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Midwater trawl catches of adolescent and adult anguilliform fishes during the Sargasso Sea Eel Expedition 1979

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ABSTRACT: During the research program on the biology and migration of *Anguilla* spp. carried out with F.R.V. "Anton Dohrn" in 1979, approximately 1300 adolescent and adult anguilliform individuals were caught covering 8 families, 10 genera and 12 species. Observations on each of these species, including horizontal and vertical distributional patterns, are dealt with herein. The appearance of various species in hauls and the absence of adult *Anguilla* spp. in the catches obtained are discussed.

INTRODUCTION

The research program carried out with F.R.V. "Anton Dohrn" during its 210th (92) cruise (Part II) from 19 March to 9 May 1979 can be subdivided into two periods of different strategy. The main purpose of the first one was the exploration of the migration and biology of *Anguilla* spp. in the Sargasso Sea. Part of this program was the capture of adult eels by an experimental midwater trawl. The second period was devoted to the *Anguilla*-problem as well as to a research program on faunal communities in selected depth-zones. This period also included a series of midwater trawl hauls along an Atlantic transect from the Sargasso Sea to the European slope at 48 °N 08 °W via the Azore Islands. R. V. "Friedrich Heincke" which was present in the Sargasso Sea during the same period occasionally made midwater trawl hauls for the same purpose. In this paper we describe anguilliform fish and discuss the reasons for the absence of anguillid adults from our hauls. The results for other deep sea fishes are presented elsewhere.

TRAWLING TECHNIQUES

Except for a few specimens of migrating silver-eels which have been caught in deep layers of the Shetland-Faroe Channel (Ernst, 1975; Boëtius, pers. communication), no records are known concerning catches of *Anguilla* spp. during its spawning migration to the Sargasso Sea.

As far as is presently known with the aid of different research techniques, i. e. tracking experiments in the North East Atlantic (0–500 m) (Tesch, 1978 a, b) or in the

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Sargasso Sea (0–700 m) (Tesch, 1982); analysis of stomach content of predatory fish in the North East Atlantic (depth 730 m) (Reinsch, 1968) and photographs in the Bahama area in a depth of 2000 m (Robins et al., 1979), migrating eels do not seem to be linked to a special depth-layer but may swim near the surface and in different depths down to 2000 m or even more.

Using the facilities of F.R.V. "Anton Dohrn", which is built as a stern-trawler, we were able to employ a commercial herring-trawl for our research program. This Engel-trawl (Schärfe, 1969) has a circumference of 1600 meshes and a mouth area of about 700 m^2. It can be towed at depths ranging from about 50 m to a maximum of 2000 m. The stretched mesh size is 200 mm at the mouth of the gear, and diminishes successively to 40 mm at its codend. For our program the codend was provided with an inlet of 4 mm mesh size for the purpose of gathering large and small fishes as well. For midwater-trawling, the engine power used was 1680 kw for a speed of 3 to 4 kn.

During the first period (Sargasso Sea) the gear was towed at different depths (step-hauls), starting in the deepest layer, followed by steps of 30 to 100 m for 10 to 20 min in each layer. Trawling was carried out during daylight as well as after dusk.

During the second period (Transect Sargasso Sea to Bay of Biscay) the gear was towed in one layer only for each haul. According to the methods used on board F.R.V. "Walther Herwig" and F.R.V. "Anton Dohrn" at previous oceanic transects, trawling-time ranged from 15 min for shallower layers to one hour for hauls below 1000 m.

Midwater catches in depths shallower than 1000 m were obtained after dusk only, while hauls deeper than 1000 m were carried out in daylight, except for one single night-haul.

As mentioned above, 8 additional trawling stations were carried out by R.V. "Friedrich Heincke". Owing to the much lower engine-power of this vessel a smaller herring-trawl with a circumference of 650 200 mm-meshes and a mouth area of about 110 m^2 only was used. Following the experiences in the North Sea, a 8.3 m long codend (mesh size: 20 to 10 mm) was used; with a maximum cable length of 750 m and a speed of 1 to 3 kn a maximum depth of 370 m could be attained. Actual depths of the trawl were obtained by a pressure sensing transmitter, receiving signals from a hydrophone below the ship (Tesch, 1982). Two hauls were performed during daylight, with the maximum cable length (duration 3 and 6 h). Of six night hauls two lasted about one hour (depth 160 and 300 m), four were hauls at different depths of 50 to 100 m depth each and lasting 4 to 6 h.

RESULTS

The geographical distribution of hauls made by "Anton Dohrn" and "Friedrich Heincke" in the Sargasso Sea are presented in Fig. 1 (Position of ship stations see Tesch, 1982). The transect of "Anton Dohrn" from the Sargasso Sea to the Bay of Biscay is roughly evident from Figs 2 to 4.

From a total of 66 hauls, 36 of which were carried out in the Sargasso Sea, we did not receive one adult *Anguilla* individual. As far as "Friedrich Heincke" is concerned, it has become obvious that the gear used is hardly suitable for catching adult or adolescent eels of any kind. Only three small specimens were collected from 8 hauls.

The "Anton Dohrn" collections of adolescent to adult anguilliform specimens in the Sargasso Sea (28 hauls) comprise 733 specimens. Taking the 58 hauls from the transect to

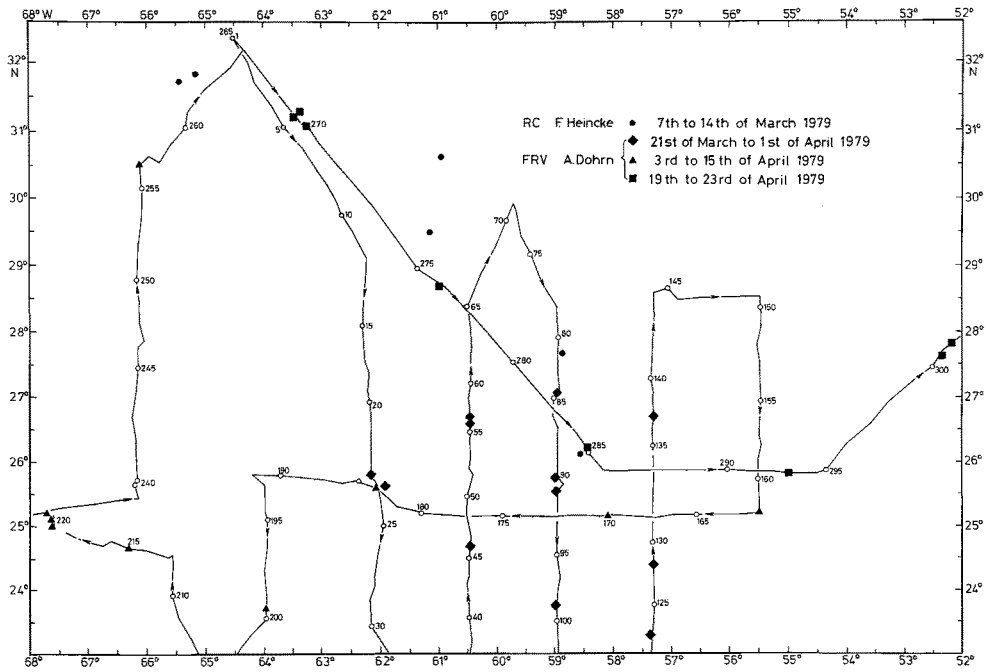

Fig. 1. Positions of pelagic trawl collections of "Anton Dohrn" and "Friedrich Heincke" in the Sargasso Sea. The numbered circles indicate each fifth station during the cruise of "Anton Dohrn"

Europe also into account, 1282 specimens were captured covering 8 families, 10 genera and 12 species. As shown by Figs 2–4, no essential differences exist between species occurrence in the Sargasso Sea and in the area from there to the Azores. The most common species *(Nemichthys scolopaceus, Serrivomer brevidentatus, Eurypharynx pelecanoides)* show no difference of occurrence even far north of the Azores when compared with the occurrence in southern areas.

About 80 % of the total collection was made up by two species only: *Serrivomer beani* (57 %) and *Eurypharynx pelecanoides* (23 %); the remaining 20 % cover 10 species.

27 hauls, including 9 step-hauls, were carried out in depths below 1000 m. These hauls brought a markedly higher diversity in species as well as higher numbers of specimens than hauls from shallower layers (Table 1).

Table 1. Number of species collected in different depths

Maximum trawling-depth (m)	Frequency in number								
	0	1	2	3	4	5	6	7	8
200	4	6	–	2	–	–	–	–	–
400	2	7	–	1	1	–	–	–	–
800	1	1	1	1	1	–	–	–	–
>1000	–	–	1	4	6	–	–	3	3

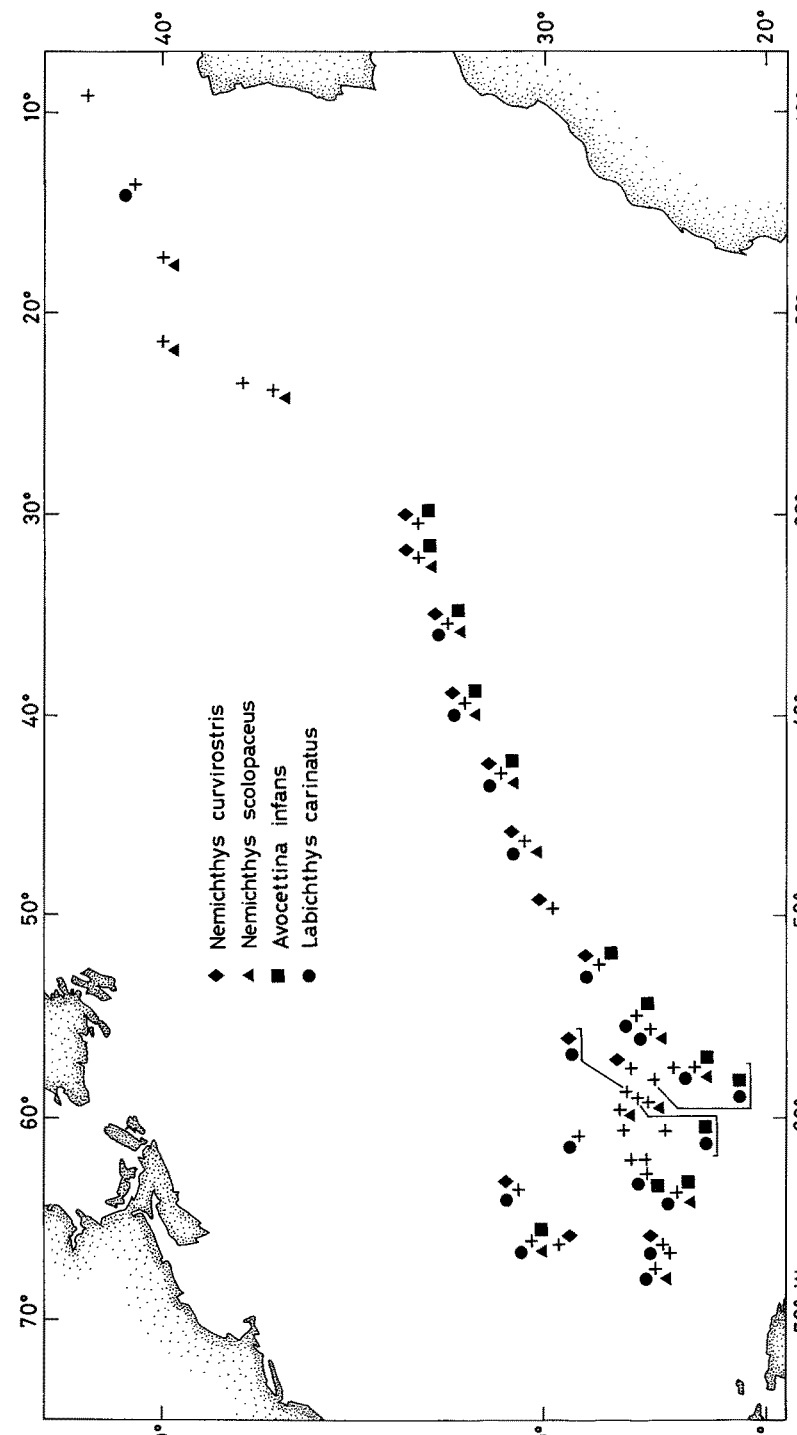

Fig. 2. Occurrence of *Nemichthys curvirostris, N. scolopaceus, Avocettina infans* and *Labichthys carinatus* at "Anton Dohrn" stations during the Sargasso Sea cruise

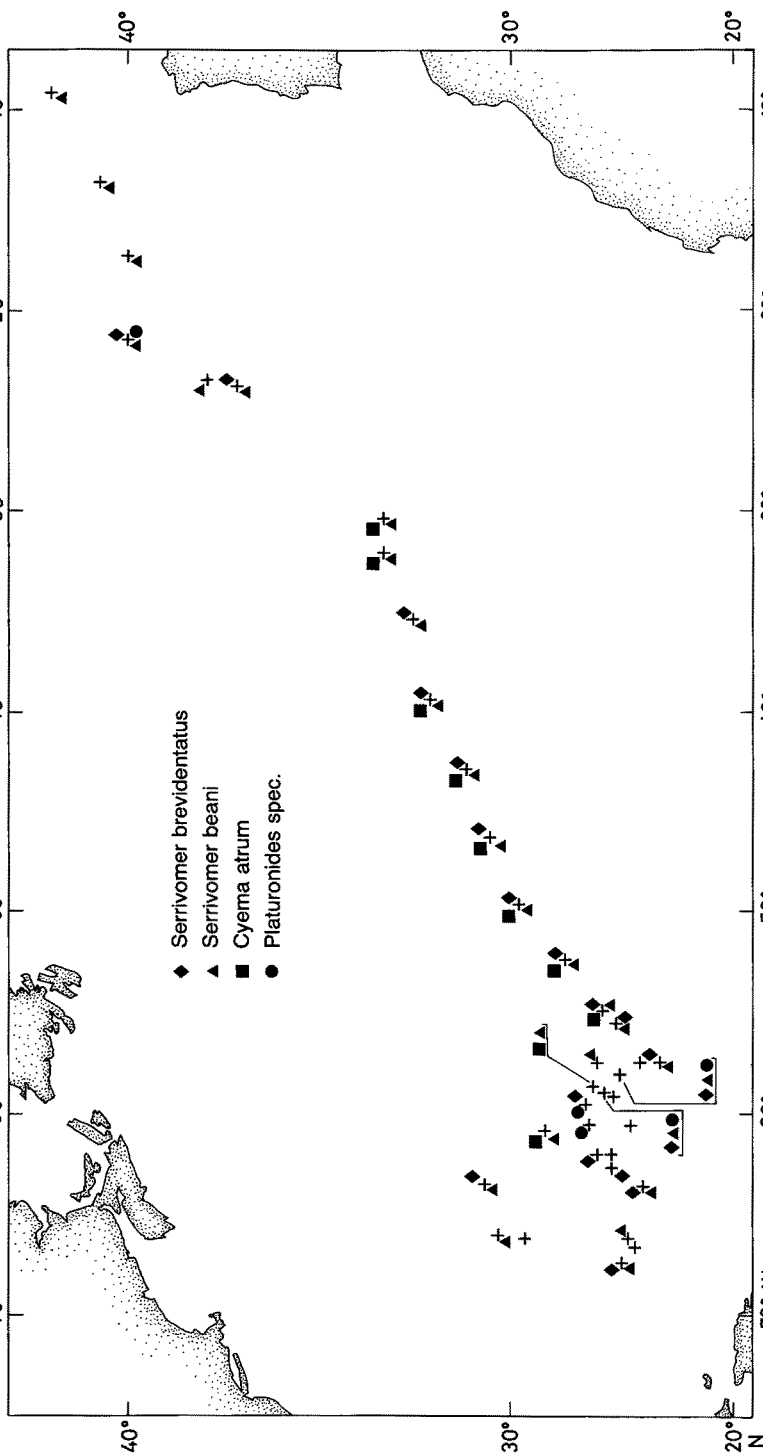

Fig. 3. Occurrence of *Serrivomer brevidentatus*, *S. beani*, *Cyema atrum* and *Platyronides* spec. at "Anton Dohrn" stations during the Sargasso Sea cruise

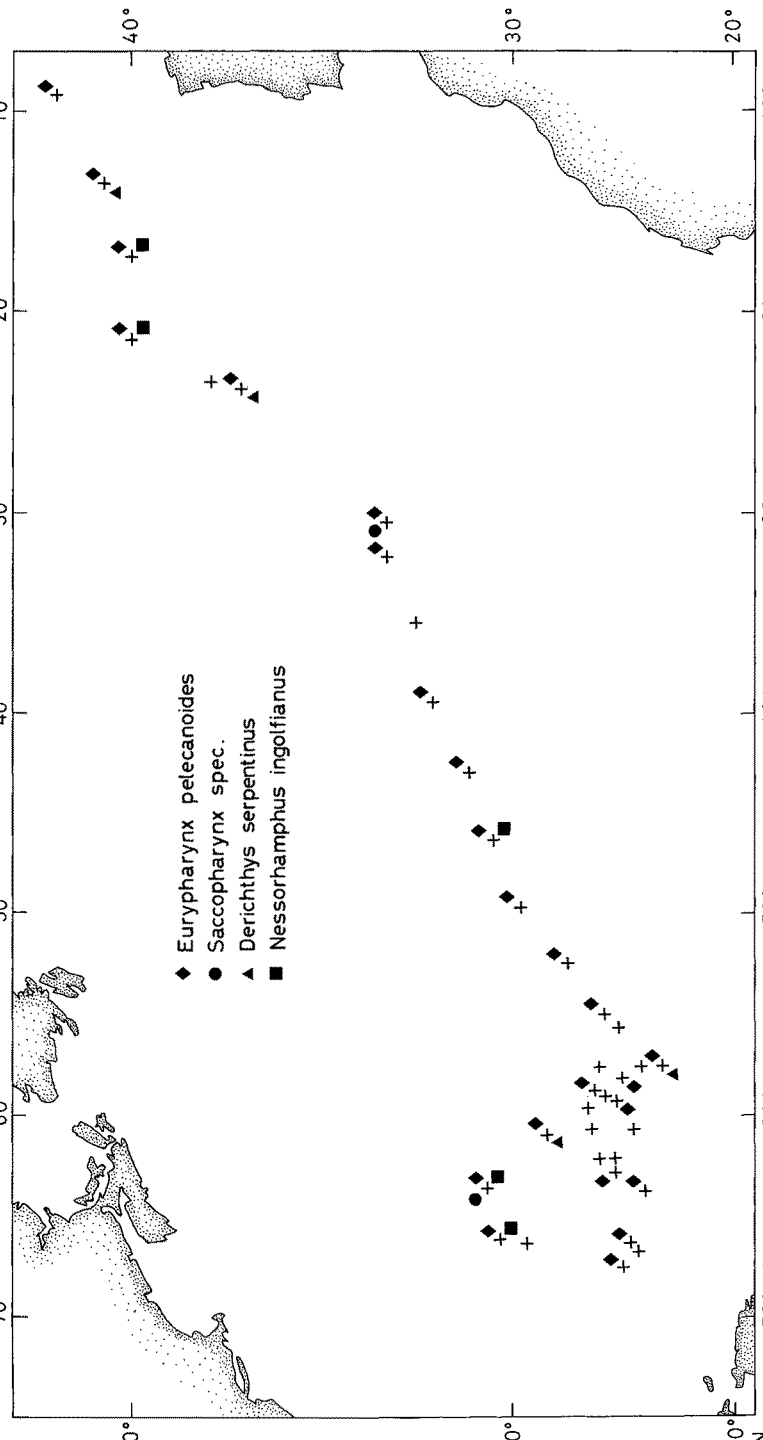

Fig. 4. Occurrence of *Eurypharynx pelecanoides*, *Saccopharynx* spec., *Derichthys serpentinus* and *Nessorhamphus ingolfianus* at "Anton Dohrn" stations during the Sargasso Sea cruise

Low numbers of species (2 or 3) in deep-sea hauls refer to the northern-most stations, which lie outside the distributional area of some species, and to step-hauls, carried out during daylight, towing in deep layers for a few minutes only.

Differences in the number of catches of adult eels according to depths possibly reflect differences in abundance of species. Moreover, it also could be due to the fact, that the net was towed for a period four times longer in deep hauls than in shallower ones. Table 2 shows the amount of specimens, collected during the 2nd period of the expedition (37 hauls) for three depth-layers and 12 species.

Survey of species

Nemichthys scolopaceus

"Anton Dohrn" station number and number of specimens (in brackets): Stations 5550 (1); 5588 (1); 5596 (1); 5627 (1); 5666 (1); 5702 (1); 5738 (1); 5760 (1); 5819 (1); 5825 (1); 5826 (2); 6827 (1); 5833 (1); 5834 (1); 5842 (1); 5850 (2); 5865 (2); 5877 (2); 5884 (1); 5885 (2); 5886 (1).

Nemichthys scolopaceus Richardson, 1848 (Fig. 2) is broadly distributed all over the area covered by the expedition, except for the northern-most stations at 45° to 48 °N. Thus, a slight gap in geographical distribution between 30 °N 50 °W and the Azore Islands, as reported by Nielsen & Smith (1978), can be closed now. The absence of samples from our northern-most stations is accidental, as records of this species are known from north of the 50° latitude.

8 specimens were collected from bathypelagic hauls; 13 from hauls shallower than 400 m, carried out after dusk (Table 1). This is in accordance with our findings from former cruises and indicates a possible nocturnal vertical migration of the species. Usually one, occasionally two specimens were caught per haul. Probably *N. scolopaceus* lives singly or in very small groups; samples of more than 5 specimens are exceptional and then usually refer to leptocephali and young adolescents.

Among the total of 17 specimens there was one ripe adult male only (Stat. 5623), measuring 512 mm total length (TL); 7 specimens having 750 to 890 mm TL were recognized as adult females. The remaining specimens, 160 to 470 mm long, were juveniles or adolescents.

Nemichthys curvirostris

Stations 5641 (2 spec.); 5720 (1); 5756 (3); 5772 (2); 5788 (2); 5805 (1); 5813 (1); 5819 (2); 5825 (1); 5826 (1); 5833 (1); 5842 (1); 5849 (2); 5852 (3).

The distribution pattern of *Nemichthys curvirostris* (Strömman, 1896) (Fig. 2), as represented in our catches, fits into the pattern of records given by Nielsen & Smith (1978) showing that *N. curvirostris* does not appear north of the 40° latitude. The species was frequently represented in the Sargasso Sea and along the transect south of the Azore Islands. 15 of the total of 20 specimens, collected at 13 stations, were caught by hauls going deeper than 1000 m. This may indicate a slight difference in vertical distribution betweeen this species and its congener *N. scolopaceus,* or in its behaviour as far as vertical migration is concerned. In accordance with the latter, only one or two, in exceptional cases three, specimens of *N. curvirostris,* were caught per haul. All specimens were adolescent or subadult; not one male was discovered.

Labichthys carinatus

Stations 5594 (1); 5602 (2); 5627 (4); 5666 (1); 5674 (1); 5688 (5); 5702 (2); 5720 (1); 5725 (1); 5731 (1); 5738 (6); 5760 (8); 5772 (4); 5780 (2); 5797 (4); 5805 (1); 5817 (1); 5819 (1); 5825 (2); 5833 (1); 5842 (1); 5894 (1).

Labichthys carinatus (Gill & Ryder, 1883) (Fig. 2) is distributed in all oceans but records are relatively rare. The only one from north of 40 °N is the type locality (41°13'N 66°00'50''W), a second record is known from north of 30 °N (32°12'N 64°36'W); all the rest were collected in the tropical zones between 29 °N and 21 °S. Our findings augment records for the Sargasso Sea as well as giving new records for Central North Atlantic, north of 30 °N from 30° to 50 °W. In 22 hauls we caught a total of 51 specimens, 49 of these in hauls fishing from 1200 m depth or deeper. The remaining two specimens were juveniles of 200 and 250 mm TL respectively. The former was caught after dusk at a depth of 306 and the latter by a step-haul, fishing from 800 m in daylight.

We are in accordance with Nielsen & Smith (1978) who characterized *L. carinatus* as a meso- to bathypelagic species, but our results indicate its higher preference for bathypelagic life. Usually one or two specimens were caught per haul but occasionally we collected 4 to 8 specimens, probably owing to a relatively high abundance of this species in our research-area. The majority of the specimens were juveniles, 157 to 590 mm long. Only a few were longer than 600 mm and apparently adult, but no studies of sex have been undertaken yet.

Avocettina infans

Stations 5594 (2); 5602 (3); 5627 (1); 5688 (1); 5702 (1); 5760 (3); 5772 (5); 5797 (3); 5805 (1); 5825 (8); 5833 (9); 5842 (4); 5849 (1); 5852 (1).

Avocettina infans (Günther, 1878) (Fig. 2) is broadly distributed in tropical and subtropical regions of all oceans, but is more abundant in the northern hemisphere (Nielsen & Smith, 1978). Our findings complement the only record known as yet from the Sargasso Sea and from the region between the Sargasso Sea and the Azores. In 14 hauls, all from below 1200 m, we caught a total of 43 specimens. The occurrence in deep layers can only be regarded as accidental but could also be due to the hydrographic conditions in the subtropical region.

From previous hauls carried out in the tropical Atlantic with F.R.V. "Walther Herwig" and F.R.V. "Anton Dohrn", we know this species to live in depths of 160 to 600 m as well, at least after dusk. If *A. infans* were adapted to a relatively narrow range of water temperature, it would live in much shallower depths in tropical zones than it does in subtropical ones. The species seems to be relatively abundant. Samples of 3 to 9 specimens were as frequent as samples of one or two only. Most specimens were juveniles; only 10 specimens, with lenghts varying between 500 and 600 mm, seem to be subadults or adults, but no special studies on sex and age have been undertaken yet.

Serrivomer beani

Stations 5594 (44); 5602 (31); 5627 (41); 5641 (2); 5666 (9); 5674 (27); 5688 (39); 5702 (15); 5720 (17); 5725 (16); 5738 (23); 5738 (47); 5760 (52); 5772 (23); 5780 (6); 5788 (6); 5797 (16); 5805 (14); 5812 (23) 5817 (12); 5825 (20); 5827 (1); 5833 (39); 5842 (42) 5843 (55); 5852 (37); 5865 (36); 5869 (2), 5875 (18); 5884 (8); 5893 (5); 5911 (7).

Serrivomer beani (Gill & Ryder, 1884) (Fig. 3) is broadly distributed in the Atlantic Ocean from 65 °N through the subtropics and tropics to the southern subtropical convergence at about 42 °S. *S. beani* is one of the most abundant mesopelagic eel species, if not the most abundant, in the Atlantic.

We always caught it when fishing deeper than 1000 m in the Sargasso Sea and along the transect, receiving on an average 25 specimens per haul. 11 specimens were collected from stephauls beginning at 600 and 800 m respectively. Six further samples of one or two specimens were collected from shallower hauls in less than 300 m. But these may not be real samples. At all doubtful stations, the haul was carried out immediately after the net had fished 1200 m deep or more. So we suspect that at least some of the fish from the greater depth remained in the net and consequently should be referred to the deeper haul. In 32 hauls – excluding the 6 mentioned above – we caught a total of 731 specimens, 710 coming from hauls deeper than 1000 m. The preference for bathypelagic life in *S. beani* could be due to the same hydrographical conditions as described for *A. infans*, as numerous specimens of *S. beani* were caught by F.R.V. "Walther Herwig" and "Anton Dohrn" in the tropical Atlantic in layers shallower than 600 m. Our smallest specimen measured 90 mm, the longest one 780 mm in TL. Studies on sex and age have not been undertaken yet but ripe females have been caught from at least one of the westernmost stations.

Serrivomer brevidentatus

Stations 5594 (2); 5602 (1); 5627 (7); 5666 (1); 5674 (2); 5688 (3); 5702 (2); 5738 (3); 5760 (1); 5772 (3); 5774 (2); 5797 (4); 5805 (1); 5812 (4); 5817; 5818 (3); 5825 (6); 5827 (4); 5833 (5); 5842 (5); 5865 (2).

Serrivomer brevidentatus (Roule & Bertin, 1929) (Fig. 3) is widely distributed in the Sargasso Sea and along our transect up to 41 °N, but is less frequent than its congener *S. beani*. The highest number of specimens caught was 7, received at station 5627 by a step-haul beginning at a depth of 1800 m. During previous cruises in the Atlantic with F.R.V. "Walther Herwig" and F.R.V. "Anton Dohrn" we caught *S. brevidentatus* from about 55 °N through the subtropics and tropics to about 37 °S. No records are known from other oceans so far.

In 20 hauls of the Sargasso Sea Expedition we caught a total of 58 specimens, 51 of which were collected by 18 hauls fishing deeper than 1000 m. Six juveniles (110 to 265 mm TL) were caught after dusk in 250 m and 380 m depth respectively. Both hauls were not preceeded by deeper ones. The remaining specimens were received from a step-haul after dusk, beginning at 800 m depth. Except for four specimens which were longer than 550 mm TL, all specimens seem to be juveniles, but no studies on sex and age have been carried out yet.

Platuronides sp.

Stations 5560 (3); 5588 (1); 5594 (1); 5602 (1); 5875 (1).

From 5 hauls in the Sargasso Sea we received 9 specimens of *Platuronides* sp.; an additional one was caught at station 5875 (45 °N), when the net was towed at a depth of 2000 m. 5 of the specimens from the Sargasso Sea were caught by net fishing below 1000 m, the remaining four by step-hauls, beginning at 600 m, after dusk. The specimens range in length from 111 to 470 mm TL.

The taxonomical status of *Platuronides* sp. and its respective relationship to *Serrivomer* spp. is uncertain and has come under discussion recently. The Serrivomeridae as a whole need to be revised.

Cyema atrum

Stations 5780 (4); 5788 (8); 5797 (2); 5805 (3); 5812 (1); 5817 (2); 5825 (6); 5827 (1); 5833 (6); 5849 (1); 5850 (1); 5852 (1).

Cyema atrum (Günther, 1878) (Fig. 3) is broadly distributed in all oceans but was regarded as relatively rare. The distributional pattern as given by Grey (1956) includes the tropical and southern Pacific from Lower California to north-east of New Zealand, the Indian Ocean from Maledives Islands to 50 °S and the Atlantic Ocean from 39 °N to 30 °S. Our findings fit into this pattern so far, as we caught *C. atrum* from the Sargasso Sea along the transect to 36 °N. But this does not indicate the northernmost distribution of this species: *C. atrum* was caught by F.R.V. "Walther Herwig" during the Overflow-Expedition in 1973 between about 55 °N and 62 °N. Further records of this species from the "Walther Herwig" and "Anton Dohrn" cruises to South America refer to the northern tropical Atlantic and to the South Atlantic from 5 °S to about 51 °S.

Grey calls *C. atrum* a bathypelagic species. We are in accordance with her as 34 out of 36 specimens were collected from hauls fishing deeper than 1200 m. But two records of adult specimens collected from 380 m and 350 m depth respectively (Stations 5827 and 5850) indicate occasional presence of this species in mesopelagic layers. *C. atrum* cannot be regarded explicitely as a rare species. It seems to live singly or in small groups. Usually we caught one or two specimens only but there are samples of three to 8 and – at a previous cruise of "Walther Herwig" – of up to a maximum of 17 specimens per haul. The smallest specimen taken during the present cruise was 95 mm, the largest one 122 mm standard length (SL). This is within the range of subadults and adults.

Derichthys serpentinus

Stations 5588 (1); 5627 (2); 5780 (1); 5865 (1); 5894 (1).

A total of six specimens of *Derichthys serpentinus* (Gill, 1884) (Fig. 4) were collected at three stations in the Sargasso Sea and at two additional stations north of the Azores Islands.

D. serpentinus is broadly distributed in the Atlantic and has been caught by F.R.V. "Walther Herwig" and F.R.V. "Anton Dohrn" from about 58 °N through the central Atlantic to about 40 °S by meso- to bathypelagic trawling, the shallowest positive haul at 200 m, the deepest one at 2000 m. It seems to live singly, as usually only one specimen is caught per haul. Two, three or four specimens per haul are exceptional. Our present records refer to juveniles and adults measuring from 176 to 349 mm TL; one specimen was in spawning condition (Stat. 5725).

Nessorhamphus ingolfianus

Stations 5760 (1); 5772 (1); 5875 (1); 5884 (1); 5818 (1).

Nessorhamphus ingolfianus (Schmidt, 1912) (Fig. 4) an oceanic form is known from all oceans, ranging in depth from the surface to bathypelagic realms. In the Atlantic it has been collected by F.R.V. "Walther Herwig" and "Anton Dohrn" from about 60 °N through the tropics to about 40 °S.

On the present cruise we received a total of 5 specimens, 3 collected in the Sargasso

Sea and 2 during the transect, north of the Azores Islands. Four of these specimens were taken in hauls deeper than 1000 m, the fifth one was caught in a depth between 155 and 195 m only and after dusk. A single adult of 656 mm TL was caught by a step-haul starting in 1800 m depth. The others were juveniles of 252 mm TL. According to our experiences, *N. ingolfianus* is rarely caught in midwater trawls, since on the occasion of our previous cruises this species was either missing completely, or was represented by only 1 or very exceptionally by 2 or 3 specimens.

Eurypharynx pelecanoides

Stations 5594 (6); 5602 (10); 5627 (13); 5688 (6); 5702 (10); 5720 (12); 5725 (15); 5738 II (8); 5738 IV (11); 5760 (32); 5772 (8); 5780 (16); 5788 (7); 5797 (9); 5805 (9); 5812 (11); 5817 (4); 5825 (19); 5833 (12); 5835 (1); 5849 (13); 5852 (16); 5865 (16); 5875 (4); 5884 (12); 5893 (7); 5911 (1).

Eurypharynx pelecanoides (Vaillant, 1882) (Fig. 4) is distributed in all oceans but records are more frequent from the Atlantic, where it has been caught by F.R.V. "Walther Herwig" and "Anton Dohrn" from about 65 °N through the tropics to about 41 °S. Except for two hauls, it was always present in our hauls throughout our cruise whenever the net fished deeper than 1200 m. From 26 bathypelagic hauls we collected 287 specimens. One additional adolescent of 230 mm TL was caught at 345 m depth after dusk, thus representing the shallowest record so far.

E. pelecanoides is one of the most abundant bathypelagic eels. It seems to swim in small groups, as we caught from 4 to 32 specimens (an average of 7 to 12 specimens) per haul. The specimens' lengths range from 95 to 750 mm TL. Special studies on sex and age have not been undertaken yet.

Saccopharynx sp.

Stations 5772 (1); 5852 (1).

Two unidentified specimens of *Saccopharynx* (Fig. 4) were collected from south of Bermuda Islands and south of Azores Islands respectively, caught by nets fishing below 1600 m depth. Both specimens were adults, measuring 980 and 1080 mm TL respectively.

Table 2. Number of specimens collected of each species in different depths

Depth (m)	Minutes of towing	*Nemichthys scolopaceus*	*Nemichthys curvirostris*	*Labichthys carinatus*	*Avocettina infans*	*Serrivomer beani*	*Serrivomer brevirostris*	*Derichthys serpentinus*	*Nessorhamphus ingolfianus*	*Cyema atrum*	*Synaphobranchus kaupi*	*Eurypharynx pelecanoides*	*Saccopharynx* spec.
to 200 m	15	3	2	0	0	26	1	0	1	0	0	0	0
to 400 m	15	7	3	1	0	4	5	1	0	2	0	1	0
>1000 m	60	7	15	31	36	405	33	2	4	34	1	206	2
total number of specimens	–	17	20	32	36	435	39	3	5	36	1	207	2

Table 3. Relative frequency at which each species occurred in the hauls together with each of the other species

Species	Number of positive hauls	*N. scolopaceus*	*N. curvirostris*	*L. carinatus*	*A. infans*	*S. beani*	*S. brevidentatus*	*D. serpentinus*	*N. ingolfianus*	*C. atrum*	*S. kaupi*	*E. pelecanoides*	*Saccopharynx* sp.	None	Average of percentage
N. scolopaceus	21	·	24	43	29	57	48	14	10	19	0	38	0	23	22
N. curvirostris	13	39	·	62	54	85	46	0	8	46	0	62	15	0	35
L. carinatus	22	41	36	·	60	91	73	9	9	32	0	82	5	0	37
A. infans	13	46	54	100	·	100	92	8	15	46	0	100	15	0	48
S. beani	32	34	31	62	41	·	59	6	13	34	3	78	3	6	30
S. brevidentatus	24	42	25	67	50	83	·	8	13	29	0	67	4	8	32
D. serpentinus	5	60	0	40	20	40	40	·	0	20	0	40	0	20	(20)
N. ingolfianus	5	40	20	40	40	80	60	0	·	0	0	80	20	20	(30)
C. atrum	12	33	50	58	50	92	58	8	0	·	0	83	8	0	37
S. kaupi	1	0	0	0	0	100	0	0	0	0	·	100	0	0	(16)
E. pelecanoides	24	29	29	75	54	100	67	8	17	47	4	·	4	0	36
Saccopharynx sp.	2	0	100	50	100	50	50	0	50	50	0	50	·	0	(42)

Synaphobranchus kaupi

Station 5893.

A single juvenile specimen of *Synaphobranchus kaupi* (Johnson, 1862) was caught at the northernmost station of the transect. This species lives in the benthic zone on the continental slope. It was pure chance that this species was caught in a midwater trawl.

Survey of anguilliform communities

Analysis of species communities in different depths at different seasons and during different hours of the day demands intensive research, far more intensive than was in our power to carry out during our cruise. Consequently, the information provided by our results is meagre and should be used with precaution. Nevertheless, we shall show the rate of association observed during our cruise in respect to the anguilliform species (Table 3).

Table 3 provides information about the relative frequency at which each species, named in the left vertical column, occurred in our hauls (numbers in first vertical column after species' name). This relative frequency of positive hauls is compared to the relative frequency (%) at which other species, named in the horizontal column, were present in these positive hauls (numbers at conjunction of vertical and horizontal column). For example: 13 of our hauls contained *N. curvirostris*; in 85 % of these positive *N. curvirostris* hauls, *S. beani* was also present. However, *N. curvirostris* was present in only 31 % of the positive *S. beani* hauls. This table must thus be read horizontally.

The percentages presented in Table 3 offer no special information of their own accord; however, comparison of the multiple correlation of the species studied points out interesting implications. For example, *A. infans* and *C. atrum,* both of which were caught at a similar frequency, are present together with *S. beani* as well as with *E. pelecanoides* to a very high degree; i.e. in 80 to 100 % of the hauls in which *A. infans* and C. atrum occurred, *S. beani* and *E. pelecanoides* were present. *A. infans* and *C. atrum,* however, were quite distinctly not caught together so frequently. It is quite possible that these two species have a slightly overlapping distribution whereas *E. pelecanoides* is able to live in a biotope encompassing the two.

The last vertical column of Table 3 presents the averages taken of the percentages. Each number, having no meaning in its own right, offers us however, when the species are compared, an indication of the "associational trend" of each species – always based, of course, on our data. For example, we find that *A. infans* occurs to a much higher extent together with other species than does *N. curvirostris* or *S. brevidentatus,* even though the two latter species were caught just as frequently and just as numerously as the former.

DISCUSSION

Attempts to capture adult *Anguilla* spp. were unsuccessful. This could have had several reasons:

(1) The midwater trawl used to catch herring is not suitable for the capture of eels. The meshsize, from the front part to nearly the beginning of the codend, is too big. The eel fisheries in the North Sea use bottom trawls with smaller meshsizes. However, the alternative use of modified Krill-net, with a smaller mesh-size, was renounced because

of its having too small a mouth. On the other hand, it has been proven on previous cruises that the MT 1600 is able to catch quick-swimming fishes and in addition adult eels of different families. For instance, large adults of *Saccopharynx* sp. and of *Nessorhamphus ingolfianus*, and even the smaller *Derichthys serpentinus* and *Cyema atrum* were caught during our cruise, indicating the capability of the gear to catch eels. Keeping in mind that mature *Anguilla* sp. are usually of a low vitality and a delicate condition, as known from hormonal experiments (e.g. Tood, 1979), we should have caught some if there had been any.

(2) *Anguilla* spp. may travel at greater depth than suspected and perhaps close to the bottom. The maximum fishing depth was 2000 m. Another 2000 or 3000 m below this level were left untouched by our trawling-techniques. So, if *Anguilla* specimens migrate or inhabit layers deeper than 2000 m we could never have picked them up from there. Some facts indicate that *Anguilla* specimens sink into great depths or are even bottom dwelling fishes (Robins et al., 1979). But there are some contraindications too which seem to force *Anguilla* spp. into much shallower layers, at least for a while. Experiments on artificial ripening of eels only took place when temperatures were not lower than 18 °C (see review: Tesch, 1977). Larvae occurrence, including specimens a few days old, was found to be not deeper than 160 m (Schoth & Tesch, 1982).

(3) *Anguilla* may be too scattered on their way to or in the Sargasso Sea or they may also be clumped in groups. Trying to detect a limited number of eels during a limited time space and in a large area is like trying to find a needle in a haystack and success finally depends on the amount of effort. Fishing for about 16 hours in 100 to 400 m, 6 hours in 400 to 1000, and 25 hours in 1000 to 2000 m as we did, may indeed still be far too small an effort to catch *Anguilla* specimens.

But obviously it is not too small an effort when trying to catch other eels from other families. But all these eels are not just visitors to the Sargasso Sea. They all spend their lives or long parts of their lives in this area. They are adapted to feed there, not only to spawn there. They undertake diurnal vertical migration, following their prey into various depth layers such as those within reach of our nets and even rush actively into the fishing net while hunting. After having started its migration to the Sargasso Sea, *Anguilla* does not feed; consequently, it does not follow migrating prey.

On studying the abundance of leptocephali, *Anguilla* turns out to be the most abundant eel of all, closely followed by *Serrivomer* spp. (Tesch et al., 1979). While *Serrivomer* spp. is the most common metamorphosed eel in our catches, *Anguilla* spp. is totally lacking. In fact the occurrence of leptocephali of these two genera may not be correlated to the occurrence of any other developmental stages of the genera in question. Stages to be correlated are leptocephali to leptocephali and ripe adults to ripe adults respectively, as no adolescents of *Anguilla* spp. exist in the area. From this point of view, the abundance of Serrivomer – and of any other eel-species – decreases remarkably. Only very few of our collected anguilliform specimens are really adult. The majority belongs to ontogenetic stages which are not represented by *Anguilla* spp. in this area.

But back to *Serrivomer* spp., the obviously most abundant eel genus of the Sargasso Sea: adults inhabiting this area are presumably born here, or not far away. The fluctuation of individuals is stable and well-balanced. Not so with *Anguilla* spp. which have a long way to migrate and the success of this migration depends on their overcoming difficulties. Loss of individuals cannot be compensated so easily. Evolu-

tional compensation of high loss in individuals usually results in increasing reproductional rates. *Serrivomer* spp. have much smaller ovaries than *Anguilla* spp. but their eggs are about ten times larger in volume than the eggs of the latter (Stibane, 1981). Nevertheless, a higher number of *Anguilla* leptocephali can be collected in the Sargasso Sea than *Serrivomer* leptocephali. Consequently the number of spawning females in *Serrivomer* must be considerably higher than in *Anguilla* to compensate the low number in offspring. Vice versa the high number of eggs in an *Anguilla* ovary allows a reduction in the rate of spawning females in this species. This underlines once more how small the chance is of meeting adult *Anguilla* specimens in the Sargasso Sea.

Calculations, based on stock estimates of the European eel (Tesch, 1980 a) ($30–10^6$ females) and a spawning area of $2–10^6$ km^2, prove that 500 hauls of "Anton Dohrn" are necessary to catch one female eel, provided its occurrence is not deeper than 2000 m and half of the stock is present during the peak of the spawning time. Another estimate presented by Harding (Tesch, 1980 b) suggests that 10 000 hauls are required to capture one adult female with the present techniques.

The likelihood of successful trawling on adult *Anguilla* spp. – without the necessary information of its whereabouts – is therefore very small. Other techniques should therefore be developed. We propose an improvement of the tracking method as used during this expedition (Tesch, 1982) or the use of hormonally maturated eels as lures or the direct use of a possible eel pheromone, hydro-acoustic techniques, television and the use of light as an attractant.

With respect to other anguilliform fish, all the hauls of R.V. "Friedrich Heincke" except one exhibited negative results. An easy explanation is the sixfold smaller mouth area of its midwater trawl compared with that of F.R.V. "Anton Dohrn". In addition, the towing depth was so shallow that the mesopelagic eels could only seldom be caught.

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