A comparison of the vertical distribution and species composition of Chaetognaths between high and low production areas in Dipolog Bay, East Sulu Sea, Philippines

Cristy S. Acabado[1], Wilfredo L. Campos[2]

[1]Institute of Marine Fisheries and Oceanology, College of Fisheries and Ocean Sciences, University of the Philippines Visayas, Miagao, Philippines
[2]OceanBio Laboratory, Division of Biological Sciences, College of Arts and Sciences, University of the Philippines Visayas, Miagao, Philippines

ABSTRACT

The East Sulu Sea, the area off the coast of the Zamboanga peninsula, is one of the major fishing grounds for sardine in the Philippines principally driven by primary production that follows seasonal upwelling in the area. Chaetognaths are zooplankton predators whose abundances may serve as control to overall plankton biomass in such productive waters. This study aims to compare and characterize chaetognath assemblages associated with structural attributes between high and low production areas within an upwelling area. Zooplankton were collected in February 2013 during an upwelling season using a 45cm-diameter NORPAC net with a 200um mesh bag attached to it. Three depth intervals (0-65m, 65-135m and 135-200m) were examined in each station for the vertical profiling of zooplankton. The mean zooplankton biomass for the high (Stn 24) and low (Stn 22) production stations were 51.8 ml 100m^{-3} and 75.8 ml 100m^{-3}, respectively. A total of 993 chaetognaths with an average density of 47.5 ind. m^{-3} were collected from the Stn 24, and only 334 individuals accounting for an average density of 10.6 ind. m^{-3} from the Stn 22. The results show an aggregation of chaetognaths in the surface layer of the two stations, particularly in the high production station, contributing 80.96 ind. m^{-3} to the total zooplankton. *Flacisagitta enflata* was the most dominant species found in both stations. This study suggests that physical and biological controls may dictate chaetognath assemblage composition and distribution.

KEYWORDS:

Chaetognatha, East Sulu Sea, productivity, upwelling, vertical migration

INTRODUCTION

The eastern Sulu Sea, particularly along the coast of Zamboanga Peninsula, is a major fishing ground in the Philippines for the planktivorous *Sardinella lemuru* and at least 3 other species of sardines (Willete and Santos 2013). The coastline of Dipolog exhibits wind-driven upwelling during the northeast monsoon (DeVantier et al. 2004; Miki et al. 2008). Winds during the northeast monsoon blow parallel to the northern coast of Zamboanga Peninsula (Villanoy et al. 2011) and drives a relatively strong offshore Ekman transport that leads to the upward movement of nutrient-rich water from deeper layers (Villanoy et al. 2011). Upwelling of the subsurface water in the coast replaces the transported layer, bringing nutrients to the surface. This seasonal upwelling event in the southeastern Sulu Sea influences plankton productivity in the area that becomes more available to higher trophic levels. Thus, the upwelling phenomenon makes the Sulu Sea an excellent commercial fishing ground for planktivorous fish such as sardines. The hydrography of the area is relatively well-known, but detailed consideration of its effects on zooplankton distribution is still sparse. Several factors may trigger the vertical migration of planktonic organisms. Light intensity and the depth of the "deep scattering layer" are significant factors that may dictate the vertical position of a plankter (Banse 1964). Temperature and the depth of the thermocline may also serve as a barriers for various species (Banse 1964).

Chaetognaths, commonly called "arrow-worms, are a phylum of marine invertebrates (Pierrot-Bults and Nair 2010). They are strictly marine and commonly planktonic found from the surface down to great depths (Kehaiyas et al. 1994). They are good

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*Corresponding Author:

Institute of Marine Fisheries and Oceanology, College of Fisheries and Ocean Sciences, University of the Philippines Visayas, Miag-ao (5023), Iloilo;
Email address: csacabado@up.edu.ph

indicators of water masses because they are found within narrow ranges of different water parameters, such as salinity, temperature and turbulence. Hence, they are likely to have species-specific horizontal and vertical patterns of distribution (Terazaki 1998). They are known to feed mostly on early stages of copepods, larvacea (i.e. *Oikopleura*) and even larval fish (Terazaki 1998; Tönnesson and Tiselius 2005). As predators, they control the abundance of their planktonic prey, and play an important role in the transfer of energy to higher trophic levels (Kehayias et al. 1994). Chaetognaths have been reported to regulate copepod numbers especially during blooms or upwelling (Sullivan 1980, Gibbons and Stuart 1994, Terazaki 1998), especially in tropical coastal areas. However, their role in oceanic regions is largely unexplored.

Several investigations in the Sulu Sea examined vertical distribution of zooplankton in general (Nishikawa et al. 2007, Acabado et al. 2010), and of the calanoid *Rhincalanus nasutus* (Metillo et al. 2014). Johnson et al. (2006) studied the offshore distribution of chaetognaths, but did not compare upwelling and non-upwelling areas.

This study was done to determine and compare the vertical distribution patterns of chaetognaths between high and low production areas within an upwelling region on the coast of Dipolog Bay, Zamboanga del Norte, Philippines.

MATERIALS AND METHODS

An upwelling area has been established by Villanoy et al. (2011) along the western side of the Dipolog Strait, which corresponds to the coast of Zamboanga peninsula. Zooplankton samples were collected during the latter part of northeast monsoon (24 February 2013) on board the R/V BFAR – DYCA. Two stations from Dipolog Bay were picked out and examined to represent an area with strong signals of upwelling (Stn 24), and another which is further offshore (Stn 22) and away from the upwelling area (Fig. 1B). The upwelling signal is depicted by the higher chlorophyll concentration in the inner portion of Dipolog Bay (Fig. 1B). This information is based on underway measurement of chlorophyll along the cruise path.

Both stations were sampled during the day so as to avoid bias due to differences in abundance and composition between night and day samples, which may be largely affected by diel vertical migration of zooplankton. Station (Stn) 24 was located N 8° 36.90’, E 123° 0.91’ within the upwelling area with

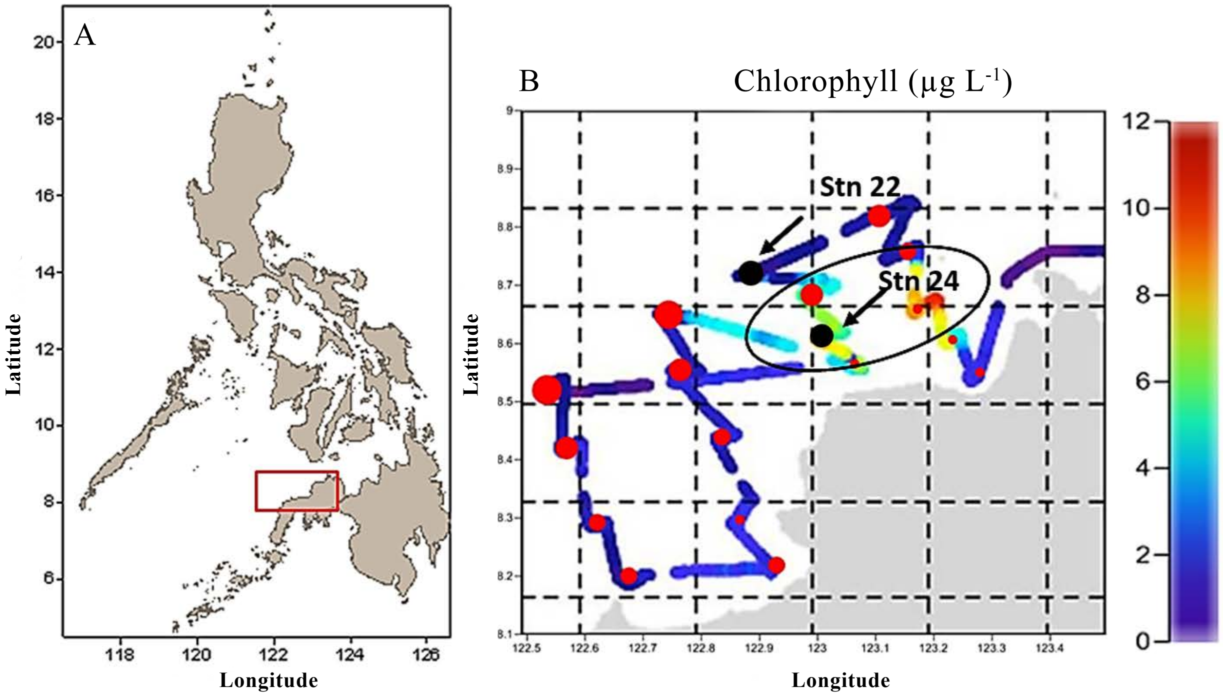

Figure 1. Location of stations along the upwelling area in Dipolog and Sindangan Bays, Zamboanga del Sur, Philippines (red box). A) Area of study (red box) of SARDYN Project 2013; B) actual cruise path on 20-27 February 2013 superimposed on underway chlorophyll data. Red dots indicate sampling stations. Station 24 is found within the area of relatively higher surface chlorophyll concentration (encircled region) in Dipolog Bay.

bottom depth of 1097m, while Stn 22 was further offshore located N 8° 43.95’, E 122° 55.06’ in a non-upwelling area (Fig. 1). Station 22 is a deeper region with bottom depth of 1901m.

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Zooplankton samples were preserved in 10% seawater-buffered formalin solution and brought back to the lab for processing. The volume of water filtered was computed using the towed distance multiplied by the area of the net mouth assuming high filtration efficiency. Zooplankton biomass was computed using the displacement volume and the volume of water filtered and expressed as ml m^{-3}. The zooplankton samples collected at Stn 24 included a large proportion of salps, which were removed prior to displacement volume measurements. This was done to avoid bias in density and biomass measurements for mesozooplankton. Densities were expressed as ind. m^{-3}.

All chaetognaths were sorted out and subsampling was avoided to minimize underestimation of the taxon. The total number of individuals counted and identified from each station are presented in Table 1. Matured individuals were identified to species level using the keys of Alvariño (1967), Pierrot-Bults and Chidgey (1988), Bieri (1991) and Cassanova (1999). Juvenile chaetognaths were separated from the matured specimens (Stage II-V brooding phases) based on Alvariño (1992) and were only counted to also report abundance of early stage chaetognaths.

Underway measurements of chlorophyll was also employed. An SBE19 SEACAT CTD Profiler which measures vertical profiles of temperature and chlorophyll was deployed down to 200m at each station (Fig. 2). The mixed layer depth (MLD) was computed as the depth where the temperature cools down by 0.2°C from 10m depth (de Boyer Montégut 2004). Chlorophyll *a* Ocean color data (1 km resolution) on chlorophyll was automatically downloaded from MODIS Level 2 data immediately after the cruise (Fig. 2). Figures from MODIS are shared data within the SARDYN Research Program.

RESULTS

Hydrography

Figure 2 reveals the upwelling signal and primary production in Dipolog Bay. The MODIS Aqua Ocean Color provided the spatial, sea surface distribution of chlorophyll *a* as seen in Fig. 2A. This establishes the distinction between the two stations investigated, wherein Stn 24 lies on the upwelled region (described by elevated levels of chlorophyll *a*) in Dipolog Bay.

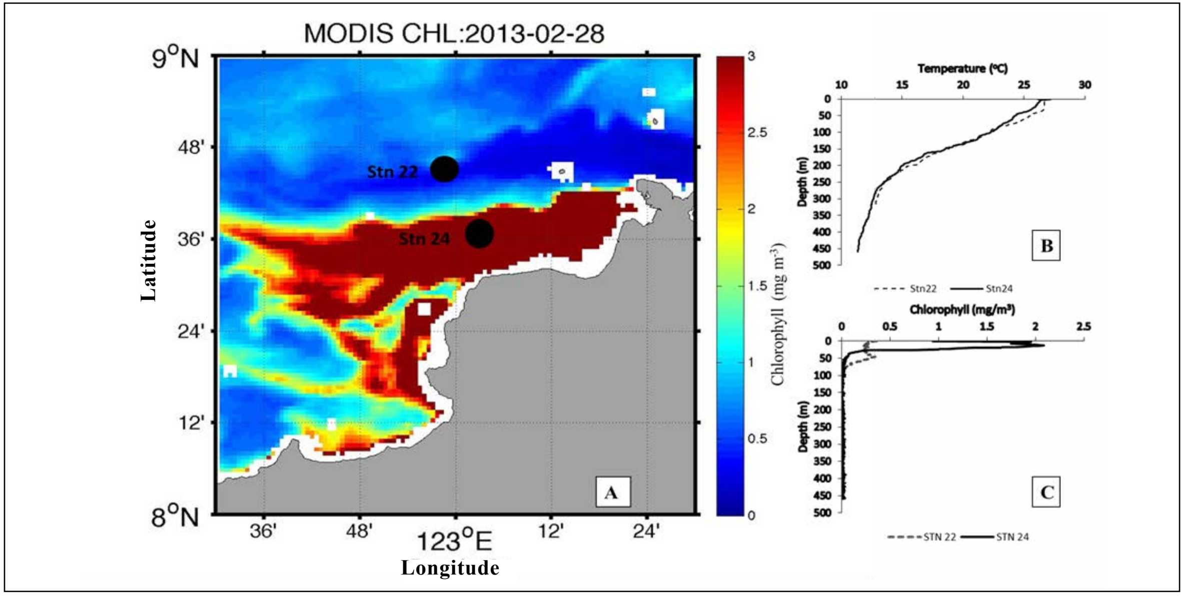

Figure 2. Evidences of upwelling in Station 24 during the sampling in 24 February 2013. A) Surface chlorophyll-a image for Dipolog-Sindangan Bay after the oceanographic cruise (28 February 2013) conducted by SARDYN Project on 20-27 February 2013, B) vertical temperature (°C) profile, and C) vertical chlorophyll (mg m^{-3}) profile from CTD casts during the actual sampling.

Stn 22, on the other hand, lies on a low production region with chlorophyll *a* concentration of <0.5 mg m^{-3}. The chlorophyll vertical profile (Fig. 2C) is congruent with the upwelling event in Stn 24, where surface chlorophyll was one magnitude higher than that in Stn 22 at least in the upper 30 m (mean chlorophyll concentration: 1.44 and 0.26 mg m^{-3}, respectively). The vertical profiles of temperature in the 2 stations show similar patterns, with a very subtle difference in the upper 100m with slightly colder temperature at Stn 24 (Fig. 2B). The MLD was also shallower in Stn 24 (29m) compared to Stn 22 (MLD = 42m).

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Abundance and species composition

This study shows the comparison of chaetognath vertical distribution between high (Stn 24) and low production (Stn 22) areas in Dipolog Bay. Only two stations were compared, but showed a substantial difference in terms of density and species composition of chaetognaths. Table 1 shows chaetognath density (ind. m^{-3}), zooplankton biomass (displaced volume in ml 100m^{-3}) and no. of species identified in each stratum of both stations. The number of chaetognaths collected in Stn 24 (993 individuals) was two folds of that in Stn 22 (334 individuals) despite the smaller sampling volume in the former. The low production station (Stn 22) showed relatively higher zooplankton biomass ranging from 48.37 – 116.08 ml 100m^{-3} from the surface down to 200m. The biomass of the remaining samples in Stn 24, after the removal of salps, ranged from 35.93 – 67.71 ml 100m^{-3}. The zooplankton collected in the high production station was fewer than in Stn 22 in terms of biomass.

Table 1. Chaetognath density and zooplankton biomass per depth layer in each station. Sampling in Stn 24 was limited to a maximum depth of 135m only. The variation between depths is expressed as the standard deviation (s).

A total of 1,327 chaetognath individuals were collected from the two sampling stations. Approximately over 60% of these were juveniles. Nineteen identifiable species belonging to 9 genera were identified from the remaining matured specimens (Table 2). Both stations showed highest chaetognath

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Depth Layer (m)	Chaetognath Density (ind. m^{-3})	Zooplankton Biomass (ml 100m^{-3})	No. of Chaetognath Taxa
Station 24			
0-65	80.96	67.71	9
65-135	14.01	35.93	13
135-200	-	-	-
Mean	47.49	*51.82*	**19**
s*	*47.34*	*22.47*	
no. of specimens	**993**		
Station 22			
0-65	21.09	116.08	5
65-135	6.20	62.88	4
135-200	4.55	48.37	6
Mean	*10.61*	*75.77*	**10**
s*	*9.11*	*35.65*	
no. of specimens	**334**		

s* = standard deviation

Table 2. Chaetognath species composition in upwelling (Stn. 24) and non-upwelling stations (Stn. 22) surveyed in Dipolog Bay in 24 February 2013. Since the bulk of the samples in both stations were juveniles, their overall density and relative contribution were separated to show the actual contribution of identifiable specimens. The percent contribution of juveniles is based on the overall density per station, while relative contribution of the identified species was based on the total density of the matured specimens only. Note: Sd = standard deviation.

Taxon	**Distribution (WoRMS 2018)**		**Spatial Distribution**	**Station 24**			**Station 22**		
	Horizontal	**Vertical**	**This study**	**Mean Density (ind. m^{-3})**	**Sd**	**%**	**Mean Density (ind. m^{-3})**	**Sd**	**%**
Juveniles				32.6	33.3	**68.6**	4.3	1.2	**40.4**
Flacisagitta enflata	Oceanic	Epipelagic	Both	7.0	7.3	46.9	5.6	8.0	88.5
Serratosagitta pacifica	Oceanic	Epipelagic	Both	3.6	4.8	24.0	0.1	0.2	1.4
Sagitta spp.				1.4	0.7	9.2	0.3	0.2	4.0
Pterosagitta draco	Oceanic	Epipelagic	Neritic	1.1	1.1	7.1	-	-	-
Mesosagitta minima	Oceanic	Epipelagic	Both	0.1	0.2	0.9	0.2	0.1	2.5
Aidanosagitta neglecta	Neritic	Epipelagic	Both	0.5	0.7	3.2	0.0	0.1	0.5
Zonosagitta pulchra	Neritic	Epipelagic	Both	0.2	0.3	1.2	0.1	0.1	1.0
Flacisagitta hexaptera	Oceanic	Mesopelagic	Neritic	0.3	0.5	2.3	-	-	-
Zonosagitta bedoti	Neritic	Epipelagic	Both	0.0	0.1	0.3	0.1	0.1	1.0
Serratosagitta serratodentata	Oceanic	Epipelagic	Neritic	0.2	0.3	1.5	-	-	-
Serratosagitta pseudoserratodentata	Oceanic	Epipelagic	Oceanic	-	-	-	0.0	0.1	0.5
Ferosagitta ferox	Oceanic	Epipelagic	Oceanic	-	-	-	0.0	0.1	0.5
Krohnitta subtilis	Oceanic	Mesopelagic	Neritic	0.1	0.2	0.9	-	-	-
Sagitta bruuni	Neritic	Epipelagic	Neritic	0.1	0.1	0.6	-	-	-
Serratosagitta tasmanica	Oceanic	Epipelagic	Neritic	0.0	0.1	0.3	-	-	-
Zonosagitta nagae	Oceanic	Epipelagic	Neritic	0.0	0.1	0.3	-	-	-
Sagitta bipunctata	Oceanic	Epipelagic	Neritic	0.0	0.1	0.3	-	-	-
Serratosagitta bierri	Oceanic	Epipelagic	Neritic	0.0	0.1	0.3	-	-	-
Krohnitta pacifica	Oceanic	Epipelagic	Neritic	0.0	0.1	0.3	-	-	-
Aidanosagitta oceanica	Neritic	Mesopelagic	Neritic	0.0	0.1	0.3	-	-	-
Overall density (including juveniles)				47.49		100	10.61		100
Total density of identified adult specimens				14.90			6.33		
Shannon-Wiener Index (H')				1.14			1.01		
Species Richness				19			10		
Pielou's Evenness				0.39			0.44		
Simpson's Index				0.50			0.55		

abundance in the surface layer, with a higher mean density in the upwelling station (mean = 47.49 ind. m^{-3}; range: 14.01 – 81.96 ind. m^{-3}) than in Stn 22 (mean = 10.61 ind. m^{-3}; range: 4.55 – 21.09 ind. m^{-3}), although these were not significantly different (t' = 1.088, p = 0.237). In contrast, mean zooplankton biomass was over 40% higher in Stn 22 (mean = 75.77 ml $100m^{-3}$), but this was also not significantly different from mean biomass in the high production station (mean = 51.82 ml $100m^{-3}$; t' = 0.923; p = 0.212). Species richness, as an index of diversity, was considerably higher in Stn 24, with 19 species from the 2 layers sampled, than in Stn 22, with only 10 species observed in the 3 layers sampled (Table 1). Pielou's evenness values between the two stations do not vary greatly. However, the lower evenness value in Stn 24 (0.39; Stn 22= 0.44) suggests more variation in densities in the high production region (Table 2). Simpson's index of dominance in Stn 22 is slightly higher (0.55) which reflects the lower diversity in the same station (Shannon-Weiner Index (H') = 1.01) compared to Stn 24 (Table 2).

The species composition is summarized in Table 2. Information on their distribution is based on the website of the World Register of Marine Species (WoRMS Editorial Board, 2018). Juvenile chaetognaths made up a large portion of the assemblages, comprising 68.6% in the upwelling station, and 40.4% in the non-upwelling station. Of the identifiable (matured) fraction of the samples, *Flacisagitta enflata* (Bieri) was the most abundant species in both stations, but dominated the assemblage in Stn 22, making up 88.53% of the mean chaetognath density in that station. They were likewise abundant in the upwelling station, but made up only half as much (46.93%). A few other species, including *Serratosagitta pacifica* (Tokioka)*, Pterosagitta draco* (Krohn) and *Aidanosagitta neglecta* (Aida) showed moderate abundances in Stn 24 as well, jointly comprising 34.29% of overall mean density. Of the 19 identified species, 11 were recorded only in the upwelling station and not identified in the non-upwelling station. On the other hand, only 2 of the oceanic species, the *Serratosagitta pseudoserratodentata* (Tokioka) and *Ferosagitta ferox* (Doncaster), were recorded in Stn 22 and absent in the upwelling area (Table 2). able 2. Chaetognath species composition in upwelling (Stn. 24) and non-upwelling stations (Stn. 22) surveyed in Dipolog Bay in 24 February 2013. Since the bulk of the samples in both stations were juveniles, their overall density and relative contribution were separated to show

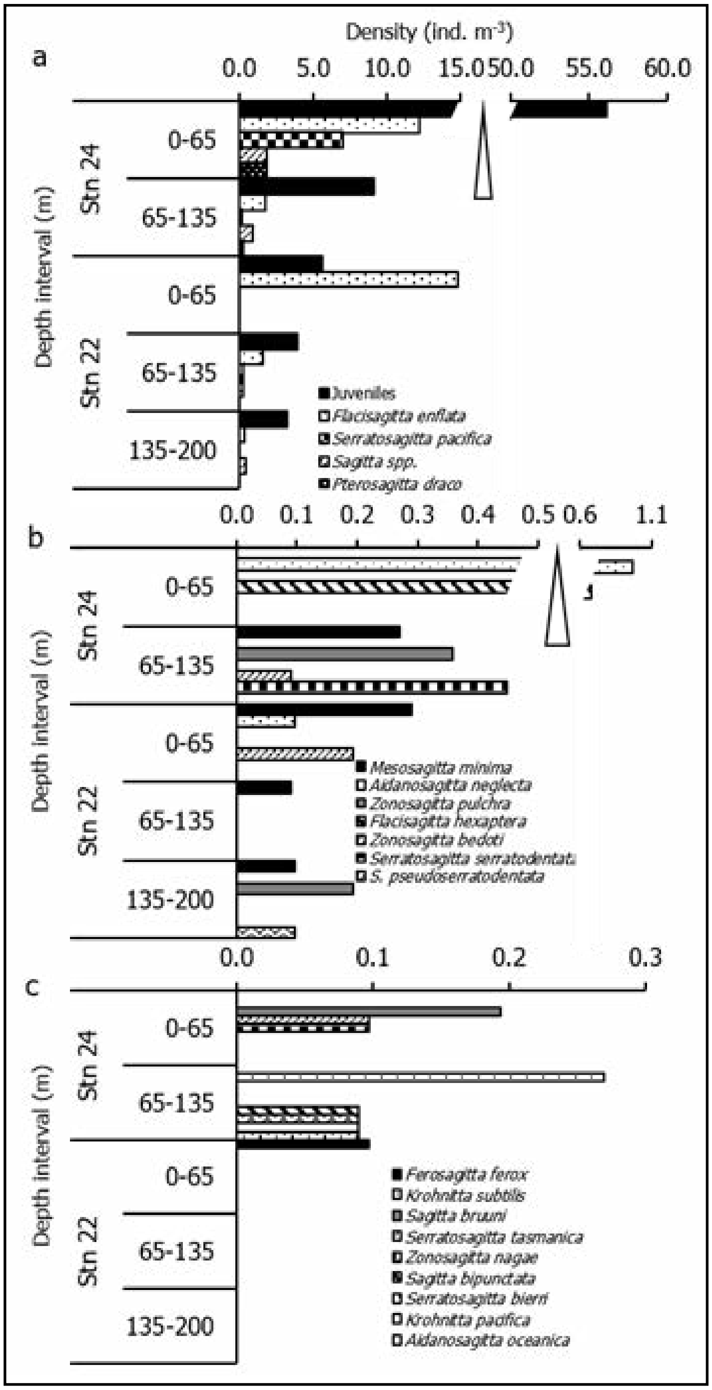

Figure 3. Vertical distribution of chaetognath species grouped according to densities (a. high, b. mid-, and c. low density). The x-axes indicate densities expressed as ind. m^{-3} and the y-axes correspond to the depth intervals (m) investigated in each station. The white triangles in a and b indicate the spliced portions of the bars to magnify lower density taxa.

the actual contribution of identifiable specimens. The percent contribution of juveniles is based on the overall density per station, while relative contribution of the identified species was based on the total density of the matured specimens only. Note: Sd = standard deviation.

Vertical Distribution

The vertical distribution of the identified matured specimens are shown in Fig. 3 below. Of those occurring in both stations, epipelagic *A. neglecta* was recorded only in the surface layer, while epipelagic *Zonosagitta pulchra* (Doncaster) only in deeper layers. The others were recorded in all layers, but were generally more abundant in the surface. These include the epipelagic taxa of *F. enflata*, *S. pacifica* and *Mesosagitta minima* (Grassi). Among the species found only in the upwelling station, only *P. draco* was recorded in all depths sampled, while the others were recorded only in either surface or deeper layers. These include *Flacisagitta hexaptera* (d'Orbigny) and *Sagitta bruuni* (Alvariño), which were recorded only in the surface, as well as *Serratosagitta serratodentata* (Krohn) and *Krohnitta subtilis* (Grassi) which were recorded only in deeper water. While the rest of the species seemed to be concentrated in specific layers, their relatively low densities may not be representative of their true vertical distribution in the water column.

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DISCUSSION

General distribution patterns

Regions of high and low production in the upwelling area in Dipolog Bay were investigated. Similar temperature and chlorophyll profiles were observed between the two stations with subtle differences that, otherwise, indicate signals of higher productivity in Stn 24. Stn 22 had low chlorophyll *a* concentration (<0.5 mg m^{-3}) that is typical of an oligotrophic area (Berman et al. 1983). The sea surface color, together with the shallower MLD in Stn 24 (29 m) indicates a more intense near-surface mixing, compared to Stn 22 (42 m).

A large portion of the chaetognath samples were comprised of unidentifiable juveniles. In the high production station (Stn 24), the mean density of juveniles was 32.59 ind. m^{-3}, representing over 69% of all chaetognaths. In the low production station (Stn 22), however, juveniles made up only 40% (4.28 ind. m^{-3}). Since nanophytoplankton (2 - 20μm) are known to be abundant in upwelling areas (Estrada and Blasco 1985), small and early stage copepods that feed on them flourish. These copepodites, further, are food for juvenile chaetognaths. Thus, juvenile chaetognaths are likely to be also abundant in this area following predator and prey relationship. Further down the food chain, the juvenile chaetognaths themselves are food for larger zooplankton, especially the larval stages of fish, such as sardines.

Nineteen species of chaetognaths were identified in the Bicol Shelf, Pacific Coast (Noblezada and Campos 2008) and the internal waters of Central Philippines (Noblezada and Campos 2009). Of these 19 species in these previous accounts, 14 species were shared with this study. Similar to these reports, *F. enflata*, a widespread epiplanktonic species (Terazaki 1996), also dominated in this study. *Flacisagitta enflata* was significantly dominant in Stn 22 contributing to 88.5% of the total sample, while contributing only 46.9% in Stn 24. This increased abundance of *F. enflata* explains the lower diversity index in Stn 22 (Table2). The difference in the number of species between the two stations is mainly due to the presence of mesopelagic groups in the upwelling station, such as *F. hexaptera, K. subtilis* and *Aidanosagitta oceanica* (Grey), resulting to the higher species diversity in this station. These species were completely absent in the other station, which suggests that the horizontal extent of the upwelling is only very close to the coast of Dipolog.

The study of Johnson et al. (2006) was one of the first to describe the distribution patterns of chaetognaths in the Sulu Sea and the Celebes Sea, however, limited to the central basin only in the former. There were 20 species reported in the central part of the Celebes Sea, and 22 species were identified in the Sulu Sea off the south west coast of Zamboanga peninsula. The majority of the samples were also concentrated above 65m, with an estimated average density of 30.0 ind. m^{-3} in the Celebes and 50.0 ind. m^{-3} in the Sulu Sea. Although less diverse, the density of chaetognaths in Dipolog Bay, especially in the upwelling area (47.49 ind. m^{-3}), is comparable with the densities in these adjacent bodies of water.

At least the five dominant genera observed by Johnson et al. (2006) were similarly found to be abundant in this present study. The two seas observed by Johnson et al. (2006) harbor different assemblages of chaetognaths. Celebes Sea was observed to have 11 species common with the present study and the rest is comprised of several representatives of the genus *Eukrohnia*. The Sulu Sea chaetognath assemblage in the study of Johnson et al. (2006) had 13 common species to the study. However, epipelagic *Krohnitta pacifica* (Aida) which had a low density contribution in this study, was among the top 3 species (12.1%) in the offshore Sulu Sea (Johnson et al. 2006). *Krohnitta pacifica* was one of the rare species in this study, but these have been reported to be epipelagic and well-represented in more open seas like the offshore station in the Sulu Sea and the Bicol Shelf (Johnson et al. 2006; Noblezada and Campos 2008) as it is reported in WoRMS (2018).

On the other hand, *Sagitta bipunctata* (Quoy and Gaimard) and *Zonosagitta bedoti* (Beraneck)*,* which were among those with relatively low densities in this study, were the most dominant in the report of Noblezada and Campos (2009). These two species, being neritic, are expected to be more abundant in semi-enclosed bodies of water near islands, such as the Visayan Sea.

Upwelling Influence to Chaetognath Distribution Patterns

Upwelling can displace planktonic organisms to depths which they do not commonly inhabit. Similarly, horizontal currents (i.e. Ekman transport; Villanoy et al. 2011) may carry those plankton that are usually recognized as neritic species further offshore. Several studies have attempted to link upwelling with the distribution of zooplankton (Wing et al. 1998; Coyle 2005; Barth et al. 2007; Wiafe et al. 2008). During an upwelling event, meroplankton that are locally produced near the coast has a higher probability to be carried offshore through the Ekman transport (Archambault et al. 1998). Mussel and barnacle recruitment were reported to be altered and reduced during the upwelling season because of loss through horizontal transport (Barth et al. 2007). The onshore movement and settlement of meroplankton in coastal water, such as crab species, were reported to occur primarily during upwelling lulls or relaxation (Wing et al. 1998). These are some of the evidences wherein upwelling can alter assemblages due to advection of plankton to different directions. It is largely plausible that chaetognaths follow the same pattern of dispersal.

Chaetognaths have been reported to be closely associated with different water masses often in relation to food, physical forces, and the thermocline (Giesecke and Gonzales 2004). They have also been characterized by their spatial and vertical distribution patterns (Bieri 1959, Pierrot-Bults and Chidgey 1988). Most of the chaetognaths observed in the two stations are epipelagic. Mesopelagic species (*F. hexaptera, K. subtilis, A. oceanica)* were only recorded in the upwelling station (Table 2, Fig. 3), possibly uplifted to the epipelagic water column due to upwelling.

Three equatorial and neritic species, *Aidanosagitta neglecta, Zonosagitta pulchra* and *Z. bedoti*, were observed in the inshore upwelling station as well as in the offshore station. The distribution of these species have been associated with upwelling regions, possibly due to their tolerance with pronounced changes in temperature (Bieri 1959). Apart from physiological features, physical mechanisms may explain fine scale variations in the distribution of specific groups of zooplankton.

Zonosagitta bedoti is classified as neritic and commonly distributed in the epipelagic regions. This species had a very low contribution in the chaetognath population in two stations, but equally interesting distribution because the species' observed distribution in this study does not match its reported distribution. Higher concentration was observed in the 0-65m layer in the offshore station, but absent in this layer in Stn 24. Instead, *Z. bedoti* concentration was observed at 65-135m at Stn 24, and with lower density. *Zonosagitta bedoti* are large-bodied chaetognaths (Alvariño 1967), however information on their mobility is unavailable. It is, however, quite probable that they were carried away from the high production regions due to Ekman transport.

Influence of High Productivity to Chaetognath Distribution Patterns

Food is one of the major factors that lead to the variation in plankton distributions. Because of high primary production (Fig. 2), Stn 24 is likely to show high secondary production as well. This is consistent with the high abundance of salps in Stn 24, which are filter feeders that are capable of controlling phytoplankton abundance (Shiga et al. 1998; Madin et al. 2006). Turbulent areas, such as those affected by coastal upwelling, are often dominated by large-bodied organisms, mainly because their tougher bodies can tolerate rough conditions (Manriquez et al. 2009). Smaller and more fragile zooplankton dominate in more stable conditions (i.e. offshore areas), as was observed in the Stn 22.

Some species observed were found to match their distribution based on literature. *Sagitta bipunctata* was only observed in the 65-135m layer in the upwelling area. The vertical distribution of this species was studied off California by Bieri (1959). Their migration towards the surface during the night is mainly for feeding, while their daytime abundance occurs along the thermocline region (at 65-135m in this study). Similarly, the distribution of *Zonosagitta pulchra* in this study is parallel to the report of Bieri (1959), where they are often found in the upper 200m in the neritic zone, but may also oftentimes migrate kilometers away from the shore.

Those species that occurred rarely, in either single strata or single station are useful for identifying distribution patterns. *Mesosagitta minima* is characterized as oceanic with epipelagic distribution, and was observed to be very abundant in the uppermost layer in the offshore Stn 22 with sizeable contribution in the deeper layers of this station and Stn 24, but not present in the surface layer of the latter. The low contribution of *F. enflata* in deeper layers is even possibly due to the high contribution of *M. minima* (Figure 3). These two species have been reported to follow the same period of intensive feeding and breeding (Batistić 2003), thus a likely instance of restriction due to competition. On the other hand, *Krohnitta subtilis* and *Aidanosagitta oceanica*, which are both classified as mesopelagic, were distributed only in the 65-135m layer in the upwelling station. The inshore appearance of these deep water groups illustrates the high productivity of the upwelling area in Dipolog Bay, however, these species are possibly restricted to the lower limit of the epipelagic region (near 200m).

Summary and Conclusions

In the present study, the dominant species were more common in the surface layer, while less-abundant species often had their maximum abundance in deeper stratum (Fig. 3). Juveniles have considerable distribution across the water column down to 200m. However, the density of juvenile chaetognaths in the surface layer of the high production region (Stn 24) was an order of magnitude higher (Fig. 3; 56.1 ind. m^{-3}) than the rest of the water layers sampled. This further supports the likelihood of feeding on phytoplankton and small zooplankton that are more concentrated in the surface layer (Kehaiyas et al. 1994). Since this study was focused on the epipelagic stratum, it is likely that the species composition will be dominated by those tolerant in these conditions. However, it is noticeable that chaetognaths are capable of periodically moving beyond their habitat (presence of mesopelagic species). Thus, chaetognath distribution may be dictated by different factors, including the availability of prey items. However, this may also be a result of vertical transport via upwelling.

This study is one of the few works on the vertical distribution of chaetognaths in high and low production zones in upwelling areas in the Philippines. The ecological role of these chaetognaths in regulating phytoplankton and zooplankton blooms in upwelled areas as voracious predators of copepods and other zooplankton (Noblezada and Campos 2008) is apparent, though not fully defined in the study. Juvenile chaetognaths feed mainly on small sized and early stage cyclopoids, such as *Oithona* (Sullivan 1980). The high concentration of juvenile chaetognaths in the high production area (Stn 24) may serve to control copepod production. On the other hand, the significance of the offshore distribution of observed neritic species is not thoroughly explained. Trophic-dynamic measures must be made to establish some ecological aspects on their existence offshore. Future studies may focus on the predator-prey relationship between chaetognaths and early stage copepods and other possible prey. This will aid in explaining if food absolutely controls the distribution and success of the different assemblages between upwelling and non-upwelling areas.

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