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Using Ichthyoplankton Distribution in Selecting Sites for an MPA Network in the Sulu Sea, Philippines

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Abstract. This investigation was conducted to provide data and information needed to establish an ecologically functional network of MPAs in the Sulu Sea Basin, by making use of data on fish larval (ontogenetic) distribution and composition, as well as dispersal modeling in identifying areas with potentially high recruitment (sink) and or areas with high potential as egg and larval sources. During the transition to the NE Monsoon (October), highest egg concentrations were observed in the immediate vicinity of the atolls and reefs along Cagayan Ridge and in embayments along the western border of Sulu Sea (east coast of Palawan), but larvae were most abundant along a north-south mid-basin transect from Cuyo Shelf. to Cagayan Ridge. Large-scale circulation shows that the Cuyo Group of Islands to be a major source of larvae to the western half of Sulu Sea, while the prevailing strong northeasterly current isolates Cagayan Ridge from Western Sulu Sea. The ontogenetic distributions of larval groups are consistent with the above scenario. The results are discussed in the context of connectivities within Sulu Sea and their implications to fisheries management.

Key Words: ichthyoplankton, connectivity, Sulu Sea

Introduction

Most shallow water fish species produce pelagic eggs and larvae (Bone et al. 1995). As such, these early life stages may be carried by ocean currents away from where they were spawned (dispersal) and or retained by local circulation (e.g., entrainment cells) within the vicinity of spawning grounds. The extent of dispersal/retention ultimately determines how important source-sink connectivity (Roberts and Polunin 1991; Ratikin and Kramer 1996) is to recruitment and in what spatial scales this is relevant. Making this a major consideration in establishing ecologically functional networks of marine protected areas enhances success of management efforts in the long run. In this context, examining the distribution of ichthyoplankton (fish eggs and larvae) and relating this to potential dispersal or transport of planktonic larvae as influenced by circulation patterns are of critical importance.

The Sulu Sea is a deep semi-enclosed basin whose connections with neighboring basins is limited to passes with very shallow sills (Menez et al. 2006), which also serve as important “marine corridors” for larval exchange. This study characterizes the distribution of fish eggs and larvae in Central Sulu Sea in relation to basin-scale circulation during the transition to the Northeast monsoon season.

Materials and Methods

The ichthyoplankton survey was conducted in October 2006 and covered the area of Central Sulu Sea from Panay and Negros Islands along the eastern border westwards to the eastern coast of Palawan (Fig. 1). Transects were strategically located to allow sampling across simulated current flow patterns (Villanoy et al. 2007) typical for this time of the year, the transition to the NE monsoon which is a major spawning season for many tropical marine organisms in the Philippines.

Stations were laid out approximately every 10-15nm along each transect. Samples were collected by means of 15 minute horizontal (sub-surface; within upper 1m) and double oblique tows (maximum targeted depth of 100m) using a 335 µm conical plankton net attached to a 60cm diameter ring. Mechanical flowmeters were mounted across the mouth of the net to measure the volume of water filtered. Horizontal tows were intended to sample fish eggs which are normally buoyant and inactive, and are thus generally found close to the surface. Double oblique tows, on the other hand, were used primarily to reduce the effect of time of day on the samples. Fish larvae and other plankton exhibit vertical movement in the water column in relation to light, affecting their vulnerability to plankton nets during the daytime. By employing a combination of tows, comparisons of estimates of egg and larval

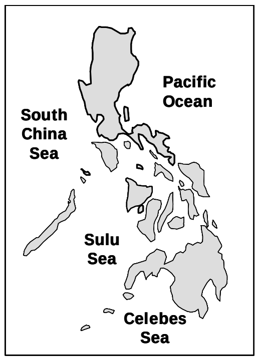
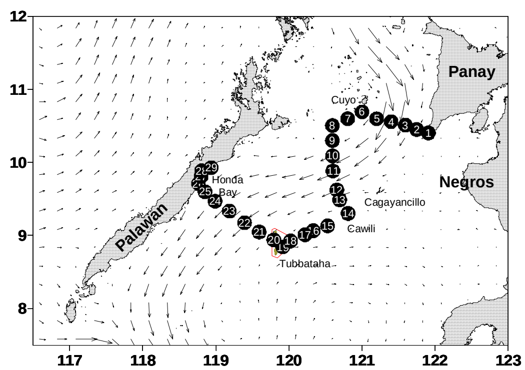


Figure 1. Map of the Philippines showing Sulu Sea (left) and the locations of stations surveyed in October 2006 (below). Note: arrows indicate the direction and relative magnitude of prevailing currents in the Sulu Sea in October (Villanoy et al., 2007)



concentrations at different times of the day can be made.

Samples were fixed in 10% buffered seawater-formalin solution in the field and brought back to the laboratory for sorting, identification and stage (developmental) determination.

Results & Discussion

Plankton Abundance and Distribution

The distributions of fish eggs and larvae are shown in Figures 2a and b. Across all 29 stations, mean larval density was 113.6 ind/100m^3, which is around 5 times the overall mean larval density recorded for the same general area in April 2006 (mean = 18.0 ind./100m3; sd 20.3; Campos et al., 2007). Moderate to high larval concentrations were recorded in the three transects traversing the main current flow, with highest densities (mean = 189.6 ind./100m^3; sd = 32.5) observed between Cuyo Shelf and Cawili Is.. Moderate larval densities were observed along the transect from the southern tip of Panay Is. west to Cuyo Shelf (mean = 123.1 ind./100m^3; sd = 52.0) and from mainland Palawan east to Tubbataha (mean = 103.0 ind./100m^3; sd = 55.8), respectively. The lowest densities (mean = 33.5 ind/100m^3; sd = 25.1) were recorded along the transect from Cawili Is. to Tubbataha (Fig. 2a).

Mean egg densities in October (mean = 2.1 eggs/m^3; sd = 4.9) were also higher by an order of magnitude than observed concentrations in April 2006 (mean = 0.29 eggs/m^3; sd = 0.45; Campos et al. 2007), although variability in both surveys was high. High variability is generally due to the patchy distribution of fish eggs. During the survey, high egg concentrations were recorded off the tip of Panay, in the Cuyo group of islands, Cawili Is., Tubbataha atoll, and Honda Bay in Palawan (Fig. 2b). Mean densities in these locations showed a mean of 5.7 eggs/m^3 (sd = 7.3), which is about 30 times the average densities in the rest of the other stations (mean = 0.2 eggs/m^3; sd = 0.12).

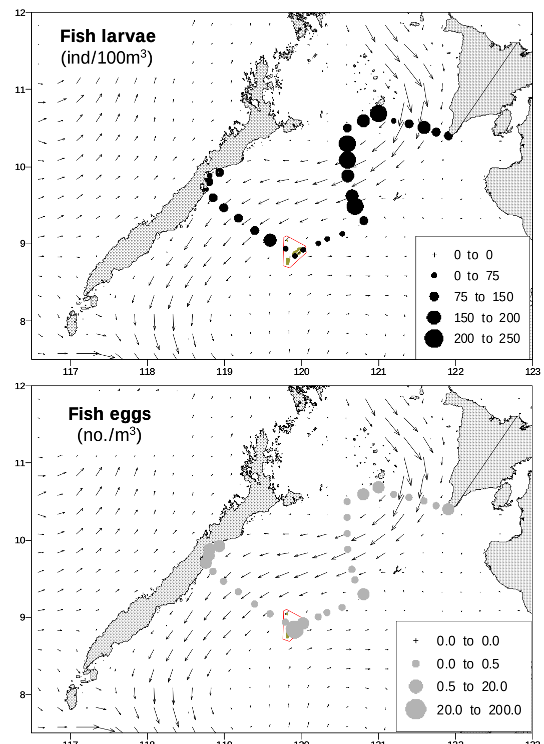


Figure 2. The density distribution of fish larvae (upper) and eggs (lower) in the Central Sulu Sea in October 2006.

Larval Assemblage Structure

A cluster analysis was performed on larval composition data from the 29 stations and the results are summarized in Fig. 3 and Table 1. Three major station clusters were formed by the analysis: Palawan Coast, Cagayan Ridge (Tubbataha to Cawili), and stations within the main flow. The latter group was further subdivided into a sub-group along the eastern margin of the main flow, and another within the main axis. The relative composition of larval assemblages in these clusters is shown in Table 1. The cluster of shallow stations along the coast of Palawan is dominated by larvae of soft-bottom demersal fish, such as gobiids, nemipterids and cynoglossids. On

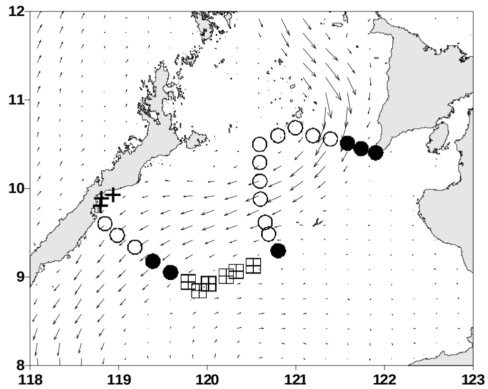


Figure 3. Location of station clusters in the Central Sulu Sea in October 2006: Palawan coast (+), Cagayan Ridge (⊞), Main flow (○), and main flow margin (●).

the other hand, the Cagayan Ridge cluster of deep

Table 1. Relative abundance (%) of the various larval groups in the four station clusters.

Larval groups	Palawan Coast	Cagayan Ridge	Main Flow Margin	Main Flow
Demersal	67.0	12.1	11.1	21.3
Mesopelagic	3.8	44.8	57.0	22.7
Reef-associated	23.5	23.2	17.0	41.0
Epipelagic	1.3	5.3	8.7	8.7
Unidentified	4.3	14.5	6.2	6.3
	100	100	100	100

open water stations was dominated by larvae of mesopelagic fish, such as myctophids, gonostomatids and paralepidids, but showed substantial contributions (23.2%) from reef-associated groups like scorpaenids and balistids. Reef-associated larvae in this cluster likely originate from the atolls or islands along the Ridge. The stations of the main current flow showed assemblages comprised primarily of reef-associated and mesopelagic fish larvae. These stations are in deep open water and this explains the abundance of mesoplegaic fish larvae which are likely spawned in open water. However, because reef fish generally spawn in reef areas, their abundance in this cluster indicates their origin from sources upstream of the main current flow, like Cuyo Shelf, where extensive shallow reef areas are located. Among stations in this cluster, the ones along the eastern margin of the main flow show much larger contributions from mesopelagic fish larvae (57%) than stations within the main axis of the flow (22.7%).

Ontogenetic Distribution

The ontogenetic distribution of reef-associated larvae show a progression from higher upstream concentrations in younger (preflexion) stages to higher downstream concentrations in older (postflexion) stages (Figs. 4a-c). A similar pattern was shown by larvae of demersal fish. These results are consistent with spawning in Cuyo Shelf and subsequent transport towards the southwest in the direction of the main flow as larvae age and develop. In contrast, mesopelagic larvae do not show any progression of concentrations with age (Figs. 5a-b). This may be attributed to more open and deep water

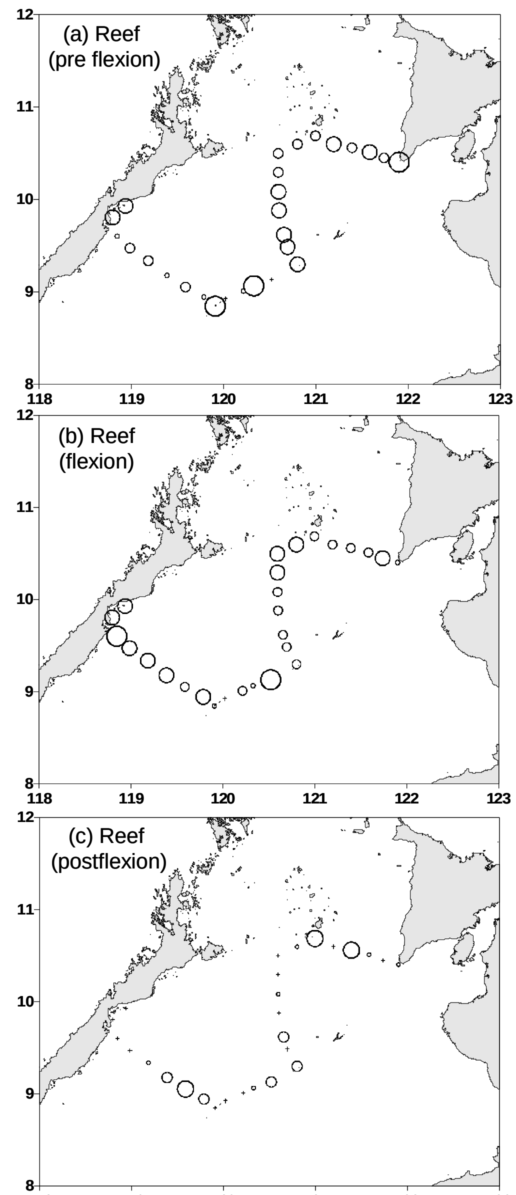


Figure 4. Ontogenetic distribution of larvae of reef-associated fish in the Central Sulu Sea in October 2006.

spawning grounds of these fish, which covers most of the Sulu Sea. No examination of epipelagic larvae was done due to their low number in the samples.

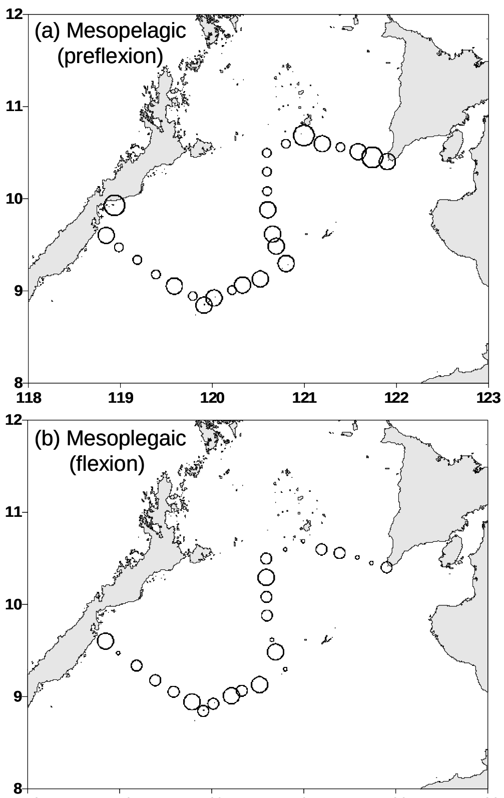


Figure 5. Ontogenetic distribution of larvae of mesopelagic fish in the Central Sulu Sea in October 2006.

Larval distribution patterns and hydrography

Large scale circulation in the Sulu Sea in October is dominated by a strong current flowing from the northeast and then southwards along the coast of Palawan (Fig. 1). This current covers a wide path, extending from Cuyo Shelf all the way to Panay, and from the east coast of Palawan to just west of Cawili Island. Because of the relatively strong current in the main axis, it is unlikely that plankton are able to cross it. This effectively isolates the atolls and islands of Cagayan Ridge from western Sulu Sea, at least during this time of the year. However, entrainment further upstream may result in downstream dispersion within the flow.

A review of egg and larval distributions in relation to large-scale water movement allows scenario-building. The patchy larval concentrations along the transect from Cuyo to Panay (Fig. 2a) would be consistent with spawning at the endpoints of this transect, as also shown by egg concentrations at these locations (Fig. 2b), and not further north. If major spawning had taken place further north of Cuyo Shelf, entrainment in the strong southward current would have caused larval concentrations along this entire transect to be more homogeneous. On the other hand, major spawning in the Cuyo group of islands would still be delimited by the south-flowing current in the area near Panay, but entrainment would result in high and relatively homogeneous larval concentrations in transects further downstream (i.e., Cuyo to Cawili), as was observed during the survey (Fig. 2a). The preponderance (> 70%) of shallow water fish larvae (e.g., demersal, epipelagic and reef-associated) within the main flow (Table 1) is consistent with Cuyo Shelf being the major source. The reduced larval concentrations between Tubbataha and mainland Palawan may be due to larval settlement (recruitment) along the stretch of Palawan's coastline north of Honda Bay.

The difference in assemblage composition between the cluster of stations along the eastern margin of the main flow and those within the main axis of the flow is consistent with Cagayan Ridge being isolated from Western Sulu Sea during this time of the year. Spawning grounds along the Ridge, as indicated by egg concentrations (Fig 2b), will likely be self-feeding, at least during this season, with apparent transport being facilitated by a weak gyre formed by currents immediately west of the Ridge flowing towards the southwest and those immediately east flowing towards the opposite direction. Again, the similarity in taxonomic make-up of assemblages in the main flow margin and the Ridge (i.e. > 44% mesopelagics; moderate amounts of reef-associated larvae; Table 1) is consistent with this scenario.

Implications for fisheries management

For the Central Sulu Sea, the extensive Cuyo Shelf area appears to be a major source of larvae for habitats along the East Coast of Palawan, and perhaps even further south, at least during the transition to the NE monsoon. Improving protective management efforts in Cuyo Shelf would benefit an extensive area downstream. Also during this season, spawning and recruitment within Cagayan Ridge seem to be limited locally. Hence, management efforts here would have little impact on fishing to the west, although the situation will likely be different in other seasons. What happens during the rest of the year is still largely unknown but on-going analyses of survey data from the Summer (April) 2007 will provide more information on this.

While it is believed that dispersal from MPAs with increased spawning biomass is the mechanism that enhances sustainability of fishing downstream, unequivocal empirical evidence for this is still largely unavailable (Russ 2002). The results of this study do not provide such data, but they indicate which portions of the Central Sulu Sea are functionally connected during the transition season to the NE monsoon, and where improved management can be focused.

There are currently over a thousand marine protected areas in the Philippines, with more than 1/3 covering less than 10 ha. Recent figures show that only about 10% of these are properly managed (Campos and Alino 2008), due primarily to scarce support resources that are also spread out thinly. Under such circumstances, information provided from this study provides a strategic framework for optimizing management efforts with enhanced prospects for long term success.

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