I.O.S.

CHAETOGNATHA FROM THE SOND CRUISE 1965

(RRS DISCOVERY CRUISE 8)

BY

K.C. CHIDGEY

REPORT NO. 218

1985

NATURAL ENVIRONMENT RESEARCH COUNCIL

INSTITUTE OF OCEANOGRAPHIC SCIENCES

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CONTENTS

INTRODUCTION

During the autumn of 1965 combined biological and physical investigations into the vertical distribution and diel migrations of the plankton and the sonic scattering layers were undertaken in the vicinity of Fuerteventura in the Canary Islands. The area around Fuerteventura was chosen as it combined good acoustic conditions, faunal populations and favourable weather conditions. An introductory paper by Currie, Boden and Kampa (1969) describes the objectives of the cruise and the hydrography of the area; the gear used is described by Foxton (1969). Various authors have published their results on the major taxa collected during the investigation, namely:- Ostracoda (Angel 1969), Cephalopoda (Clarke 1969), Euphausiacea (Baker 1970), Decapoda (Foxton 1970a,b), Amphipoda (Thurston 1976a, b), Fish (Badcock 1970), Copepoda (Roe 1972a,b,c,d) and Siphonophora (Pugh 1974). A summary of the plankton data using factor and cluster analyses was published by Angel and Fasham (1973).

Information on the abundance and vertical distribution of Chaetognatha in this area of the north east Atlantic is scant, therefore, although the hauls referred to in this paper were collected quite a few years ago, the information gained from them is of considerable importance. Germain and Joubin (1916) recorded twelve species from around the Canary Islands, but they were caught with open nets and no results were therefore obtained on their vertical distribution. Along the Moroccan Coast Faure (1952) and Furnestin (1957) found the same eight species and the latter also studied in detail their seasonal and geographical distribution. The sampling was restricted to the continental shelf and to depths of less than 210-220m.

MATERIAL AND METHODS

The biological sampling was undertaken with a range of nets to collect, as far as possible, the whole spectrum of animals at different depths, by day and night. The Chaetognatha examined were collected in a series of 19 day and 19 night hauls, made with a $1m^2$ ring net (N113) at depth intervals of approximately 50m down to 960m. The N113 is a modified version of the Indian Ocean Standard Net (Currie 1963) and details of the construction and methods of use are given by Foxton (1969). The N113 was towed horizontally at 2 knots for one hour and then hauled obliquely to the surface. An opening/closing device, referred to as a catch-dividing bucket (Foxton 1963), was fitted to the cod-end of the net.

This bucket had a pressure activated flap to direct the catch into one or other of the two collecting nets. By this means the sample collected during the horizontal part of the tow, at a predetermined depth, was separated from that collected as the net was paid out or hauled obliquely upwards, resulting in two catches for all hauls below 50m. The catch resulting from the horizontal tow is referred to as "deep" and the other, taken between the flap operating depth and the surface, as "shallow". Depths were recorded by a depth gauge and by depth telemeter readings. The depths used in this paper are the mean depths or where this could not be calculated, the maximum fishing depths given by Foxton (1969), followed by the flap operating depth in brackets.

Day time hauls were made between one hour after sunrise and one hour before sunset and night hauls between one hour after sunset and one hour before sunrise. The two shallowest hauls at 50-(0)m (day) and 40-(0)m (night) were made with the net open, without the catch dividing bucket, and were towed horizontally at these depths then hauled obliquely to the surface. The absence of the catch dividing bucket inadvertently changed the mesh size of the N113 for these two hauls (see Roe 1972a).

The results from the N113 series show that the number of Chaetognatha caught in the shallowest night haul is about one third of that taken in the similar daytime one, and presumably the species which migrated above 50m at night were therefore not properly sampled. In order to investigate this possibility, a series of horizontal hauls made off Fuerteventura in 1969 were also studied. These hauls were made with a Rectangular Midwater Trawl, mouth area $1m^2$ and mesh size 0.33mm (Baker, Clarke and Harris 1973), by day and night over depth ranges of 50-25m, 25-12m and 10-0m.

A star pattern of 36 surface hauls taken on the SOND cruise at the same position as the N113 hauls was also studied. These hauls, taken during a six hour period at night, were made with a neuston net (NN) fishing the top 10cm (David 1965).

Finally, the Chaetognatha from a supplementary series of day hauls, obtained with an NF70V net - a modified version of a Nansen net (Currie and Foxton 1957) - were identified.

Station data for the N113 series studied in this paper are given by Angel (1969) and for the NN and NF70V series by Currie et al. (1969). Details of the RMT 1 hauls are given in the National Institute of Oceanography Cruise Report No. 30 (issued April, 1970).

The Chaetognatha from only the "deep" N113 hauls were identified and, if the haul contained large numbers of Chaetognaths, only the larger specimens and a fraction of the remainder were identified. The Chaetognatha from the near-surface RMT 1 hauls were counted and identified from a fraction of the total sample, but the whole NN and NF70V samples were analysed.

TABLE 1. Numbers of Chaetognatha species caught.

Species	No. of hauls	N113H 38	NN 29	NF70V 24	RMT 1 6	Total number caught
Sagitta minima Grassi, 1881		8859	-	162	32704	41725
Eukrohnia hamata (Möbius, 1875)		5162	-	58	-	5220
Sagitta decipiens Fowler, 1905		4518	48	206	-	4772
Sagitta hexaptera d'Orbigny, 1834		3739	25	38	4000	7802
Pterosagitta draco (Krohn, 1853)		3533	2	10	17280	20825
Sagitta lyra Krohn, 1853		3418	-	27	1280	4725
Sagitta serratodentata Krohn, 1853		2650	468	190	24256	27564
Sagitta macrocephala Fowler, 1905		1071	-	22	-	1093
Eukrohnia fowleri Ritter-Zahony, 1911		891	-	18	-	909
Krohnitta subtilis (Grassi, 1881)		734	-	29	1056	1839
Sagitta planctonis f. zetesios Fowler, 1905		724	-	6	-	730
Sagitta planctonis f. planctonis Steinhaus, 1896		383	2	4	-	389
Sagitta enflata Grassi, 1881		260	-	4	192	456
Sagitta bipunctata Quoy & Gaimard, 1827		18	2	-	1056	1076
Sagitta friderici Ritter-Zahony, 1911		3	-	-	-	3

TABLE 2. Species Composition of the Day N113H Hauls

Station number	Serial number	Mean or maximum depth (m) / Closing depth (m)	Sagitta minima	Eukrohnia hamata	Sagitta decipiens	Sagitta hexaptera	Pterosagitta draco	Sagitta lyra	Sagitta serratodentata	Sagitta macrocephala	Eukrohnia fowleri	Krohnitta subtilis	Sagitta planctonis f. zetesios	Sagitta planctonis f. planctonis	Sagitta enflata	Sagitta bipunctata	Sagitta friderici	Number of species	Total number*
5827	#5	40- (0)	7577	3	-	969	2293	1430	897	-	-	68	-	206	210	4	-	10	13994
5828	#1	85- (50)	-	-	-	224	53	106	194	-	-	26	-	66	29	9	2	9	742
5816	#7	150- (90)	1	-	-	375	1	38	162	-	-	1	-	1	3	-	-	8	704
5816	#6	205-(150)	-	-	155	199	2	44	97	-	-	25	-	1	-	-	-	7	643
5816	#4	250-(190)	-	-	262	53	-	95	-	-	-	28	-	-	-	-	-	4	438
5816	#3	300-(240)	24	2	355	37	1	103	-	-	-	14	-	-	-	-	-	7	584
5816	#2	350-(280)	18	41	642	81	1	219	-	-	-	47	-	-	-	-	-	7	1188
5816	#1	400-(360)	12	207	1065	22	-	119	12	-	-	31	-	-	-	1	-	8	1478
5814	#1	450-(410)	-	344	390	-	-	91	8	-	-	8	-	28	-	-	-	6	975
5814	#2	500-(460)	7	475	68	-	-	90	14	-	-	54	-	51	-	-	-	7	811
5825	#1	570-(475)	-	973	145	2	-	31	-	2	-	96	145	8	-	-	-	8	1462
5825	#5	600-(475)	8	269	126	7	9	33	4	4	-	45	72	-	-	-	-	10	585
5825	#2	625-(550)	9	275	131	1	-	71	17	9	-	112	104	-	-	-	-	9	809
5827	#1	720-(600)	13	131	36	9	1	34	6	59	35	5	28	-	-	-	-	11	368
5827	#2	780-(650)	6	136	26	7	3	23	1	49	52	7	22	-	2	-	-	12	348
5825	#4	800-(680)	8	153	54	4	-	33	8	211	147	8	51	-	-	1	-	11	679
5827	#3	900-(750)	-	82	4	6	-	10	1	32	59	2	10	-	1	1	-	11	231
5825	#3	940-(700)	2	76	13	2	1	30	3	132	143	9	23	-	1	1	-	13	446
5827	#4	950-(800)	15	81	14	9	7	19	7	83	61	9	16	-	-	-	2	12	334
																			26804

*Totals include unidentified specimens

TABLE 3. Species Composition of the Night N113H Hauls

Station number	Serial number	Mean or maximum depth (m) / Closing depth (m)	Sagitta minima	Eukrohnia hamata	Sagitta decipiens	Sagitta hexaptera	Pterosagitta draco	Sagitta lyra	Sagitta serratodentata	Sagitta macrocephala	Eukrohnia fowleri	Krohnitta subtilis	Sagitta planctonis f. zetesios	Sagitta planctonis f. planctonis	Sagitta enflata	Sagitta bipunctata	Sagitta friderici	Number of species	Total number*
5819	#5	50- (0)	1063	44	2	997	1078	189	991	-	-	-	3	2	1	-	-	10	4679
5819	#3	100- (50)	9	-	-	248	34	45	107	-	-	2	-	12	6	-	1	9	499
5819	#2	150-(100)	9	-	5	63	1	7	37	-	-	3	-	3	2	-	-	9	145
5819	#1	220-(150)	10	-	75	106	9	15	24	-	1	1	-	-	-	-	-	8	286
5818	#6	250-(180)	2	4	132	103	-	49	4	-	-	-	-	-	-	-	-	6	310
5818	#5	300-(240)	6	4	82	35	2	51	5	-	-	7	-	-	1	1	-	10	224
5818	#4	360-(280)	-	4	22	38	3	108	1	-	-	8	-	-	-	-	-	7	209
5818	#3	410-(350)	3	35	122	33	2	111	2	-	-	20	-	-	-	-	-	8	368
5818	#2	460-(400)	3	58	48	8	1	21	3	-	-	10	2	1	-	-	-	10	193
5818	#1	500-(450)	4	652	51	3	1	15	3	-	-	12	43	2	-	-	-	10	792
5819	#4	550-(500)	4	203	4	28	5	21	5	-	-	4	13	-	-	-	-	9	289
5823	#5	580-(440)	2	328	64	10	1	47	4	4	2	39	29	-	-	-	-	11	543
5825	#6	660-(510)	23	204	296	20	5	38	9	139	29	36	68	-	-	-	-	11	872
5823	#1	700-(550)	8	92	33	6	6	20	-	58	38	7	18	-	-	-	-	10	299
5825	#7	720-(600)	4	97	29	7	-	21	9	107	123	5	29	1	3	-	-	12	444
5823	#2	800-(650)	6	52	33	6	4	11	3	56	78	1	9	-	1	-	-	12	273
5823	#3	830-(775)	1	48	14	6	3	13	2	38	37	1	10	1	-	-	-	12	179
5825	#8	910-(825)	2	52	12	6	2	8	7	41	44	-	9	-	-	-	-	10	183
5823	#4	960-(800)	-	37	8	9	4	9	3	47	42	3	11	-	-	-	-	10	176
																			10963

*Totals include unidentified specimens

TABLE 4. Species Composition of the Day NF70V Hauls

Station number	Depth in metres	*Sagitta minima*	*Eukrohnia hamata*	*Sagitta decipiens*	*Sagitta hexaptera*	*Pterosagitta draco*	*Sagitta lyra*	*Sagitta serratodentata*	*Sagitta macrocephala*	*Eukrohnia fowleri*	*Krohnitta subtilis*	*Sagitta planctonis f. zetesios*	*Sagitta planctonis f. planctonis*	*Sagitta enflata*	Number of species	Total number*
5805	55-0	12	-	-	4	2	-	22	-	-	2	-	-	-	5	44
"	99-48	84	-	-	9	3	5	40	-	-	3	-	3	-	7	156
"	150-103	1	-	8	4	-	-	4	-	-	2	-	-	-	5	22
"	197-155	-	-	19	1	-	-	-	-	-	-	-	1	-	3	22
"	285-180	1	2	14	-	-	1	1	-	-	2	-	-	-	6	27
"	360-247	3	5	19	-	-	2	4	-	1	1	-	-	-	7	42
"	465-360	-	6	11	-	-	-	2	-	-	1	2	-	-	5	24
"	590-490	-	3	2	-	-	1	-	2	-	-	-	-	-	4	8
"	680-590	-	-	-	-	-	-	2	1	5	-	1	-	-	4	14
"	790-710	-	1	-	-	-	-	-	5	2	-	-	-	-	3	8
"	885-790	-	1	-	-	-	-	5	4	1	-	-	-	-	4	12
"	927-850	-	-	6	-	-	-	-	1	2	-	-	-	-	3	17
5806	52-0	27	-	-	9	4	-	28	-	-	-	-	-	3	5	74
"	95-40	34	-	-	7	1	12	69	-	-	4	-	-	1	7	135
"	147-95	-	-	10	3	-	2	4	-	-	3	-	-	-	5	25
"	205-155	-	1	23	-	-	-	1	-	-	3	-	-	-	4	34
"	297-200	-	7	36	1	-	-	1	-	-	1	-	-	-	5	61
"	387-297	-	7	30	-	-	3	2	-	1	2	-	-	-	6	55
"	490-385	-	12	15	-	-	-	-	-	-	-	-	-	-	2	28
"	612-450	-	13	10	-	-	1	-	-	-	5	-	-	-	4	29
"	680-590	-	-	3	-	-	-	1	4	4	-	1	-	-	5	14
"	770-680	-	-	-	-	-	-	1	1	-	-	2	-	-	3	4
"	907-850	-	-	-	-	-	-	2	3	1	-	-	-	-	3	10
"	950-860	-	-	-	-	-	-	1	1	1	-	-	-	-	3	5

*Totals include unidentified specimens

TABLE 5. Species Composition of the Night NN Hauls

Station number	Serial number	Depth in metres	Sagitta minima	Sagitta decipiens	Sagitta hexaptera	Pterosagitta draco	Sagitta serratodentata	Sagitta planctonis f. planctonis	Sagitta bipunctata	Number of species	Total number
5802	# 2	0	-	-	-	-	2	-	-	1	2
"	# 3	0	-	-	-	-	6	-	1	2	7
"	# 4	0	-	-	2	-	4	-	-	2	6
"	# 5	0	-	-	3	-	8	-	-	2	11
"	# 6	0	-	-	-	-	2	-	-	1	2
"	# 7	0	-	-	-	-	2	-	-	1	2
"	#11	0	-	-	1	-	23	-	-	2	24
"	#12	0	-	-	-	1	6	-	-	2	7
"	#14	0	-	32	1	-	71	-	-	3	104
"	#15	0	-	-	2	-	14	-	-	2	16
"	#16	0	-	-	1	-	3	-	-	2	4
"	#17	0	-	-	1	-	3	-	-	2	4
"	#18	0	-	-	1	-	3	-	-	2	4
"	#20	0	-	-	4	-	7	-	-	2	11
"	#21	0	-	-	1	-	1	-	-	2	2
"	#22	0	-	-	2	-	2	-	-	2	4
"	#23	0	-	-	-	1	7	-	-	2	8
"	#24	0	-	-	-	-	12	2	-	2	14
"	#25	0	-	-	-	-	13	-	-	1	13
"	#26	0	-	-	-	-	11	-	-	1	11
"	#27	0	-	16	1	-	21	-	-	3	38
"	#28	0	-	-	-	-	18	-	1	2	19
"	#29	0	-	-	-	-	26	-	-	1	126
"	#30	0	1	-	1	-	50	-	-	3	52
"	#31	0	1	-	3	-	10	-	-	3	14
"	#32	0	4	-	-	-	48	-	-	2	52
"	#34	0	5	-	-	-	-	-	-	1	5
"	#35	0	-	-	1	-	-	-	-	1	1
"	#36	0	-	-	-	-	4	-	-	1	4

TABLE 6. Species Composition of the Day and Night RMT 1 Hauls

	Station number	Depth in metres	Sagitta minima	Sagitta hexaptera	Pterosagitta draco	Sagitta lyra	Sagitta serratodentata	Krohnitta subtilis	Sagitta enflata	Sagitta bipunctata	Number of species	Total number*
DAY	7136	10-0	256	96	1280	-	4480	32	64	608	7	6848
	7131	25-10	4480	896	2560	-	5760	-	-	-	4	13952
	7130	50-25	6464	832	3456	384	3264	320	-	-	6	15040
												35840
NIGHT	7134	10-0	8448	1152	4480	256	2816	256	-	128	7	18043
	7133	25-12	5760	256	2816	256	3968	256	128	128	8	14080
	7132	50-25	7296	768	2688	384	3968	192	-	192	7	16000
												48128

*Total numbers include unidentified specimens

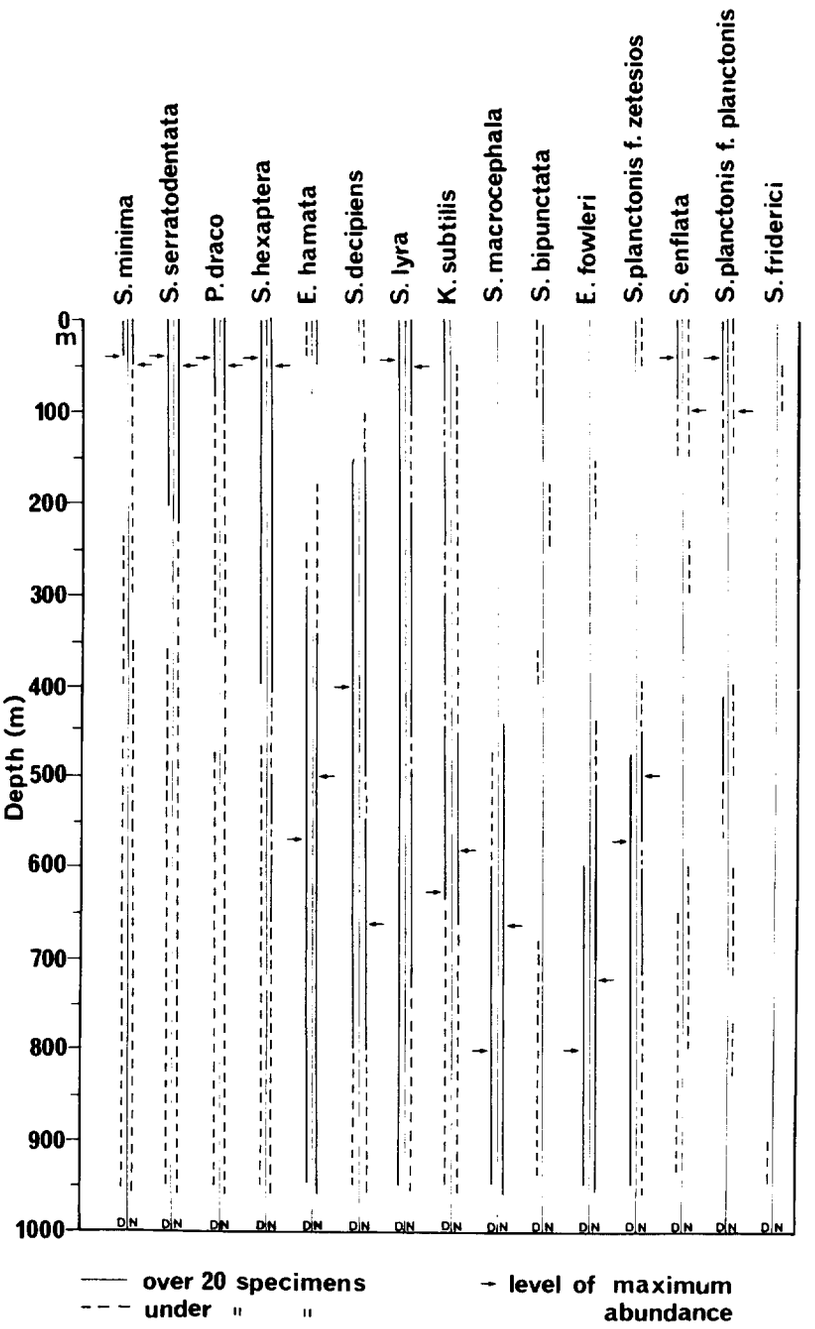

Figure 1. Vertical distributions of species in the N113 hauls

RESULTS

Table 1 gives the total numbers of each species in the various nets, and the species are discussed in order of their abundance in the "deep" N113 hauls.

The N113 and NF70V hauls sampled approximately the same depth layers and caught 15 and 13 species respectively (Tables 2, 3 and 4); the 2 absent from the NF70V samples were Sagitta bipunctata and S. friderici, both of which are epipelagic species. The RMT 1 hauls in the upper 50m and the NN hauls in the top 10cm caught 8 and 7 species respectively (Tables 5 & 6).

The vertical distributions of all the species caught in the "deep" N113 hauls are shown in Fig. 1.

The term juvenile is used for immature specimens i.e. maturity Stage I (Alvarino 1965) and the term adult for all the other maturity stages.

Sagitta minima Grassi, 1881
(Size range in the N113 hauls 3.5-6mm)

Sagitta minima was the most abundant chaetognath caught (Table 1) with 98.4% (day) and 91.7% (night) of the total population in the N113 series occurring in the two near surface hauls. No specimens were found in the 85-(50)m day haul and very few in the 100-(50)m night haul. However, in the NF70V day series the highest numbers of S. minima occurred in the 99-48m and the 95-40m hauls (Table 4).

There was a great disparity between the numbers caught by day and night in the N113 series (Tables 2 and 3) which might indicate a small scale vertical migration of the population to shallower depths at night. However, S. minima was relatively rare in the NN series and clearly does not migrate right to the surface to any significant degree. In the RMT 1 hauls there was a marked increase in the population at night (Table 6) within the top 50m.

There were more adults caught than juveniles in all the nets and this scarcity of juveniles at the surface is also mentioned by Furnestin (1957). Cheney (1982) points out though, that this species matures at a small size and the mesh sizes generally used (around 0.33mm) will not adequately sample the smaller and

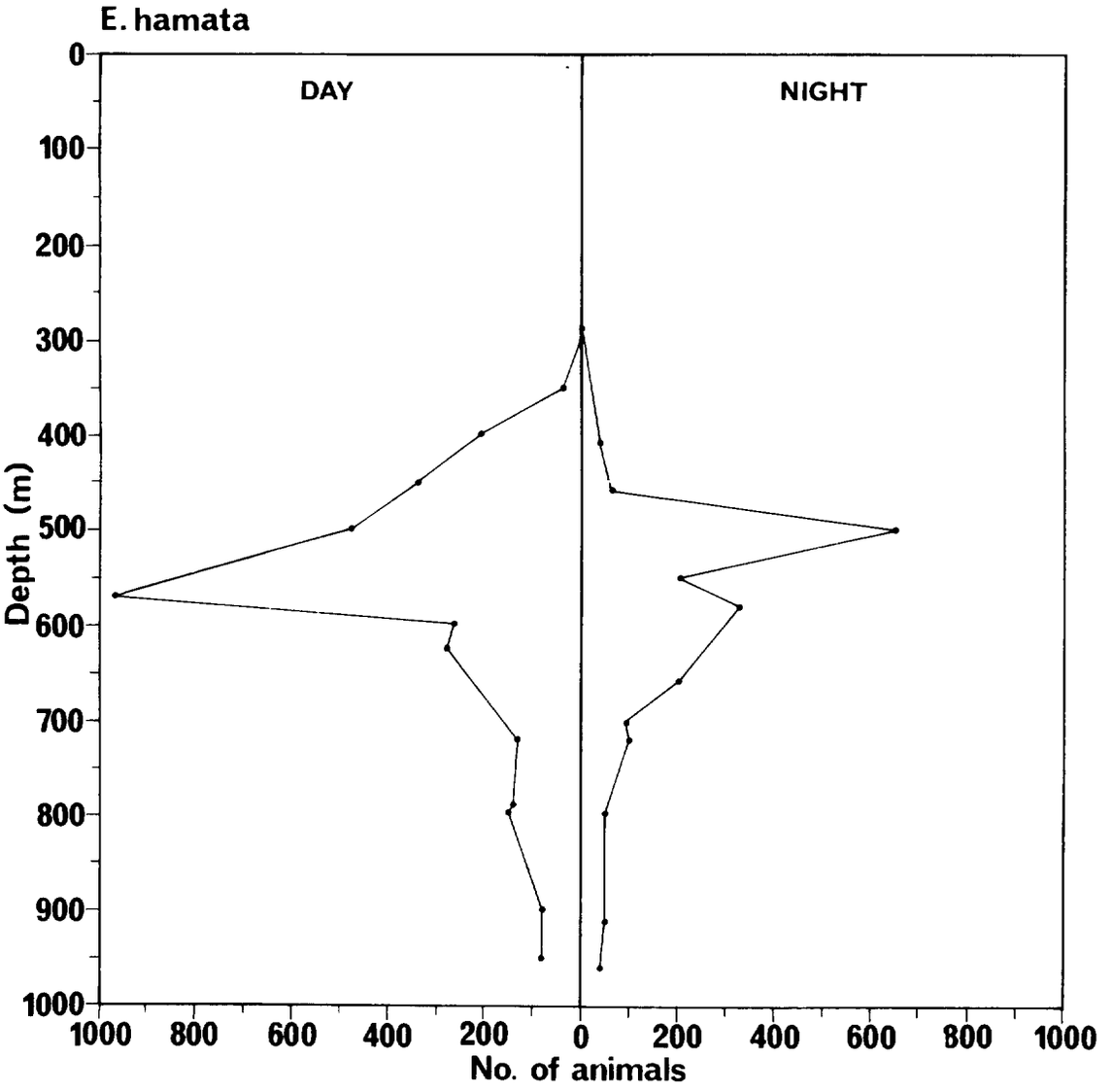
E. hamata
DAY
NIGHT
Depth (m)
0
100
200
300
400
500
600
700
800
900
1000
1000 800 600 400 200 0 200 400 600 800 1000
No. of animals

Figure 2.

therefore immature sizes. However, Pierrot-Bults (1982) found in the northwest Atlantic near Bermuda that by day the adults of S. minima had a slightly deeper distribution than the juveniles but the same maximum abundance levels at night.

Eukrohnia hamata (Möbius, 1875)
(Size range in the N113 hauls 7-18mm)

Eukrohnia hamata is a classic example of a species having a bipolar distribution with tropical submergence (David 1958; Alvarino 1964). In the N113 series E. hamata was the second most abundant chaetognath with a distribution between 450 and 900m (Tables 2 and 3) and it was the dominant species at these depths. Maximum numbers were found at 570-(475)m during the day and at 500-(450)m at night, indicating a slight upward migration of the population (Fig. 2), but there is a difference in total numbers caught by day and night (3248 day; 1914 night). This difference is also reflected in the ratios of juveniles to adults caught by day and night. Nearly all the specimens caught were juveniles with some adults present in the deeper hauls. The maximum abundance of juveniles remained around 500m during the day and night, but the maximum number of adults caught was between 940 and 700m by day and 660 and 510m at night.

Neither Faure (1952) nor Furnestin (1957) recorded E. hamata in the Moroccan Coast area because of the depth limitations of their sampling, but Germain and Joubin (1916) found it in the vicinity of the Canary Islands.

Sagitta decipiens Fowler, 1905
(Size range in the N113 hauls 4-13mm)

Sagitta decipiens was caught by all the "deep" N113 hauls below 200m with maximum numbers in the 400-(360)m day and the 660-(510)m night hauls. It was the dominant species between 250 and 450m representing up to 72% of the total chaetognaths caught and was the third most abundant species in the N113 hauls (Tables 2 & 3). In the NF70V hauls it was the most numerous chaetognath caught between 100 and 600m (Table 4).

The majority of specimens caught were juveniles and their level of maximum abundance remained approximately the same during the day and night (Fig. 3). The maximum number of adults caught was at 400-(360)m during the day and

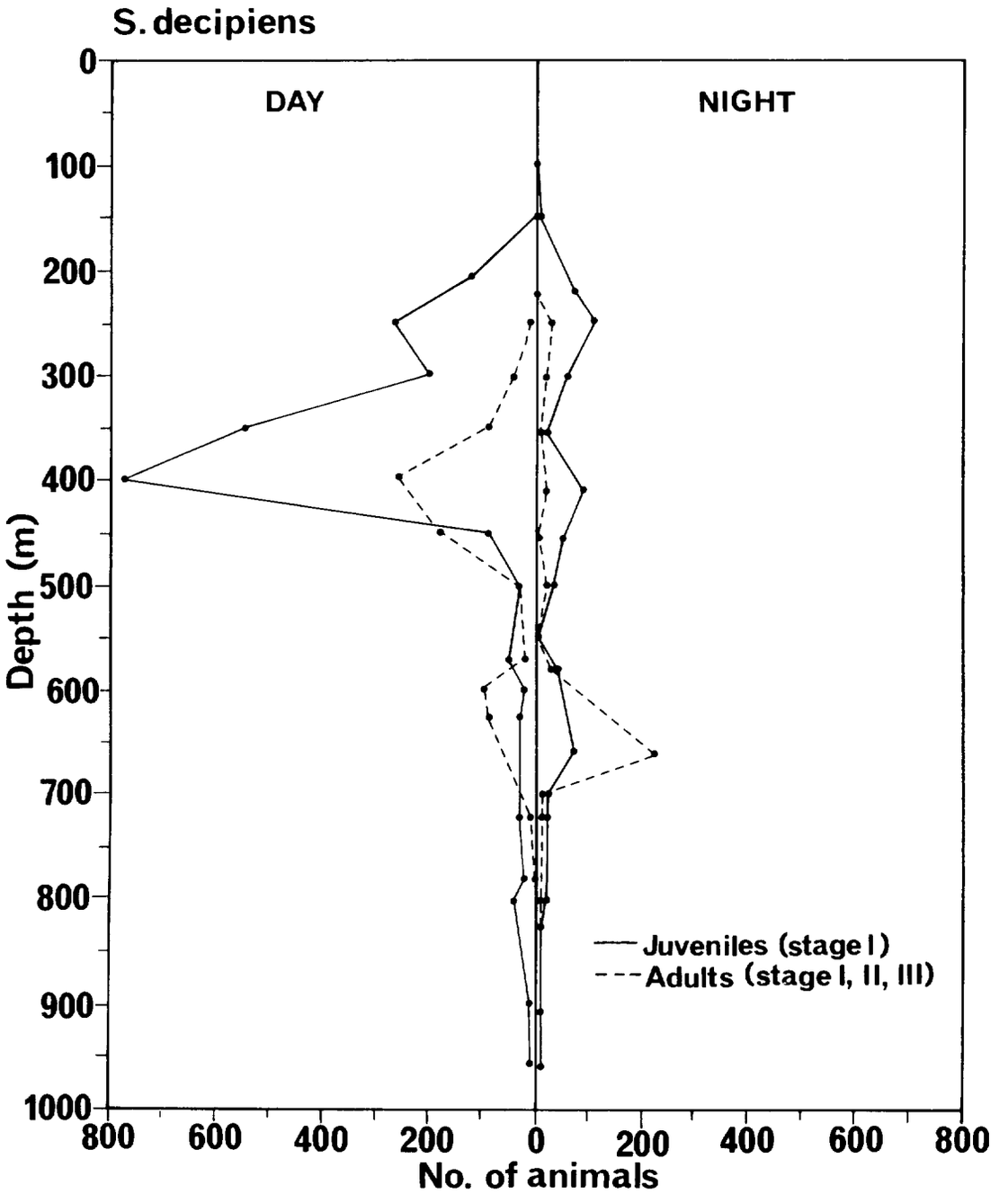
S. decipiens
DAY
NIGHT
Depth (m)
0
100
200
300
400
500
600
700
800
900
1000
800
600
400
200
0
200
400
600
800
No. of animals
Juveniles (stage I)
Adults (stage I, II, III)

Figure 3.

660-(510)m at night, possibly indicating a reverse vertical migration of the adult population (Fig. 3). However, as with Eukrohnia hamata, there was a disparity in the total numbers caught by day and night (3485 day; 1032 night) for which there is no apparent explanation.

Previous data for the vertical distribution of S. decipiens are somewhat confusing. Owre (1960) found evidence of diel vertical migration by S. decipiens in the Florida Current, with maximum numbers usually below 100m but at times relatively abundant in the upper 50 and 100m. Similarly Alvarino (1967) found that it was quite abundant in the upper 100m off San Diego, California and believed its presence was due to upwelling. However, Dallot and Ducret (1968) state that S. decipiens is a mesopelagic chaetognath found mainly between 200 and 900m with maximum densities between 500 and 600m and Cheney (1982) says that it is very rare in the upper 100m in the western north Atlantic. Pierrot-Bults (1979) states in her paper on the synonymy of S. decipiens and S. sibogae that these two closely related species have often been confused. She states that S. decipiens is a deep mesopelagic species whilst S. sibogae is shallower living and so widely differing records of the depth distribution of S. decipiens might be explained.

Neither Germain and Joubin (1916), Faure (1952) nor Furnestin (1957) reported S. decipiens in the areas they studied.

Sagitta hexaptera d'Orbigny, 1834
(Size range in the N113 hauls 4-35mm)

Sagitta hexaptera was caught in the N113 hauls mainly above 400m and was the dominant species between 50 and 200m (Tables 2 and 3). The N113 data give no indication of any diel vertical migration but the RMT 1 series of hauls (Table 6) indicates such a migration, although small scale, within the upper 50m of the water column. A few specimens were caught close to the surface in the night NN hauls (Table 5).

The majority of specimens caught in all the hauls were juveniles as were those reported by Furnestin (1957) and Pierrot-Bults (1982). No adults at all were caught in the 10-0m RMT 1 hauls by day or night, nor in the NN series of hauls, indicating that only the juvenile population is migrating.

Furnestin (1957) found S. hexaptera off the Moroccan Coast and classed it as a mesopelagic species, whereas Alvarino (1964) described it as epipelagic but extending to the upper layers of the mesoplankton. Pierrot-Bults (1982) reported S. hexaptera from the surface down to about 300m.

Pterosagitta draco (Krohn, 1853)
(Size range in the N113 hauls 4-9.5mm)

Pterosagitta draco was abundant in the N113 and RMT 1 hauls above 50m and very few specimens were caught below this depth (Tables 2 & 3). Overall more juveniles were caught than adults. The day/night ratio for the total number of specimens found in the shallowest N113 hauls was approximately 2:1, indicating a migration to shallower depths at night. However, this migration did not extend to the surface as P. draco was virtually absent in the NN hauls. This small scale diel vertical migration of the mainly juvenile population is also indicated in the RMT 1 hauls.

Alvarino (1965) describes P. draco as an oceanic epipelagic cosmopolitan species of warm temperate regions, Pierrot-Bults (1982) found this species above 300m and considered any specimens caught below this depth as contaminants. Furnestin (1957) caught P. draco in the area off the Moroccan Coast mainly between 100 and 400m.

Sagitta lyra, Krohn 1853
(Size range in the N113 hauls 5-35mm)

Sagitta lyra occurred in every N113 haul with maximum numbers in the 40-(0)m day and in the 50-(0)m night hauls (Tables 2 & 3). In the N113 series the specimens were nearly all juveniles above 205m during the day and above 250m at night. No adults were caught in the RMT 1 shallow hauls. The maximum number of adults caught by the N113 was around 400m both during the day and at night. The larger and therefore more mature specimens were found progressively deeper in the water column, with a direct relationship between size and depth.

The difference in the total numbers of S. lyra caught by day and night is perhaps due to the juveniles moving above 50m at night and this is confirmed by the increased number of juveniles caught in the RMT 1 night hauls (Table 6). However, S. lyra was not found in the surface NN hauls.

Furnestin (1957) classed S. lyra as mesopelagic even though she found that, off the Moroccan Coast, the juveniles migrated to the surface at night. Alvarino (1964) however, calls S. lyra epipelagic. Pierrot-Bults (1982) reported it as having an extensive distribution from 50 to 1250m but with maximum densities of mainly juveniles between 100 and 200m by day and 50 and 100m by night.

Sagitta serratodentata, Krohn, 1853
(Size range in the N113 hauls 5-9mm)

In the N113 series of hauls nearly all the specimens of S. serratodentata were caught above 220m (Tables 2 & 3) and represented about 25% of the total chaetognatha caught in the 50-150m layer. The ratio of juveniles to adults was 2:1 in the day N113 40-(0)m haul and 1:4 in the night 50-(0)m haul. Pierrot-Bults (1982) also found that more adults were caught overall at night.

The total numbers of S. serratodentata caught by day and night do not show any clear evidence of a diel vertical migration, but the juvenile/adult data indicate a migration of adults into the 50m depth zone at night, while the juveniles migrated above it. This is confirmed by the results of the night NN hauls which caught more juveniles than adults. In the 100-200m depth zone there were more adults than juveniles by day than by night; the ratio of juveniles to adults being approximately 1:16 and 1:2 respectively. However, the RMT 1 results differ and less specimens overall were caught at night with no significant changes in the juvenile/adult population.

Fraser (1952) states that S. serratodentata is epipelagic, being found above 200m, and this is confirmed by Pierrot-Bults (1982) and Cheney (1982). Both Faure (1952) and Furnestin (1957) record S. serratodentata in the areas they studied.

Sagitta macrocephala Fowler, 1905
(Size range in the N113 hauls 3-16mm)

This species was caught in all the N113 hauls below 570m by day and below 580m at night (Tables 2 & 3). Maximum numbers of specimens, which were all juveniles, were caught in the 800-(680)m day and the 660-(510)m night hauls indicating a diel vertical migration in the juvenile population (Fig. 4).

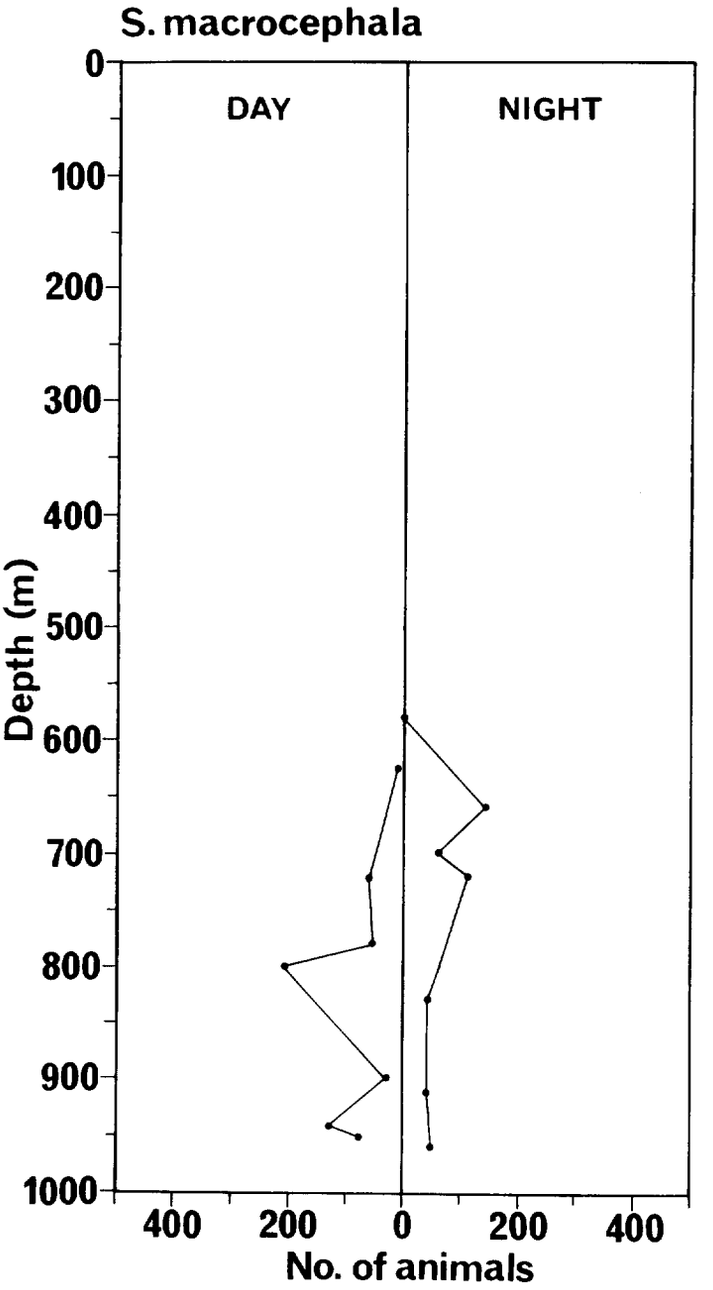
S. macrocephala
DAY
NIGHT
Depth (m)
0
100
200
300
400
500
600
700
800
900
1000
400
200
0
200
400
No. of animals

Figure 4.

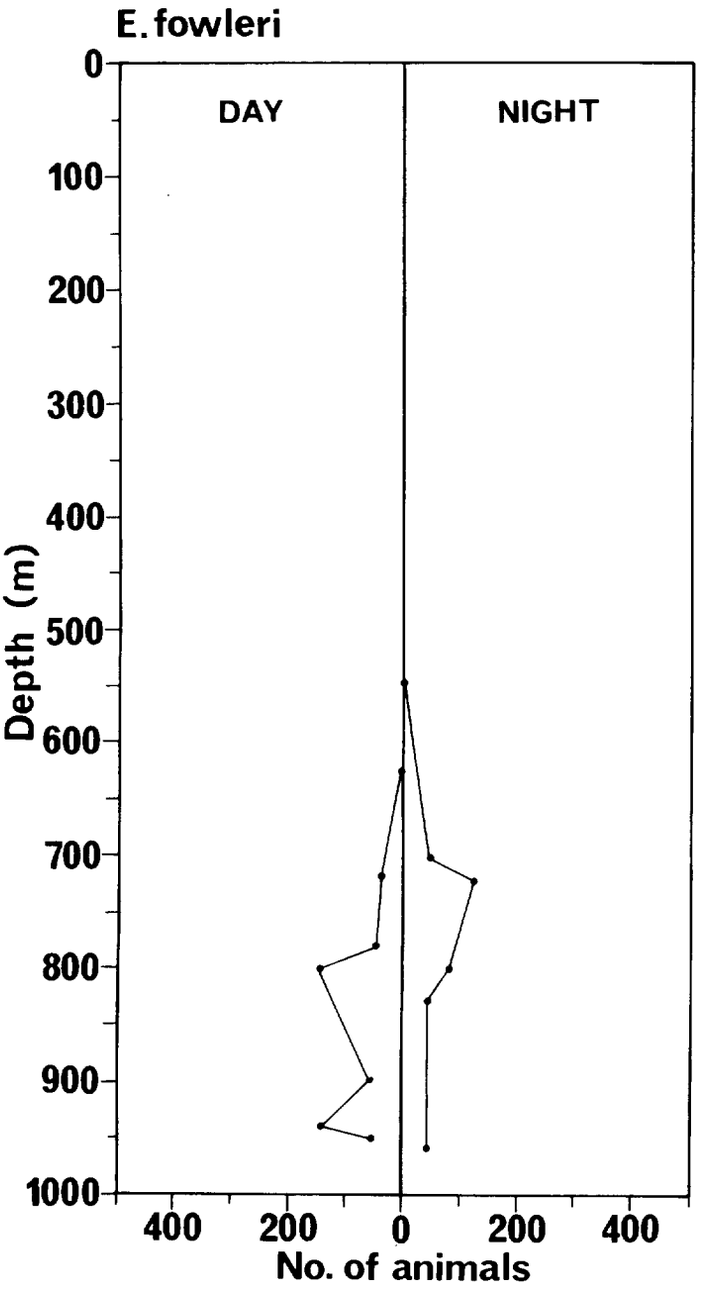
E. fowleri
DAY
NIGHT
Depth (m)
0
100
200
300
400
500
600
700
800
900
1000
400
200
0
200
400
No. of animals

Figure 5.

Pierrot-Bults (1982) also reported that the levels of maximum density of juveniles move upwards at night.

Only one adult specimen was found in the N113 series but this was not surprising as the N113 did not sample below 960m. S. macrocephala is a bathypelagic species with ontogenetic distribution and Pierrot-Bults (1982), for example, observed adults only below 1250m by day and below 900m at night. Cheney (1982) found that the larger sized and therefore more mature specimens were caught at progressively deeper levels. In the N113 series of hauls, even in the juvenile population, there was a direct relationship between increasing size and depth.

S. macrocephala is a widespread deep living species (Alvarino 1965). Germain and Joubin (1916) reported it in their deeper hauls around the Canary Islands.

Eukrohnia fowleri Ritter-Zahony, 1911
(Size range in the N113 hauls 5-33mm)

Eukrohnia fowleri was caught in all the N113 hauls below 720m during the day and 580m at night. The maximum numbers caught were in the 800-(680)m day and in the 720-(600)m night N113 hauls (Tables 2 & 3). E. fowleri is a bathypelagic species, described by Alvarino (1965) as abundant below 800m and Pierrot-Bults (1982) also states that adult specimens were only present below 900m. The majority of specimens found in the N113 series were juveniles, as the N113 did not sample below 960m, and this juvenile population shows an upward movement at night (Fig. 5). The maximum number of adults caught in the N113 hauls was around 900m day and night with none occurring above 720m.

Germain and Joubin (1916) recorded E. fowleri at one station (27°43'N, 18°28'W) in a 0-3000m haul.

Krohnitta subtilis (Grassi, 1881)
(Size range in the N113 hauls 4-14.5mm)

Krohnitta subtilis was caught in all the day series of N113 hauls, with the maximum number between 475 and 625m, and in nearly all the night N113 hauls with the maximum number between 440 and 660m (Tables 2 & 3). The majority of specimens caught were adults (the N113 40-(0)m haul contained only adults) and

the maximum number of adults caught was at approximately the same depth during the day (570-(475)m) and at night (580-(440)m). However, the maximum number of juveniles caught was in the 620-(550)m day N113 haul and in the 410-(350)m night N113 haul, indicating a diel vertical migration of the juvenile population, but the numbers caught were possibly too low to validate this.

There was a difference in the total numbers of K. subtilis caught by day and night, 595 v. 159, for which again there is no apparent explanation. Fairly high numbers were caught in the six shallow RMT 1 hauls and they contained more juveniles than adults and seem to indicate a diel vertical migration within the 50m layer (Table 6).

Alvarino (1965) described K. subtilis as an oceanic epipelagic cosmopolitan species, but neither Germain and Joubin (1916), Faure (1952) nor Furnestin (1957) recorded it in the areas they studied. Pierrot-Bults (1982) found K. subtilis between 10 and 900m with the maximum number, mostly adults, caught below 500m, Cheney (1982) describes K. subtilis as mesopelagic, being found between 200 and 1000m.

Sagitta planctonis

In this paper, Sagitta zetesios Fowler, 1905 and Sagitta planctonis Steinhaus, 1896 are regarded as two formae of the same species i.e. Sagitta planctonis f. zetesios and Sagita planctonis f. planctonis, as proposed by Pierrot-Bults (1975).

Sagitta planctonis f. zetesios Fowler, 1905
(Size range in the N113 hauls 8.5-32mm)

This chaetognath occurred below 475m (actual closing depth) in the day N113 hauls and below 400m (actual closing depth) in the night N113 hauls. The maximum numbers caught were between 475 and 625m in the day hauls and 600 and 800m at night. The majority of specimens caught were juveniles with the maximum number caught between 500 and 600m both by day and night. The maximum number of adults, which were all at an early stage of maturity, was in the 800-(680)m day N113 haul and in the 660-(510)m night haul, possibly indicating a diel vertical migration of the adult population.

S. planctonis f. zetesios is a mesopelagic species and Pierrot-Bults (1982) states that it is found mainly between 500 and 900m.

Sagitta planctonis f. planctonis Steinhaus, 1896
(Size range in the N113 hauls 5-24mm)

In the N113 series of hauls the majority of specimens were caught by day in the top 100m with a secondary population around 450-500m. All except one of the specimens were juveniles. Only four specimens were caught in the NF70V hauls, two in the NN hauls and none in the RMT 1 hauls. The results do not provide any conclusive information on its vertical distribution except to show clearly, especially in the N113 day hauls, the almost total depth separation from S. planctonis f. zetesios. Pierrot-Bults (1975) states that S. planctonis f. planctonis is adapted to higher temperatures than S. planctonis f. zetesios and this factor controls their depth distributions at different latitudes.

Neither Faure (1952) nor Furnestin (1957) record this species off the Moroccan Coast. Alvarino (1964) considered it to be mesoplanktonic but David (1956) thought it to be a separate species from S. planctonis f. zetesios and believed it to be epipelagic.

Sagitta enflata Grassi, 1881
(Size range in the N113 hauls 7-16mm)

In the N113 hauls Sagitta enflata was caught mainly in the hauls above 100m and in the RMT 1 hauls it was only caught in the 10-0m day haul and the 25-12m night haul. It was absent in the NN surface night hauls. In the shallow N113 hauls all the specimens were adult and, overall, only two juveniles were caught. S. enflata is not represented well enough in this series of hauls to draw any conclusions about its depth distribution.

Alvarino (1965) described S. enflata as an epipelagic species. Faure (1952) found this species off the Moroccan Coast and Furnestin (1957) called it a warm water species with a variable distribution depending mainly on temperature and found only a few specimens in her shallow hauls. Germain and Joubin (1916) recorded quite a few specimens from around the Canary Islands.

Sagitta bipunctata Quoy and Gaimard, 1827
(Size range in the N113 hauls 7.5-14mm)

Only eighteen specimens were caught in the N113 series of hauls of which four must be considered contaminants, and all but two were adult specimens. However, S. bipunctata was caught in the RMT 1 hauls, with more juveniles than adults in the 10-0m day haul, and only juveniles in the 10-0m night haul. In the other two RMT 1 night hauls only adults were caught, suggesting that the adult population spreads downwards at night. Only two specimens were caught in the NN hauls, one adult and one juvenile.

S. bipunctata is considered to be a cosmopolitan epipelagic species (Alvarino 1964). Germain and Joubin (1916), Faure (1952) and Furnestin (1957) all record it from the Canary Islands and Moroccan Coast area.

Sagitta friderici Ritter-Zahony, 1911
(Size range in the N113 hauls 6-8.5mm)

Only five specimens were caught in the N113 hauls, two in the 85-(50)m day haul, one in the 100-(50)m night haul and two in the deepest day haul where they must be considered as contaminants. None of the other nets caught any specimens. Its rarity in this series of hauls is probably due to the fact that it is a neritic species.

Faure (1952) found S. friderici the most abundant chaetognath off the Moroccan Coast and the specimens which Germain and Joubin (1916) recorded as S. bipunctata are considered by her to be S. friderici. Furnestin (1957) reported numerous specimens, but never below 300m, and classified S. friderici as a neritic species, typical of coastal waters in this area. Alvarino (1965) also describes this species as neritic and epipelagic.

DISCUSSION

One of the main features of the N113 chaetognaths as a whole collection is the difference in numbers caught during the day (26,804) and at night (10,963). Such a disparity in numbers has also been recorded in other groups e.g. copepods (Roe 1972a). The suggestion of inadequate sampling of the 0-50m layer by the N113 has already been mentioned and the results obtained from the RMT 1 shallow

hauls in the 0-50m layer seem to confirm this. So one of the reasons for the difference in total day and night numbers of the N113 series could be the diel vertical migration of the epipelagic species into the top 50m of the water column at night. However, the decrease in numbers at night of the deeper living species e.g. Eukrohnia hamata, Sagitta decipiens and Krohnitta subitlis remains unexplained. Similar discrepancies were noticed and possible explanations discussed for euphausiids (Baker 1970) and copepods (Roe 1972a). Although no flow measurements were made, the N113 hauls were all fished for approximately 1 hour under similar conditions.

In general the vertical distributions of the species found in this present study conform well with previous reports (Alvarino 1964, 1965; Pierrot-Bults 1982; Cheney 1982). The fact that the deepest N113 hauls were only fished down to 960m prevented the deeper living species and more mature specimens of others from being sampled.

A difference in the depth distribution of juveniles and adults was found for some species. In the two deepest living chaetognaths caught in the N113 series, Sagitta macrocephala and Eukrohnia fowleri, the adult population was deeper than the juvenile one. There was an increase in size and maturity with depth as also was the case for S. lyra. It is also possible that the most mature specimens of S. planctonis f. zetesios occurred below 960m as only juveniles and adults at an early stage of maturity were caught. In E. hamata and S. decipiens the adults tended overall to be deeper and increasing in size with depth but not as distinctly as in S. lyra. Cheney (1982) also found that larger specimens of S. decipiens were caught at progressively deeper levels in the western north Atlantic.

There is also a marked separation in the depth distribution of S. planctonis f. planctonis and S. planctonis f. zetesios in the N113 results. Baker (1970) found that for the euphausiids in mainly non migrant genera there is a marked tendency towards the vertical segregation of species of the same genera. Foxton (1970b) found stratification of species in the decapoda and Pugh (1974) found very little overlap in the vertical distribution of certain congeneric species of siphonophore.

Diel vertical migration has been reported in chaetognaths by many authors. Light is considered to be an important controlling factor as well as temperature

and salinity (Russell 1931; Cheney 1982). Differences in migratory behaviour in juveniles and adults in some species have also been observed (Russell 1931; Cheney 1982; Pierrot-Bults 1982).

In this study most of the epipelagic species appear to undergo a small scale diel vertical migration within a limited depth range, either as a whole population or as juveniles and adults. Some epipelagic species, such as S. serratodentata migrate right up to the surface, others such as P. draco do not extend that far. Definite conclusions on diel vertical migration occurring in the mesopelagic chaetognaths are difficult to reach because of the complication of the unexplained disparity in day/night numbers. For example, the apparent reverse diel vertical migration of S. decipiens could well be an artifact due to this numerical decrease. A diel vertical migration of two bathyepalgic species, E. fowleri and S. macroscephala was indicated in these results.

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