



# Horizontal and vertical distribution of Chaetognatha in the upper 1000 m of the western Sargasso Sea and the Central and South-east Atlantic

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## ABSTRACT

The chaetognath abundance, species richness and bathymetric distribution in the upper 1000 m in two regions of the Atlantic Ocean is discussed based on samples collected on two cruises, one to the Sargasso Sea (Northwest Atlantic) on board the R/V *R.H. Brown* in April 2006, the other along the eastern boundary of the Atlantic (Canary Islands to South Africa) on board the FS *Polarstern* in November 2007. During both cruises the MOCNESS-1 was used for the sampling. Seventeen species were found in the Sargasso Sea (Ron Brown Cruise) and twenty along the eastern boundary of the Atlantic (the Polarstern Cruise). *Sagitta hispida* and *Krohnitta mutabii* were restricted to the Sargasso Sea, and *Sagitta tasmanica*, *S. gazellae*, *Eukrohnia macroneura* and *Krohnitta pacifica* to the East Atlantic. In the East Atlantic the most abundant species were *Pterosagitta draco*, *Sagitta enflata*, *S. serratodentata* and *Krohnitta subtilis*, and in the Sargasso Sea, the most abundant species in Stations 1 and 2 was *Sagitta minima*. In the other stations *S. serratodentata*, *S. enflata*, *Pterosagitta draco* and *Krohnitta subtilis* were most abundant. *Sagitta zetesios*, *S. planctonis*, *S. decipiens*, *S. sibogae* and *Eukrohnia fowleri* were present at all stations but always in low numbers.

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## 1. Introduction

Chaetognatha is a strictly marine phylum, which comprises about 100 pelagic species and about 40 benthic ones. In pelagic waters they are predators mainly of copepods and play an important role in the foodwebs, whereas in benthopelagic layers they are detritus feeders (Casanova, 1986a). They are ubiquitous in the ocean occurring at all depths from the surface to the bottom, and from the coastal waters to the open ocean. Their highest abundances are in the epipelagic layer, and diminish with increasing depth. Generally the epipelagic species are smaller than the meso- and bathypelagic ones, and warm water species are smaller than coldwater species. Many mesopelagic species show diurnal vertical migration. The greatest species richness is found in the mixed epi- and mesopelagic. In the Atlantic species richness is lower than in the Indian Ocean, which in turn is lower than in the Pacific. The usual number of species in the open ocean in the subtropical and tropical Atlantic is about 20 and most of these species have worldwide distributions.

Two dedicated plankton cruises were held in 2006 and 2007 by the Census of Marine Zooplankton, a Census of Marine Life project; one to the Sargasso Sea (Northwest Atlantic) on board the R/V *R.H. Brown* in April 2006, the other along the eastern

boundary of the Atlantic (Canary Islands to South Africa) on board the FS *Polarstern* in November 2007. The main objective of these cruises was to sample macrozooplankton quantitatively within the whole water column with special focus on the under-sampled meso and bathypelagic depth zones.

In this paper the results of sampling the upper 1000 m will be discussed for species richness, horizontal and vertical distribution, and abundance of Chaetognatha. Results of sampling below 1000 m will be dealt with in a later paper.

## 2. Material and methods

Fig. 1 shows the tracks and stations of the two cruises in the Atlantic. The Sargasso Sea samples are from seven tows at five stations (1–5), the East Atlantic samples are from four tows at 4 stations (2, 3, 6 and 8) (Fig. 1). During both cruises, the same nets were used for sampling; a MOCNESS-1 was used for sampling the upper 1000 m, and a MOCNESS-10 specially fitted with a similar fine 335  $\mu\text{m}$  mesh for the layers 1000–5000 m (Wiebe et al., 1985).

In the Sargasso Sea samples were collected at different times of the day and night, whereas in the East Atlantic all the samples were collected in the evening, approximately between 19.00 h and 23.00 h.

The MOCNESS-1 has a mouth opening of 1 m<sup>2</sup> and a mesh size of 335  $\mu\text{m}$ . It is a multiple sampling system fitted with 9 nets which are opened sequentially during an oblique tow. The first net (sample #0) was fished, as the sampler was being lowered

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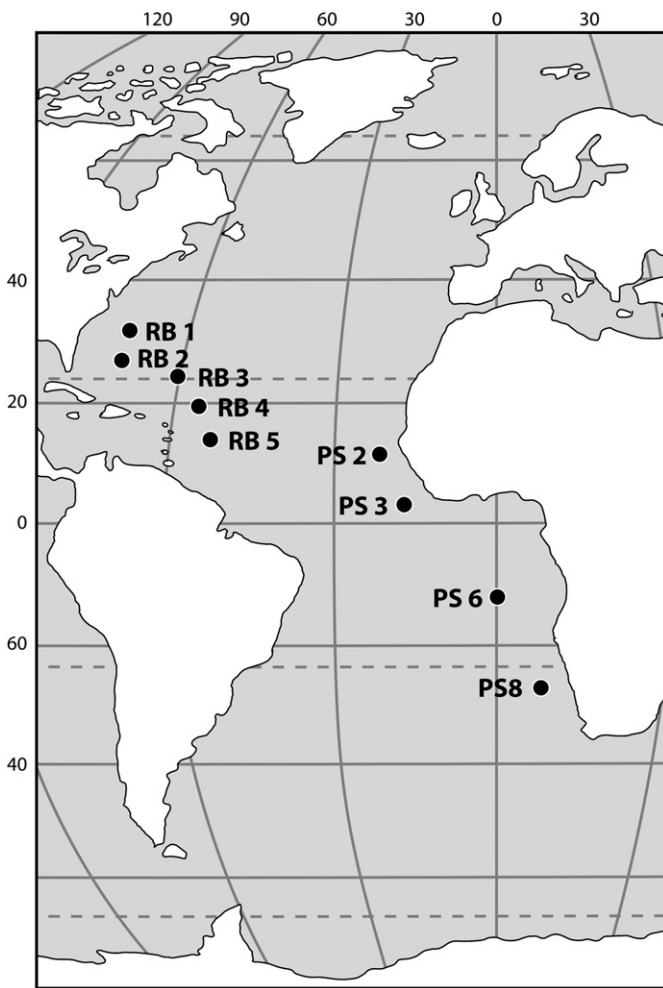


Fig. 1. Cruise tracks of the R/V *R.H. Brown* and the FS *Polarstern*.

from the surface to 1000 m, where the next net was opened. Sample #1 (referred to as net #1) was collected as the net was hauled in from 1000–800 m, sample #2 from 800–600 m, sample #3 from 600–400 m, sample #4 from 400–200 m, sample #5 from 200–100 m, sample #6 from 100–50 m, sample #7 from 50–25 m, and sample #8 from 25–0 m. The samples collected in net #0 have not been used in this study. The volumes of water filtered are recorded in real time by the flow meter data transmitted via the conducting cable to the control panel onboard ship.

After the sampler was retrieved the catch from each net was split. One half was immediately fixed in 4% borax buffered formaldehyde/seawater, the other half was split again into a ¼ fraction that was used as a source of live specimens and the other ¼ fraction was immediately fixed in 100% ethanol.

This study is based on the samples preserved in formaldehyde, which were, if necessary, split again and the species were identified and counted using a dissecting microscope. The results were then calculated for the total sample.

### 3. Results and discussion

#### 3.1. Species composition and overall abundance

Table 1 lists the species found during the two cruises. Seventeen species were found in the Sargasso Sea collections and twenty in the East Atlantic collections.

Table 1

List of species found in the Sargasso Sea (Ron Brown) and the East Atlantic (Polarstern).

Ron Brown	Polarstern
<i>Eukrohnia fowleri</i> Von Ritter-Zahoney, 1909	<i>Eukrohnia fowleri</i>
<i>Eukrohnia hamata</i> (Möbius, 1875)	<i>Eukrohnia hamata</i> <i>Eukrohnia macroneura</i> Casanova, 1986
<i>Krohnittia mutabii</i> Alvarino, 1969 <i>Krohnittia subtilis</i> (Grassi, 1881)	<i>Krohnittia subtilis</i> <i>Krohnittia pacifica</i> (Aida, 1897)
<i>Sagitta bipunctata</i> Quoy & Gaimard, 1827	<i>Sagitta bipunctata</i>
<i>Sagitta decipiens</i> Fowler, 1905 <i>Sagitta enflata</i> Grassi, 1881	<i>Sagitta decipiens</i> <i>Sagitta enflata</i> <i>Sagitta gazellae</i> Von Ritter-Záhony, 1909
<i>Sagitta hexaptera</i> d'Orbigny, 1843 <i>Sagitta hispida</i> Conant, 1895 <i>Sagitta lyra</i> Krohn, 1853 <i>Sagitta macrocephala</i> Fowler, 1905	<i>Sagitta hexaptera</i> <i>Sagitta lyra</i> <i>Sagitta macrocephala</i> <i>Sagitta maxima</i> (Conant, 1896) <i>Sagitta minima</i>
<i>Sagitta minima</i> Grassi, 1881 <i>Sagitta planctonis</i> Steinhaus, 1896 <i>Sagitta serratodentata</i> Krohn, 1853 <i>Sagitta sibogae</i> Fowler, 1906	<i>Sagitta planctonis</i> <i>Sagitta serratodentata</i> <i>Sagitta sibogae</i> <i>Sagitta tasmanica</i> Thomson, 1947
<i>Sagitta zetesios</i> Fowler, 1905 <i>Pterosagitta draco</i> (Krohn, 1853)	<i>Sagitta zetesios</i> <i>Pterosagitta draco</i>

The quantitative data are shown in Table II for the Sargasso Sea and in Table III for the East Atlantic. The overall abundances for the two regions are compared in Table IV. In the East Atlantic population densities were very similar between the 4 stations with total numbers per m<sup>2</sup> sea surface in the upper 1000 m ranging between 933 and 807. In the Sargasso Sea the pattern was different. At Stations 1 and 2 chaetognath abundances were much higher than either in the East Atlantic or at the other Sargasso Sea stations mainly because of the very high number of *Sagitta minima*. At Stations 1 and 2 chaetognaths were particularly abundant between 1153 and 3053 specimens per m<sup>2</sup> sea surface over 0–1000 m. However, at the other Sargasso Sea stations abundances were lower than in the East Atlantic, ranging between 333 and 768 per m<sup>2</sup>. At Stations 1 and 2 the temperature-salinity profiles showed isothermal 18 °C water (MODE) from just subsurface to more than 400 m deep (Wiebe, this volume), which may have created favourable stable conditions

The bathymetric data showed that that the epipelagic realm between 200–0 m harboured the greatest densities of specimens contributing 80 and 92% of the total in both study areas. The disparity between the epipelagic and deeper layers in terms of biomass was probably less because the species inhabiting the deeper layers are larger, but we do not have data on wet or dry weight to quantify the differences in biomass.

A great variation in n/m<sup>2</sup> was observed in earlier studies. Pierrot-Bults (1982) reported 951/m<sup>2</sup> in the upper 500 m, which was considerably less than Deevey and Brooks (1971) and Deevey (1971) who reported numbers between 2,500/m<sup>2</sup> and 5,580/m<sup>2</sup> in the top 500 m. Such a wide disparity could either be the result of difference in the mesh size of the samplers used or indicate that there are wide fluctuations in abundances caused either by seasonal or local hydrographic differences. The most abundant species in the East Atlantic were *Pterosagitta draco*, *Sagitta enflata*, *S. serratodentata* and *Krohnittia subtilis*.

In the Sargasso Sea the most abundant species in Stations 1 and 2 was *Sagitta minima*. This species was either not present or only in low numbers in the other stations. As said above at

**Table II**Ron Brown stations. Number of specimens per 1000 m<sup>3</sup> at different depths (net 1–8) and number of specimens per m<sup>2</sup> sea surface.

Species	net 1	net 2	net 3	net 4	net 5	net 6	net 7	net 8	n/m2	n/m2
<b>MOC-1 sta 1/1 Ron Brown 06.19 h</b>										
Sagitta macrocephala	48	2								10
Eukrohnia fowleri	6									1
Eukrohnia hamata cf	22	10								6
Sagitta zetesios		14								2
Sagitta planctonis cf				48	38	32	32			20
Sagitta lyra	9		3	263	977					197
Sagitta decipiens	14	16								5
Krohnitta subtilis	38	48			128	32	448	544		93
Sagitta serratodentata				64	224	704	1824	1912		259
Sagitta sibogae				64						11
Sagitta hexaptera				188	132	64	128	416		89
Pterosagitta draco						576	576	1024		88
Sagitta enflata				96	288	1152	2624	1912		465
Sagitta minima						2336	2528	7392		530
Sagitta bipunctata							64	32		6
Sagitta hispida										
Krohnitta mutabbii										
damaged/unidentified										
TOTAL	76	86.7	67	723	1787	4896	8224	13232		
volume filtered/1000	1.0349	1.1548	1.3193	1.1551	0.6551	0.4140	0.3845	0.5049		
<b>N/1000 m<sup>3</sup></b>	<b>73</b>	<b>75</b>	<b>51</b>	<b>626</b>	<b>2728</b>	<b>11826</b>	<b>21389</b>	<b>26207</b>		
<b>N/m<sup>2</sup></b>	<b>15</b>	<b>15</b>	<b>10</b>	<b>125</b>	<b>273</b>	<b>591</b>	<b>535</b>	<b>655</b>	<b>2219</b>	
<b>N/m<sup>2</sup> 1000–200 m</b>									<b>165</b>	
<b>N/m<sup>2</sup> 200–0 m</b>									<b>2054</b>	
<b>MOC-1 sta 1/2 Ron Brown 18.03 h</b>										
Sagitta macrocephala	18									4
Eukrohnia fowleri	14	4								4
Eukrohnia hamata		10								2
Sagitta zetesios	2	4								1
Sagitta planctonis cf				2			16			3
Sagitta lyra		34	14	114						30
Sagitta decipiens		12	6	20						7
Krohnitta subtilis		18	10	18	48	256	176	64		99
Sagitta serratodentata						64	498	340		43
Sagitta sibogae				108		288				73
Sagitta hexaptera				4	64		272	102		62
Pterosagitta draco					8	112	112	32		42
Sagitta enflata				2	200	934	1536	864		515
Sagitta minima					24	560	560	128		202
Sagitta bipunctata						48		16		11
Sagitta hispida										
Krohnitta mutabbii										
damaged/unidentified	10	10	20	62						
TOTAL	44	92	50	330	344	2262	3170	1546		
volume filtered/1000	0.8024	0.9249	0.8204	1.1936	0.4717	0.2640	0.1780	0.2722		
<b>N/1000 m<sup>3</sup></b>	<b>55</b>	<b>99</b>	<b>61</b>	<b>276</b>	<b>729</b>	<b>8568</b>	<b>17809</b>	<b>5680</b>		
<b>N/m<sup>2</sup></b>	<b>11</b>	<b>20</b>	<b>12</b>	<b>55</b>	<b>73</b>	<b>428</b>	<b>445</b>	<b>142</b>	<b>1187</b>	
<b>N/m<sup>2</sup> 1000–2000 m</b>									<b>98</b>	
<b>N/m<sup>2</sup> 200–0 m</b>									<b>1089</b>	
<b>MOC-1 sta 2/3 Ron Brown 00.42 h</b>										
Sagitta macrocephala	16	12	18							7
Eukrohnia fowleri	12	2								4
Eukrohnia hamata		4								1
Sagitta zetesios		8								1
Sagitta planctonis cf										0
Sagitta lyra		6	92	10	518	704				92
Sagitta decipiens										
Krohnitta subtilis		26		18	58	322	320	156		60
Sagitta serratodentata				16	116	655	5392	9419		1445
Sagitta sibogae			22	36	76					13
Sagitta hexaptera			2	20	82	90		106		32
Pterosagitta draco					72	2880	816	64		204
Sagitta enflata				16	66	416	1920	290		141
Sagitta minima					8	2356	7264	4268		951
Sagitta bipunctata				26	4			26		7
Sagitta hispida										
Krohnitta mutabbii										
damaged/unidentified				12	179	256	188	516		
TOTAL	28	58	134	154	1179	7679	15900	14845		
volume filtered/1000	1.087	1.313	1.716	1.624	1.297	0.907	0.645	0.198		
<b>N/1000 m<sup>3</sup></b>	<b>26</b>	<b>44</b>	<b>78</b>	<b>95</b>	<b>909</b>	<b>8466</b>	<b>24651</b>	<b>74975</b>		
<b>N/m<sup>2</sup></b>	<b>5</b>	<b>9</b>	<b>16</b>	<b>19</b>	<b>91</b>	<b>423</b>	<b>616</b>	<b>1874</b>	<b>3053</b>	

Table II (continued)

Species	net 1	net 2	net 3	net 4	net 5	net 6	net 7	net 8	n/m2	n/m2
<b>N/m2 1000–200 m</b>									<b>49</b>	
<b>N/m2 200–0 m</b>									<b>3005</b>	
<b>MOC-1 sta 2/4 Ron Brown 06.58 h</b>										
Sagitta macrocephala	16	4								5
Eukrohnia fowleri	4	12	2							5
Eukrohnia hamata	24	16	12	8						15
Sagitta zetesios										0
Sagitta planctonis cf			2	2	2	10				4
Sagitta lyra	6	24	16	16	6	100				39
Sagitta decipiens	4	6			6					4
Krohnitta subtilis	12	2			8	4	188	76		44
Sagitta serratodentata				24		98	742			152
Sagitta sibogae					6					1
Sagitta hexaptera		2	24	10	72	384	28			92
Pterosagitta draco					4	140	560			70
Sagitta enflata					4	656	624			109
Sagitta minima			8	2	8	484	3128			340
Sagitta bipunctata			112	18	26	2	70			42
Sagitta hispida										
Krohnitta mutabii										
damaged/unidentified						96		1348		
TOTAL	44	54	50	194	72	418	2596	5834		
volume filtered/1000	0.7828	0.7548	0.8219	0.8960	0.4121	0.2037	0.1509	0.3058		
<b>N/1000 m3</b>	<b>56</b>	<b>72</b>	<b>61</b>	<b>217</b>	<b>175</b>	<b>2052</b>	<b>17203</b>	<b>19078</b>		
<b>N/m2</b>	<b>11</b>	<b>14</b>	<b>12</b>	<b>43</b>	<b>17</b>	<b>103</b>	<b>430</b>	<b>477</b>	<b>1153</b>	
<b>N/m2 1000–200 m</b>									<b>81</b>	
<b>N/m2 200–0 m</b>									<b>1027</b>	
<b>MOC-1 sta 3/8 Ron Brown 19.03 h</b>										
Sagitta macrocephala	8							no data		1
Eukrohnia fowleri	2									0
Eukrohnia hamata										
Sagitta zetesios	2	8								2
Sagitta planctonis cf			2							0
Sagitta lyra										
Sagitta decipiens		4	6		6					3
Krohnitta subtilis					96	2				11
Sagitta serratodentata				6	64	14	96			21
Sagitta sibogae					6					1
Sagitta hexaptera				16	256	4	10			34
Pterosagitta draco				4	608	12	6			72
Sagitta enflata				4	704	42	96			97
Sagitta minima				2	2	8	484			61
Sagitta bipunctata				10			224			30
Sagitta hispida										
Krohnitta mutabii										
damaged/unidentified						96				
TOTAL	12	12	8	42	1742	178	916			
volume filtered/1000	1.4841	1.0932	0.9766	1.1596	0.8722	0.6341	0.2008			
<b>N/1000 m3</b>	<b>8</b>	<b>11</b>	<b>8</b>	<b>36</b>	<b>1997</b>	<b>281</b>	<b>4562</b>			
<b>N/m2</b>	<b>2</b>	<b>2</b>	<b>2</b>	<b>7</b>	<b>200</b>	<b>7</b>	<b>114</b>		<b>333</b>	
<b>N/m2 1000–200 m</b>									<b>13</b>	
<b>N/m2 200–0 m</b>									<b>321</b>	
<b>MOC-1 sta 4/9 Ron Brown 15.21 h</b>										
species	net 1	net 2	net 3	net 4	net 5	net 6	net 7	net 8	n/m2	n/m2
Sagitta macrocephala	8									4
Eukrohnia fowleri	4									2
Eukrohnia hamata		14		8						4
Sagitta zetesios										0
Sagitta planctonis cf										0
Sagitta lyra		2	46	92	88	44				39
Sagitta decipiens			42							9
Krohnitta subtilis				12	40	12		36		6
Sagitta serratodentata						208	44	852		95
Sagitta sibogae				100	88	2		4		29
Sagitta hexaptera			28	56	360	88	28			54
Pterosagitta draco					56	448	484	128		68
Sagitta enflata						394	276	256		61
Sagitta minima										
Sagitta bipunctata						100	2	72		12
Sagitta hispida										
Krohnitta mutabii										
damaged/unidentified			36	192	168	96		116		
TOTAL	12	16	152	460	800	1392	834	1464		
volume filtered/1000	0.3631	1.0052	0.9082	0.9463	1.2303	1.0192	0.4091	0.2591		

Table II (continued)

Species	net 1	net 2	net 3	net 4	net 5	net 6	net 7	net 8	n/m2	n/m2
<b>N/1000 m3</b>	<b>33</b>	<b>16</b>	<b>167</b>	<b>486</b>	<b>650</b>	<b>1366</b>	<b>2039</b>	<b>5650</b>		
<b>N/m2</b>	<b>7</b>	<b>3</b>	<b>33</b>	<b>97</b>	<b>65</b>	<b>68</b>	<b>51</b>	<b>141</b>	<b>466</b>	
<b>N/m2 1000–200 m</b>									<b>140</b>	
<b>N/m2 200–0 m</b>									<b>326</b>	
<b>MOC-1 sta 5/11 Ron Brown 09.16 h</b>										
<i>Sagitta macrocephala</i>	30							no data		7
<i>Eukrohnia fowleri</i>	12	24	2							9
<i>Eukrohnia hamata</i>	16	4								4
<i>Sagitta zetesios</i>			2							0
<i>Sagitta planctonis</i> cf										0
<i>Sagitta lyra</i>			10	60	640					146
<i>Sagitta decipiens</i>			2							0
<i>Krohnitta subtilis</i>			2	44	42					18
<i>Sagitta serratodentata</i>					252	96	1454			93
<i>Sagitta sibogae</i>				82	10					18
<i>Sagitta hexaptera</i>			6		198	48				46
<i>Pterosagitta draco</i>					68	264	1036			57
<i>Sagitta enflata</i>					54	488	3836			133
<i>Sagitta minima</i>					36		32			8
<i>Sagitta bipunctata</i>						8	2			1
<i>Sagitta hispida</i>							118			3
<i>Krohnitta mutabbii</i>							80	24		7
damaged/unidentified			2	16	70	96				
TOTAL	58	28	20	208	1370	1080	6502			
volume filtered/1000	0.9224	0.8392	0.9446	1.0437	0.4753	0.6644	1.1252			
<b>N/1000 m3</b>	<b>63</b>	<b>33</b>	<b>21</b>	<b>199</b>	<b>2882</b>	<b>1626</b>	<b>5779</b>			
<b>N/m2</b>	<b>13</b>	<b>7</b>	<b>4</b>	<b>40</b>	<b>288</b>	<b>81</b>	<b>144</b>		<b>577</b>	
<b>N/m2 1000–200 m</b>									<b>63</b>	
<b>N/m2 200–0 m</b>									<b>514</b>	
<b>MOC-1 sta 5/12 Ron Brown 17.25 h</b>										
<i>Sagitta macrocephala</i>	16	28								11
<i>Eukrohnia fowleri</i>	16	48								17
<i>Eukrohnia hamata</i>	8	60	10							20
<i>Sagitta zetesios</i>										0
<i>Sagitta planctonis</i> cf										0
<i>Sagitta lyra</i>			20							3
<i>Sagitta decipiens</i>		4	6		6					3
<i>Krohnitta subtilis</i>				88	130		2			34
<i>Sagitta serratodentata</i>					60	10	632	2104		200
<i>Sagitta sibogae</i>				198						29
<i>Sagitta hexaptera</i>				134	348					77
<i>Pterosagitta draco</i>					122	132	210	158		65
<i>Sagitta enflata</i>					2	262	1160	598		160
<i>Sagitta minima</i>					126			8		21
<i>Sagitta bipunctata</i>							16	32		3
<i>Sagitta hispida</i>						4	106	144		18
<i>Krohnitta mutabbii</i>						80				12
damaged/unidentified			12	198	244	14		310		
TOTAL	40	140	48	618	1038	502	2124	3356		
volume filtered/1000	1.0170	0.7035	1.1894	1.3857	0.6051	0.3419	0.3641	0.3611		
<b>N/1000 m3</b>	<b>39</b>	<b>199</b>	<b>40</b>	<b>446</b>	<b>1715</b>	<b>1468</b>	<b>5834</b>	<b>9294</b>		
<b>N/m2</b>	<b>8</b>	<b>40</b>	<b>8</b>	<b>89</b>	<b>172</b>	<b>73</b>	<b>146</b>	<b>232</b>	<b>768</b>	
<b>N/m2 1000–200 m</b>									<b>145</b>	
<b>N/m2 200–0 m</b>									<b>623</b>	

Stations 1 and 2 hydrographic conditions with 18° MODE water might be the cause for these high numbers. In Stations 3 and 4 *S. serratodentata*, *S. enflata*, *Pterosagitta draco* and *Krohnitta subtilis* were most abundant. This is comparable to the data in the East Atlantic. At Station 5 *Sagitta lyra* and *S. hexaptera* were the most abundant. At Station 5 there were distinctly different water properties; sea surface temperatures were around 27 °C and sea surface salinity was very low, because of the fresh water outflows extending from the South. In general, the surface low salinity water comes from the South, and at about 100 m Subtropical Under Water (SUW) coming from the North introduces higher salinities, and at about 800 m Antarctic Intermediate Water (AAIW) results in a salinity minimum (Wiebe, this volume). Several species were usually present but were never common, namely *Sagitta zetesios*, *S. planctonis*, *S. decipiens*, *S. sibogae* and

*Eukrohnia fowleri*. This was also the case in samples from Bermuda (Pierrot-Bults, 1982).

### 3.2. Horizontal distribution patterns

The horizontal distributions show that subtropical and tropical species are for the most part distributed throughout both sampling regions, as was expected from previous studies of the biogeography of Chaetognatha of the Atlantic Ocean (Thiel, 1938; Furnestin, 1957, 1959; Owre, 1962; Ducret, 1962, 1968; Alvarino, 1969; Aurich, 1971; Deevey and Brooks, 1971; Bückmann and Kapp, 1973; Pierrot-Bults, 1982, 1997; Pierrot-Bults and Nair, 1991; Van der Spoel and Heyman, 1982; Casanova, 1986a,b, 1999);

**Table III**Polarstern stations. Number of specimens per 1000 m<sup>3</sup> at different depths (net 1–8) and number of specimens per m<sup>2</sup> sea surface.

species	net 1	net 2	net 3	net 4	net 5	net 6	net 7	net 8	n/m2	n/m2
<b>MOC-1 Sta 2 Polarstern</b>										
Sagitta macrocephala	36									5
Eukrohnia fowleri	32	56								12
E.hamata/macroneura	12		56	20	76					2
Sagitta zetesios	8	4	28							4
Sagitta planctonis cf				4	8	4	16			3
Sagitta maxima cf		4								1
Sagitta lyra		8	56	160		80				36
Krohnitta subtilis				56	68	112	232	12		42
Sagitta serratodentata				4	4	120	160	444		48
Sagitta sibogae			20		48					7
Sagitta hexaptera					8		120	216		22
Pterosagitta draco					4	60	1904	764		194
Sagitta enflata						236	400	940		104
Sagitta minima						12	328			45
Sagitta bipunctata								148		8
Krohnitta pacifica						4		4		1
damaged/undidentified		28	24	76	72	232	2280	1024		
TOTAL	88	100	164	340	288	860	5440	3552		
volume filtered/1000	1.538	1.380	1.965	1.403	1.156	0.586	0.326	0.445		
<b>N/1000 m3</b>	<b>57</b>	<b>72</b>	<b>83</b>	<b>242</b>	<b>249</b>	<b>1468</b>	<b>16687</b>	<b>7982</b>		
<b>n/m2</b>	<b>12</b>	<b>15</b>	<b>17</b>	<b>49</b>	<b>25</b>	<b>73</b>	<b>417</b>	<b>200</b>	<b>807</b>	
<b>N/m2 1000–200 m</b>									<b>92</b>	
<b>n/m2 200–0 m</b>									<b>716</b>	
<b>MOC-1 Sta 3 Polarstern</b>										
Sagitta macrocephala	16	4								3
Eukrohnia fowleri	26	47								13
E.hamata/macroneura	24	16	68	28						18
Sagitta zetesios	2	5	8							2
Sagitta planctonis cf						56				4
Sagitta maxima cf	1									0
Sagitta lyra			24	76	36	152				25
Krohnitta subtilis				8	140	952				80
Sagitta serratodentata						64		340		47
Sagitta sibogae				56	48					9
Sagitta hexaptera					8	40		7		4
Pterosagitta draco					24	528				40
Sagitta enflata					216	2632		936		208
Sagitta minima						144				6
Krohnitta pacifica						80		88		17
Sagitta bipunctata								8		1
damaged/undidentified		12	24	96	408	1832	1496	164		
TOTAL	69	84	124	264	880	6480	1496	1379		
volume filtered/1000	1.432	0.987	1.661	1.839	1.447	0.682	0.243	0.200		
<b>N/1000 m3</b>	<b>48</b>	<b>85</b>	<b>75</b>	<b>144</b>	<b>608</b>	<b>9501</b>	<b>6156</b>	<b>6895</b>		
<b>N/m2</b>	<b>10</b>	<b>17</b>	<b>15</b>	<b>29</b>	<b>61</b>	<b>475</b>	<b>154</b>	<b>172</b>	<b>933</b>	
<b>N/m2 1000–200 m</b>									<b>71</b>	
<b>n/m2 200–0 m</b>									<b>862</b>	
<b>MOC-1 Sta 6 Polarstern</b>										
Sagitta macrocephala	8	4								2
Eukrohnia fowleri	7	47								8
E.hamata/macroneura	48	72	24	104						35
Sagitta zetesios		9	12							3
Sagitta planctonis cf				16	20					4
Sagitta maxima cf										
Sagitta lyra		8	12	64	168					23
Krohnitta subtilis			4	12	84	144	48			18
Sagitta serratodentata					484	320	896	1232		245
Sagitta sibogae										
Sagitta hexaptera					76	952	144	40		69
Pterosagitta draco					72	2880	816	64		204
Sagitta enflata					116	952	320	48		80
Sagitta minima					4					0
Krohnitta pacifica										
Sagitta bipunctata							16	8		
damaged/undidentified		12	12	80	588	528	336	328		
TOTAL	63	152	64	276	1612	5776	2576	1720		
volume filtered/1000	1.087	1.313	1.716	1.624	1.297	0.907	0.645	0.198		
<b>N/1000 m3</b>	<b>58</b>	<b>116</b>	<b>37</b>	<b>170</b>	<b>1243</b>	<b>6368</b>	<b>3994</b>	<b>8687</b>		
<b>N/m2</b>	<b>12</b>	<b>23</b>	<b>8</b>	<b>34</b>	<b>124</b>	<b>318</b>	<b>100</b>	<b>217</b>	<b>836</b>	
<b>N/m2 1000–200 m</b>									<b>76</b>	
<b>n/m2 200–0 m</b>									<b>760</b>	
<b>MOC-1 Sta 8 Polarstern</b>										

Table III (continued)

species	net 1	net 2	net 3	net 4	net 5	net 6	net 7	net 8	n/m2	n/m2
<i>Sagitta macrocephala</i>	16	4								3
<i>Eukrohnia fowleri</i>	26	47								10
<i>E.hamata/macroneura</i>	24	16	68	28						16
<i>Sagitta zetesios</i>	2	5	8							1
<i>Sagitta planctonis</i> cf						56				5
<i>Sagitta maxima</i> cf										
<i>Sagitta gazellae</i> cf	2									0
<i>Sagitta lyra</i>			24	76	36	152				29
<i>Krohnitta subtilis</i>				8	140	952				94
<i>Sagitta serratodentata</i>						64		340		25
<i>Sagitta sibogae</i>				56	48					12
<i>Sagitta hexaptera</i>					8	40		40		6
<i>Pterosagitta draco</i>					24	528		1232		116
<i>Sagitta enflata</i>					216	2632		48		246
<i>Sagitta minima</i>						144				12
<i>Krohnitta pacifica</i>						80				7
<i>Sagitta bipunctata</i>								8		0
<i>Sagitta tasmanica</i>								4		0
damaged/unidentified		12	24	96	408	1832	1496	164		
TOTAL	70	84	124	264	880	6480	1496	1836		
volume filtered	1.538	1.380	1.965	1.403	1.156	0.586	0.326	0.445		
<b>N/1000 m3</b>	<b>46</b>	<b>61</b>	<b>63</b>	<b>188</b>	<b>761</b>	<b>11058</b>	<b>4589</b>	<b>4126</b>		
<b>N/m2</b>	<b>9</b>	<b>12</b>	<b>13</b>	<b>38</b>	<b>76</b>	<b>553</b>	<b>115</b>	<b>103</b>	<b>919</b>	
<b>Total N/m2 1000–200 m</b>									<b>72</b>	
<b>Total N/m2 200–0 m</b>									<b>847</b>	

Table IV

Comparison of abundance per depth layer (net 1–8) between the Sargasso Sea (RB) and East Atlantic (PS) samples.

	1000–800 m	800–600 m	600–400 m	400–200 m	200–100 m	100–50 m	50–25 m	25–0 m	Total per m2
<b>N/1000 m3 RB</b>									
MOC-1 sta 1/1	73	75	51	626	2728	11826	21389	26207	2219
MOC-1 sta 1/2	55	99	61	276	729	8568	17809	5680	1187
MOC-1 sta 2/3	26	44	78	95	915	8466	24651	74975	3053
MOC-1 sta 2/4	56	72	61	217	175	2025	17203	19078	1153
MOC-1 sta 3/8	8	11	8	36	1997	281	4562		333
MOC-1 sta 4/9	33	16	167	486	650	1366	2039	5650	466
MOC-1 sta 5/11	63	33	21	199	2882	1626	5779		577
MOC-1 sta 5/12	42	213	42	475	1719	1498	5850	9294	768
<b>N/1000 m3 PS</b>									
MOC-1 Sta 2	57	72	83	242	249	1468	16687	7982	807
MOC-1 Sta 3	48	85	75	144	608	9501	6156	6895	933
MOC-1 Sta 6	58	116	37	170	1243	6368	3994	8687	836
MOC-1 Sta 8	46	61	63	188	761	11058	4589	4126	919

the exceptions were *Sagitta hispida* and *Krohnitta mutabbii*, which were restricted to Station 5 of the Sargasso Sea.

*Sagitta hispida* is a neritic species found in shelf areas (Almeido Prado, 1959, 1961, 1967; Bumpus and Pierce, 1955; Pierce, 1951, 1953, 1954; Deevey, 1971), such species are not expected to occur at oceanic stations, although Alvarino (1969) reported this species as being more widely distributed in tropical oceanic waters.

*Krohnitta mutabbii* was described as a tropical Atlantic species by Alvarino (1969) but was subsequently synonymised with *K. pacifica* by other authors working in the Atlantic (Almeido Prado, 1961, 1967; Deevey, 1971; Kolesnikov, 1966; Legaré and Zoppi, 1961; Grant, 1963; McLelland and Heard, 1991; Michel, 1984; Pierce, 1951; Pierce and Wass, 1962; Wroblewski and Cheney, 1984). The description and figures in the literature seem to agree with those of *K. pacifica*, but this species is essentially a tropical Indo-Pacific species with a restricted 30°N–30°S distribution (Pierrot-Bults and Nair, 1991). However the characteristics of the specimens found in this study agree with the original description, and the habitus is very different when one is familiar

with the Indo-Pacific species. So the specimens of *Krohnitta* found in Station 5 have been identified as *K. mutabbii* and not as *K. pacifica*. According to Alvarino (1969) *K. mutabbii* is present throughout the tropical Atlantic. The closing of the Panama isthmus could have split a once circumglobal tropical species into separate Atlantic and Indo-Pacific populations, which subsequently evolved into two closely related species, e.g. *K. pacifica* and *K. mutabbii*. Molecular analyses should resolve this matter.

*Krohnitta pacifica* is reported regularly in low numbers in the south-eastern Atlantic (Ducret, 1962, 1968; Duro and Gili, 1996; Furnest, 1959; Hernández, 1985; Hernández and Lozano, 1987). Occasionally an Agulhas ring spawned from the Agulhas retroversal to the south of South Africa advects northwards into the Southern Atlantic entraining Indian Ocean water and presumably planktonic species more typical of the Southern Indian Ocean (Lutjeharms, 1996). So *K. pacifica* may be episodically introduced into the southern Atlantic. But there is also the possibility that the specimens mentioned in the literature may have been misidentified *K. mutabbii*.

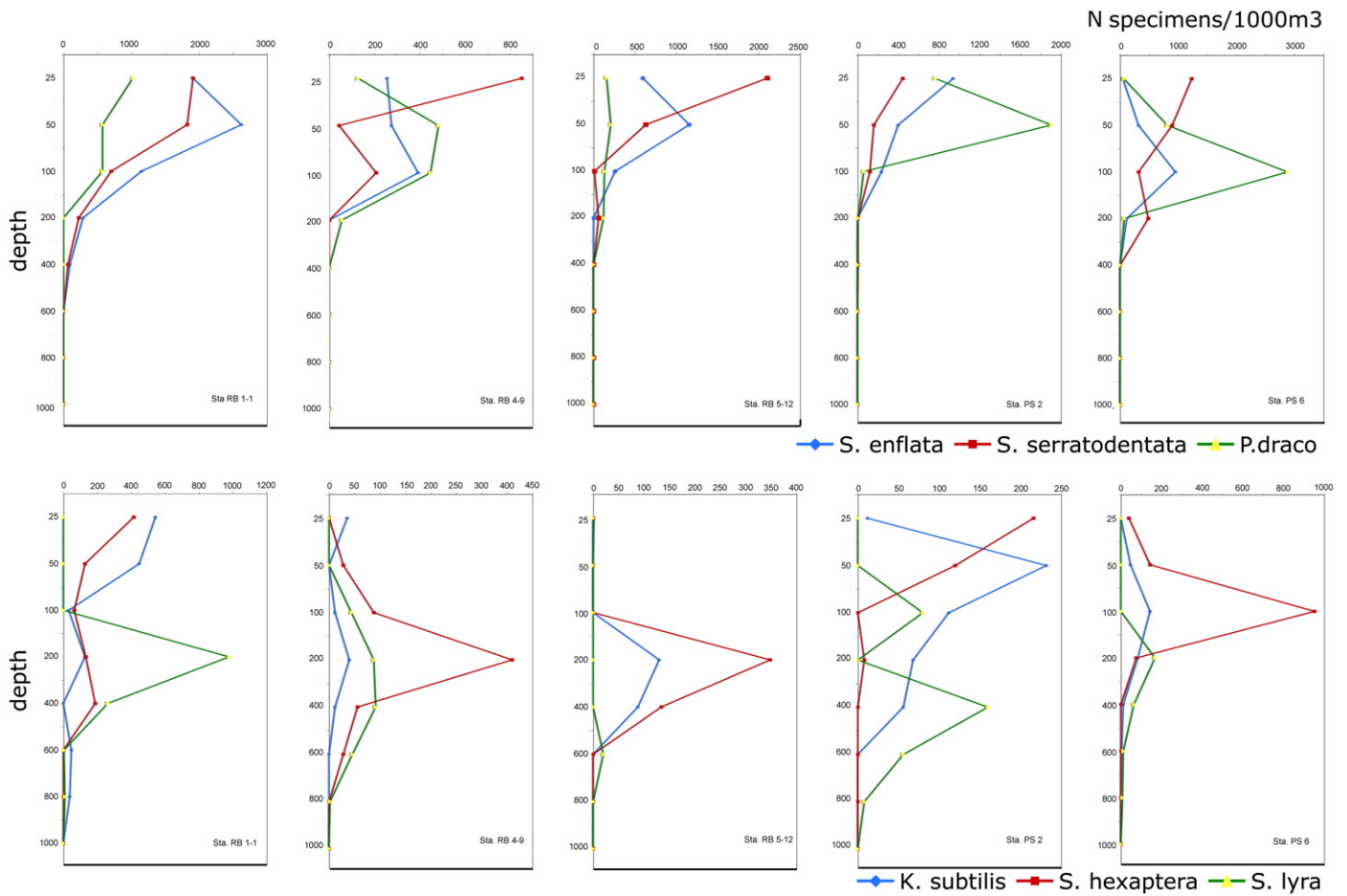


Fig. 2. Vertical distribution of number of specimens of *Sagitta enflata*, *S. serratodentata* and *Pterosagitta draco* (upper panel) and *Sagitta hexaptera*, *S. lyra* and *Krohnitta subtilis* (lower panel) in 3 stations from the Sargasso Sea and two stations from the East Atlantic. Note that scales on the number of specimens are all different.

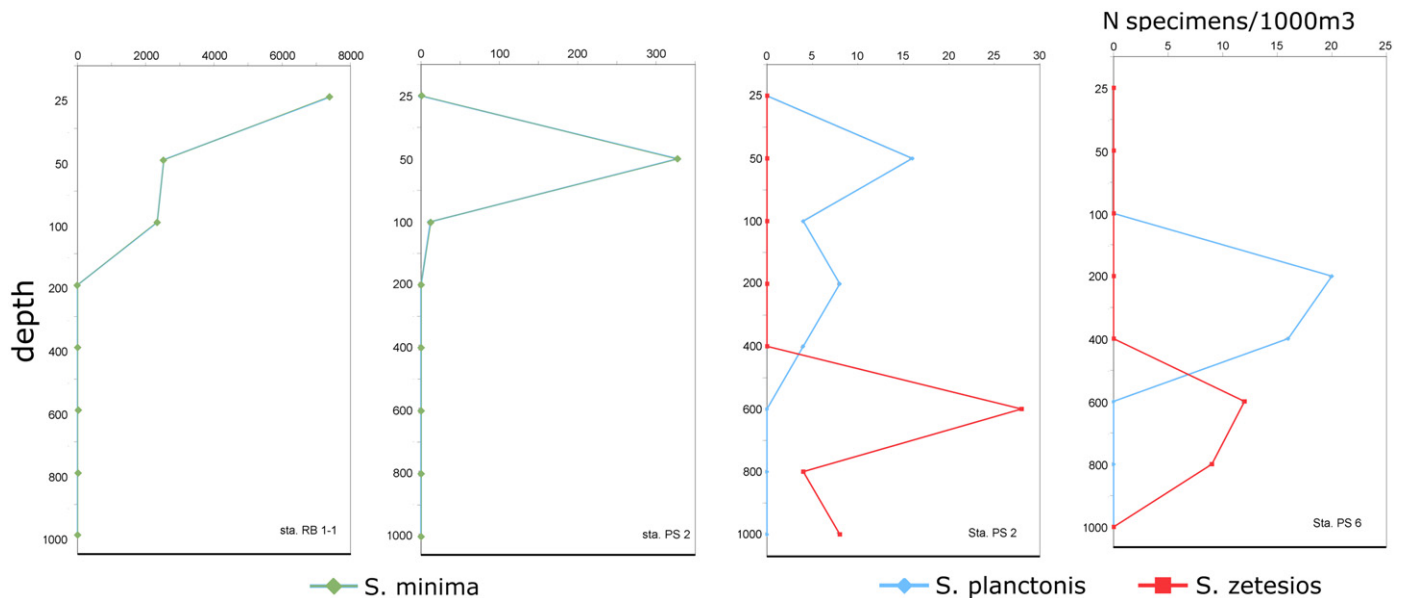


Fig. 3. Vertical distribution of number of specimens of *Sagitta minima* from sta RB 1 to 1 (Sargasso Sea) and sta PS 2 (East Atlantic) and *S. planctonis* and *S. zetesios* from stations PS 2 and 6 from the East Atlantic. Note that scales on the number of specimens are all different.

The T-S curves from Station 5 (Wiebe, this volume) shows that the hydrographic structure was very different from the other stations in the Sargasso Sea. So, our hypothesis is that both *Sagitta*

*hispid* and *Krohnitta mutabii* were being advected from the coastal waters of South America in the current that flow from the south into the Sargasso Sea.



*Eukrohnia macroneura* and a few specimens of *Sagitta maxima* were only found in the east Atlantic in layers below 800 m.

*Sagitta tasmanica* and *S. gazellae* were only present in very small numbers in the most southern station, e.g. Station 8 in the east Atlantic. *S. tasmanica* is found in the Benguela upwelling region and not expected so far out at sea. *S. gazellae* is a (sub)Antarctic species and also an expatriate in these waters.

### 3.3. Bathymetric distribution patterns

The vertical distributions we observed follow the known patterns for Chaetognatha in the open ocean (Nair, 1978; Pierrot-Bults, 1982; Pierrot-Bults and Nair, 1991). Fig. 2 shows the vertical distribution of the more abundant species from west to east and from north to south (Sargasso Sea Station 5 tow 11, Station 4 tow 9 and Station 1 tow 1, and East Atlantic Stations 2 and 6). Fig. 3 shows the vertical distribution of *S. minima* in two stations (Sargasso Sea Station 1 and East Atlantic Station 2), and *S. planctonis* and *S. zetesios* in East Atlantic Stations 2 and 6, they were not found or very scarce in the other samples.

The upper 50 m of the water column in the Sargasso Sea were dominated by *S. serratodentata*, *S. enflata* and *S. minima*. The latter species was present in very high numbers at Station 1. In the East Atlantic the dominant species in the upper 50 m were *S. enflata*, *S. serratodentata* and *P. draco*, with the latter as the most numerous one. *S. minima* was found at Station 2 but the numbers were very much lower than in the Sargasso Sea. *Pterosagitta draco* was the dominant species in the layer from 100–200 m in the Sargasso Sea at Station 4 tow 9 where the juveniles were occurring from 0–25 m, the adults were found between 100–200 m. In the East Atlantic at Stations 2 and 6 this species showed high abundancies at 50 m and 100 m respectively.

Among the species found in the collections, *Krohnitta subtilis*, *Pterosagitta draco*, *Sagitta bipunctata*, *S. enflata*, and *S. minima* are typical circumglobal epipelagic chaetognaths of the Atlantic, Indian and Pacific Oceans with a 40°N–40°S distribution. The presence of both *S. serratodentata* and *S. minima* in samples from much deeper layers, are considered to be contaminants leaking into the nets during their retrieval (Pierrot-Bults, 1982).

*Sagitta lyra* and *S. hexaptera* occur over a wide depth range of 800–50 m but the main concentrations of adults were at shallow-mesopelagic depths between 200–400 m, *S. lyra* occurred slightly deeper than *S. hexaptera*. Especially in the East Atlantic samples the adults of *S. lyra* were found mainly below 400 m. *Krohnitta subtilis* occurred from 600–0 m, but showed ontogenetic vertical distribution, with the adults occurring deeper in the East Atlantic than in the Sargasso Sea.

The adults of *S. planctonis* had a shallow mesopelagic range between 400–600 m, at deeper depths it was replaced by the similar looking species *S. zetesios*. The juveniles of both species are known to occur at shallower depths but in these samples only *S. planctonis* was found between 25 and 400 m.

On both cruises *Eukrohnia fowleri* was only found below 600 m which is to be expected for a deep meso- to bathypelagic species.

*E. hamata* is a species observed to show tropical submergence. It is found much more superficially at higher latitudes but its occurrence below 600 m in the Sargasso Sea waters is to be expected (Thiel, 1938; Pierrot-Bults, 1982; Pierrot-Bults and Nair, 1991) in these subtropical and tropical waters. In the East Atlantic this species was found at shallower depths than in the Sargasso Sea probably because the temperatures were lower in the more superficial layers in these locations.

The low abundances of *Sagitta macrocephala* in the samples may have a somewhat different explanation. *S. macrocephala* is a

bathypelagic species that is mainly distributed below 1000 m depth.

*Eukrohnia macroneura* is another deep-living species (Casanova, 1986b).

A very few juvenile specimens in the East Atlantic seemed to belong to *Sagitta maxima*. This species is also reported as showing tropical submergence so that the northern and southern populations of this cold water species are thought to be connected, but this has not been proven adequately.

The pattern for each species to have a more or less distinct and separate layer of maximum abundance has previously been described at a Station near Bermuda (Pierrot-Bults, 1982). The bathymetric patterns of species distribution derived from the two cruises are very similar, although the East Atlantic samples were all made in the evening between about 19.00 and 23.00 h, whereas the samples collected in the Sargasso Sea were taken both by day and by night (see Table III), but no clear indication of diurnal vertical migration is apparent in the data from these samples. The numbers of species generally decline with increasing depth with the greatest richness at 200–400 m in both Station 2 in the Sargasso Sea and Station 6 in the east Atlantic where the

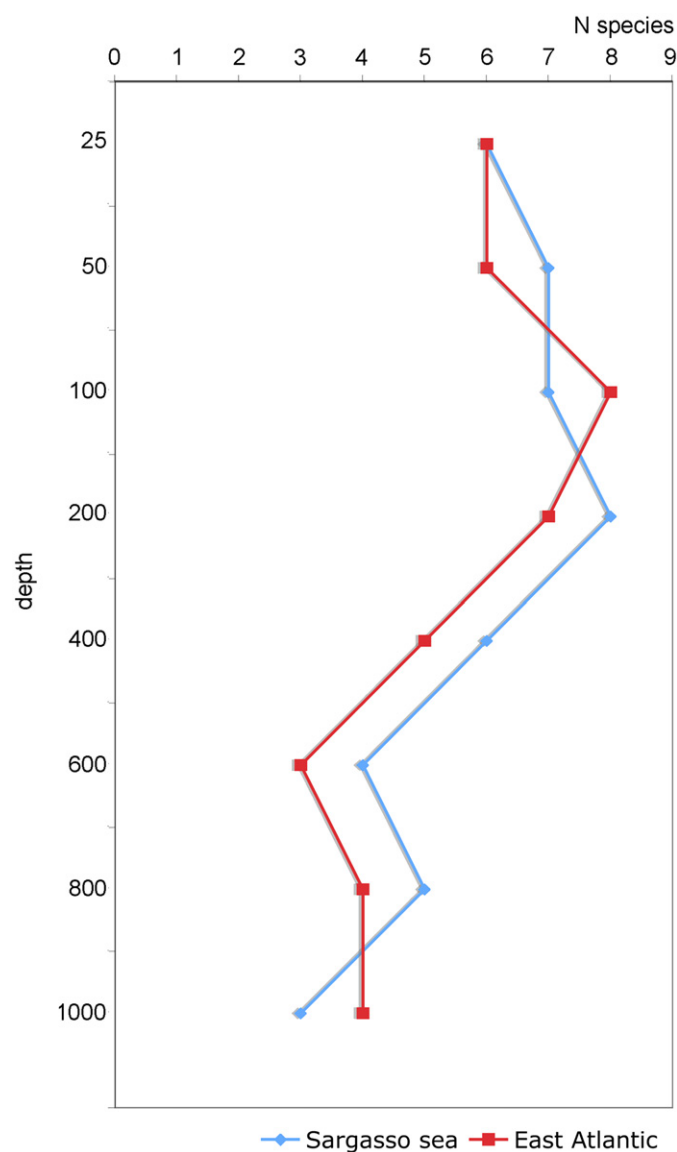


Fig. 4. Vertical distribution of species richness in Station 2 tow 3 in the Sargasso Sea (A) and Station 6 in the East Atlantic (B) samples.

epipelagic and mesopelagic mix (Fig. 4). In contrast Pierrot-Bults (1982) reported the highest species richness at 800 m in the Bermuda area.

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