Establishing Spatio-temporal Profile of Scombrid Larvae: the Philippine Eastern Pacific Seaboard in Focus

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Scombridae is a family of fishes consisting of 51 species in 15 genera and two sub-families all of which belong to the Sub-family Scombrinae, except the butterfly kingfish which belongs to Sub-family Gasterochismatinae. The Sub-family Scombrinae comprises four tribes, namely: Scombrini (mackerels), Scomberomorini (Spanish mackerels), Sardini (bonitos), and Tunini (tunas). Scombrids have two dorsal fins and a series of finlets behind the rear dorsal fin and anal fin. The caudal fin is strongly divided and rigid. The first (spiny) dorsal fin and the pelvic fins are normally retracted into body grooves. Lengths of the species belonging to Family Scombridae vary from 20.00 cm (7.9 in) of the island mackerel to 4.58 m (15.0 ft) recorded for the immense Atlantic bluefin tuna. Scombrids are generally considered predators of the open ocean, and are found worldwide in tropical and temperate waters. Most species of Scombrids are economically-important to the Philippines. In 2013 for example, the country's production of tunas and mackerels accounted for about 31% of the country's total production volume from marine capture fisheries and about 42% in terms of value, of which 78% of the Scombrids production volume and 80% of the value was contributed by tunas (SEAFDEC, 2015). This makes tunas the most economically-important Scombrid species for the Philippines. Establishing the spatio-temporal profile of Scombrid larvae especially in the country's Eastern Pacific Seaboard would therefore provide a picture of the abundance, distribution and diversity of Scombrid species in the Philippines.

Tunas are known to be migratory and usually rely on favorable oceanographic conditions to continue their biological processes. Environmental factors such as food availability, temperature, oxygen, and thermocline depth have been known to contribute to their abundance and distribution (SPC, 2010; FAO, 2014). The Philippine Eastern Pacific Seaboard (PEPS) has been viewed as a migration path of tunas that go along with the movements of the world's major currents.

The open-ocean current influencing the eastern side of the Philippines is the North Equatorial Current (NEC) which separates correspondingly into the Kuroshio Current and Mindanao Current on the northern and southern side of the country (Nitani 1972; Toole *et al*., 1990; Hu and Cui 1991; Qui and Chen, 2010). NEC has a velocity of 3-6 km/day with strength that extends up to the 100-200 m depth waters (Foster and Gong, 1971). The bifurcation of this current as reported by Bingham and Lukas (1995) takes place during the month of June at 13°N off Catanduanes waters. Qui and Chen (2010) indicated that the inter-annual-decadal variability of the NEC bifurcation off the Philippines shows relevance to the El Niño phenomenon, and therefore pointed out that the exact NEC bifurcation should be at 12-14°N. Qui and Chen (2010) also cited that when NEC bifurcates northerly, its surface transports tend to increase, intensifying the Kuroshio Current and Mindanao Current. Bacordo *et al*. (2012) also cited that there is a possible influence of the bifurcation of NEC on the abundance and distribution of ichthyoplankton and tuna larvae in the PEPS.

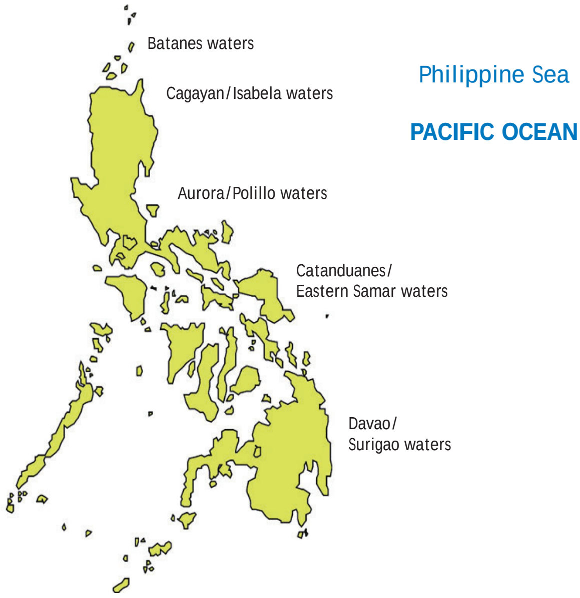


Fig. 1. Map of the Philippines showing its Eastern Pacific Seaboard and sampling stations of the case study

Considering that there has been no solid information at the national level defining the spatio-temporal abundance, composition and distribution of tuna larvae in the eastern side of the country, an analysis was therefore conducted based on the 108 samplings carried out by the M/V DA-BFAR in PEPS from 2006 to 2011. The sampling stations used for the case study stretched from Batanes in the north to Davao in the southern part of the Philippines. Oceanographic samplings were done during the months of April, May, June, and August. The sampling stations were categorized into five zones, namely: Batanes waters, Cagayan/Isabela waters, Aurora/Pollilo waters, Catanduanes/Eastern Samar waters, and Davao/Surigao waters, as shown in **Fig. 1**. The specific sampling sites are indicated in **Fig. 2**.

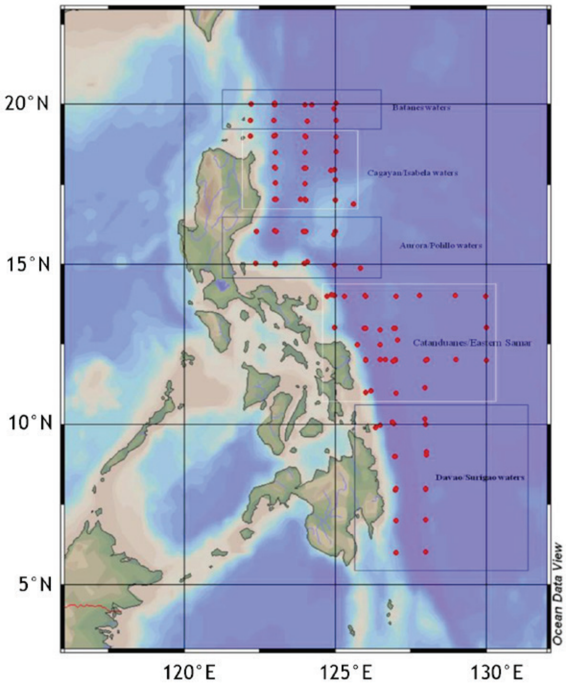


Fig. 2. Specific sampling sites for Scombrid larvae in the Philippine Eastern Pacific Seaboard

Spatio-temporal Abundance and Diversity of Scombrid larvae

The analysis which was carried out up to species-level, include the influence of food availability (phytoplankton) using the chlorophyll-*a* data compiled through the M/V DA-BFAR in relation to the total density of the Scombrid larvae. However, only the stations observed with tuna larvae were found to be related to the mean chlorophyll-*a* (1-150 m depth) as some larvae sampling stations did not coincide with the sampling stations for chlorophyll-*a*.

Thus, stations without chlorophyll-*a* data were not included in the analysis. The same method was also used to analyze the relevance of temperature to the abundance, distribution and diversity of the Scombrid larvae. For the effect of season (monthly variation) and time of day, all sampling stations were considered in order to get the average densities of Scombrid larvae. For spatial abundance, distribution and diversity of Scombrid larvae, five classified distances from the nearest shoreline were used, namely: <50 km; 51-100 km; 101-200 km; 201-300 km and > 300 km, which were obtained from the National Mapping and Resource Information Authority (NAMRIA) chart available onboard the M/V DA-BFAR. Moreover, in order to determine the zonation of the Scombrid species, data were compared with those from the abovementioned sampling stations. To determine the diversity of Scombrid species, Simpson's and Shannon's Indices were used while the density of each species by sampling area were used to determine the diversity. Correlation of Simpson's and Shannon's Indices was also analyzed to compare the results.

Abundance and Distribution of Scombrid Larvae

Results of the analysis indicated high abundance of the larvae along the Aurora/Polillo waters and Cagayan/Isabela waters with mean densities of 85 and 92 larvae/1000 m^3 seawater, respectively. However, low abundance was noted along the Catanduanes/Eastern Samar waters with mean density of 24 larvae/1000 m^3 seawater (**Fig. 3**). The mean densities of the Scombrid larvae from different sampling stations are shown in **Fig. 4**.

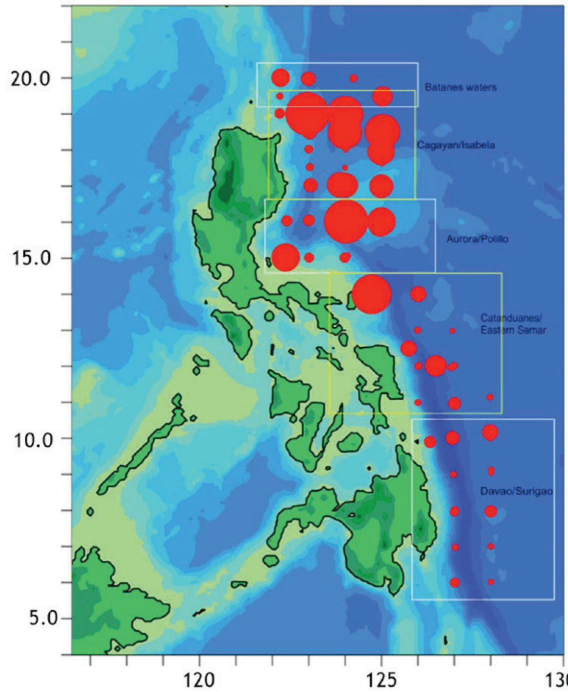


Fig. 3. Abundance of Scombrid larvae in the Philippine Eastern Pacific Seaboard with corresponding densities *(Scale: 0.025 in dia = 10 larvae/1000 m^3 of seawater; 0.250 in dia= 500 larvae/1000 m^3 of seawater)*

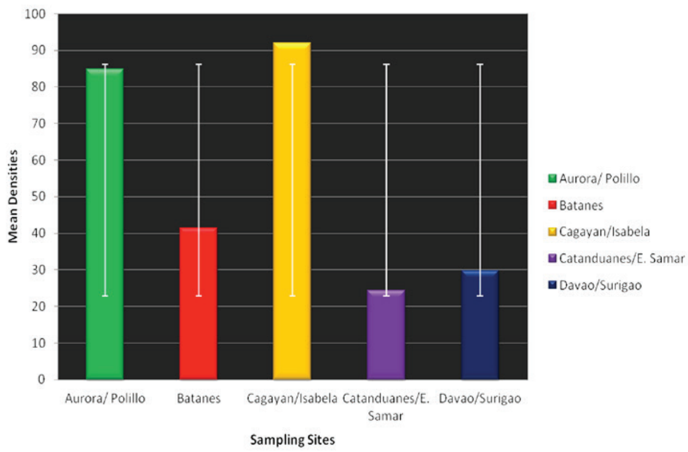
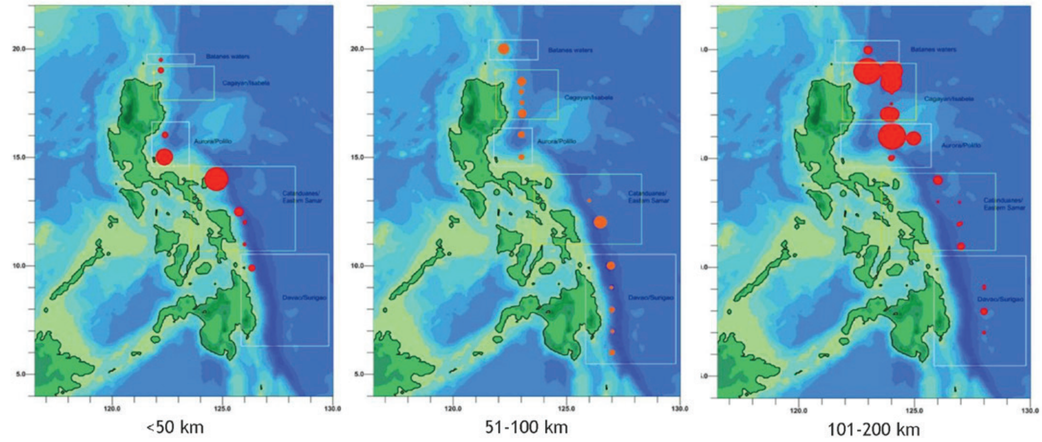


Fig. 4. Mean densities of Scombrid larvae from different sampling stations

In terms of distance from the shore, the spatial abundance of Scombrid larvae in PEPS (**Fig. 5**) suggests high abundance of larvae in stations located 201-300 km away from shore and lowest at a distance greater than 300 km from shore. Similarly,



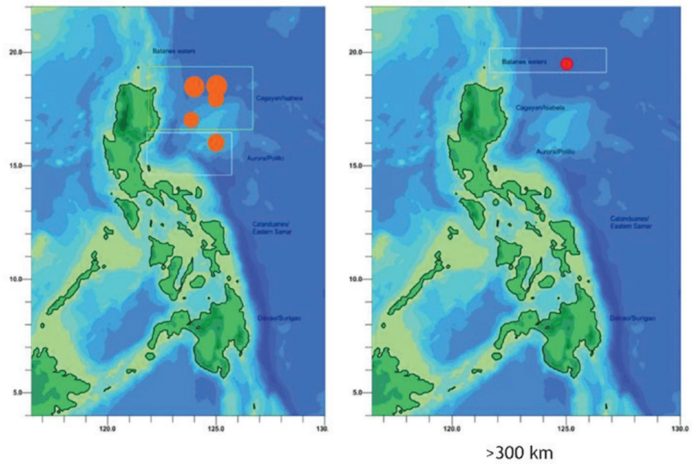


Fig. 5. Abundance and distribution of Scombrid larvae at various distances from shore *(Scale: 0.025 in dia = 10 larvae/1000 m^3 of seawater; 0.250 in dia= 500 larvae/1000 m^3 of seawater)*

relatively high density of larvae was observed in stations less than 50 km away from shore as well as in stations 101 to 200 km away from the shore, as indicated in the mean densities of Scombrid larvae at various distances from the shore (**Fig. 6**).

In terms of the abundance of tuna larvae by sampling zone, high mean densities were recorded along Aurora/Polillo waters at less than 50 km and 101-200 km away from nearest shore as well as in the Batanes waters from 51 to 100 km and greater than 300 km away from the shore, and across Cagayan/Isabela waters from 101 to 300 km from shore. Catanduanes/Eastern Samar and Davao/Surigao waters on the other hand, exhibited high concentration of larvae at less than 50 km distance from the shoreline but such abundance was comparatively lower than those observed in the Aurora/Polillo waters (**Fig. 7**).

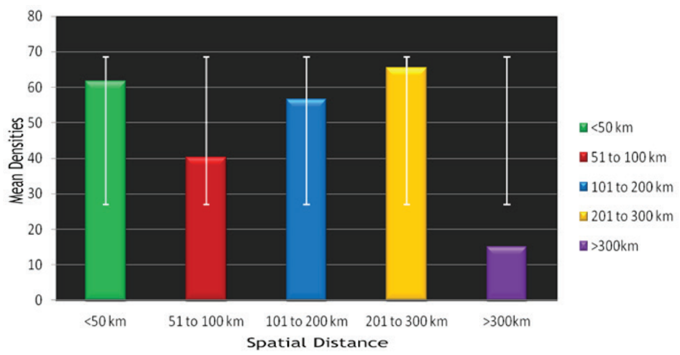


Fig. 6. Mean densities of Scombrid larvae at various distances from the shore

Abundance, Distribution and Diversity of Scombrid Species

While **Fig. 8** exhibits the abundance and distribution of each species of Scombrid larvae in PEPS, **Fig. 9** illustrates the species diversity index, evenness and richness of the Scombrid larvae.

The species diversity in PEPS could be considered high with 6 (Simpson's estimate) to 9 (Shannon's estimate) dominant species from the 13 accounted species of Scombrids. Results of the analysis of the species diversity by area indicated high species diversity along Batanes and Cagayan/Isabela waters but low along Aurora/Polillo waters (**Fig. 10**). The Simpson's reciprocal index suggests 6 dominant species in Batanes waters and 5 along Cagayan/Isabela waters which is comparable with the Shannon's estimates of 6 dominant species for both areas.

The dominant species are: *Thunnus albacores* (yellowfin tuna), *Thunnus obesus* (big-eye tuna), *Thunnus alalunga* (albacore tuna), *Acanthocybium solandri* (wahoo), *Katsuwonus pelamis* (skipjack tuna), and *Auxis* spp. (bullet tuna) based on their relative abundance in the total samples. Aurora/Polillo waters had the lowest diversity index value because the collected larvae species on the area were dominated by 3 (Simpson's estimates) to 4 (Shannon's estimates) species only, namely: *Thunnus* spp., *Euthynnus affinis* (kawakawa), *Allothunnus* spp. (slender tuna), and *Thunnus obesus*.

An analysis of the samples obtained from the Aurora/Polillo waters which indicated low evenness value could also have contributed to the low diversity index. The relative abundance of Scombrid species per sampling zone is shown in **Fig. 11**. The slight discrepancy of the Shannon's estimates with that of Simpson's Index could be explained by Shannon's sensitivity to species richness and dependence on sample size because Simpson's Index although not dependent on the sample size

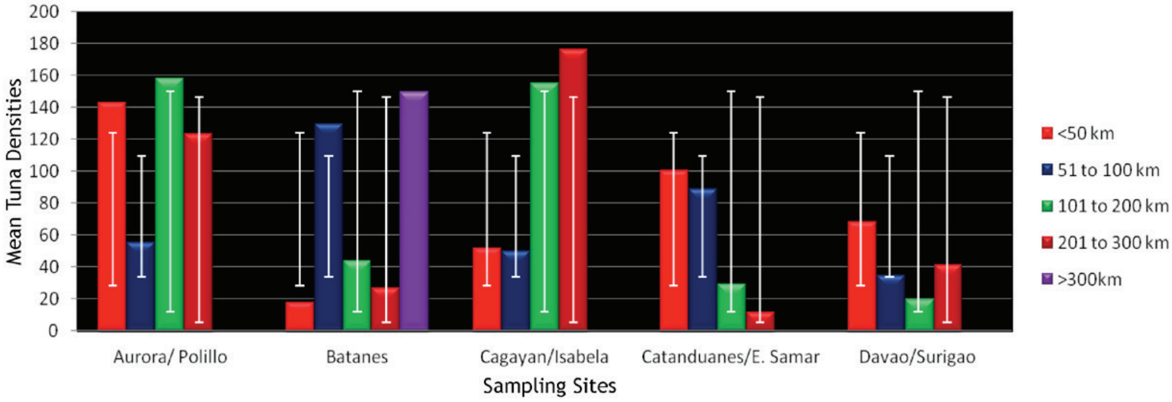


Fig. 7. Mean densities of tuna larvae at various sampling stations and distances from shore

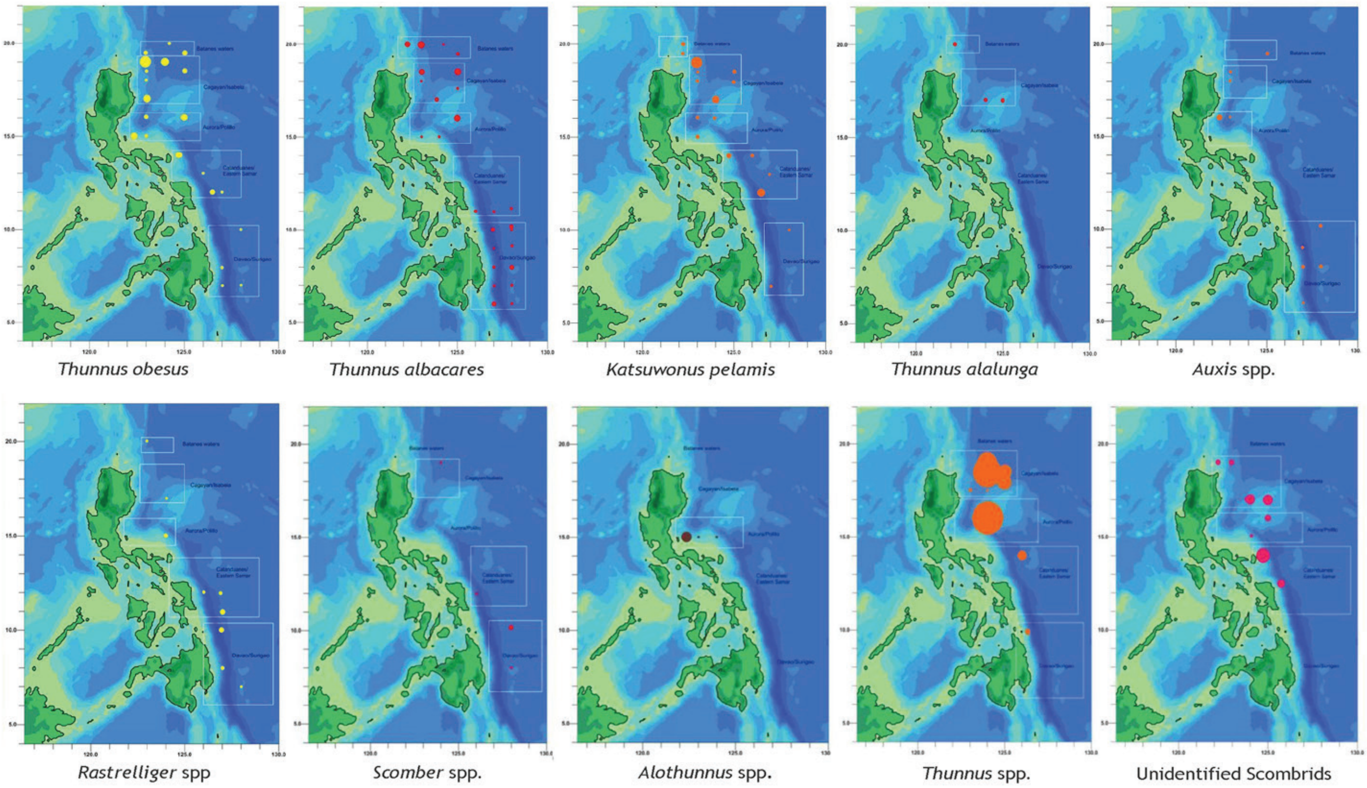


Fig. 8. Abundance and distribution of different species of Scombrid larvae in the Philippine Eastern Pacific Seaboard
(Scale: 0.025 in dia = 10 larvae/1000 m³ of seawater; 0.250 in dia= 500 larvae/1000 m³ of seawater)

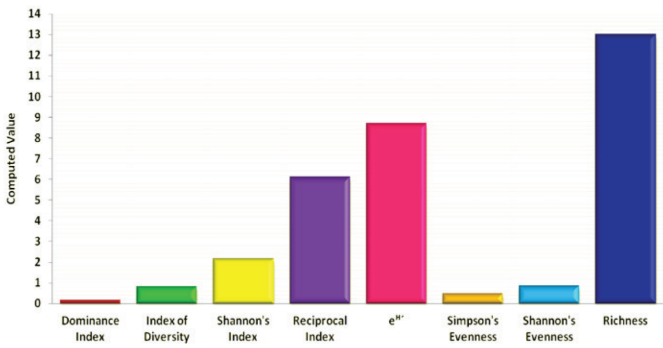


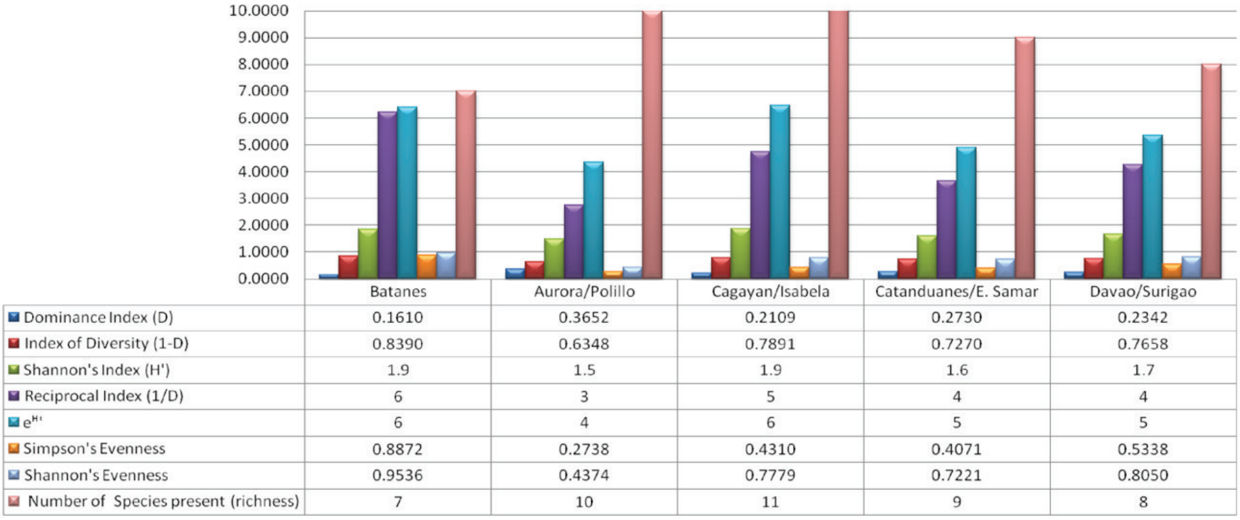
Fig. 9. Total species diversity, evenness and richness of Scombrid larvae in the Philippine Eastern Pacific Seaboard

is somewhat sensitive to the evenness. Thus, the Shannon estimates of the dominant species appear higher compared with those of Simpson's (*i.e.* e$^{H'}$) and to the total number of species present per fishing ground as shown in **Fig. 10**). Nonetheless, both indices showed significant relationships in the diversity estimates as shown in **Table 1**.

Table 1 also indicates the correlation of Shannon's and Simpson's Indices in terms of diversity estimates. All of the compared indices bring out positive relationships except Simpson's D and Shannon's Index which had negative relationship. This happened because the Simpson's D value implies high diversity as it approaches zero while the rest of the indices means otherwise.

Variation in Monthly Abundance

The abundance and distribution of Scombrid larvae in different months are indicated in **Fig. 12**. The sampling area for the month of April covered only the waters across Catanduanes/ Eastern Samar and Aurora/Polillo; while Aurora/Pollilo,



	Batanes	Aurora/Polillo	Cagayan/Isabela	Catanduanes/E. Samar	Davao/Surigao
Dominance Index (D)	0.1610	0.3652	0.2109	0.2730	0.2342
Index of Diversity (1-D)	0.8390	0.6348	0.7891	0.7270	0.7658
Shannon's Index (H')	1.9	1.5	1.9	1.6	1.7
Reciprocal Index (1/D)	6	3	5	4	4
$e^{H'}$	6	4	6	5	5
Simpson's Evenness	0.8872	0.2738	0.4310	0.4071	0.5338
Shannon's Evenness	0.9536	0.4374	0.7779	0.7221	0.8050
Number of Species present (richness)	7	10	11	9	8

Fig. 10. Species density of Scombrid larvae from various sampling stations in the Philippine Eastern Pacific Seaboard

Cagayan/Isabela and Batanes waters were covered in May and the whole Eastern Pacific Seaboard (except Aurora/Pollilo waters) during the month of June. The August sampling on the other hand, covered only the waters of Eastern Samar and Surigao. Comparative analysis per sampling station brought about high density of the Scombrids along Catanduanes/Eastern Samar waters during the month of April; along Aurora/Pollilo waters in May, and Cagayan/Isabela waters in June while in August the larvae tend to aggregate along the Davao/Surigao waters (**Fig. 13**).

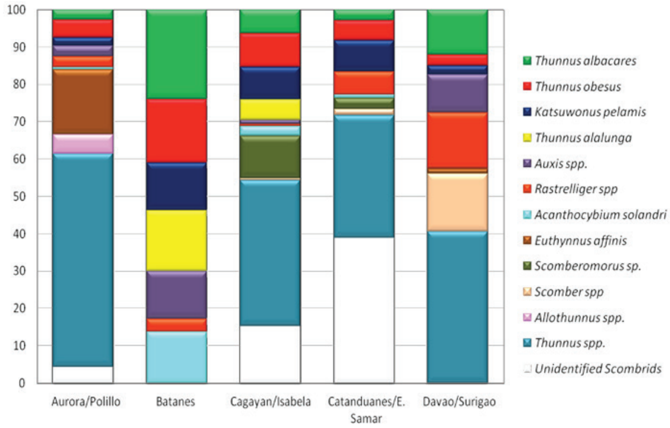


Fig. 11. Relative abundance (%) of various species of Scombrid larvae by sampling station

Table 1. Correlation values of Simpson's and Shannon's Indices

Indices Compared	Correlation Values
Simpson's Dominance Index (D) and Shannon's Index Correlation	-0.932234200
Simpson's Index of Diversity and Shannon's Index Correlation	0.932234200
Simpson's Reciprocal Index and $e^{H'}$ Correlation	0.901072446
Simpson's Evenness and Shannon's Evenness Correlation	0.867941819

On the total densities per month, Scombrid larvae were found to be more abundant in May with mean density of 65 larvae/1000 m³ of seawater but least in August with 36 larvae/1000 m³ of seawater (**Fig. 14**).

In terms of species diversity, the month of May had the most diverse species of Scombrid larvae compared with those during other sampling months and low in April as well as in June (**Fig. 15**). The relative abundance of Scombrid species per month is shown in **Fig. 16**.

Influence of Temperature

Temperature plays a major role in the spawning habit of most fishes, as adequate temperature is necessary for most fish eggs to hatch as well on the development of the appendages of the larvae. Unsuitable temperature could mar the hatching of fish eggs and is detrimental to development of the larvae (FAO, 1994; Margulies *et al*., 2007).

When the mean temperatures of the sampling stations from 1-150 m were compared to the total densities of the Scombrid larvae, results showed that the larvae were more abundant in stations with mean temperature of 27°C and low at stations with 23°C mean temperature. In the same way, relatively high density was noted at stations with 26°C mean temperature (**Fig. 17**).

The relative abundance of each species of Scombrids at various temperature ranges is shown in **Fig. 18**.

Food Availability

The influence of food availability based on chlorophyll-*a* concentration was assessed to determine its possible effect on the abundance and distribution of the Scombrid larvae. Specifically, the mean chlorophyll-*a* concentration from

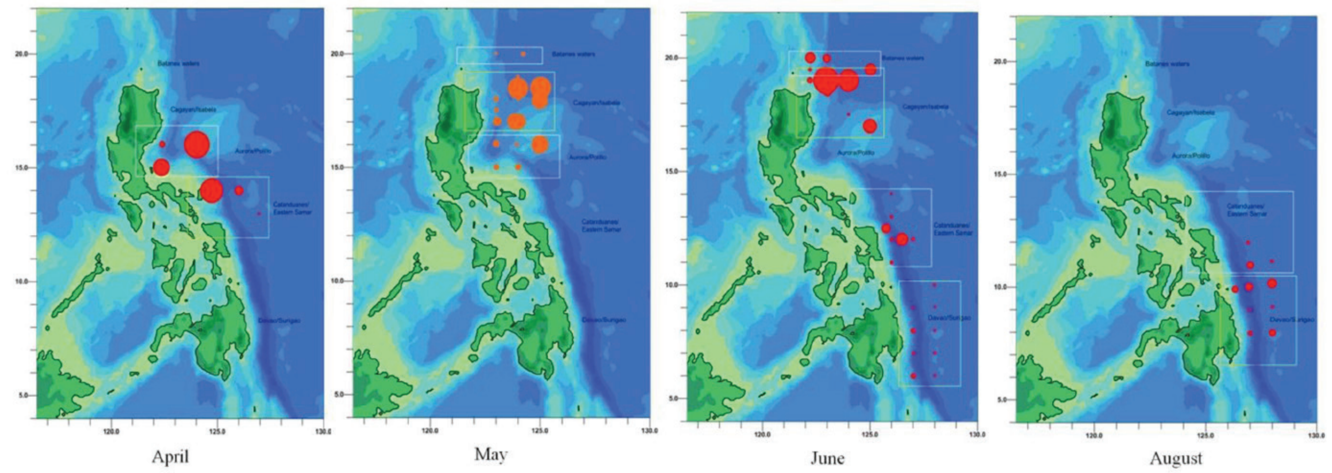


Fig. 12. Abundance and distribution of different species of Scombrid larvae in different months
(Scale: 0.025 in dia = 10 larvae/1000 m^3 of seawater; 0.250 in dia= 500 larvae/1000 m^3 of seawater)

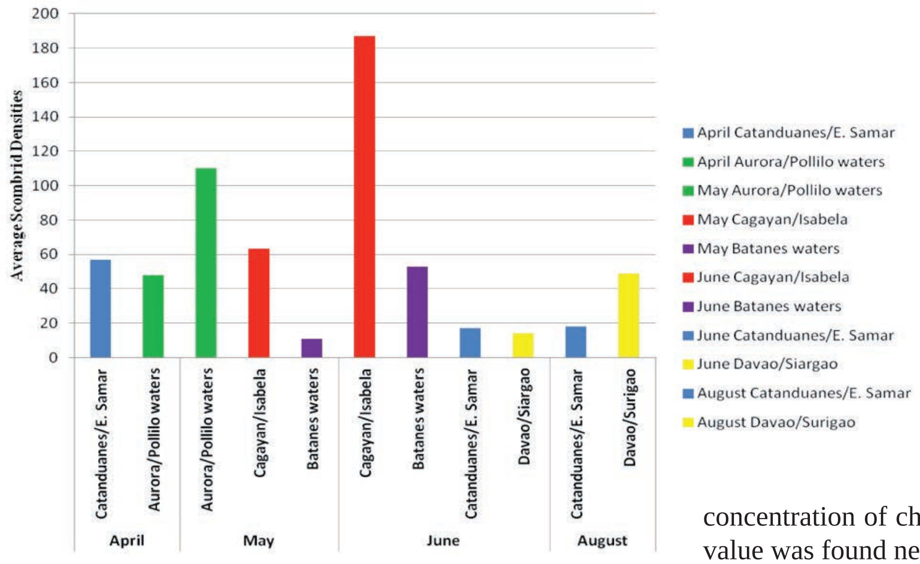


Fig. 13. Monthly variation of the densities of Scombrid larvae from different sampling sites

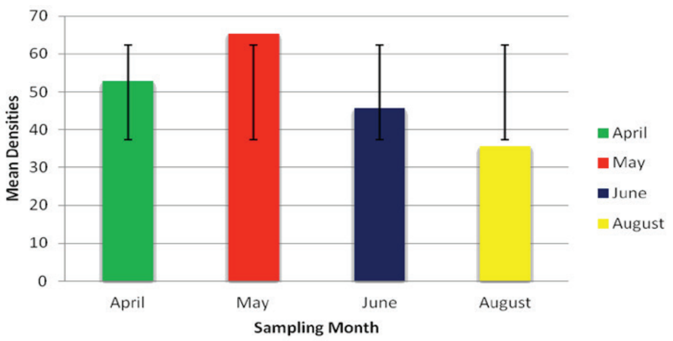


Fig. 14. Monthly variation of the densities of Scombrid larvae

1-150 m was used to determine if the availability of food (phytoplankton) in a certain station at said depth range affects the density of tuna larvae. Results of the analysis showed that the tuna larvae tend to aggregate at stations with mean chlorophyll-*a* concentration of 0.2 µg/L, 0.3 µg/L and 0.8 µg/L. Densities of the tuna larvae also tend to decrease as the concentration of chlorophyll-*a* increases but the correlation value was found negligible (**Fig. 19** and **Fig. 20**).

Sampling Time

Sampling time was also considered for its importance in finding out the diel migration patterns of oceanic organisms. Results indicated that afternoon sampling gathered more Scombrid larvae than evening and morning samplings but the mean density of the Scombrid larvae in the evening sampling slightly differs from the abundance of the Scombrid larvae collected during the afternoon sampling (**Fig. 21**).

Conclusion and Recommendations for Future Works

From the results of the study, it can be concluded that the total abundance and distribution of Scombrid larvae in the Philippine Eastern Pacific Seaboard is affected by temperature, sampling area, sampling season, sampling time, and spatial distance. Food availability was however, found to be a non-significant factor affecting the abundance of Scombrid larvae although species diversity was influenced by the sampling area and sampling season.

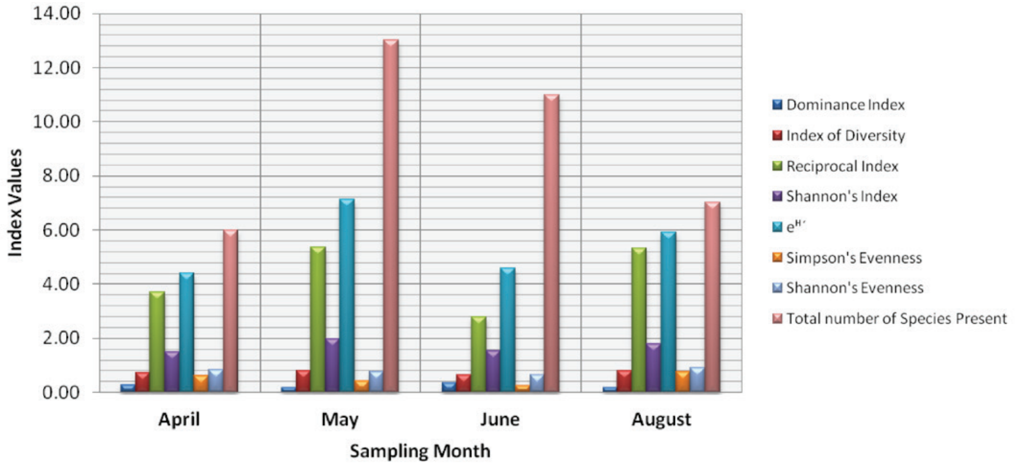


Fig. 15. Species diversity index of Scombrid larvae by sampling month

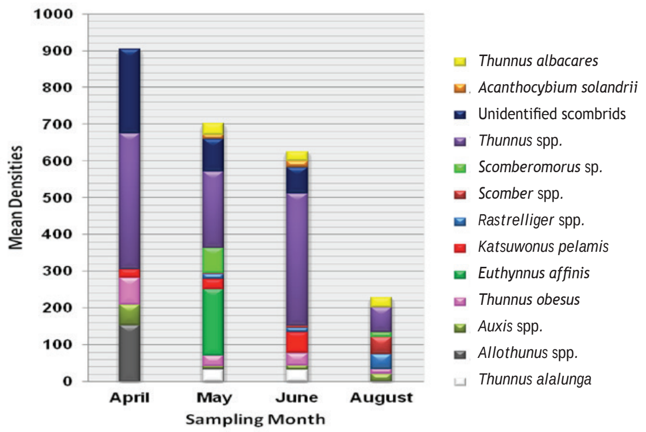


Fig. 16. Relative abundance (%) of species of Scombrid larvae by sampling month

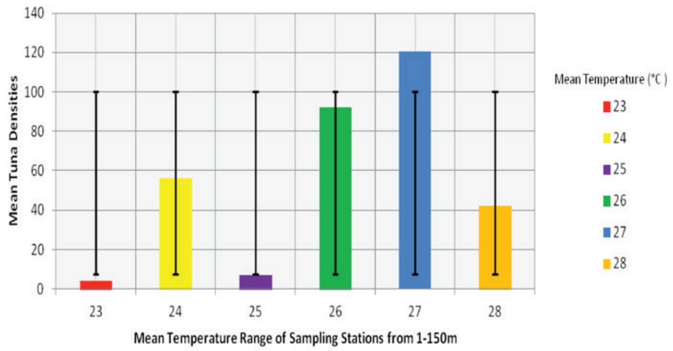


Fig. 17. Mean densities of Scombrid larvae in various temperature ranges

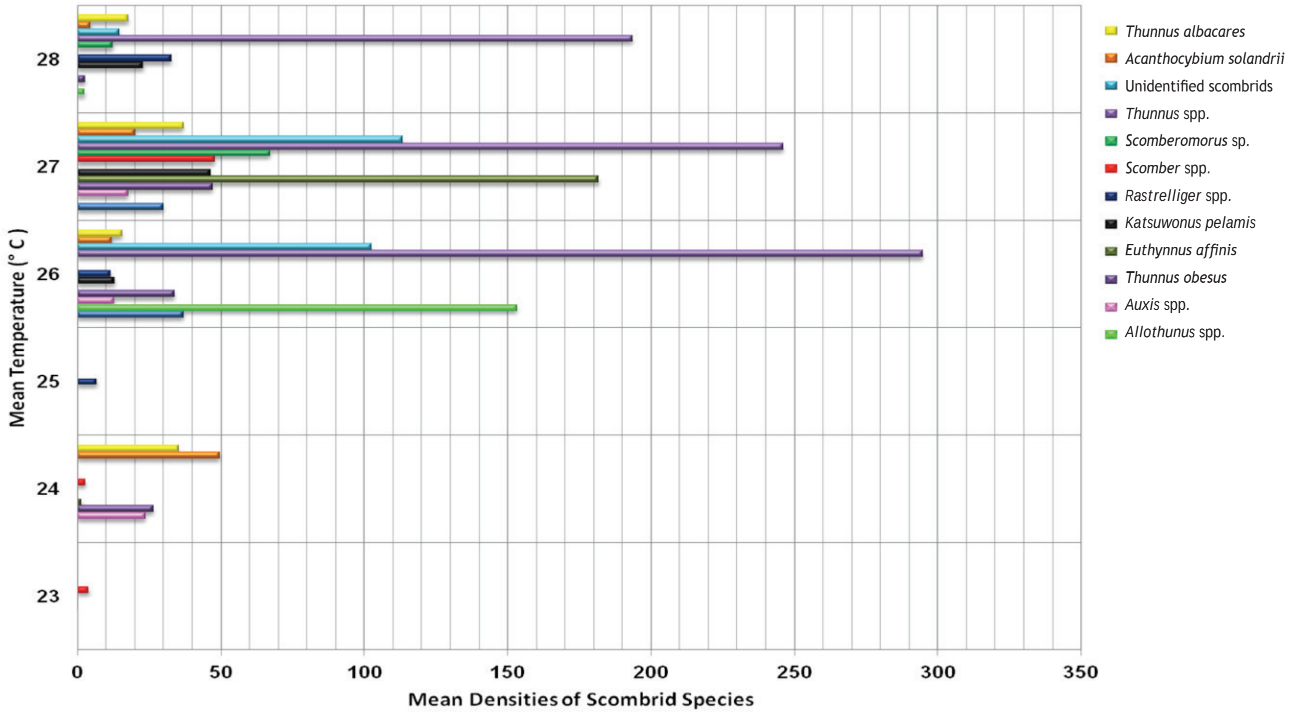


Fig. 18. Species of Scombrid larvae in PEPS corresponding to various temperature zones

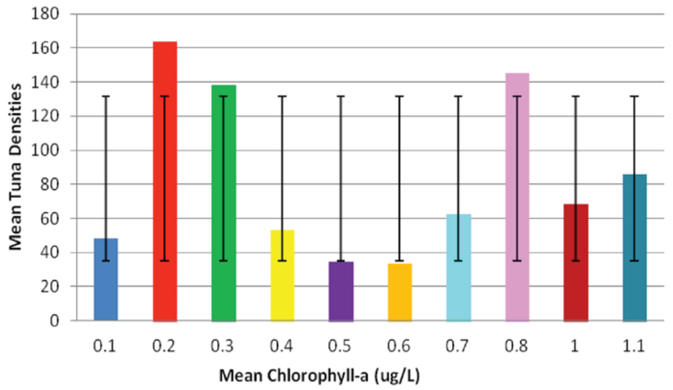


Fig. 19. Mean densities of tuna larvae at various ranges of mean chlorophyll-*a* concentrations

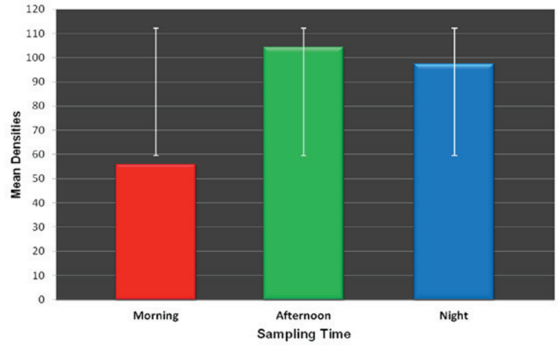


Fig. 21. Mean densities of Scombrid larvae at different sampling times

Results of studies conducted on the variability of water current in the Philippine Eastern Pacific Seaboard could be used to correlate with the results of this study in order to assess the possible relationship between current variability and larvae retention sites in the PEPS. Statistics on catch landings of tuna and tuna-like species should also be used to determine whether the dominant species of the Scombrid larvae observed in a particular sampling station of this case study coincides with the most common tuna and tuna-like species caught from the same area. Transects along the Davao/Surigao waters should be expanded in future oceanographic studies in the area for better comparison of spatial densities of the Scombrid larvae. Studies on seasonal variability of Scombrid larvae in the Philippine Pacific Seaboard should be pursued to create a more comprehensive profile of the larvae's abundance and distribution at different seasons. Moreover, there is a need to widen the sampling area for the seasonal variability study and increase sampling stations to avoid possible sampling bias. Molecular analysis should also be carried out for the unidentified species of Scombrid larvae to confidently classify them into species level.

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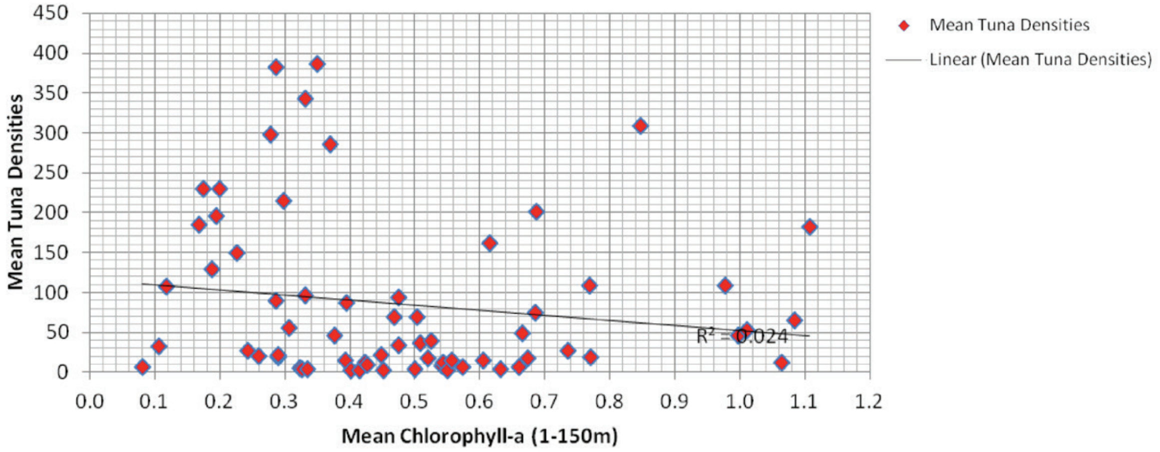

Fig. 20. Correlation between densities of tuna larvae and mean chlorophyll-*a* concentrations

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