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Larval Dispersal of Reef Fish Along Three Major Coastal Ecosystems in Misamis Occidental

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ABSTRACT

The study was carried out to determine the connectivity of major coastal ecosystems of coral reefs, seagrass beds and mangrove areas through fish larval dispersal. Investigation was conducted in Lopez Jaena, Panaon and Tudela, Misamis Occidental from January to March 2011. Collection of fish larvae was done using a 300µm rectangular framed plankton net employing horizontal towing technique during springtide nights. Identification of fish larvae was limited to family level. A total of 559 fish larvae represented by 11 fish families were collected during the three sampling periods. Family Gobiidae and Apogonidae were the most common in all three ecosystems in the study sites. Fish larval density was significantly highest in the mangrove areas of Lopez Jaena and Tudela. Densities of post-flexion larvae were significantly high dominating the three ecosystems in all study sites. The ratio of stage 4 against stage 3 larvae was similar in all three ecosystems, which suggest that during flood tides fish larvae are passively drifted by the prevailing water current in the three study areas. Environmental parameters measured in the area showed an optimum range of temperature, pH and salinity for fish larvae to survive. Current velocity ranges from 0.1m/sec – 2.69m/sec, flowing southwest during flood tide. The present study indicates strong connectivity of the three contiguous ecosystems of mangrove areas, seagrass beds, and coral reefs. The results also confirm the important role of mangrove areas and seagrass beds as true nursery grounds for many fish families. The latter suggest that in addition to coral reefs, the mangrove areas and seagrass beds should be considered in establishing sustainable marine protected areas.

Keywords: coral reefs, fish larvae and connectivity, Larval dispersal, mangroves, seagrass.

INTRODUCTION

Vast majority of marine reef-fishes or demersal, teleost fishes have pelagic larval stages (Leis, 1991). The latter are generally considered to have open populations, thus population of marine, reef or demersal fishes in different locations may be connected by dispersal between them, and the extent of which populations are linked is termed connectivity (Palumbi, 2003). Studies have shown that dispersal of these reef-fishes takes place during the pelagic larval stage before it ends dramatically by settlement into a demersal way of life (Kinlan and Gaines, 2003; Armsworth et al., 2001). It is therefore suspected that it is the pelagic larval stage, rather than the adult stage that sets the scale for population connectivity and for the geographic size of fish populations (Kinlan and Gaines, 2003; Cowen, 2002; and Sale, 2004).

Shallow coastal and estuarine areas represent very important habitats as spawning and nursery grounds for many species of fish (Weistein and Brooks, 1983; Boehlert and Mundy, 1988). Many of those species enter the system as larvae and some as juveniles, but typically, only a few species spawn within the main bodies of estuaries or in a mangrove system (Dando, 1984). While many studies focus on the use of mangrove ecosystems by juveniles rather than many larvae, several studies have been conducted on the spatio-temporal distribution of fish larvae in bays (Dovel, 1981; Roper, 1986; Steffe and Westoby, 1991), in seagrass beds (Olney and Boehlert, 1988), in high marsh pools, (Talbot and Able, 1984), in surfing zones (Modde and Ross, 1981; Ruple, 1984), and in coral reefs (Leis, 2006). Apparently, it appears that these habitats play an important role for the staging and growth of fishes. And as far as protection and food source are concerned, the respective roles of these habitats played still unclear (O'Neil, and Weinstein, 1987; Jacoby and Greenwood, 1988). The relationship and its ecological role on larval distribution, particularly on its ontogenetic stages, and the effect of lunar phases are yet poorly understood.

Distributional studies of larval fishes frequently show that larvae of different species originating from the same sort of habitat (often, a coral reef) have differing distributions (Boehlert, 1996; Cowen and Sponaugle, 1997). Some authors speculated that behaviour might be responsible for such distribution (Leis and Miller, 1976; Leis, 1982; Suthers and Frank, 1991), but there was little or no hard information on behaviors of the larvae, other than vertical distribution (Leis, 2006; Steffe, 1991; Steffe and Westoby, 1991).

Larval dispersal refers to the spread of larvae from a spawning source to a settlement site (Pineda et al., 2007). Several factors may influence the dispersal of many reef-fishes, like temperature, water hydrography or currents, swimming abilities, behaviors, sizes and stages of growth.

At present, coastal environments have suffered a tremendous decline and devastation brought about by various environmental stresses such as overexploitation, rapid industrialization, and the detrimental effects brought by climate change. Thus, many government and non-governmental organizations have come up with an adaptive plan to resolve such problem by establishing various marine protected areas (MPAs) on our country's coastlines with a goal of protecting, preserving, and conserving what is left of it, and also to enhance fisheries stocks to sustainable level (Leis, 2006; Palumbi, 2001). But many locals, particularly those coastal dwellers whose livelihood mainly depends on those coastal ecosystems (declared as MPA) are quiet skeptic and tend to deviate from such ideas of MPA establishment. For many of them believe that MPA establishment should only include coral reefs, and not to extend such prohibitions to shallow seagrass beds and mangrove estuaries. To generate data that will resolve these controversies, coastal ecosystem should be well understood in terms of its major ecological role in preserving and in enhancing fisheries stocks through connectivity studies.

This study was conducted for the following reasons: (1) Rarity of scientific data on connectivity studies of various reef fish larvae; (2) limited knowledge about the role of these three major coastal ecosystems (as habitats) on the ontogenetic development of many reef fishes; and finally, (3) to generate data to complement other existing studies and information about MPA establishment. The study aims to show that these three major ecosystems, namely; coral reef, seagrass beds, and mangrove estuary are vitally connected to one another, by studying the larval dispersal of reef fish along these contiguous ecosystems. The vast majority of marine reef fishes or demersal, teleost fishes have a pelagic larval stage (Leis, 1991). Furthermore, most of these reef fishes have open population (Sale, 1991; Johnson, 2005), thus population of marine, reef or demersal fishes in different locations may be connected by dispersal between them. The extent of which populations are linked is termed connectivity (Palumbi, 2003). The study specifically aims to answer the following questions: (a) Are these three major coastal ecosystems interlinked by reef fish larval dispersal? (b) Is there connectivity for all developmental stages of reef fish larvae in these three ecosystems? (c) What is the state of the three coastal ecosystems where these reef fish larvae inhabit? The results from the study hope to give us an insight on the activities of some reef-fish larvae species caught by horizontal towing. Furthermore, it hopes to provide and contribute knowledge on the ecological role of these distinctive coastal ecosystems on the ontogenetic development of various species of fish through reef-fish larvae samplings.

The study was conducted in the coastal areas of the province of Misamis Occidental, particularly, in the municipalities of Lopez Jaena, Panaon, and Tudela (Fig. 1 and Table 1) during the months of January 2011 to March 2011. The study focused only on ichthyoplankton or fish larvae samples collected on subsurface level using horizontal net towing method, along the three major contiguous coastal ecosystems of mangrove, seagrass, and coral reef during nighttime sampling. Identification of reef fish larvae is limited only to major family groups of fishes due to limited references and facilities in determining fish larvae up to species level. Surface current measurements were taken only during flood tides when water reached shallow seagrass beds and mangrove areas.

Table 1. Study sites and locations of the sampling area.

Site	Coordinates		
	Mangrove	Seagrass	Coral
Lopez Jaena	8.26094N, 123.86595E	8.25958N, 123.86609E	8.26088N, 123.86692E
Panaon	8.35408N, 123.84619E	8.35511N, 123.84821E	8.56671N, 123.76682E
Tudela		8.56277N, 123.76651E	8.35681N, 123.85197E

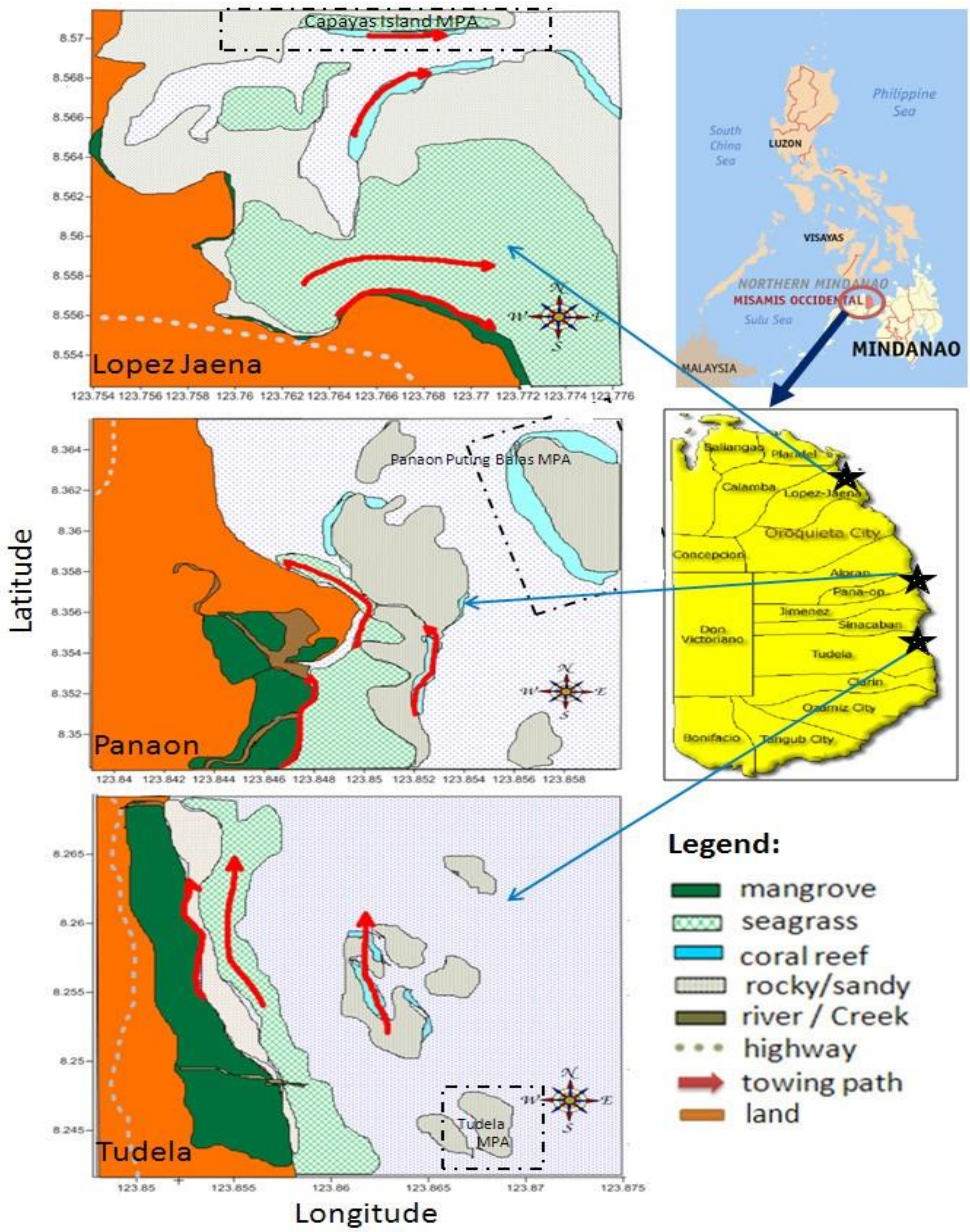

Figure 1. Geographical locations of the sampling sites in the municipalities of Lopez Jaena, Panaon, and Tudela Misamis Occidental, where plankton towings were done. Inset is the map of the Philippines and the province of Misamis Occidental (bottom right) emphasizing the location of the municipality (*) in Mindanao Island.

MATERIALS AND METHODS

Collection of fish larvae

To determine the distribution of reef fish larvae in the three major coastal ecosystems, horizontal net tows were undertaken using a 300µm mesh plankton net, 2meter long and 1m by 0.75m dimension (rectangular frame), with a flow meter (Sea-Gear), and a 500ml collecting jar at the bottom end. Tow duration was kept for 5 minutes at a constant speed of 1.5 to 2 knots for each towing covering a tow distance of approximately 232 m. Once the tow was completed, the net was carefully backwashed with sea water so that captured organisms would be caught in the collecting jar. The contents of the jar were carefully poured into a clean 1 liter plastic bottle and immediately fixed with 100ml of 40% formalin before being topped up with fresh seawater to make a solution of 4% formalin. Bottles were properly labeled with date, site name, sample number and fixative. All reef fish larvae collection was done at night during spring tide.

For every site, two tows were taken for every station (major ecosystem), a total of six tows per site. For mangrove areas, tows were done within the periphery of the area as possible. As for seagrass beds and coral reefs, tows were taken inside the seagrass beds area (about >100m away from the mangrove area), parallel to the shoreline of either southwest or northeast direction facing the current direction (Fig.1). There were three night-time samplings for each site for the whole period of the study, and all of which were conducted during springtides during the months of January to March year 2011. Weather conditions, sea state, and depth of the water were noted during sampling.

Sample preparation

Samples were emptied onto a 300µm mesh sieve, sorted, and washed thoroughly with fresh water to remove residual formalin. Then, the samples were carefully backwashed into 50ml- plastic containers using 70% ethanol to preserve it.

Taxonomic identification of fish larvae

Reef fish larvae species were identified to family level, using an identification guide to marine fish larvae (Leis and Carson-Ewart, 2004), and taxon abundance (ind. 100 m^{-3}) counted under a stereomicroscope, using the entire sample filtered. Representative samples for each major taxonomic group of fish larvae collected were photographed using a high resolution (27X, 35X, and 400X magnifications) USB microscope (VEHOO) on board with video camera, place at constant distance and focus.

Identification of reef fish larvae species (up to family level) were carried out and validated with the aid of: web database (www.coralreef.com; www.fishlarvae.com; and www.

fishbase.com); Ichthyoplankton study in Guinean and Senegalese coastal and estuarine waters (UNESCO, 1994); (Leis and Carson-Ewart, 2004). Still pictures taken by a portable USB microscope were also used in identifying reef-fish larvae.

Larval stages

Reef fish larvae were identified, counted and classified according to its ontogenetic stages during larval period (Fig. 2). Larval stage begins with hatching to attainment of complete fin ray counts and beginning of squamation (Leis and Carson-Ewart, 2004). The larval period subsequent to the yolk-sac stage falls into three stages related to flexion of the notochord during caudal fin development. These three stages are termed preflexion-, flexion- and postflexion-stage larvae (Leis and Carson-Ewart, 2004; Re and Meneses, 2009).

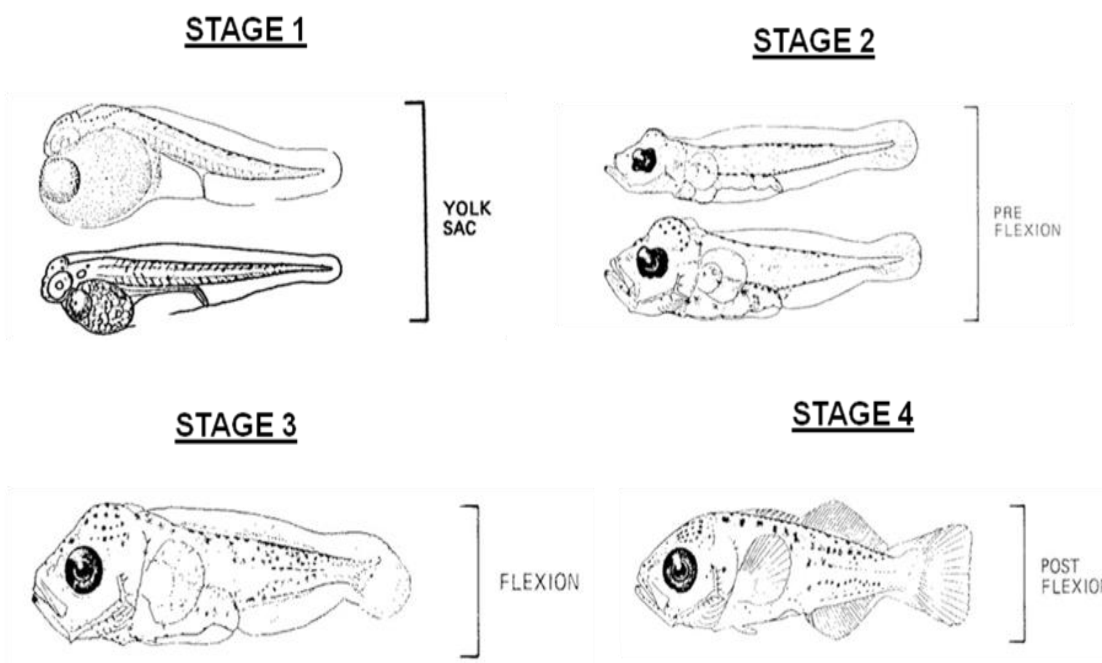

Figure 2. Guide to different stages of reef fish larvae (after Leis and Carson-Ewart, 2004).

Environmental parameters

To characterize the ecosystems where reef fish larvae are present, data for selected physical parameters were collected simultaneously during the sampling. Collections were done at subsurface level of the water. For temperature, laboratory (alcohol-based) thermometer was used, hand-held refractometer for salinity, and pH meter for pH.

Current speed and direction were measured using current drogue and GPS instrument (Garmin e-Trex). Ten cylindrical current drogues were deployed in the study area, for about 10-15 minutes, during flood tide. The coordinates, time of the deployment, and retrieval for each drogue was precisely recorded using a GPS. Then, the recorded data from (deployed and retrieved) drogue were analyzed using a vector calculator (Tomzhak, 2005). Then, data obtained were plotted using the Golden Software Surfer version 7.0 mapping software to illustrate the current velocity in the three study sites.

Data analyses

All univariate analyses were performed using statistical software.. The larval densities taken from each tow for each ecosystem per site were used for statistical analyses. Data were tested for model conformity to meet assumptions for analysis of variance (ANOVA) using Levene's test, and whenever necessary, the data was log (x+1) transformed to meet the requirements. Larval density data from three (3) samplings were pooled in the analysis. Comparison of overall fish larval density and larval density per developmental stages between the sites and ecosystems were analyzed for significance using Two-way GLM -ANOVA and One-way ANOVA at 5% level of significance. Post-hoc Tukey's tests were conducted to determine the source of variation. No statistical test was conducted for physical parameters due to limited data obtained from the field. Ranges of these parameters were noted and reported.

RESULTS AND DISCUSSIONS

Fish larvae in the three major coastal ecosystems

A total of 559 fish larvae representing 11 fish families (Gobiidae, Apogonidae, Carangidae, Clupeidae, Labridae, Mullidae, Ambliopidae, Monacanthidae, Ophiidae, Pomacentridae, and Tetraodontidae) were collected during the study (Fig. 3). Family Gobiidae and Apogonidae were the only fish families occurring in all ecosystems in all study sites. Family Gobiidae dominates the number of fish larvae in all sites accounting for more than 90.74% of the fish larvae collected, while apogonid larvae comprised of 53.70%. Mean larval density of fish larvae also shows the dominance of gobiid larvae in all sites and almost all ecosystems except in the coral reef area of Panaon (Fig. 4). All other fish families caught except for gobiids and apogonids were only noted once, and were considered as rare samples collected during the study.

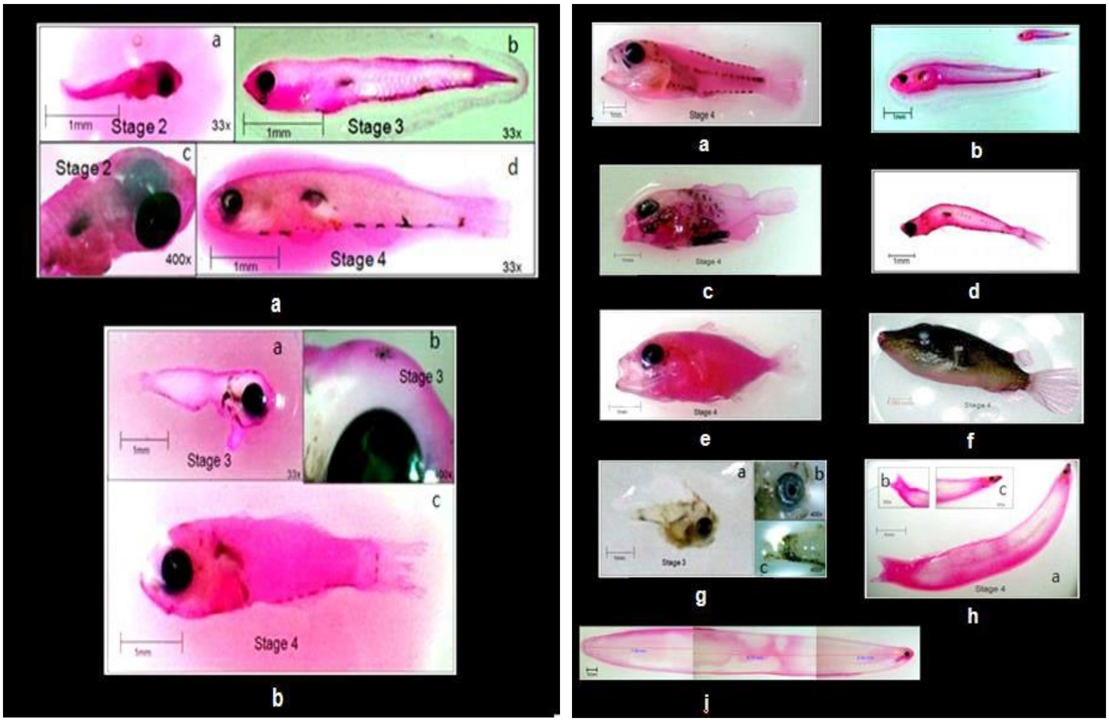

Figure 3. Representative samples fish larvae collected in Misamis Occidental from January to March 2011, along the three contiguous coastal ecosystems. A) Gobiidae; B) Apogonidae. a) Mullidae; b) Amblyopidae; c) Pomacentridae ; d) Labridae; e) Carangidae ; f) Tetraodontidae; g) Monacanthidae ; h) Clupeidae and; i) Ophidiidae. Pink coloration is due to pigment from Rose Bengals's solution.

Distribution and abundance of fish larvae along contiguous ecosystems

In the context of larval distribution across the three contiguous ecosystems during flood tides showed that in Lopez Jaena and Tudela, fish larvae tend to acummulate significantly in mangrove areas and less in coral reefs and seagrass beds (Fig. 4). However in Panaon, the distribution of fish larvae did not vary significantly across ecosystems (Fig. 5). Most of the larval samples of gobiids and apogonids collected during the study were mostly in stage 4 and stage 3. In Tudela and Lopez Jaena, stage 4 gobiid larvae tend to accumulate in the mangrove area than in coral reef and seagrass beds (Fig. 5). However in Panaon, the distribution of stage 4 gobiid larvae did not vary significantly across ecosystems (Fig. 5, Right). The fish larval percentage ratio of stage 4 against stage 3 gobiids larvae was almost the same between ecosystems and among site regardless of its abundance (Fig. 5, Left). The relative percentage

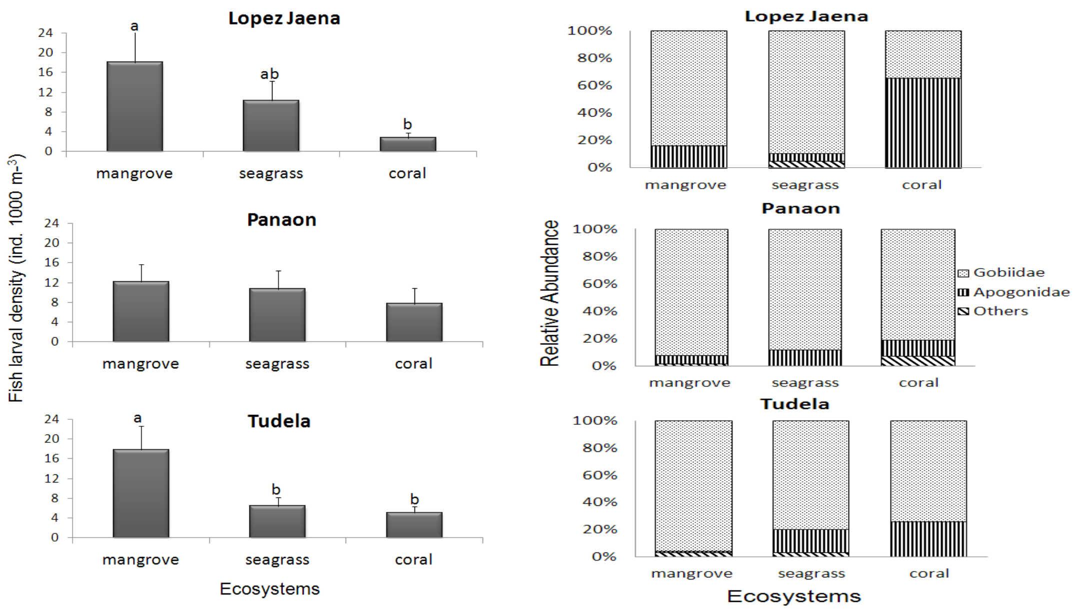

Figure 4. LEFT: Density of fish larvae in Lopez Jaena, Panaon, and Tudela across three contiguous coastal ecosystems. Data sampling (n=18 tows) were pooled for each site. Common letters within a site indicate that mean values are not significantly different at 5% level of significance (ANOVA). RIGHT: Relative abundance of fish larvae families in Lopez Jaena, Panaon, and Tudela along three contiguous coastal ecosystems. Gobiidae and Apogonidae were listed as common families, while all rare fish families were pooled and listed as others.

of stage 4 and stage 3 among ecosystems and among sites, suggest that during flood tides fish larvae are passively drifted by the prevailing water current in the three study areas.

Flushing of tides (during flood tide in Fig. 6) into the shallow coastal area particularly in seagrass beds and in the base of mangrove areas tend to bring nutrients and a variety of living phytoplankton, zooplankton and other particulate matters in the water column which would nourish a variety of fish larvae (Walters and Bell, 1986; Robertson et al.,1998). Since stage 3 and 4 larvae have well developed gas bladder, they can vertically migrate (Ruple, 1984; Leis and Carson-Ewart, 2004) and be exposed to moving currents. This may explain why fish larvae are present in the subsurface water columns together with other passively drifted plankton species to feed.

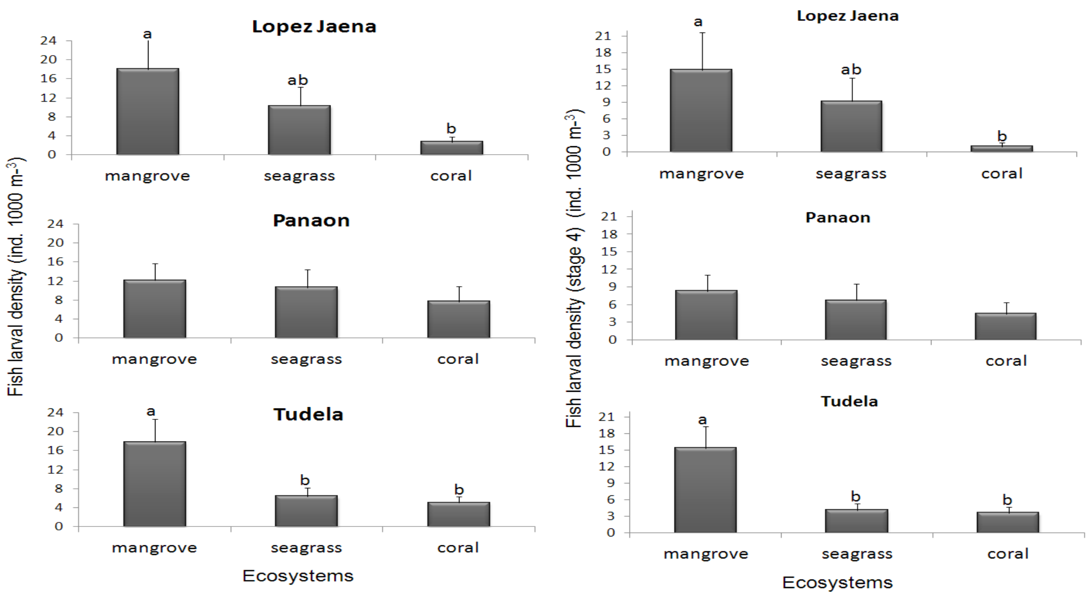

Figure 5. LEFT: Fish larval percentage of family Gobiidae according to different larval stages along three contiguous coastal ecosystems. Data sampling (n=18 tows) were pooled for each site. RIGHT: Fish larval density of Stage 4 family Gobiidae along three coastal ecosystems in Lopez Jaena, Panaon, and Tudela. Data sampling (n=18) were pooled for each site. Common letters within a site indicate that mean values are not significantly different at 5% level of significance (ANOVA).

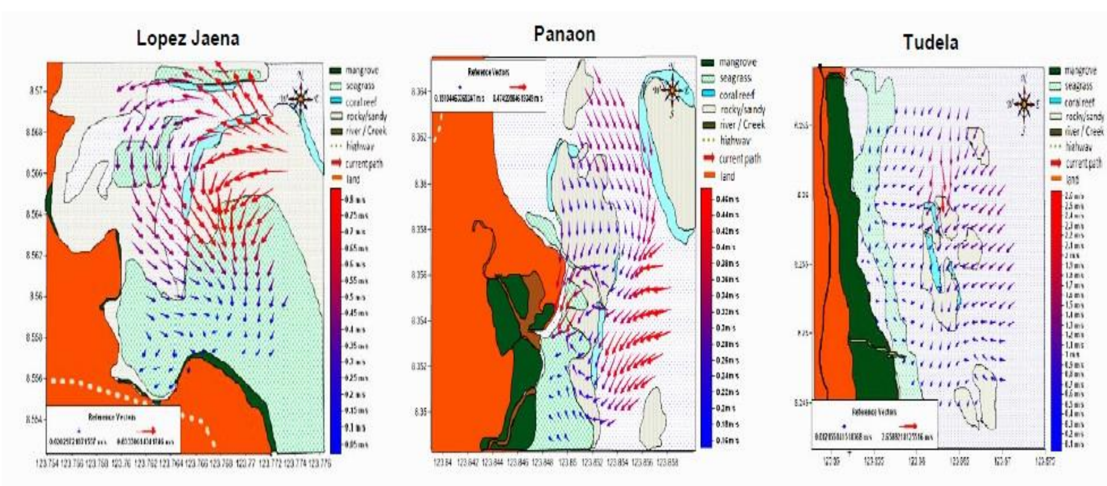

Figure 6. Hydrological Map of the study area in Misamis Occidental showing current velocities (m/sec) during flood tide. Colored arrows indicate current speeds and current paths.

CONCLUSION

Results of the study illustrate the importance of various shallow coastal habitats such as mangrove areas, seagrass beds, and coral reefs in the life stages of various fish families. The present study indicates strong connectivity of the three contiguous ecosystems of mangrove areas, seagrass beds and coral reefs. Hence, they are very important habitats utilized in the early life stages of fish larvae. That is, during flood tide nights, fish larvae tend to be drifted away, together with other plankton, in the subsurface water level, by tidal currents carrying them into shallow ecosystems of mangrove and seagrass beds where larvae feed and seek temporary refuge, as the two mentioned ecosystems functioned as nursery grounds providing food, and protection from predators. The three ecosystems are so connected that when you destroy one of these habitats, it would affect the ecological functions of the other as fish larvae utilized all these three contiguous ecosystems critically during their early life stages.

In order for the management of marine resource to be effective, it is important that management policies be made consistent with the socio-cultural-political realities of the locality and with the natural biological rhythms of the marine environment. Local government units (LGUs), in close cooperation with institution of higher learning in coastal areas, need to intensify their information drive about the role of major coastal ecosystems (mangrove, seagrass and coral reef) with emphasis on their nursery, feeding and post-settlement functions. The knowledge of habitat connectivity of various fish larvae introduced in this study can be used by the Protected Area Management in-charge, Coastal Resource Management practitioners, and by the LGU, to design coastal resource management program particularly in the establishment of Marine Protected Areas considering the three major coastal ecosystems

To understand further the seasonal trends of different larval dispersal of other fish families in the three contiguous coastal ecosystems studies on fish larval dispersal in the coastal ecosystems should be conducted on a monthly basis for one year. Further, lunar phases' variation should also be considered in the sampling procedure to effectively improve the collection of other early life stages of fish larvae.

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LITERATURE CITED

Armsworth, P. R., M. K. James and L. Bode. 2001. When to press on, wait or turn back: dispersal strategies for reef fish larvae. American Naturalist 157, 434-450.

Boehlert, G. W. 1996. Larval dispersal and survival in tropical reef fishes. In "Reef Fisheries" (N.V.C. Polunin & C.M. Roberts, eds.), Chapman & Hall Fish and Fisheries Series, Vol. pp. 61-84. Chapman & Hall, London.

Boehlert, G. W. and B. C. Mundy. 1988. The role of behavioral and physical factors in fish recruitment, to estuarine nursery areas. Trans. Am. Fish. SOCS. yrnp. 3: 51-6.

Cowen, R. K. 2002. Larval dispersal and retention and consequences for population connectivity. In "Coral Reef Fishes: Dynamics and Diversity in a Complex Ecosystem" (P.F. Sale, ed.), pp. 149-170. Academic Press, San Diego.

Cowen, R. K. and S. Sponaugle. 1997. Relationships between early life history traits and recruitment among coral reef fishes. In "Early Life History and Recruitment in Fish Populations" (R.C. Chambers & E.A. Trippel, eds.), Chapman & Hall Fish and Fisheries Series, Vol. Chapman & Hall, London. 423-449.

Dando, P. R. 1984. Reproduction in estuarine fishes. In "Fish Reproduction: Strategies and Tactics, Chapter: Reproduction in Estuarine Fish", Publisher: Academic Press, Editors: Potta GW, Wooton RJ, pp.155-170.

Dovel, W. L. 1981. Ichthyoplankton of the lower Hudson Estuary, New York, N. Y Fish. Games., J.28:21-39.

Jacoby, C. A. and J. G. Greenwood. 1988. Spatial, temporal, and behavioral patterns in emergence of zooplankton in the lagoon of Heron Reef, Great Barrier Reef, Australia.Mar. Biol. 97: 309- 328.

Kinlan, B. P. and S. D. Gaines. 2003. Propagule dispersal in marine and terrestrial environments: a community perspective. Ecology 84: 2007-2020.

Leis, J. M. 2006. Are larvae of demersal fishes plankton or nekton?. Advances in Marine Biology. 51: 57–14.

Leis, J. M. 1991. The pelagic phase of coral reef fishes:larval biology of coral reef fishes. In "The ecology of fishes on coral reefs" (P.F. Sale, ed.), pp. 183-230. Academic Press, San Diego.

Leis, J. M. 1982. Nearshore distributional gradients of larval fish (15 taxa) and planktonic crustaceans (6 taxa) in Hawaii. Marine Biology 72: 89-97.

Leis, J. M. and B. M. Carson-Ewart. 2004. The larvae of indo-Pacific coastal fishes: An identification guide to marine fish larvae. Fauna Malesiana Handbooks. 2nd Edition. 850p, Brill. The Netherlands.

Leis, J. M. and B. M. Carson-Ewart. 2003. Orientation of pelagic larvae of coral-reef fishes in the ocean. Marine Ecology Progress Series 252: 239-253.

Leis, J. M. and B. M. Carson-Ewart. 2001. Behavioural differences in pelagic larvae of four species of coral-reef fishes between two environments: ocean and atoll lagoon. Coral Reefs 19: 247- 257.

Leis, J. M. and B. M. Carson-Ewart. 1998. Complex behaviour by coral-reef fish larvae in open - water and near-reef pelagic environments. Environmental Biology of Fishes 53: 259 - 266.

Leis, J. M. and B. M. Carson-Ewart. 1997. In situ swimming speeds of the late pelagic larvae of some Indo-Pacific coral reef fishes. Mar Ecol Prog Ser 159:165 -174.

Leis, J. M. and J. M. Miller. 1976. Offshore distributional patterns of Hawaiian fish larvae. Marine Biology 36: 359-367.

Modde, T. and S. T. Ross. 1981. Seasonality of fishes occupying a surf zone habitat in the northern Gulf of Mexico. Fish. Bull. U.S. 78: 911-921.

O'neil, S. P. and G. W. Boehlert. 1987. Feeding habitats of spot, *Leistomus xanthurus*, in polyhaline versus meso-oligohaline tidal creeks and shoals. U.S. Fish Bull. 85: 785-796.

Olney J. and G. W. Boehlert. 1988. Nearshore ichthyoplankton associated with seagrass beds in the lower Chesapeake Bay. Mar. Ecol. Prog. Ser. 45: 33-43. 1988.

Palumbi, S. R. 2003. Population genetics, demographic connectivity, and the design of marine reserves. Ecological Applications 13: S146–S158.

Penida J., J. A. Hare, and S. Sponaugle. 2007. Larval transport and dispersal in the coastal ocean and consequences for population connectivity. Marine Population Connectivity. Oceanography. Vol 20 (3): 23-39.

Robertson, A. I. and R. K. Howard. 1978. Die1 trophic interactions between vertically-migrating zooplankton and their fish predators in an eelgrass community. Mar. Biol. 48:207-213.

Robertson, A. I., P. Dixon and P. A. Daniel. 1988. Zooplankton dynamics in mangrove and other nearshore habitats in tropical Australia. Mar. Ecol. Prog. Ser. 43: 139-150.

Roper, D. S. 1986. Occurrence and recruitment of fish larvae in a northern New Zealand estuary. Estuary coast. Shelf. Sci. 22: 705-717.

Ruple, D. L. 1984. Occurrence of larval fishes in the surf zone of a northern Gulf of Mexico Barrier Island. Estuar. coast. Shelf Sci. 18: 191-208.

Sale, P. F. 2004. Connectivity, recruitment variation, and the structure of reef fish communities. Integrative and Comparative Biology 44: 390-399.

Steffe, A. S. 1991. Larval Fish Distributions WithinBotany Bay: Implications for Estuarine Recruitment and Management. Ph.D. thesis, Macquarie University, Sydney, New South Wales, Australia. 668pp.

Suthers, I. M. and K. T. Frank. 1991. Comparative persistence of marine fish larvae from pelagic versus demersal eggs of southwestern Nova Scotia, Canada. Marine Biology 108: 175 - 184.

Talbot, C. W. and K. W. Able. 1984. Composition and distribution of larval fishes in New Jersey high marshes. Estuaries 7: 434-443.

Walter, K. and S. S. Bell. 1986. Die1 patterns of active vertical migration in seagrass meiofauna. Mar. Ecol. Prog. Ser. 34: 95-103.

Weinstein, M. P. and H. A. Brooks. 1983. Comparative ecology of nekton residing in a tidal creek and adjacent seagrass meadow: community composition and structure. Mar. Ecol. Prog. Ser. 12: 15-27.

Coastal Conservation Education Foundation, accessed 15 April 2011 available at: http://www.coast.ph/coastdb/.

Tomzhack, F. 2005. Oceanography web site. Available at http://www.es.flinders.edu.au/.