May 2006 and April-May 2007; R=0.107, p<0.01) whereas biomass did so slightly. This was attributed to an increase in target species at Verde from 2006 to 2007 and a decrease at Tubbataha from 2006 to 2007.

Table 1. ANOSIM of adult fish abundance and biomass for the five municipalities surveyed over three monitoring periods. Factor with highest R-value contributes more to the community structure.

Factors	R-value	Sig. Level (%)
Abundance		
Time	0.101	0.4^{**}
Site	0.369	0.1^{**}
Biomass		
Time	0.046	6.7^{ns}
Site	0.507	0.1^{**}

The abundant presence of species belonging to the large, top trophic groups (Lutjanidae, Serranidae, Acanthuridae, and Scaridae) resulted in higher biomass in Tubbataha. This was not surprising since Tubbataha is a no-take National Marine Park with strict enforcement resulting in a considerable number of large, top predatory fish whereas Balabac and Mabini/Verde sites are under various levels of exploitation with few smaller marine reserves.

Table 2. Pair-wise test for difference in reef fish abundance (Ab) and biomass (Bm) between groups of municipalities surveyed for the three monitoring periods. R-values approaching ‘1’ indicate large differences.

Groups	R-value		Sig. level (%)	
	Ab	Bm	Ab	Bm
Bal, Mab	0.32	0.34	10.7	9.5
Bal, Ver	0.26	0.43	0.3	0.1
Bal, Cag	0.39	0.41	0.1	0.1
Bal, Tub	**0.75**	**0.91**	**0.1**	**0.1**
Mab, Ver	0.13	0.50	20.6	0.2
Mab, Cag	0.26	0.29	1.4	0.2
Mab, Tub	**0.51**	**0.84**	**0.1**	**0.1**
Ver, Cag	0.35	0.48	0.1	0.1
Ver, Tub	**0.50**	**0.78**	**0.1**	**0.1**
Cag, Tub	0.17	0.50	0.7	0.1

Juvenile abundance

Density (no. per area) of juveniles showed different seasonal pattern compared to adults. Tubbataha, Cagayancillo and Verde peaked in juvenile abundance during October while Balabac and Mabini peaked during April-May (Fig.4). Tubbataha and Cagayancillo recorded very high juvenile densities, about 6 to 9 times more than the other municipalities surveyed, coincident also with high abundance in adult fish. nMDS analysis for juveniles showed less distinct patterns than that of the adult fish (Fig.2b). In order to identify which taxonomic group of fish drives the variation in abundance, BVSTEP analysis was undertaken. Families Apogonidae and Cirrhitidae were the important fish groups for Balabac and Cagayancillo, while it was Anthiinae for Tubbataha, Verde and Cagayancillo. Gobiidae, on the other hand, was prominent in Cagayancillo and Verde whereas Labridae subfamily Bodianinae was the significant fish group in Cagayancillo and Tubbataha. ANOSIM revealed that both factors Site and Time had very low R values (0.183 and 0.094, respectively) which suggest that the temporal patterns of juvenile abundance are similar among sites. Nonetheless, there appears a difference in the level of abundance between years and seasons at some sites (Fig. 4). There were more juveniles of family Pomacentridae and Anthiinae in April and October 2006 at Tubbataha and Cagayancillo. There was generally higher abundance of juveniles of family Pomacentridae and Anthiinae in 2006 than in 2007 at Tubbataha, Cagayancillo and Verde. These results indicate that recruitment may be seasonal at least at Tubbataha, Cagayancillo and Verde (Fig. 4).

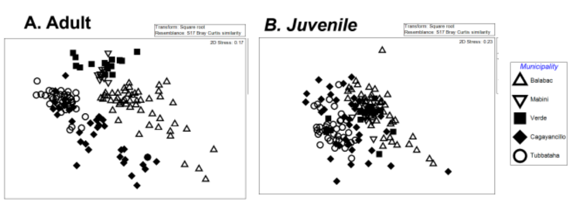

Figure 2. Spatial pattern of (a) adult (b) juveniles fish abundance in 44 transect sites in three monitoring seasons.

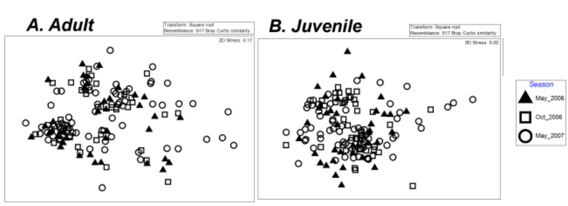

Figure 3. Temporal pattern (a) adult and (b) juvenile abundance in 44 transect sites in three monitoring seasons.

MDS analysis also showed no clear patterns on juvenile abundance (Fig. 3b).

Correlation between adult and juvenile reef fish abundance among the five municipalities for the three sampling seasons revealed low but significant correlations overall ($r=0.4$, $p<0.01$) and per sampling season (May 2006: $r=0.4$, $p<0.01$, Oct. 2006: $r=0.5$, $p<0.01$, and May 2007: $r=0.5$, $p<0.01$). These similarities in abundance trends in adults and juveniles at specific sites can be drawn from patterns in community structure exhibited by dominant families. An example in the study would be Anthiinae identified in the BVSTEP analysis. There was good correlation between juveniles and adults of Anthiinae in Balabac ($r=0.73$, $p<0.05$) and in Verde ($r=0.78$, $p<0.05$). Apogonidae, on the other hand, was highly correlated in Balabac ($r=0.69$, $p<0.05$) but not so much in Cagayancillo ($r=0.14$, $p>0.05$) wherein Cirrhitidae correlated well ($r=0.62$, $p<0.05$). Cirrhitids also significantly showed good correlation in Tubbataha ($r=0.42$, $p<0.05$) together with Bodianinae ($r=0.42$, $p<0.05$). However, this phenomenon is not common in many reef fish families (e.g. Srinivasan and Jones 2006).

Discussion

Some patterns in adults showed decreasing similarity with increasing distance as exemplified by the distant Tubbataha-Balabac sites and proximal Tubbataha-Cagayancillo sites. This pattern could be influenced by processes driving larval dispersal (e.g. Cowen et al., 2000) and thus provides an explanation of the present fish community structure (e.g. Sale and Kritzer, 2003). Beldia et al. (this symposium) have provided data on larval distribution together with oceanographic profiles of the study sites and clearly showed potential larval sources and sinks. However, there were contrasting patterns which showed similarity even in distant sites (e.g. Balabac-Verde). This scenario is completely different and hardly invokes ecological processes as to explain the community structure. Stressors such as fishing and habitat degradation also potentially influence the variation in the patterns. There were differences in the occurrence of target species such as caesionids, acanthurids, labrids and lutjanids among the sites.

Juvenile abundance showed slightly different temporal pattern compared to adult abundance. Recruitment may be seasonal at least in Tubbataha, Cagayancillo and Verde, which peak during October month. However, temporal pattern may be site specific and seasonal trend may not always be consistent between sites (Sale et al., 1984) and seasons (Arceo 2004, Booth and Beretta 2004, Srinivasan and Jones 2006). Among the municipalities, Tubbataha and Cagayancillo recorded very high juvenile abundance than the other sites surveyed, coincident also with high abundance in adult fish (Srinivasan and Jones 2006). This suggests that recruitment is high in Cagayancillo and Tubbataha sites or it has dual functionality of being a source and sink area. Furthermore, Cagayancillo sites might also act as a sink, receiving larvae from areas farther north such as the Calamianes group of Islands, Cuyo, Agutaya and Apo Reefs via the prevailing water currents during the Northeast monsoon, and receiving larvae from Tubbataha during Southwest monsoon (Fig. 5). Mabini/Verde, on the other hand, may be receiving larvae from Mindoro and Tayabas Bay. This however still remains to be confirmed.

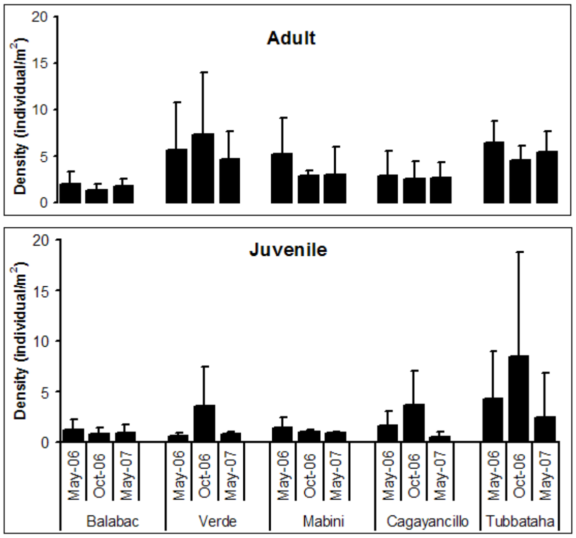

Figure 4. Density of adult and juvenile fish. Recruitment may be seasonal at least in Tubbataha, Cagayancillo and Verde, which peak during October.

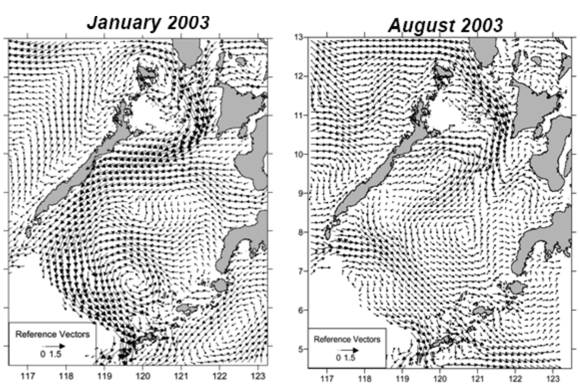

Figure 5. Current patterns in Sulu Sea derived from the Pacific HYCOM (http://hycom.rsmas.miami.edu/) used to force dispersal model for the entire basin (Sulu-Sulawesi Seascape).

These matching and mismatching of spatial patterns of distributions of the various life stages of benthic reef-associated fishes in Sulu Sea are influenced by two major environmental factors. One is the local water circulation pattern (Sale et al., 1984, 2005, Bode et al., 2006) at the different corridors in the Sulu Seascape, which potentially disperses egg and larvae within and between corridors, implicating shifts in connectivity potential of fish populations. There is a concordance on the diversity of juvenile fish species in areas of high entrainment (Carassou and Ponton, 2007) and with adult fish species. The second major factor is disturbance and/or stresses such as over-fishing and habitat degradation. Mortality in fish populations at varying stages of their life history will therefore reduce the connectivity potential in a range of spatial scales in the Sulu Sea (e.g. Sale et al., 1984, Sale and Kritzer, 2003).

Conclusions

Abundances of adult and juvenile fishes were high in Tubbataha and Cagayancillo suggesting that recruitment, survivorship and growth rates in these areas are also high which may serve both as a source and as a sink.

Adult fish had clearer spatial pattern than juveniles. ANOSIM revealed significant differences vis-à-vis their location among sites indicating site as a factor affecting fish community structure. However, juvenile had clearer patterns in terms of temporal pattern than former.

Spatial distribution patterns were influenced by (a) local water circulation patterns which potentially influence the connectivity of fish populations and (b) disturbance and/or stresses (i.e., over-fishing and habitat degradation) which increase the mortality of fish populations at varying life stages and therefore affect their survivorship and reproductive outputs at each corridor.

Results from this study fill critical gaps in developing scenarios on connectivity and their implications to management and biodiversity conservation. These areas would be important in the design of MPA networks and in the improvement of critical management gaps such as reducing threats through integrated coastal management, enhancing survivorship, strengthening enforcement and education about reducing threats and disturbances.

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