Composition, Abundance and Distribution of Chaetognaths Along the Pacific Coast and Adjacent Internal Waters of the Philippines

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ABSTRACT

Chaetognath species composition, distribution and relative abundance along the Pacific Coast and the internal waters of the Philippines are presented based on the analysis of 12 samples collected from two oceanographic cruises in April-May 2001. The occurrence of species in relation to water masses is noted and results are analyzed with regards to the main hydrologic features of the surveyed area.

Nineteen species of chaetognaths belonging to 3 genera were identified from the samples. In order of relative abundance, these include: *Sagitta enflata, S.bipunctata, S. bedoti, S. neglecta, S. robusta, S. ferox, S. pacifica, S. hexaptera, S. serratodentata, S. decipiens, S. regularis, S. macrocephala, S. minima, S. oceanica, S. pulchra, Pterosagitta draco, Krohnitta subtilis, S. nagae,* and *S. johorensis.* The overall mean density of all arrow worms was 4.85 ind.·m-3 (range 0.90-30.89). *Sagitta enflata* was the most abundant and frequent species in all stations analyzed and comprised 49.7%. Based on their respective distributions reported in the literature, the results indicate a strong influx of oceanic water from the Pacific Ocean into the Visayan Sea.

Keywords: chaetognaths, epiplanktonic, mesoplanktonic, bathyplanktonic, oceanic, and neritic.

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INTRODUCTION

The phylum Chaetognatha is comprised of vermiform marine invertebrates commonly called "arrow-worms". At recent estimate, they include about 150 species from 24 genera and 10 families (Johnson 2005). They are exclusively marine organisms and majority of them are planktonic. They can be found in all oceans from the surface to great depths, and are often second or third in abundance after copepods (Kehayias 2003).

Although chaetognaths are eaten by numerous larger carnivorous organisms, they are themselves active predators (Casanova 1999) and are believed to be major predators on copepods (Reeve 1970 and Feigenbaum 1991). They also prey on other small crustaceans, larval fish and other chaetognaths. They thus play an important role in the transfer of energy from copepods to higher trophic levels.

Their role as predators and competitors of larval fish has been evaluated in recent years (Baier and Purcell 1997; Brodeur and Terazaki 1999). The impact of chaetognath predation on fish larvae may be exaggerated due to the relative scarcity of fish larvae in the plankton. They nevertheless contribute to reduction of larval abundance during periods of fish production (Casanova 1999).

Chaetognaths are also known as excellent indicators of water masses because of their close relationships with certain environmental variables (e.g. salinity, temperature and dissolved oxygen) as well as their species-specific horizontal and vertical distribution (Terazaki and Miller 1986). As a result, chaetognaths are often categorized according to the type of water mass they are best adapted to. Warm water species are generally characteristic of tropical regions, while cold-water ones are generally characteristic of temperate regions. Those characteristic of mixed waters tend to occur in greater abundance where cold and warm water mix, though they may be found in cold or warm water occasionally.

Inspite of their abundance and importance, many aspects of chaetognath biology are not yet known. These include morphological variation, distribution and other ecological aspects. A better understanding of chaetognath assemblage distribution could be a significant "tool" in determining water mass movement and circulation, and for further validation of certain oceanographic phenomena such as upwelling events and frontal formation. Furthermore, information on their abundance and distribution can lead to the appreciation and, eventually, quantification of their impact on the abundance of fish larvae and other marine fauna, of which they are believed to be major predators and competitors for food.

Few studies on chaethognaths have been conducted in the Philippines. Among the pioneer studies are Michael (1919), Bieri (1959), Alvariño (1967), and Rottman (1978), which deal with descriptions of the different species and their observed distributions. Estudillo (1980) investigated the abundance & distribution of arrow worms in the Visayan Sea, but limited his identifications to genus level only. Other studies, including Jumao-as and von Westernhagen (1978), and Johnson (2006), have been limited to specific water basins.

This study examined the species composition, abundance and distribution chaetognaths along the Pacific coast and adjacent internal waters and provides inputs on how these are related to local hydrography.

MATERIALS AND METHODS

Samples were collected during two oceanographic cruises covering: (1) 34 stations on and off the Bicol Shelf from April 1-11, 2001 on board the R/V DA-BFAR; and (2) 46 stations from San Bernardino Strait into the Visayan Sea and further west into Sibuyan Sea from April 26- May 2, 2001 on board the TRV Sardinella of the University of the Philippines in the Visayas (Fig. 1). From this grid of stations, 12 were chosen to represent the transition from open oceanic to internal waters: 6 in Bicol Shelf, 3 in San Bernardino Strait and 3 in the Visayan Sea. Samples were collected by means of double oblique tows to a maximum depth of 100 m, using a net of 60 cm mouth diameter and 335 µm mesh size. A flow meter was mounted at the mouth to measure the volume of water filtered. Since sampling during both cruises was continuous, both day and night samples in each of the 3 sub-areas were chosen. Plankton samples were preserved in 10%

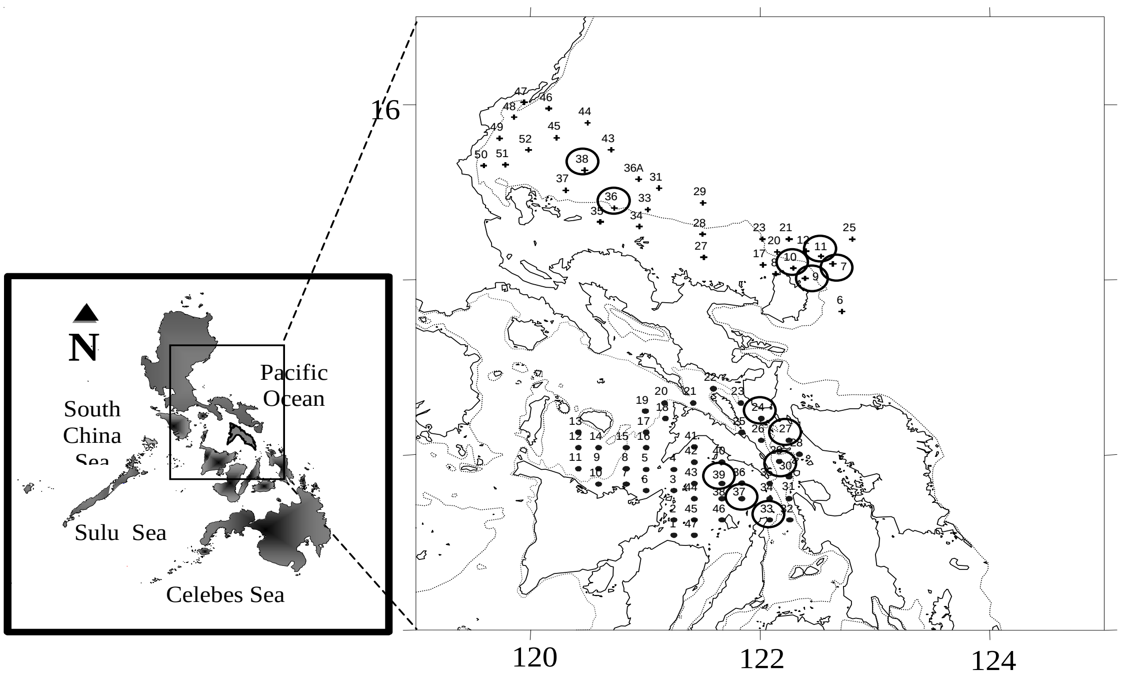

Figure 1. Map showing two oceanographic cruises: (+) denoting stations surveyed during the Bicol shelf Cruise and (o) Internal Waters. The encircled stations were samples used for this study.

buffered seawater-formalin solution in the field and brought to the laboratory for processing and identification. Biomass in each station was determined by measuring the displaced volume of each sample and expressing this as ml.·m-3 water filtered. Chaetognaths were sorted out and identified to species under compound and dissecting microscopes, using the keys of Michael (1911, 1919), Alvariño (1967), Michel (1984), Pierrot-Bults (1988), Bieri (1991) and Casanova (1999).

RESULTS AND DISCUSSION

Species composition

A total of 2,963 specimens were examined. From these, 19 species from 3 genera were identified. Table 1 lists the species recorded, their mean densities and relative abundance in the samples examined. *Sagitta enflata* was the most dominant species and comprised 49.7 % of all chaetognaths recorded. Among the top ten species were S. *bipunctata, S. bedoti, S.neglecta, S. robusta, S. ferox, S. pacifica, S. hexaptera, S. serratodentata* and *S. decipiens*. Together, these species comprised 96.4% of the total.

In general, the observed composition is consistent with those reported in previous investigations in various areas in the country (Alvariño 1967, Jumao-as and von Westernhagen 1978, Rottman 1978 and Johnson et al.., 2006). In Hilutungan Channel, Cebu, Jumao-as and von Westernhagen (1978) reported 13 species of chaetognaths, all of which have also been recorded in the present study. *Sagitta enflata* was the most common and abundant species. Of the thirteen, 12 were described as epiplanktonic, while only *Sagitta decipiens* was described as mesoplanktonic. Similarly, a total of 22 species from 4 genera were recently reported from the Sulu Sea and Celebes Sea (Johnson et al., 2006). Again, *S. enflata* dominated the chaetognath assemblages, comprising about 39% of all arrow worms recorded. All 22 species have been reported in the present as well as in previous studies (Alvariño 1967, Jumao-as and von Westernhagen 1978, Rottman 1978), although the number of species recorded varied in each of these studies. Such differences attributed to differences in sampling methods and areas investigated. For example, both Jumao-as and von Westernhagen (1978) and the present study were confined to sampling the upper 100m of the water column, although the present study had a

Species	mean	sd	%	Bicol Shelf						San Bernardino Strait			Visayan Sea		
				B7	B9	B10	B11	B36	B38	S24	S27	S30	V33	V37	V39
Sagitta enflata	2.41	4.22	49.73	x	x	x	x	x	x	x	x	x	x	x	x
Sagitta bipunctata	0.46	0.68	9.54	x		x	x	x	x	x		x	x	x	
Sagitta bedoti	0.52	1.22	10.78		x	x	x	x	x		x	x	x	x	x
Sagitta neglecta	0.37	0.70	7.55	x			x	x	x	x	x	x	x		x
Sagitta robusta	0.26	0.52	5.41	x		x	x	x	x	x	x	x	x	x	
Sagitta ferox	0.22	0.44	4.63	x	x		x	x	x	x	x	x	x	x	x
Sagitta pacifica	0.10	0.16	2.15		x		x	x		x		x	x		x
Sagitta hexaptera	0.08	0.12	1.72				x	x	x			x	x		
Sagitta serratodentata	0.09	0.19	1.84		x		x		x	x		x	x		x
Sagitta decipiens	0.13	0.35	2.60					x	x	x		x	x		
Sagitta regularis	0.04	0.06	0.90				x		x		x	x	x	x	x
Sagitta macrocephala	0.11	0.33	2.18				x	x	x	x		x	x		x
Sagitta minima	0.01	0.02	0.14											x	
Sagitta oceanica	0.01	0.02	0.21									x			x
Sagitta pulchra	0.01	0.02	0.15									x			
Pterosagitta. draco	0.01	0.02	0.13							x			x		x
Krohnitta. subtilis	0.01	0.03	0.23												
Sagitta nagae	0.00	0.01	0.08						x				x		
Sagitta johorensis	0.00	0.00	0.01												
Sagitta sp.	0.00	0.00	0.02					x				x	x		x
	4.85	9.12	100.00												
Mean density (ind/m³)				0.05	0.12	0.05	0.10	1.54	0.14	0.10	0.26	0.14	0.18	0.10	0.14
sd				0.14	0.44	0.13	0.20	3.42	0.28	0.16	1.09	0.37	0.25	0.33	0.27
No spp recorded				5	5	4	11	11	12	10	6	15	15	7	11

Table 1
Mean densities, relative abundance and frequency of occurrence of the species collected in the Pacific Coast (Bicol Shelf) and Internal Waters of the Philippines. X denotes present

much more extensive spatial coverage. Johnson et al. (2006), on the other hand, employed a multiple opening-closing net to collect samples up to 1000m deep.

Abundance

Figure 2 shows the density distribution (ind.·m^{-3}) of chaetognaths in the study area. The overall mean density was 5.0 ind.·m^{-3}, with values ranging from 0.90-30.9. The highest concentration was recorded in station B36 in Bicol Shelf, with a density of 30.9 ind.·m^{-3}. The lowest concentration was also observed in Bicol Shelf, while stations in the internal waters (San Bernardino Strait and Visayan Sea) showed low to moderate concentrations. On average, densities in Bicol Shelf were almost two times higher than those in San Bernardino Strait and three times higher than those in the Visayan Sea (Table 2).

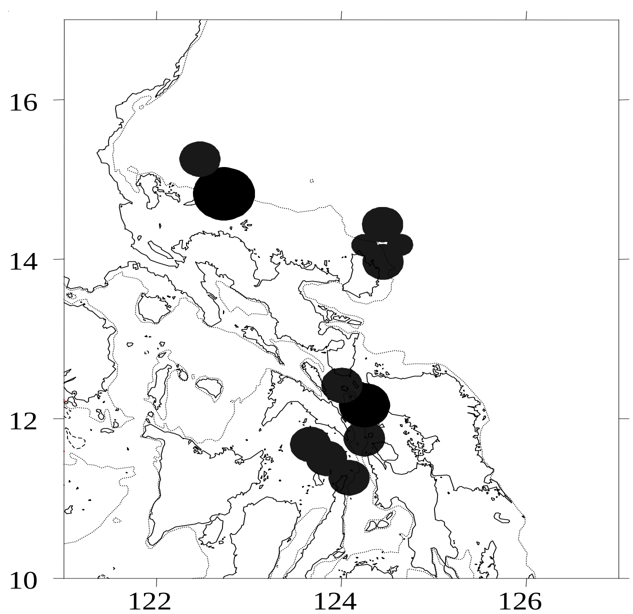

Figure 2. Density (ind.·m^{-3}) distribution of chaetognaths in the surveyed area. (Marker size increases as density increases with the following categories: <1, <5, <15, and >35).

	Bicol Shelf	San Bernardino Strait	Visayan Sea
Mean density	6.66	3.33	2.75
sd	11.90	1.66	0.82
Cumulative no. of sp.	14	17	18

Table 2
Species diversity (cumulative no. of sp.), standard deviation (sd), and density (ind.•m^{-3}) of chaeotognaths in the surveyed areas: Bicol Shelf, San Bernardino Strait and Visayan Sea

Distribution

Of the nineteen species recorded, twelve (12) were at least moderately abundant and frequently occurring, and were observed both in the more open waters outside (i.e., Bicol Shelf) and in internal waters (i.e., San Bernardino Strait & Visayan Sea). Of these, six (6) species showed comparable abundances within and outside of internal waters, including the ubiquitous species *S. enflata* and *S. ferox* (Fig. 4), which is consistent with their being reported as oceanic species

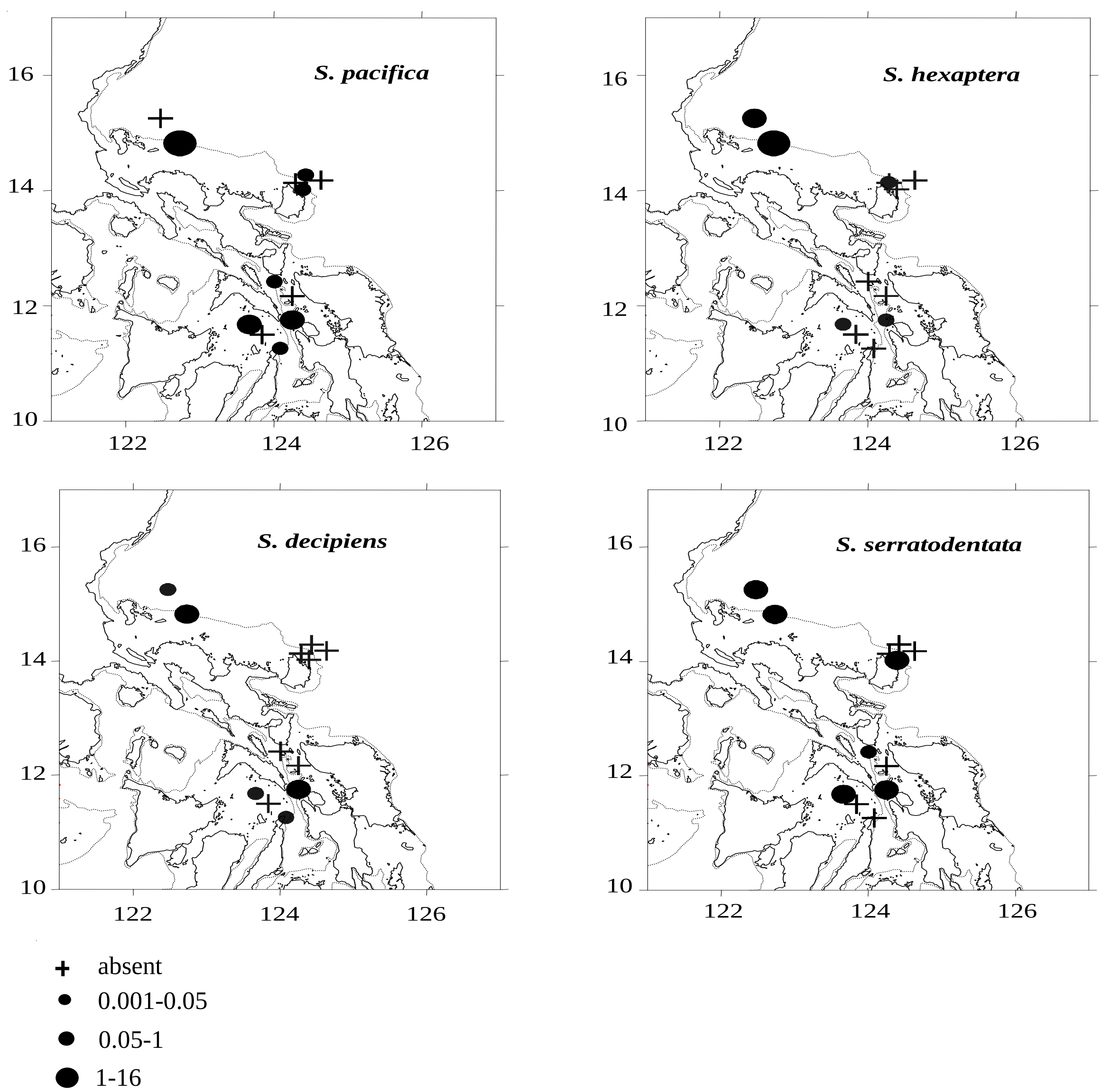

Figure 3. Horizontal distribution of S. pacifica, S. hexaptera, S. decipiens, and S. serratodentata. Frequently occurred at low-moderate densities

in previous studies (Johnson et al., 2006, Jumao-as and von Westernhagen 1978, Rottman 1978, Alvariño 1967, Bieri 1959, Michael 1919). The occurrence of primarily oceanic species in internal waters may be brought about by water exchange across channels and into adjacent waters, such as San Bernardino Strait and the Visayan Sea (Campos et al., 2002). In such cases, the resulting geographical distribution would likely be similar outside and inside internal waters, as was observed for *S. enflata, S. ferox, S,serratodentata, S. pacifica, S. macrocephala* & *S. decipiens* (Fig. 3), or with higher abundances and or frequencies outside. The latter was observed for another five (5) species, namely *S.* b*ipunctata,S. robusta, S. hexaptera, S. bedoti* & *S. neglecta* (Fig. 4), although the latter two have been previously reported as neritic (Johnson *et al*., 2006 and Jumao-as and von Westernhagen 1978). While the use of the terms "oceanic" and "neritic" is without exclusivity, it should indicate where higher abundances and or frequencies are observed. Hence, the present results do not agree with the reported neritic distribution for these two species, although more samples from other areas should be examined for a more definitive description of their distribution. Similarly, *S. regularis* is reported as oceanic, although our results show higher abundances in internal waters (Fig. 5).

Of the seven (7) rare species, those with <25% frequency of occurrence, five (5) (*S. johorensis, P. draco, S. pulchra, minima & K. subtilis*) were observed only in internal waters, although they are reported as oceanic in previous studies. While our current results suggest that these 5 species are neritic only (Fig. 5), higher abundances outside of internal waters (e.g., South China Sea) cannot be discounted. Oceanic waters from the South China Sea enter Central Philippines via channels north and south of Mindoro, although the Visayan Sea is still several water basins further inside. These species have been reported as oceanic in studies covering the Pacific Ocean (Johnson 2005), South China Sea (Alvariño 1967) and Sulu Sea (Johnson *et al*., 2066 and Michael 1919). The other two species, *S. nagae* and *S. oceanica*, are reported as oceanic (Johnson et al., 2006, Jumao-as and von Westernhagen 1978 and Michael 1919) and showed distributions consistent with the definition provided above.

Diversity

While chaetognath density increased from internal waters towards the Pacific (Bicol Shelf), diversity (cumulative number of species) decreased in the same direction (i.e., towards oceanic waters) (Table 2). The dominance of *S. enflata* was not consistent with any of these trends. *S. enflata* comprised 43.7% of all chaetognaths in the Visayan Sea, 67.9% in the San Bernardino Strait and 46.4% in the Bicol Shelf.

While overall concentrations were low in the Visayan Sea, there were several species showing similar levels of abundance. The resulting low dominance implies that the area provides a wide range of tolerable environmental conditions for more species to exist. This high diversity in the Visayan Sea might be attributed to such factors as high productivity, as reflected by chl a concentrations which are 3 times higher than in the Bicol Shelf (Campos *et al*., 2002 and Primavera *et al.*, 2002), and coastal topography, which allows water exchange with several adjacent water basins thereby adding to the heterogeneity of source-habitats for plankton, in general, and arrow worms in particular. In contrast, the Bicol Shelf area investigated is oceanic, with comparatively little, if any, topographical heterogeneity. High overall density in this area is primarily attributed to high overall chaetognath concentrations in two stations, B36 and B38, which are both located in the vicinity of an upwelling zone (Amedo *et al.*, 2002). It is also in the Bicol Shelf area where the lowest arrow worm diversities were observed (Table 1). Similarly, highest dominance (of *S. enflata*) was observed in station B36 also located within the upwelling zone where only a moderate number of species were recorded in the sample.

The occurence of mesopelagic and mesobathypelagic species *(S. decipiens, S. serratodentata, S. macrocephala, S. minima* and *Krohnitta subtilis)* in samples collected from the upper layer of water could be explained by vertical transport effected by the upwelling, in which deep-living organisms are carried to the epipelagic layer.

Most of the chaetognaths found in the studied area are epiplanktonic species, and others are migratory

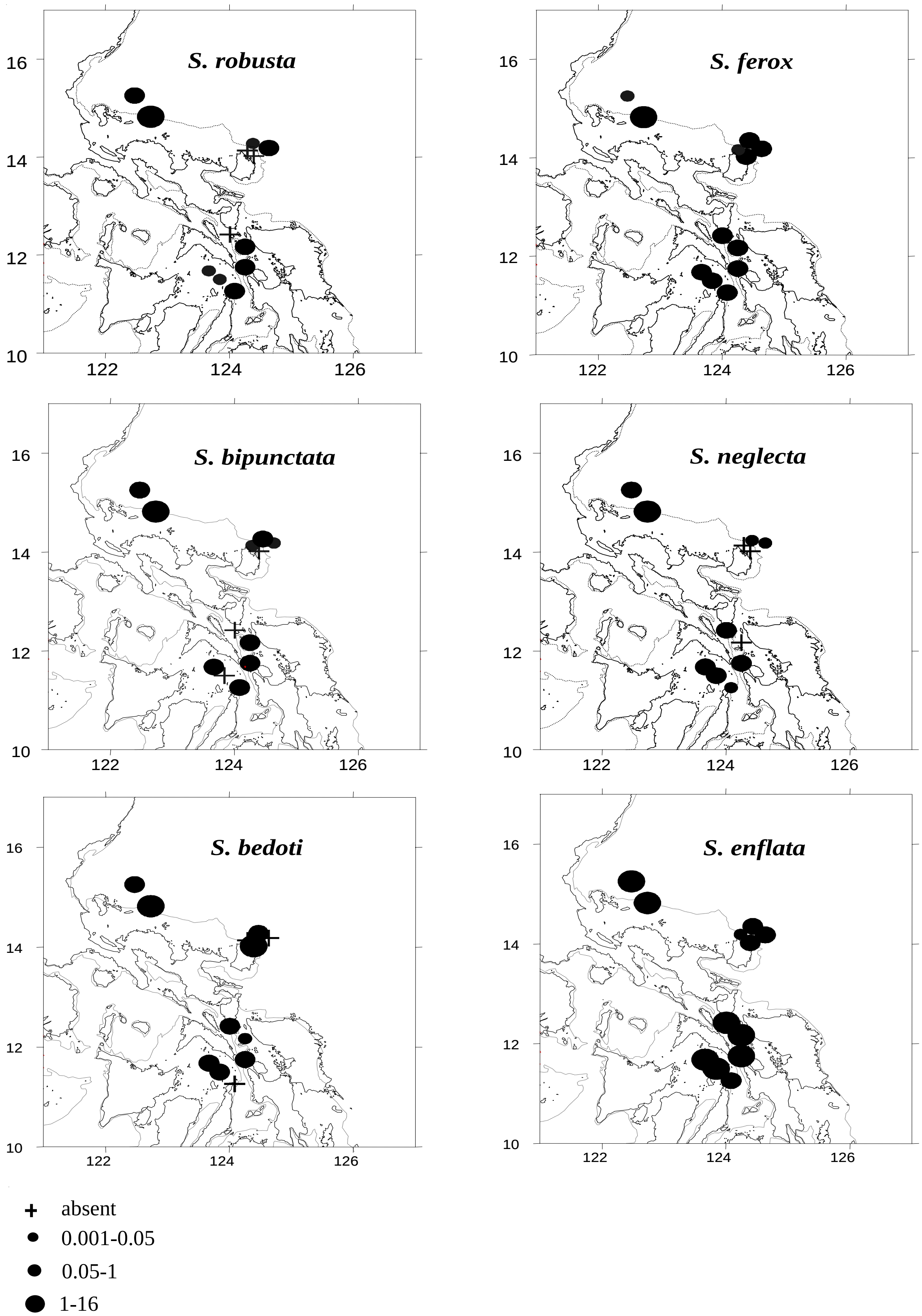

Figure 4. Horizontal distribution of S. robusta, S. ferox, S. bipunctata, S. neglecta, S. bedoti and S. enflata. Frequently occurred at high densities

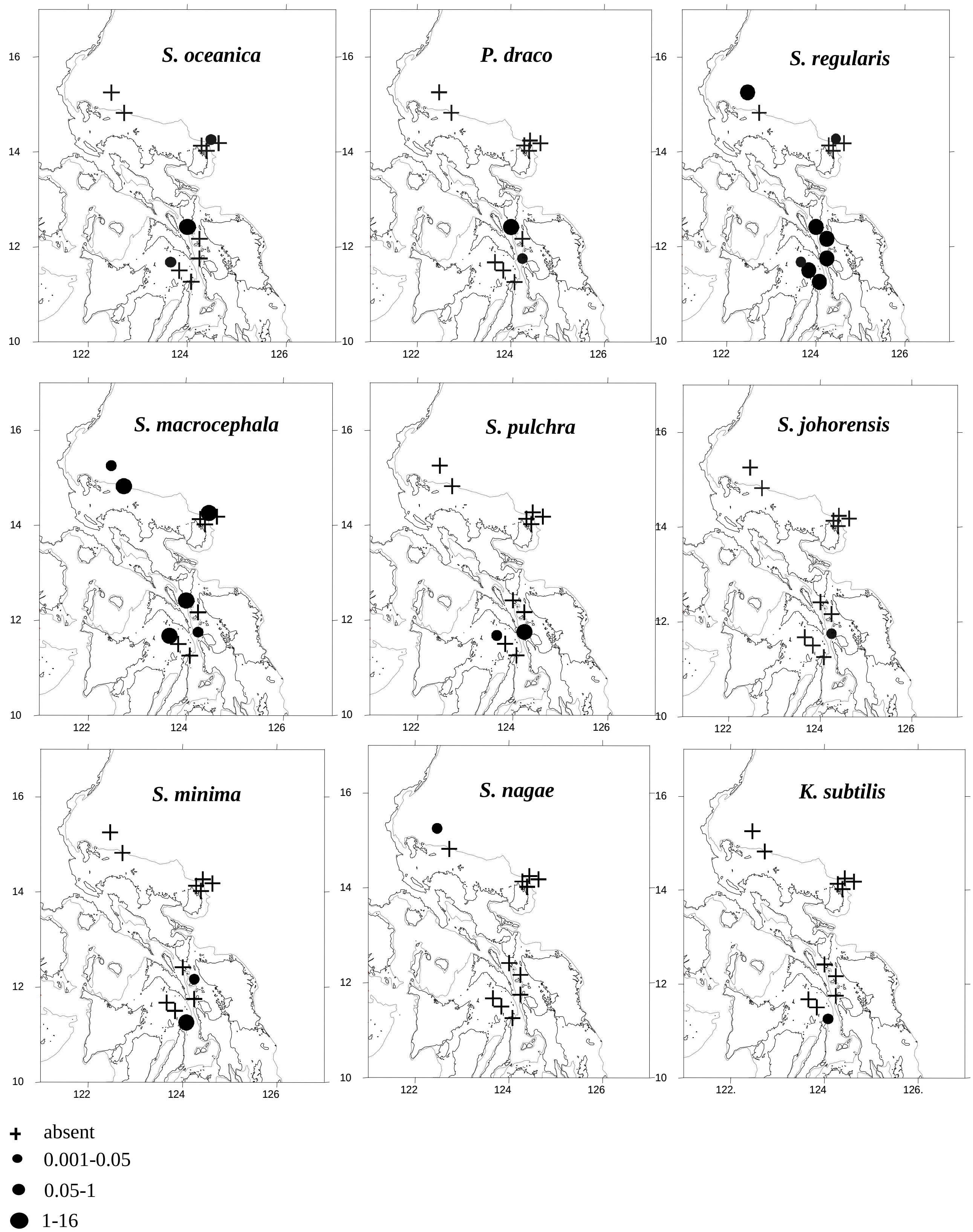

Figure 5. Horizontal distribution of S. ocenica, P. draco, S. regularis, S. macrocephala, S. pulchra,, S. johorensis, S. minima, S. nagae and K.. subtilis. Occurred at low densities and low frequency.

elements with a wide range of vertical movements in the water column. In practice, chaetognaths have been categorized by where they are most concentrated on a regular basis over a large scale. The ocean is a dynamic moving environment so species can be moved around and displaced to areas where they are otherwise uncommon.

It is not clear whether those species recorded only inshore are truly neritic only, but it is clear that these species are rare, if at all found in the Pacific oceanic waters. What is more certain is that the many connections to the Visayan Sea of various internal water basins, in addition to the potential influence from the South China Sea and the Sulu Sea, contribute to high plankton species richness in this area.

The distribution of chaetognaths has often been directly related to hydrographic factors (Michael, 1911 and Alvariño, 1964). Hydrographic factors are important in determining which oceanic species live successfully in the shallow-water environment. In this study, oceanic species were observed in large numbers in almost all the stations surveyed. This results from the direct strong influence of water exchange between open waters and internal waters through the San Bernardino Strait (Campos *et al.,* 2002). This phenomenon, together with the hydrologic influence of upwelled waters, enhances the local abundance and diversity of chaetognaths in the areas surveyed.

This initial report on the chaetognaths of the Pacific Coast and internal waters of the Philippines is a good starting point for further continuing the study to include samples collected from other internal basins adjacent to the Visayan Sea as well as the SCS and Sulu Sea, and from other months to examine seasonal variation. This will contribute to a better understanding of water movement and mixing between waters from various sources and, within a larger context, provide more insights on the sources of planktonic propagules whose stocks are heavily exploited in internal waters.

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