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SHORT COMMUNICATION

Abundance and Distribution of the Larvae of Family Carangidae in the Philippine Waters

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ABSTRACT

A spatio-temporal study on the abundance of the Carangidae larvae in Philippine waters was conducted to minimize the lack of information on their spawning grounds. The study analyzed fish larvae data from M/V DA-BFAR cruises between 2006 and 2018, covering various areas in the Philippines. A total of 589 sampling stations were examined and grouped into seven zones: Batanes-Polillo, Catanduanes-Eastern Samar, Inland waters (Bohol Sea, Davao Gulf, Lagonoy Gulf, Leyte Gulf, Ragay Gulf, Sibuyan Sea, Samar Sea, Tayabas Bay, and the Visayan Sea), Mindanao-Sulawesi Sea, Sulu Sea, West Philippine Sea, and Davao Oriental-Surigao. The results indicated a patchy distribution of carangid larvae, with the highest concentration found in northern Palawan (Sulu Sea and West Philippine Sea areas). The total density of composite samples ranged from 1 to 865 larvae/1000m^3. The abundance showed fluctuation over the years, with higher densities in 2016 and 2017 compared to other sampling years. The highest mean density was observed in September 2017 in the West Philippine Sea, while the lowest was recorded in May 2015 in Batanes-Polillo waters. The variations in carangid larvae abundance in Philippine waters are likely related to the species' spawning habits, as the timing of reproduction may vary by region based on ecological factors. Other factors influencing the results include sampling incidence and the sampling period of M/V DA-BFAR.

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Fish larvae are the transitional life forms of fishes that develop from spawned eggs through several embryonic stages. During this period, they rely solely on yolk as their source of nutrients and energy. Eventually, they hatch and become independent, capable of catching and digesting prey organisms (The Research Council of Norway 2009). The abundance and distribution of fish larvae serve as indicators for identifying spawning and nursery grounds, including those of Carangidae, a diverse family of fishes.

Carangidae, commonly known as jacks, trevallies (crevalles), amberjacks, pompanos, scads, kingfish, pilotfish, and rainbow runners (Honebrink 2000), comprises a group of fishes with varied characteristics. Most Carangidae species form schools, except for the genus *Alectis* which is solitary. Some Carangidae species predominantly inhabit continental waters, especially during their early life stages, often in brackish environments. Others, such as *Elagatis* and *Naucrates*, are pelagic and prefer the oceanic waters near or at the surface, often far from the shoreline. Carangidae species also hold commercial importance, as they are commonly consumed as food (Smith-Vaniz, 1984).

In the Philippines, Carangidae is among the top family of fishes in the market, particularly the big-eye scads (*Selar* spp.) and the round scads (*Decapterus* spp.). These two species consistently rank among the top five marine species in terms of annual production. Notably, significant production of big-eye scads occurs in the Zamboanga Peninsula (specifically Zamboanga City, Zamboanga del Sur, and Zamboanga del Norte), Palawan, Sulu, Basilan, and Cebu. Round scads, on the other hand, exhibit the highest production in Sulu, Zamboanga Peninsula, Camarines Sur, Palawan, South Cotabato, Cebu, Iloilo, and Masbate. Other important Carangidae species with substantial production include crevalle and cavalla. Palawan, Iloilo, and Masbate are the primary locations for crevalle production, while Palawan, Iloilo, Zamboanga City, Tawi-Tawi, and Quezon are significant for cavalla (Philippine Statistics Authority 2017).

However, there has been a decline in the production of these fish species in recent years, particularly in the case of round scads, commonly known as "galunggong." This decline prompted the Bureau of Fisheries and Aquatic Resources (BFAR) and the Department of Interior and Local Government (DILG) to establish a closed season for round scads in northern Palawan under the DA-DILG JAO No.1, Series of 2015. The decision to implement a three-month closed season for round scads in northern Palawan was based on reports of declining catches from local fishers, production data from the Bureau of Agricultural Statistics (BAS) and Philippine Statistics Authority (PSA), and BFAR-National Stock Assessment Program IV-B in 2015. Consequently, the closed season was implemented in the identified spawning areas in northern Palawan.

The round scads closed season was successful. However, an issue arose in the last quarter of 2018 regarding the importation of "galunggong" in the Philippines. Some local fishers, traders, and consumers questioned the necessity of importing round scads from neighboring countries, particularly China, considering the country's capacity to supply them locally (Pelayo 2018). Despite the questioning, the importation was deemed necessary to address the declining volume of fish in the local market. In 2019, BFAR conducted the National Galunggong Summit to discuss the fishery status, threats, and sustainable production strategies for round scads. A national "galunggong" management plan was also formulated during this summit. Among the topics discussed was the need for more scientific information on the major spawning areas of round scads in Philippine waters. This study was conducted to address this knowledge gap. During M/V DA-BFAR cruises, ichthyoplankton samples were collected, but species-level identification was not conducted. Analyzing the samples at the species level could help identify spawning areas and provide insights into the abundance and distribution of round scad larvae in the country.

This short communication highlights the abundance of Carangidae larvae in Philippine waters based on the data collected by the M/V DA-BFAR cruises from 2006 to 2018. Spatio-temporal profiling of the larvae was conducted to identify possible spawning ground and peak spawning periods. The sampling area covered the entire Philippine waters and was divided into seven zones: Batanes-Polillo, Catanduanes-Eastern Samar, Inland waters (Bohol Sea, Davao Gulf, Lagonoy Gulf, Leyte Gulf, Ragay Gulf, Sibuyan Sea, Samar Sea, Tayabas Bay, and the Visayan Sea), Mindanao-Sulawesi Sea, Sulu Sea, West Philippine Sea (the body of water located in the western Philippines from Batanes to Mindoro and the western side of Palawan), and Davao-Surigao (Figure 1). A total of 589 stations were analyzed to detect the presence of Carangidae larvae. The total density of composite samples of carangid larvae was used as a measure of abundance at each sampling station. In addition, mean densities of stations within each zone were compared to assess differences in abundance between zones. Furthermore, the study examined the abundance of larvae across different sampling months and years in various zones.

The abundance and distribution of carangid larvae in the Philippine waters are somewhat patchy, with the highest concentration in northern Palawan, particularly in the Sulu Sea and West Philippine Sea areas. The total density of the composite samples ranges from 1 to 865 larvae per 1000 cubic meters of seawater. The highest density was recorded at a station in the West Philippine Sea, while the lowest density

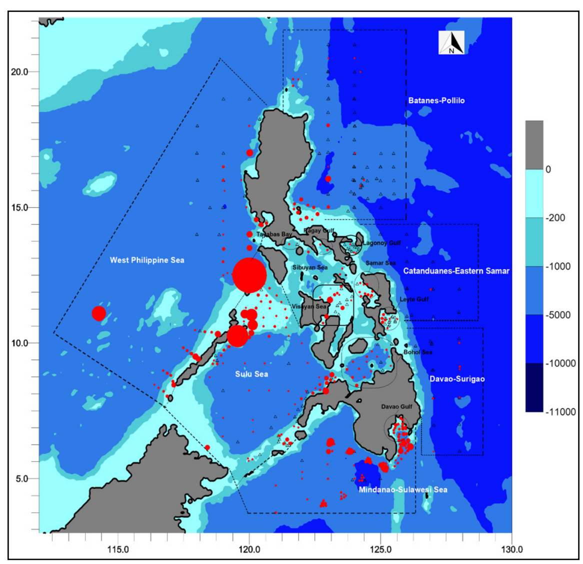

Figure 1. The abundance and distribution of the larvae of Family Carangidae in the Philippine waters. The red circles indicate the densities of the larvae, while the black triangles indicate the stations without the larvae. Surfer scale: 0.01 inches = 1 larvae; 0.25 inches = 1000 larvae/1000m^3 seawater. The color bar at the right corner indicates the ocean bathymetry of the sampling area in meters.

was found in stations located in the central part of the Sulu Sea. The highest density was recorded at a station in the West Philippine Sea, while the lowest density was found in stations located in the central part of the Sulu Sea. The West Philippine Sea displayed the highest mean density, indicating the highest overall abundance among the sampling zones. Conversely, Catanduanes-Eastern Samar exhibited the lowest mean density (Figures 1 and 2).

The abundance of carangid larvae displayed a fluctuating trend over the years, with higher densities observed in 2016 and 2017 compared to other sampling years conducted by M/V DA-BFAR. The West Philippine Sea exhibited the highest mean density of larvae in September 2017, while the lowest density was recorded in Batanes-Pollilo waters in May 2015. In Batanes-Pollilo, the highest larval abundance was observed in May 2010 and August 2009, while Catanduanes-Eastern Samar and Davao-Surigao showed peak abundance in August 2009 and May 2010, respectively. Similar to other zones, the Sulu Sea displayed the highest larval density in July 2016, followed by a September 2017 sampling. In the Internal water zone, the highest abundance of carangid larvae was observed in September 2016, while the Mindanao-Sulawesi Sea experienced a peak in December 2018 (Figure 3).

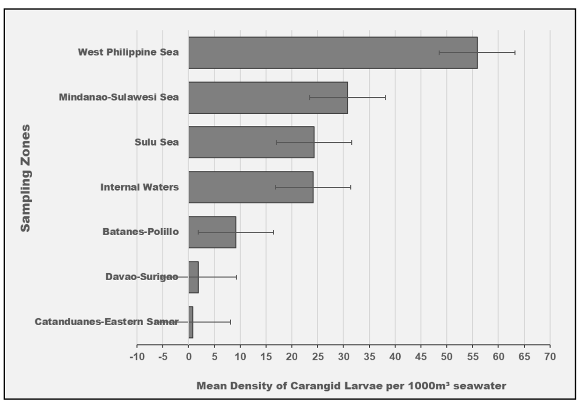

Figure 2. The mean densities of carangid larvae at different sampling areas in Philippine waters.

The Sulu Sea and West Philippine Sea are rich in coral reefs and small islands. Numerous banks and shoals also abound in these areas. Likewise, the zone along northern Palawan has a wide continental shelf. These diverse environments provide favorable conditions for marine fishes, serving as important areas for feeding, breeding, spawning, and nursery activities due to their high productivity (Alcala et al. 2003; Baviera and Batongbacal 2013; Licuanan 2020). Considering the ecological advantages of these topographies, they may have contributed to the high abundance of carangid larvae, particularly in the areas along northern Palawan.

According to Hermes and Guarin (2003), meroplankton, which comprises larvae of crabs, copepods, shrimps, and polychaetes, are significant in reefs and atolls as they serve as crucial food sources for carangids, particularly crustacean larvae. This finding was supported by a study conducted by Sivakami (1996), which identified the mentioned plankton as the preferred food of carangids, along with juveniles of fish species belonging to the genera *Stolephorus*, *Leiognathus,* and *Sardinella.* Additionally, Ronquillo (1970) observed mature and spent (IV and V stages) fishes of the genus Decapterus (round scads) appearing at the reef at certain times (Pastoral et al. 2000), confirming the importance of reefs as spawning grounds for carangids and verifying the information that their population is being centered within the Sulu Sea and adjacent shallow seas. Hermes and Guarin (2003) further conveyed that the high abundance of

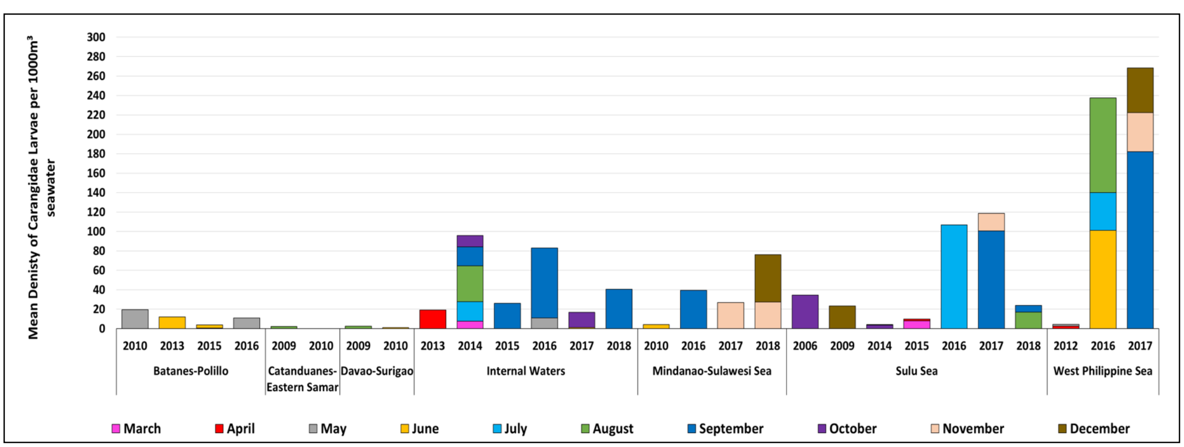

Figure 3. The mean density of carangid larvae in various sampling zones in the Philippine waters collected at different sampling periods.

zooplankton coincides well with the primary fishing grounds of round scads. In this study, the abundance of carangid larvae aligns with the *Decapterus* spawning grounds in northern Palawan, as indicated by data from the Alliance of Philippine Fishing Federation Incorporated in 2015 (Department of Agriculture 2021). However, it should be noted that the collected samples onboard M/V DA-BFAR were not subjected to species-level identification, so we cannot confirm if they belong to the genus *Decapterus*.

Furthermore, it was mentioned earlier that young carangids favor a brackish environment (Smith-Vaniz 1984). Their abundance and distribution in this study could also be attributed to their preference for less saline water conditions, thus were more abundant nearshore than offshore areas. Another factor is productivity because higher productivity means abundant food for fish larvae. The study noted a lower abundance of carangid larvae at the offshore sampling stations along the Pacific Seaboard zones (Batanes-Polillo, Catanduanes-Eastern Samar, and Davao-Surigao waters). This discrepancy might be due to higher salinity and lower productivity compared to the nearshore stations. It is widely recognized that nearshore areas exhibit higher productivity owing to the influx of nutrients and runoff from the land. The preference of carangids for nearshore or neritic areas has also been observed in studies by Chamchang and Chayakul (2000) and Souza and Mafalda Júnior (2008).

The study identified specific regions within the Pacific seaboard that exhibited a significantly higher abundance of carangid larvae. These regions include the Batanes-Polillo zone, particularly along the Bicol Shelf (Polillo Island stations), as well as one station situated within the Philippine Rise. In addition, inland water stations, particularly in the Visayan Sea (northern Iloilo and Guimaras Strait areas) and certain parts of Davao Gulf, were also noted for their high abundance of carangid larvae.

Further, the Mindanao-Sulawesi region displayed a relatively high abundance of carangid larvae. This could be attributed to the area's high productivity, which may have been influenced by the movement of currents and the presence of different carangid species that spawned in offshore areas, such as the rainbow runner (*Elagatis bipinnulata*) (Souza and Mafalda Júnior (2008). The dynamics of major currents, such as the Mindanao Current, likely played a crucial role in shaping the abundance and distribution of carangids in the Mindanao-Sulawesi region.

A study by Kashino et al. (2001) revealed that when the Mindanao Current splits into three branches, the westernmost branch enters the Celebes Sea, while a portion of it retroflects around a cyclonic eddy in the western Celebes Sea. Therefore, this cyclonic eddy might have contributed to the area's productivity. Additionally, Takeda et al. (2007) observed the entrainment of subsurface water and vertical mixing caused by intense tidal flow from the Sulu Archipelago to the Celebes Sea. This phenomenon created a low temperature, high nutrient condition at the southeastern edge of the Sulu Ridge. Consequently, high chlorophyll-a concentrations were found in the Celebes Sea, and the researchers claimed that the area's primary productivity ranged from 1.6 to 18 times higher than that measured in the oligotrophic central basin region of the Sulu Sea and Celebes Sea.

The resulting spatio-temporal variations in the abundance of carangid larvae in Philippine waters can be attributed to the spawning habits of Carangidae species, as their reproductive timing of the spawning period could vary by region based on their ecological attributes. A study conducted by Souza and Mafalda Júnior (2008) in the northeast Brazilian Exclusive Economic Zone revealed that oceanographic factors such as temperature, salinity, and primary and secondary biomass influence the abundance of Carangidae species, providing them with specific periods and locations for spawning in the area. Similar observations may apply to the abundance and distribution of carangids in Philippine waters.

Another factor that could have influenced the study's results is the sampling incidence and period of the M/V DA-BFAR. The data were collected over different years and encompassed a wide range of sampling areas. For instance, the sampling in the Eastern Pacific Seaboard (Batanes-Polillo, Catanduanes-Eastern Samar, and Davao-Surigao) was specifically conducted during the months of sea calmness (May, June, and August) to ensure the safety and feasibility of the research, considering that this region is prone to typhoons. This limited sampling period might have had an impact on the observed abundance and distribution patterns.

Based on the study's findings, researchers interested in conducting a comprehensive investigation on *Decapterus* species (round scads) should prioritize their studies in northern Palawan. This region aligns with the principal spawning grounds of round scads, which coincides with the observed abundance of carangid larvae in this study. Thus, there is a strong possibility that the larvae collected and identified aboard the M/V DA-BFAR belong to this particular genus. In addition, morphological identification of the specimens into genus or species levels would be valuable to enhance the study's completeness.

Moreover, further studies should be conducted in key areas that have shown a relatively high abundance of Carangidae larvae. These areas include the Mindanao-Sulawesi Sea, Bicol Shelf (specifically along Pollilo Island), Visayan Sea (Northern Iloilo area), and northern Zamboanga. Exploring these regions would provide valuable insights into the abundance and distribution of Carangidae larvae, complementing the results of the current study.

Furthermore, researchers interested in studying specific species such as *Elagatis bipinnulata*, *Selar* spp., *Alectis* spp., and *Naucrates* spp. should focus their investigations on areas with high densities of Carangidae larvae. Conducting species-level studies in these locations would help validate and reinforce the present study's findings.

Finally, it would be worthwhile to correlate the results of this study with physicochemical parameters. Exploring the relationship between the abundance and distribution of carangid larvae and various physicochemical factors would provide a deeper understanding of their ecological relevance and confirm their significance in the study area.

CONFLICT OF INTEREST

To the best of our knowledge, no conflict of interest exists in our work.

ETHICS STATEMENT

No animal or human studies were carried out by the authors.

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