

Chaetognath ecology in relation to hydrographic conditions in the Australian sector of the Antarctic Ocean

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Abstract: Chaetognath ecology in relation to hydrographic conditions was investigated during austral summer in the Antarctic Ocean with two cruises conducted seven years apart. Time series samples were collected at a total of five stations along 140°E in the region of the Antarctic Divergence (AD). The numerically dominant species was *Eukrohnia hamata*, averaging over 80% of the collected specimens. This species was most abundant north of the AD where bi-modal distribution was common. No species displayed regular diel vertical migration nor were their vertical distribution restricted by hydrographic clines. Breeding of *E. hamata* appeared unaffected by water conditions—the same maturity stages were present in similar percentages across the water masses. Vertical segregation of size classes among *E. hamata* was clearest north of the AD in a more stratified water column. In other locations, the size classes overlapped considerably; this is likely due to physical forcing from mixing water. Feeding activity of *E. hamata* was lowest within the AD and increased both north and south on the edges of the front. Feeding activity appeared continuous with no recognizable diel pattern. *E. hamata* containing prey items were smaller north of the AD compared to the south, suggesting two separate populations. The percentage of predators with food in their gut was much larger in this study than previously reported work. Often times nearly 50% of the *E. hamata* collected had highly digested contents in the posterior of the gut.

key words: chaetognaths, *Eukrohnia hamata*, vertical distribution, Antarctic Ocean, ecology

Introduction

Within the vast range of the Antarctic Ocean are many different water masses containing multiple plankton communities differing in structure and composition. Chaetognaths comprise a significant proportion of the total zooplankton stock in this region (Øresland, 1990, 1995; Pakhomov *et al.*, 1999, 2000; Hosie *et al.*, 2000). Indeed, chaetognaths are recognized as important components in most marine planktonic communities and are found in every marine habitat. Frequently, they are second in abundance only to copepods among all zooplankton groups (Feigenbaum and Maris, 1984). In the world oceans the biomass of chaetognaths is estimated to be 10–30% of that of copepods and as such they play an important role in energy transfer from

copepods to higher trophic levels (Bone *et al.*, 1991). Predation by chaetognaths can place heavy pressure on copepod communities (Øresland, 1990) in addition to playing a critical role in ocean flux (Terazaki, 1995).

The hydrographic conditions (*e.g.* salinity, temperature, density, and dissolved oxygen content) of the surrounding environment uniquely affect many chaetognath species and species-specific relationships to water masses as well as distinct vertical distribution profiles are common (Bieri, 1959; Sullivan, 1980; Terazaki and Miller, 1986; Terazaki, 1992; Ulloa *et al.*, 2000). Furthermore, other aspects of chaetognath ecology such as growth, sexual development and feeding rate have the potential to be influenced by hydrographic conditions (McLaren, 1963; Feigenbaum, 1982; Johnson and Terazaki, 2003).

While there have been numerous studies involving chaetognath distribution in relation to water masses in the Antarctic Ocean (Mackintosh, 1964; Alvarino, 1965; Alvarino *et al.*, 1983; Terazaki, 1989; Duró *et al.*, 1999; Pakhomov *et al.*, 2000), the studies usually did not employ time series sampling to investigate temporal changes, nor did they investigate other points of chaetognath ecology. Furthermore, studies dealing with ecology have been mostly focused on feeding and tend to be in localized near-shore regions, frequently with little comparison across major water masses in the higher latitudes of the Antarctic Ocean (Øresland, 1990, 1995; Froneman and Pakhomov, 1998; Froneman *et al.*, 1998; Duró and Gili, 2001).

As one travels north, away from the Antarctic continent, two major hydrographic boundaries are encountered. The first is the upwelling region of the Antarctic Divergence (AD) where the waters of the East Wind Drift and the Antarctic Circumpolar Current (ACC) slide past each other in opposite directions. The second is the downwelling region within the ACC known as the Antarctic Convergence (AC) or Antarctic Polar Front (APF). The differing hydrographic features across this region have a high potential to affect chaetognath ecology.

The object of this study is to briefly report on aspects of chaetognath ecology across the AD as it relates to hydrographic conditions coupled with temporal changes. The distribution, feeding, size and maturity of pelagic chaetognaths was investigated in austral summer along a north-south transect at 140°E that spanned the AD during two cruises conducted 7 years apart. By using time series sampling, this study was able to make specific comparisons of water masses in relation to time—both long and short term.

Materials and methods

Samples were collected with an ORI-VMPS (Vertical Multiple Plankton Sampler) comprising four nets, each with an aperture of 50 cm × 50 cm, and 330 µm mesh (Terazaki and Tomatsu, 1997), during the KH94-4 and KH01-3 cruises of the R/V *Hakuho Maru*, Ocean Research Institute (ORI) University of Tokyo.

During the KH94-4 cruise three stations were sampled across the Antarctic Divergence (AD). Successive tows were taken on the dates of December 20–21, 23–24 of 1994, and January 19–21 of 1995 at stations 11 (64°40'S, 140°00'E), 13 (64°20'S, 140°00'E) and 43 (65°24'S, 140°00'E) respectively (Fig. 1). Station 13 was located

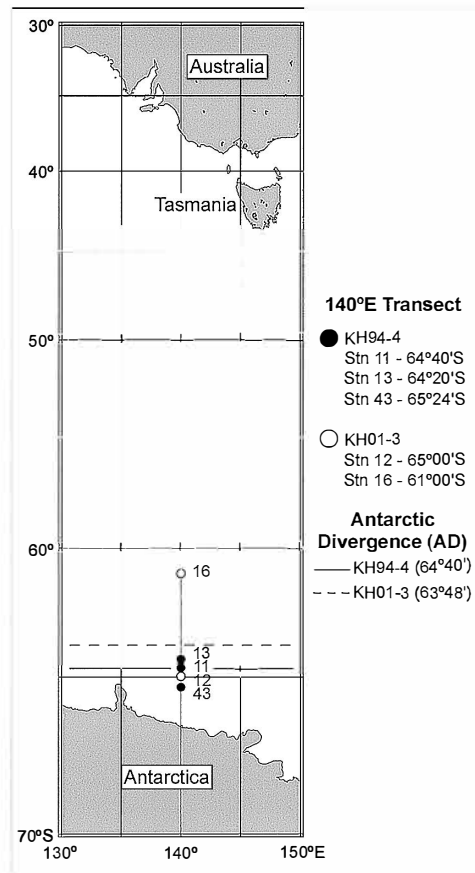


Fig. 1. Sampling area and stations along 140°E transect in the Australian sector of the Southern Ocean.

north of the AD, station 11 within the divergence (64° 40'S), and station 43 to the south of it (Ocean Research Institute, 1996).

A surface-drifting buoy was launched at the start of the sampling period and hauls were taken as close to the buoy as possible in an effort to track the same parcel of water. Four discrete layers in the water column were sampled: surface to 30 m, 30 to 120 m, 120–300 m and 300–500 m. Hauls were repeated seven times at station 11, eight times at station 13, and five times at station 43. Water depths for stations 11, 13, and 43 were 3000 m, 3450 m, and 2200 m respectively.

Time series samples were conducted at two stations during cruise KH01-3: station 12 (65°00'S, 140°00'E) and station 16 (61°00'S, 140°00'E) (Fig. 1). Sampling was carried out on the dates of January 10–11 (station 12) and January 16 (station 16) 2002. Station 12 was located south of the AD and station 16 was north of it. The AD was determined to be at about 63°48'S during cruise KH01-3 (Ocean Research Institute, 2003). No buoy was employed for these hauls. Two casts were made for each haul, sampling a total of eight discrete layers: 100 m intervals to 600 m depth, 600–800 m, and

800–1000 m. Hauls were repeated three times at each station for a total of twelve casts. Water depth was 2731 m at station 12 and 4398 m at station 16.

Upon recovery of the nets, contents were rinsed down into the cod end and the samples were fixed with a 10% buffered formalin and seawater solution. Water temperature, salinity, and dissolved oxygen data was collected by CTD casts at each station. Chaetognaths were separated out and sorted to species upon return to the ORI laboratory. Only the species *Eukrohnia hamata*, *Sagitta marri*, and *Sagitta gazellae* were considered abundant enough to warrant presentation of distribution data.

Feeding and growth analysis was limited to *E. hamata* because it was the most abundant species and no others were present in quantities suitable for comparison. All *E. hamata* were checked for the presence of food items in the gut, and if present, standard length of the predator chaetognath was measured (front of the head to the end of the tail, excluding fin). Due to their small size and highly digested condition, prey items could rarely be identified. Those that were, could only be recognized as some type of copepod. However, this is not uncommon in feeding studies involving *E. hamata* (Sameoto, 1987; Froneman and Pakhomov, 1998). Nearly all gut contents were found near the posterior end of the gut. Any oil present in the gut was ignored because *E. hamata* often accumulate oil droplets that remain after prey items have passed through the body and we feel oil is not an accurate measure of feeding activity.

The specific technique for checking gut contents involved looking at the chaetognath from a direct dorsal or ventral position using a stereomicroscope with fairly strong illumination below the specimen. In this situation, the chaetognaths were quite transparent and the gut was visible as a thin dark line running the length of the trunk. In those instances when the gut contained some food particle the gut was noticeably distorted. These distortions were usually not recognizable when the chaetognaths were viewed from a lateral position. Spots and discoloration apparent when the specimen was viewed laterally were not recorded as food particles unless the gut was also distorted when viewed as described above.

The percentage of *E. hamata* individuals containing prey items was calculated for all hauls at each station and used as an index of feeding activity. This value was called the Food Containing Ratio (FCR). The amount of prey remaining in chaetognath stomach's has previously been shown to vary depending on sampling and preservation methods due to prey loss from stressed induced gut evacuation (Baier and Purcell, 1997). For this reason, the feeding data presented herein is used only to gauge relative feeding activity—not to calculate specific amounts of the prey community consumed nor to compare directly with feeding rates calculated in other studies.

The standard length data of *E. hamata* containing prey items failed normality tests, so non-parametric statistical tests were used to analyze for differences in the median standard length of these predators. For comparisons consisting of two samples Mann-Whitney U-tests were used and for those consisting of more than two samples Kruskal-Wallis tests were used, as described by Fowler (Fowler *et al.*, 1998). Kruskal-Wallis tests were used to compare predator length between hauls at all station and between the three KH94-4 stations. Mann-Whitney U-tests were used to compare predator length between the two KH01-3 stations and between the two cruises. The test between the two cruises was only conducted on specimens from 500 m and above to account for different

maximum sampling depths between the cruises.

All *E. hamata* from each haul were sorted and divided into four size classes as follows: ≤ 10 mm, > 10 mm to ≤ 15 mm, > 15 mm to ≤ 20 mm and > 20 mm. These classes will subsequently be abbreviated as < 10 mm, $10 +$ mm, $15 +$ mm and $20 +$ mm. The tallied values were employed to check the vertical distribution of size classes.

E. hamata have been reported to show signs of advancing sexual development from 18 mm in length (Alvariño, 1967). So as not to miss any precocious individuals, all *E. hamata* greater than 15 mm (classes $15 +$ mm and $20 +$ mm) were checked for their degree of sexual maturity. The standard length was taken and the maturity stage noted. Maturity stages were based on development of the gonads according to the NAGA report (Alvariño, 1967):

Stage 1: Testes as fine tubes; seminal vesicles not present. Ovaries as fine tubes.

Stage 2: Tail segment filled with sperm; seminal vesicles incipient to full.

Ovaries longer than in previous stage.

Stage 3: Tail segment partially discharged, seminal vesicles broken. Ovaries increasing in length; ova developing.

Stage 4: Tail segment discharged; region of seminal vesicles covered by a thickening of epidermis. Ovaries reaching up to $2/3$ of distance from ventral ganglion; ova fully developed.

All statistical analyses were conducted with Statview 5.0.1, Macintosh edition (SAS Institute Inc., Cary, NC, USA).

Results

Hydrographic profile

There was quite a difference in the range of temperature among stations, however a certain amount of similarity in the shape of the CTD profiles could be seen. The temperature profile showed an upper and lower thermocline enclosing a layer of colder water in the upper 200 m. Below this, water became warmer and the temperature profile more stable (Fig. 2). Salinity had a small region of stability (~ 20 m near the surface, and increased gradually with depth (Fig. 2). Dissolved oxygen dropped rapidly between the surface and about 200 m and then became more stable (Fig. 3). Station 43 stood out among the stations with a broader layer of cold water in the upper 200 m and a more gradual thermocline below this. In addition, dissolved oxygen appeared rather stable down to 200 m. These phenomena suggest a certain amount of mixing might have occurred in the water column at station 43 between about 30 and 200 m depth.

Composition and vertical distribution

Six chaetognath species were collected: *Eukrohnia bathypelagica*, *E. hamata*, *S. gazellae*, *S. marri*, and *Sagitta maxima*. *E. hamata* was by far the most abundant species, comprising 88% of the 8419 individuals collected during cruise KH94-4 and 86% of the 2392 individuals collected during cruise KH01-3. *S. marri* was second in abundance with 9% and 7% for cruises KH94-4 and KH01-3 respectively. *S. gazellae* and *S. maxima* accounted for less than 4% of the total for each cruise, while *E. bathypelagica* was nearly absent during KH94-4 (sampling depth being too shallow) and

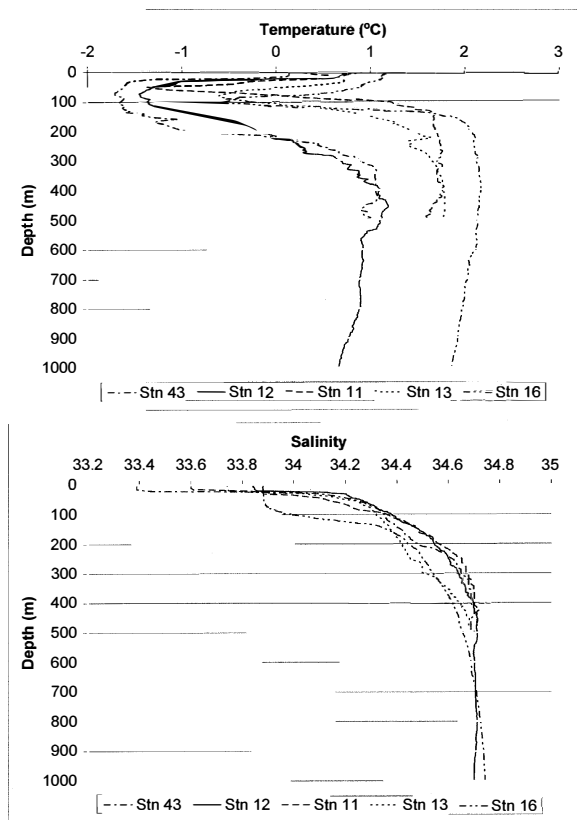


Fig. 2. Temperature and salinity profiles for all stations along 140°E transect in the Australian sector of the Southern Ocean. Stations are written from south to north beginning with station 43 and moving right.

comprised only about 1% of the total for KH01-3.

The vertical distributions of the species *E. hamata*, *S. marri* and *S. gazellae* at all stations are depicted in Figs. 4, 5, 6, and 7. The data collected suggests no regular pattern of diel vertical migration by any of these species and their vertical distribution did not appear to be restricted by any of the hydrographic clines. *E. hamata* was most abundant north of the Antarctic Divergence (AD) and the bulk of the population in general tended to be distributed in the upper 500 m. Conversely, *E. hamata* was least abundant south of the AD. A bi-modal distribution was common north of the AD, and was expressed with reduced abundance in the 100–300 m range. Within the AD and to the south of it, peaks often occurred in the upper 300 m and signs of bi-modal distribution were less common.

The abundance of *S. marri* was lowest in the north (Stn. 16) compared to the other stations. They were largely distributed below 300 m at all stations, except station 12 where they were a bit shallower. *S. gazellae* appeared to be most abundant within the AD and just north of it, occurring mostly in the upper 400 m. The largest values during

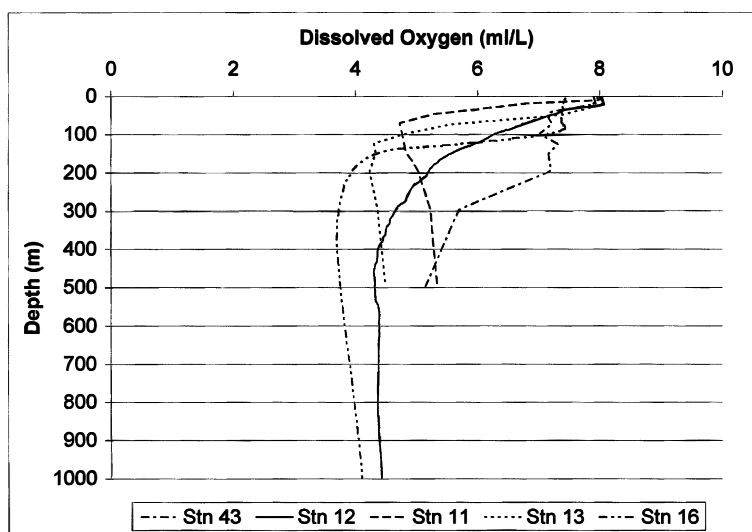


Fig. 3. Dissolved oxygen profiles for all stations along 140°E transect in the Australian sector of the Southern Ocean. Stations are written from south to north beginning with station 43 and moving right.

KH94-4 tended to be between 30–120 m, however they were a bit deeper throughout KH 01-3, peaking sometimes between 300 and 400 m.

Development and ontogenetic distribution

Vertical segregation of the different size classes of *E. hamata* was most clear at station 16 (Fig. 8). Small chaetognaths tended to concentrate near the surface, while larger specimens occupied progressively deeper layers. Abundance of < 10 mm individuals peaked in the upper 100 m, 10 + mm between 300–400 m, 15 + mm between 300–500 m, and 20 + mm below 600 m. The distribution was not so clear at station 12—different size classes overlapped considerably. The profiles for stations 11, 13, and 43 were quite similar to station 12 (Fig. 8). Since station 16 had the sharpest thermocline and oxycline of the stations studied, we attribute the clear distribution there to the stability of the water column as compared to the other stations.

Nearly all *E. hamata* larger than 15 mm from cruise KH94-4 were at stage 1 maturity and no difference in this trend was seen among the three stations. Among 274 total individuals collected, 4 of them were at stage 2 maturity and the rest were at stage 1. This was due to shallow sampling depth. The situation at KH01-3 in the upper 500 m was similar. In the deeper waters, however, KH01-3 had more mature specimens. At station 12, 127 individuals larger than 15 mm were recovered and maturity stages 1, 2, and 3 comprised 76%, 14% and 3.9% respectively—juveniles and damaged specimens made up the remainder. For station 16, stages 1, 2, and 3 comprised 68%, 13%, and 10% of the 84 collected individuals respectively—again juveniles and damaged specimens comprised the remainder.

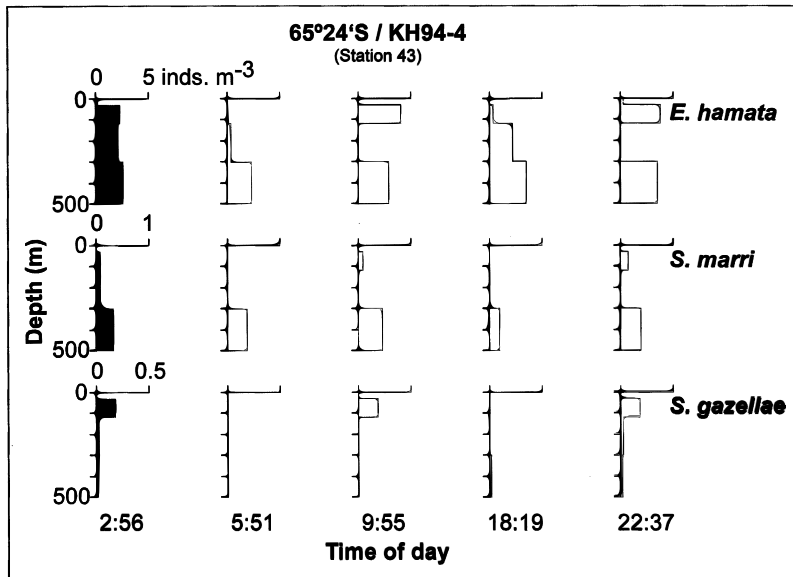


Fig. 4. Abundance (inds. m⁻³) and vertical distribution of *Eukrohnia hamata*, *Sagitta marri*, and *Sagitta gazellae* at station 43 during cruise KH94-4 (1994/5) in the Australian sector of the Southern Ocean. Sampling times and dates are as follows: 2:56 (Jan. 21); 5:51 and 9:55 (Jan. 19); 18:19 and 22:37 (Jan. 20). Night-time hauls depicted in black.

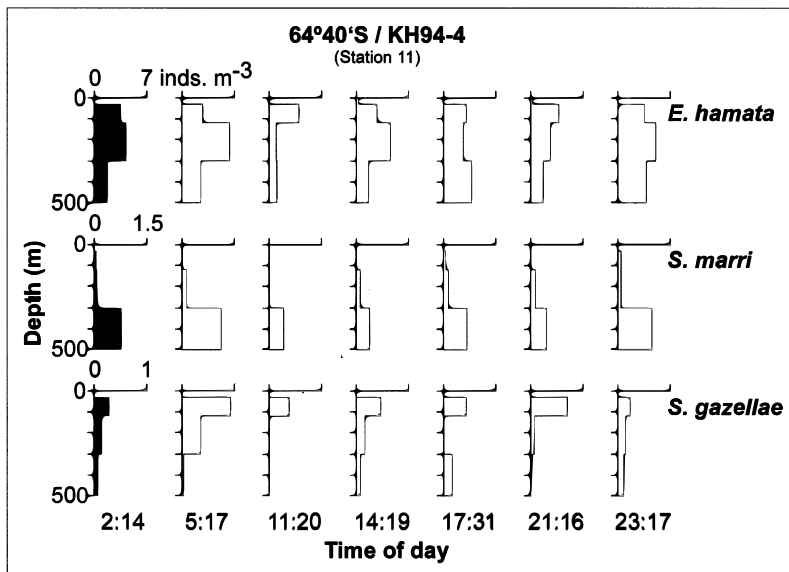


Fig. 5. Abundance (inds. m⁻³) and vertical distribution of *Eukrohnia hamata*, *Sagitta marri*, and *Sagitta gazellae* at station 11 during cruise KH94-4 (1994/5) in the Australian sector of the Southern Ocean. Hauls at 2:14 and 5:17 were conducted on Dec. 21, the remainder were conducted on Dec. 20. Night-time hauls depicted in black.

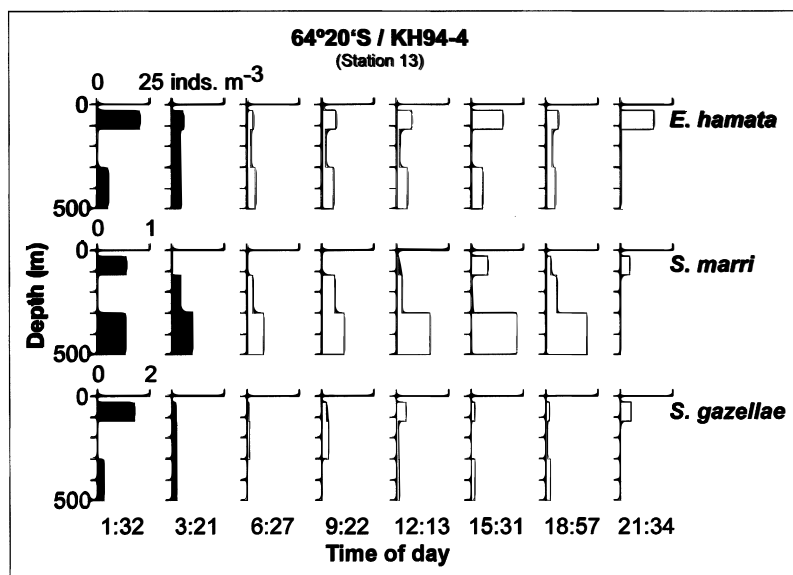


Fig. 6. Abundance (inds. m^{-3}) and vertical distribution of *Eukrohnia hamata*, *Sagitta marri*, and *Sagitta gazellae* at station 13 during cruise KH94-4 (1994/5) in the Australian sector of the Southern Ocean. Hauls at 1:32, 15:31, and 18:57 were conducted on Dec. 24, the remainder were conducted on Dec. 23. Night-time hauls depicted in black.

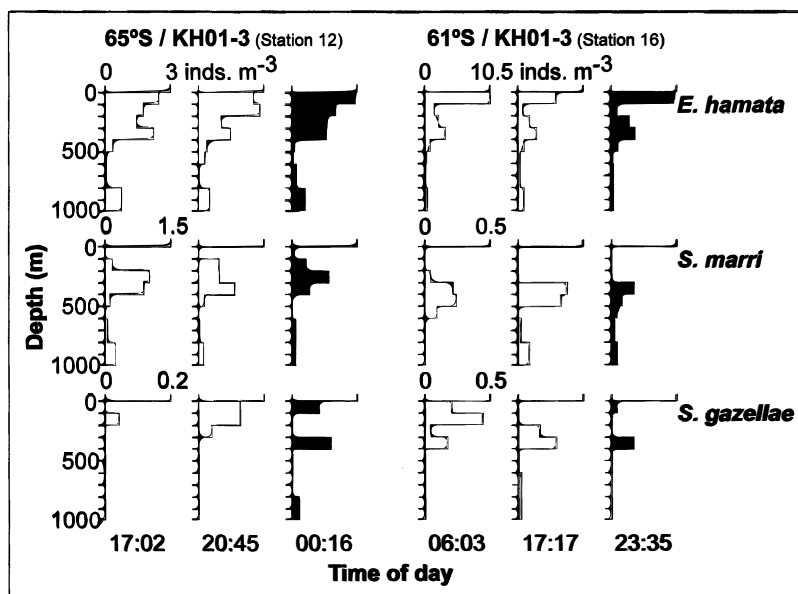


Fig. 7. Abundance (inds. m^{-3}) and vertical distribution of *Eukrohnia hamata*, *Sagitta marri*, and *Sagitta gazella* at stations 12 and 16 during cruise KH01-3 (2001/2) in the Australian sector of the Southern Ocean. For station 12, hauls at 17:02 and 20:45 were conducted on Jan. 10, 00:16 was conducted on Jan. 11. All hauls at station 16 were conducted on Jan. 16. Night-time hauls depicted in black.

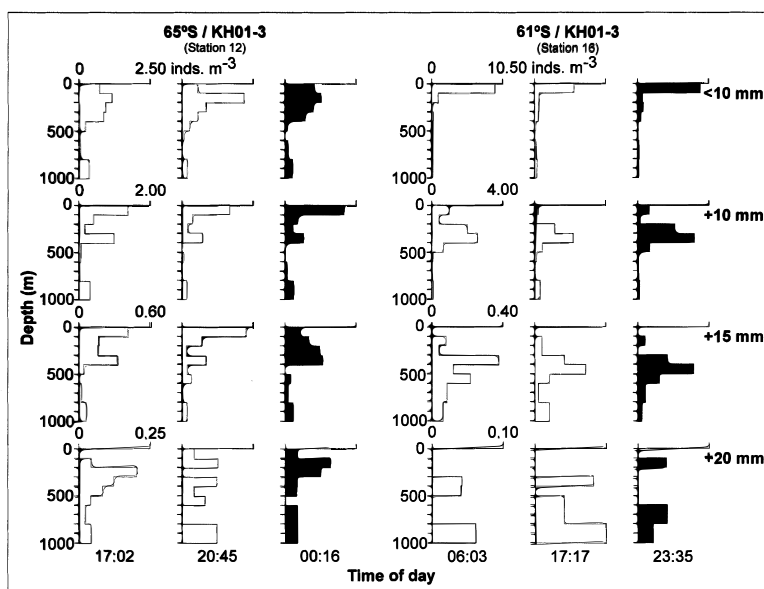


Fig. 8. Abundance (inds. m^{-3}) and vertical distribution of *Eukrohnia hamata* size classes at stations 12 and 16 during cruise KH01-3 (2001/2) in the Australian sector of the Southern Ocean. Night-time hauls depicted in black.

Feeding

No regular diel pattern of flux in the Food Containing Ratio (FCR) was recognized at any station. Station means for values ranged from 15.4 to 48.9% with feeding activity highest in the regions most removed from the AD, stations 16 and 43 (Table 1). The average standard length of predators (*E. hamata* with prey) fluctuated widely over time at each station, but like the FCR, no regular pattern was discernible. Among cruise KH 94-4, the median standard length of predators at station 13 (6 mm) was significantly smaller than for stations 11 (10 mm) and 43 (11 mm) ($H=235.417$; $P<0.0001$, Kruskal-Wallis test). For cruise KH01-3, a Mann-Whitney U-test showed a significant

Table 1. Food Containing Ratio (FCR) and standard body length of *E. hamata* with prey items in gut along 140°E transect in the Australian sector of the Antarctic Ocean.

Location	Total <i>E. hamata</i>	<i>E. hamata</i> w/ prey	FCR				Standard length (mm)					
			Min	Max	Mean	Std. Dev.	<i>n</i> *	Min	Max	Mean	Std. Dev.	Median
KH94-4	7424	1933	9.8	56.5	28.0	15.0	1879	2.5	25	9.3	4.1	9
64°20'S (Stn 13)	3913	1029	12.9	42.5	25.9	9.2	998	2.5	23	8.0	4.0	6
64°40'S (Stn 11)	2379	344	9.8	23.5	15.4	4.7	343	4	21	10.7	3.2	10
65°24'S (Stn 43)	1132	560	38.6	56.5	48.9	6.8	538	3	25	10.9	3.9	11
KH01-3	2044	886	32.0	57.8	42.0	11.8	885	3	25	10.6	4.6	11
61°00'S (Stn 16)	1323	629	32.0	57.8	48.5	14.3	629	3	24	9.6	4.4	10.5
65°00'S (Stn 12)	721	257	32.0	40.7	35.6	4.6	256	6	25	13.1	4.0	13

*The discrepancy between *n* and "*E. hamata* w/ prey" is due to damaged specimens containing prey items that could not be accurately measured.

difference in the median standard length of predators between stations 12 (13 mm) and 16 (10.5 mm) ($U=46772$; $P<0.0001$). In general terms, the predators north of the AD were smaller than those in the AD or south of it. Finally, a significant difference was found in the median standard length of predators when comparing the two cruises—KH 01-3 (11 mm) was larger than KH94-4 (9 mm) ($U=643937$; $P<0.0001$, Mann-Whitney U-test).

Discussion

Time series studies are necessary for understanding biological processes occurring in the water as well responses to environmental change. The high similarity in many aspects of chaetognath ecology between the two cruises was remarkable and demonstrates much consistency in the chaetognath environment over a fairly long time scale.

The numerical dominance of *E. hamata* was not unexpected as several other studies in the Antarctic Ocean have yielded similar results (Øresland, 1990, 1995; Froneman and Pakhomov, 1998; Froneman *et al.*, 1998; Duró *et al.*, 1999; Duró and Gili, 2001). This dominance seems to extend north as far as the Subtropical Convergence (Terazaki, 1989). Additionally, Terazaki's data also shows the abundance of *E. hamata* to be higher near the Antarctic Convergence (AC) than the continent—similar to this study. Coincidentally, copepods, the main prey of chaetognaths, are usually most abundant near the AC and decrease in abundance to the south (Hempel, 1985). However, recent data suggests that copepod abundance may actually remain high within one or two degrees South of the AC before beginning to drop off (Takahashi *et al.*, 2002).

The bi-modal distribution of *E. hamata* does not seem to be tied to vertical hydrographic features in the water column as the thermocline, halocline, and oxycline do not match with the decreased abundance through the 100–300 m range. Furthermore, the bi-modal distribution is not seen at the other stations with similar hydrographic profiles. A likely cause could be prey distribution, as copepod abundance from the same nets during cruise KH94-4 show a similar bi-modal split at station 13 (Tsuda and Nishikawa, unpublished data). Previous studies near the Antarctic peninsula reported differing vertical distributions for different species (Hagen, 1985; Duró *et al.*, 1999), and Duró suggested a connection to copepod distributions. In contrast, in the subarctic Pacific, Sullivan found the vertical distribution of *E. hamata* and *Sagitta elegans* to correlate better with temperature than with prey abundance (Sullivan, 1980). While the data from our study definitely shows different species occupying different regions in the water column, they do not appear divided along clear temperature gradients. Obviously, it is entirely possible for similar phenomena at separate areas to have different causal factors. So, while chaetognaths in the subarctic Pacific have a distribution related to temperature, their Antarctic Ocean counterparts could be governed by prey.

The time series samples of this study revealed no regular patterns of diel vertical migration for the species *E. hamata*, *S. marri* and *S. gazellae*. This is concurrent with previous reports (Terazaki, 1989; Froneman and Pakhomov, 1998) and the further need to address this particular topic in future work is questionable.

E. hamata often displays a segregation of size classes vertically in the water column. This phenomena has been documented previously in the Antarctic (Øresland,

1995), Arctic (Sameoto, 1987; Timofeev, 1998) and the North Pacific (Sullivan, 1980; Johnson and Terazaki, 2003). Segregation is considered to be part of the life cycle of *E. hamata* with sexually mature adults spawning at depth, followed by upward migration of juveniles during development, and then a return to depth as they begin to mature (Sullivan, 1980; Hagen, 1985; Sameoto, 1987; Øresland, 1995; Timofeev, 1998; Duró and Gili, 2001). However, as can be seen from our data, it is not always clearly defined. Duró noted a lack of segregation near the ice margin in the Scotia Sea, but no explanation was given (Duró *et al.*, 1999). We can see in her data a broader temperature gradient was present at the ice margin, so there is a possibility that some mixing was the driving force. Obviously, the division of size classes ought to be more apparent in highly stratified regions, such as seen at station 16 of this study.

Breeding among *E. hamata* is considered to occur at a low rate continuously throughout the year in the Antarctic Ocean (Øresland, 1995). Breeding seems unaffected by hydrographic conditions and periodicity is apparently in synchrony across the water masses as the same maturity stages were present in similar percentages at Stations 12 and 16 of KH01-3. The lack of stage 2 and stage 3 specimens for the KH94-4 cruise is due to the tendency for large, mature chaetognaths to inhabit deeper waters—they simply were not collected by our nets.

Diel patterns in feeding have been reported for *E. hamata* in areas of the northern Pacific, with peaks occurring consistently at night (Sullivan, 1980; Sameoto, 1987). In contrast, *E. hamata* in the Antarctic Ocean are reported to be continuous feeders in both summer and winter (Øresland, 1995; Froneman and Pakhomov, 1998). Continuous feeding was also observed in this study. It is unclear what specifically causes the night-time peaks in the north Pacific (*e.g.* increased encounters between chaetognath and prey, increased inclination to attack upon encounter, an increased vulnerability on the part of the prey, etc.). Thus, there is difficulty explaining why diel patterns are not observed in the Antarctic. Though clear patterns of temporal flux in FCR were lacking, spatial flux in FCR along the transect coincided well with frontal regions on either side of the Antarctic Divergence (AD). As productivity tends to be high at the edge of frontal zones, the high FCR values radiating out on either side of the AD are to be expected.

The likelihood that differences in predator length between areas is due to different levels of feeding success among size groups is small, because chaetognaths are opportunistic ambush predators and feeding success is based mostly on prey encounter. Rather, the different predator lengths are more likely to be a result of size frequencies among the population, and thus provide a nice sub-set for comparing the average population length of *E. hamata* between locations. The smaller size of *E. hamata* north of the AD compared to the south was quite similar to the situation across the AC involving *S. gazellae*. Two racially distinct forms of *S. gazellae* are recognized across the AC: small northern and large southern (Mackintosh, 1964). Though it is doubtful that *E. hamata* across the AD can or would be recognized as racially distinct forms, they are separate populations with a recognizable ecological difference occurring across the boundary zone. Additionally, the differing median length between cruises is most logically explained by a slight difference in breeding periodicity at sampling. If breeding is continuous year-round as mentioned earlier, it is very likely that cruise KH01-3 simply

fell within a later stage of a breeding period than did KH94-4.

We found quite large differences between FCR values in this study compared to maximum FCR values extrapolated from other work in the Antarctic Ocean: 24% - Øresland, 1990; 15% - Øresland, 1995; 21% - Froneman and Pakhomov, 1998; 6% - Froneman *et al.* 1998. Though the comparison is difficult, because the amount of prey remaining in chaetognath guts after collection can vary due to sampling methods, it seems odd that our values are so much higher. Given the fact that oil drops made up 73 % of the prey items recorded by Froneman and we disregarded oil drops, our FCR values seem higher still (Froneman and Pakhomov, 1998). We wonder if the discrepancy might lie in the analytical methods. The studies in question used dissection techniques to identify prey (Øresland, 1987), though it is not clear in what manner gut contents are being first recognized, tallied, and selected for dissection. When examining *E. hamata*, sometimes prey are largely intact and highly visible, but at other times, what appears to be an empty gut can in fact have contents, visible as a slight distortion in the gut when viewed dorsally or ventrally. If the distortion is overlooked, highly digested prey items can remain unnoticed and avoid dissection. If future studies clearly outline steps taken to recognize gut contents as was done in this study, in addition to any dissection that may be performed, it would be highly beneficial for ongoing research.

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