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Comparison of the diel and spatial distribution patterns of ichthyoplankton and ichthyoneuston in the Southeastern Brazilian Bight

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• *Abstract:* Fish larvae were collected by neuston and bongo nets, in the Southeastern Brazil, during four oceanographic cruises (January 1980; January 1981; October 1981; and March 1982). The results are compared and analyzed in order to study the patterns of diel vertical distributions of fish larvae and to detect sampling problems. Larvae collected with neuston net were quite different in types and size composition, when compared with those collected with bongo net in oblique tows. Clear tendency of stratification in size composition at the uppermost layer can be observed on juveniles (> 19 mm) of *Sardinella brasiliensis* which also showed day time avoidance. Most of the neustonic *taxa* were also caught in the deeper layers, although some groups, *e.g.* Mugilidae, Mullidae, and Gerreidae, were more abundant at the surface. Density of ichthyoneuston is much higher than those observed in the Northwest Atlantic and number of fish larvae collected during the day by neuston net exceeded that of night samples.

• Descriptors: Ichthyoplankton survey, Neuston, Surface microlayer, Sampling, Plankton collecting devices, Vertical distribution, Southeastern Brazilian coast.

• *Descritores:* Levantamentos do ictioplâncton, Nêuston, Microcamada de superfície, Equipamentos para coleta de plâncton, Distribuição vertical, Brasil: costa sudeste.

Introduction

The neuston is a group of planktonic organisms which inhabit close to interface between sea surface and air and include such organisms as bacteria, protozoa, phytoplankton, zooplankton and some insect (Zaitsev, 1971; Levinton, 1982). According to Hempel & Weikert (1972), the neustonic organisms can be classified into three groups : euneuston are the organisms which live in the vicinity of surface during most of time; facultative neuston are those which concentrate at the surface only during certain hour of day; and pseudoneuston are those which live mainly in deep layer, but occasionally come to surface. Due to peculiar conditions of this layer which receive constant contact with atmosphere, it became a real ecosystem with proper food web in which occurrence of specially adapted organisms are common (Champalbert, 1980). One of these specialized groups include eggs, larvae and juveniles of many fish species, therefore, this microcosms has called special attentions of ichthyoplanktologists (Ahlstrom & Stevens, 1975; John, 1981). Larvae of some species are really neustonic, for example, many species of Mugilidae (*Mugil cephalus, M. curema,* Powles, 1981; *Crenimugil labrosus, Liza* sp, Tully & ÓCéidigh, 1989), some Gadidae (*Ciliata mustela, C. septentrionalis, Gaidropsaurus mediterraneus, Rhinonemus cimbrius,* Tully & ÓCéidigh, 1989), some Coryphaenidae (*Coryphaena equisetus, C. hippurus,* Powles, 1981) and some species of the family Exocoetidae (Gruber *et al.*, 1982).

Plankton samples taken with conventional plankton nets, such as bongo net, conical-cylinder net, etc. fail to show this peculiar microcosm and tend to give some erroneous conclusion on their real importance. For this reason, several kinds of specially designed neustonic nets were developed for quantitative sampling (David, 1965; Sameoto & Jaroszymski, 1969; Matsuo *et al.*, 1976; Schram *et al.*, 1981; Brown & Cheng, 1981; etc).

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These neuston nets have similar structure, i.e. they have sledge-like frame with buoy and a rectangular net in the center of the sledge to collect upper ten centimeters. In spite of potential importance of neustonic study (David, 1965), there is no work made in the Brazilian waters.

This report presents a comparison of the ichthyoplankton assemblages taken with neuston and bongo nets in the Southeastern Brazilian Bight and discusses on their distribution patterns in space and time of day.

Material and methods

The Southeastern Brazilian Bight extends from Cabo Frio (23°S) to Cabo Santa Marta Grande (29°S) within which offshore Ekman transport and wind-induced turbulent mixing fall to coastwise minima specially during summer. The Brazil Current flows skirting across the bight opening rather than following the coastline into bight interior (Bakun & Parrish, 1990). Four cruises were conducted with R/V "Prof. W. Besnard" during 1980 through 1982 in the Southeastern Brazilian Bight (Table 1, Fig. 1). During the cruise of October 1981, 19 samplings with bongo and neuston nets were made concurrently during 36 hours at the fixed station near Cabo Frio.

The neuston net was made at the "Instituto Oceanográfico da Universidade de São Paulo" based on the model of David (1965). It has a large frame of catamaran and sustains a small rectangular plankton net inside. The net has a mouth opening of 30 cm x 20 cm and a length of 380 cm with 0.333 mm mesh size. Net towing was made at starboard with ship speed of about 1.5 and 2.0 knots during 10 minutes. The mouth of net cuts approximately 15 cm of surface layer, but because of a problem of irregular immersion of net during bad weather, no estimation of filtered water was made.

Beside the neuston net, bongo net sampling was made at the same station for comparative purpose. The bongo net has a mouth diameter of 60 cm with fine mesh net (0.333 mm) and coarse mesh net (0.505 mm) and only the samples collected with the coarse mesh net were used for comparison with neuston net samples. We followed the sampling procedure described by Smith & Richardson (1977). To measure filtered water volume, digital flowmeter was attached at the center of mouth opening.

The plankton samples were fixed immediately on board with 10% buffered formalin solution. In the laboratory, after measuring the plankton volume by the method of Kramer *et al.* (1972), fish eggs and larvae were sorted and later identified for family level. More abundant groups of fish larvae were identified for species level : *1) Sardinella brasiliensis*, 2) *Engraulis anchoita*, 3) *Harengula jaguana*, *4) Maurolicus muelleri*, 5) *Auxis* sp, 6) *Bregmaceros cantori*, 7) *B. atlanticus*, and 8) *Katsuwonus pelamis*. Notochord length (NL) and standard length (SL) were used for measurement of preflexion and flexion larvae and postflexion larvae, respectively.

Results

Ocurrences of fish larvae observed by neuston net

Taxonomic groups of fish larvae taken by the neuston net during the cruise of March 1982 are presented in Table 2. Total number of larvae caught during the cruise was separated according to time of day. Total number of taxa identified was 32, having 23 taxa in night samples and 19 taxa in day samples. Following taxa were collected exclusively in night : Myctophidae, Gonostomatidae, Diodontidae, Anguiliformes, Syngnathidae, *Trachinocephalus myops* (Synodonthidae), Trichiuridae, Holocentridae and Scombridae. The groups taken only in day time were : *Sardinella brasiliensis*, Mugilidae, Engraulididae (excluding *Engraulis anchoita*), Hemirhamphidae, *Synodus foetens* (Synodonthidae), other Clupeidae, Ophidiidae and Lutjanidae.

Specimen of the most of groups were mainly collected during day time, having 89.7 % (1288 larvae) of total larvae taken (=1436). Chi-square test applied on the predominant groups showed only Myctophidae and *Auxis* sp (Scombridae) were significantly abundant during night (=5% significance level) and Exocoetidae occurred equally in both time periods. Nine abundant groups (Mullidae, Gerreidae, *Harengula jaguana, Sardinella brasiliensis*, Blenniidae, *Engraulis anchoita,* Mugilidae, other Engraulididae and Carangidae) were significantly abundant during day.

Table 1. Date and regions of sampling stations

Cruise	Number of samples		Number of fish larvae		Survey area
	Neuston	Bongo	Neuston	Bongo	
January 1980	7	7	2008	3800	Paranaguá-Florianópolis
January 1981	5	5	352	2329	Iguape
October 1981	19	19	386	4535	Cabo Frio (Fixed Station)
March 1982	32	32	1436	8467	Cabo Frio-Paranaguá

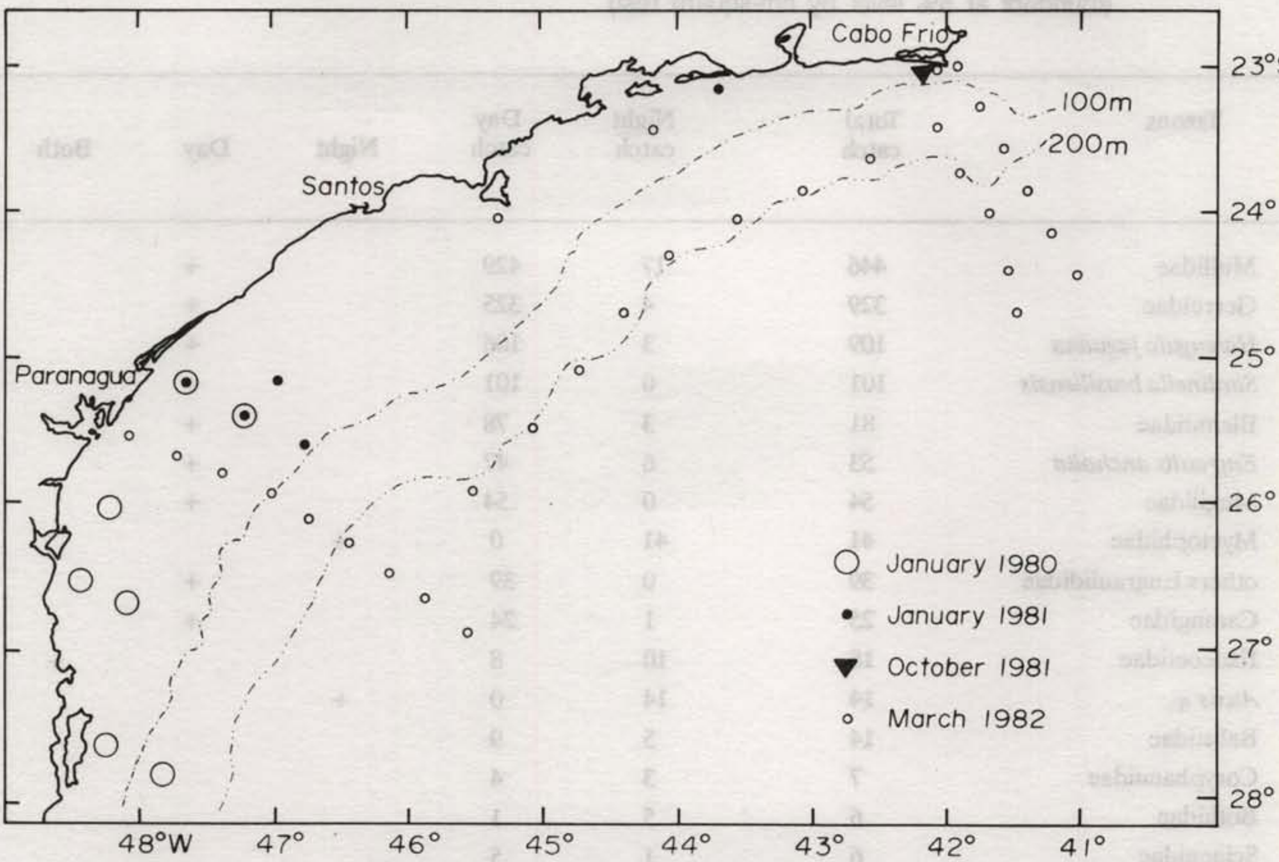

Fig. 1. Area and sampling stations of neuston and bongo nets by R/V. "Prof. W. Besnard" in the southeastern Brazilian Bight.

Larvae of three species (*S. brasiliensis, H. jaguana* and *E. anchoita)* collected during four cruises with neuston net were separated into night/day periods and size frequency distributions of two periods for three species are shown in Figures 2-4. More striking difference was observed in *S. brasiliensis*, having 1398 (93%) taken during night and only 101 (17%) taken during day. Size of sardine larvae ranged from 2.5 to 30.5 mm SL, but larvae ranging between 9.5 and 14.5 mm SL predominated the day samples, representing 80 % of total larvae taken during day. On the other hand, size class between 21.5 and 25.5 mm SL predominated in night samples, occupying about 73 % of total. Sardine larvae larger than 17.5 mm SL were taken exclusively in night.

In case of the scaled sardine (*H. jaguana*), numbers of larvae taken during day and night showed small difference, having 140 larvae (58%) during night and 101 larvae (42%) during day. For the size range from 2.5 to 5.5 mm SL, there is no difference in day and night catches, but larger larvae ranging between 6.5 and 13.0 mm SL were predominantly taken in day and those between 11.0 and 17.5 mm SL in night (Fig. 3).

Number of anchoita (*E. anchoita*) larvae taken with neuston net during four cruises was smaller than those of two other species and most of them (129 larvae) were taken during night. Most larvae taken during night were smaller specimens, ranging from 3.0 to 7.0 mm SL (Fig. 4).

Comparison between neuston net and bongo net

a) Size frequency distributions of fish larvae

From total of 4172 sardine (*S. brasiliensis)* larvae, 2710 were taken with bongo net and 1546 with neuston net (Table 3). Sizes of larvae ranged from 2.5 to 28.5 mm SL with bongo net and from 2.5 to 30.5 mm SL with neuston net. Larvae smaller than 10.5 mm SL were predominantly collected with bongo net and those larger than 19.5 mm SL with neuston net (Fig. 5). Only small number of larvae ranging from 11.5 mm to 18.5 mm SL were taken with both nets.

Table 2. Taxonomic groups of fish larvae collected with neuston net during the cruise of March 1982, separated into night and day catches (+ = significantly more abundant at 5% level by chi-square test)

Taxons	Total catch	Night catch	Day catch	Night	Day	Both
Mullidae	446	17	429		+	
Gerreidae	329	4	325		+	
Harengula jaguana	109	3	106		+	
Sardinella brasiliensis	101	0	101		+	
Blenniidae	81	3	78		+	
Engraulis anchoita	53	6	47		+	
Mugilidae	54	0	54		+	
Myctophidae	41	41	0	+		
others Engraulididae	39	0	39		+	
Carangidae	25	1	24		+	
Exocoetidae	18	10	8			+
Auxis sp.	14	14	0	+		
Balistidae	14	5	9			
Coryphaenidae	7	3	4			
Bothidae	6	5	1			
Sciaenidae	6	1	5			
Katsuwonus pelamis	3	3	0			
Diodontidae	3	3	0			
Hemirhamphidae	3	0	3			
others Scombridae	3	3	0			
Synodus foetens	2	0	2			
others Clupeidae	2	0	2			
Gonostomatidae	2	2	0			
Anguiliformes	2	2	0			
Syngnathidae	2	2	0			
Trachinocephalus myops	1	1	0			
others mesopelagics	1	1	0			
Ophidiidae	1	0	1			
Trichiuridae	1	1	0			
Holocentridae	1	1	0			
Lutjanidae	1	0	1			
not identified	65	16	49			
TOTAL	1436	148	1288			

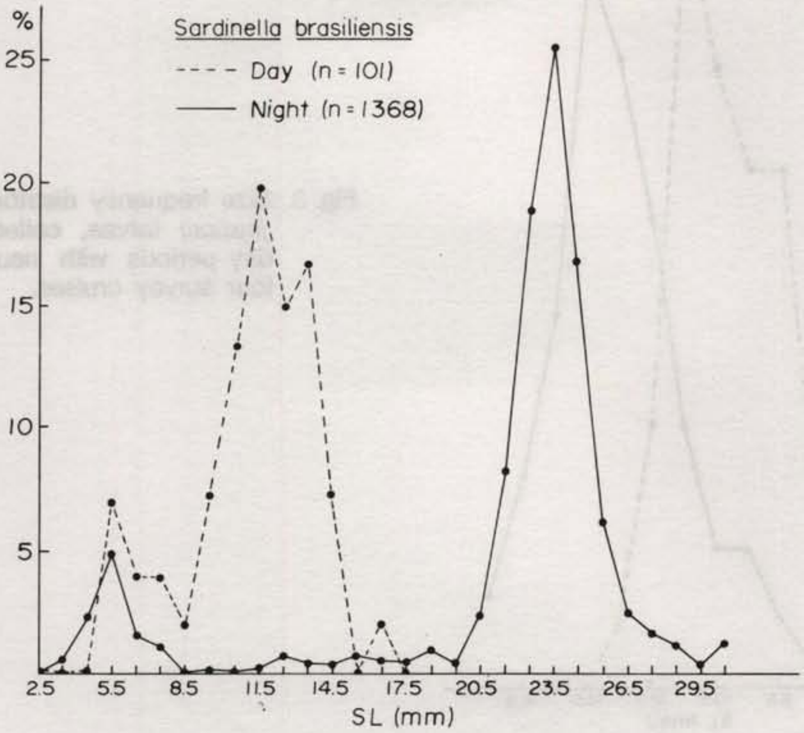

Fig. 2. Size frequency distribution of *Sardinella brasiliensis* larvae, collected at night and day periods with neuston net during four survey cruises.

Size of scaled sardine (*H. jaguana*) ranged from 2.5 to 19.5 mm SL in both nets and total numbers of larvae taken with two nets were similar (208 larvae with bongo versus 244 larvae with neuston). In average, larvae taken with neuston net were slightly larger than those taken with bongo net (Fig. 6).

Most of anchoita (*E. anchoita)* larvae were taken with bongo net (2008) and only 150 larvae were taken with neuston net. Size frequency of anchoita larvae collected with two nets showed predominance of small larvae (< 10 mm SL) (Fig. 7).

b) Comparison of variabilities in taxa

Numbers of larvae of each taxon collected during 36 hours observation at the fixed station near Cabo Frio in October 1981 are shown in Table 4. From 33 taxa identified, *Bregmaceros atlanticus* was collected only with neuston net and other 32 taxa were collected with bongo net and/or neuston net. Total number of larvae taken with bongo net (=4535 larvae) exceeded that taken with neuston net (=384 larvae). The most abundant group collected with bongo net was the family Engraulididae (including *E. anchoita*), contributing with 47.9% of total. Other abundant groups in bongo net samples were : Bothidae (6.3%), Carangidae (6.2%), Serranidae (5.0%), *Bregmaceros cantori* (4.2%), Cynoglossidae (2.8%) and Sciaenidae (2.4%). With neuston net, the more abundant taxa were as follows: Blenniidae (23.4%), Engraulididae (including *E. anchoita*) (22.7%), Gerreidae (11.2%), Mugilidae (8.9%) and Mullidae (6.8%).

During the cruise of March 1982, 32 plankton samples of bongo net and the same number with neuston net were collected from which 11759 larvae were taken with bongo net and 2820 larvae with neuston net (Table 5). From 55 taxa identified, 53 taxa were taken with bongo net and only 22 taxa with neuston net. Three groups which appeared predominantly in bongo net samples were: Myctophidae (24.6%), Gonostomatidae (22.8%), and *E. anchoita* (9.6%). With neuston net the following groups predominated: Mullidae (15.8%), Gerreidae (11.7%), *H. jaguana* (3.9%) and *S. brasiliensis* (3.6%).

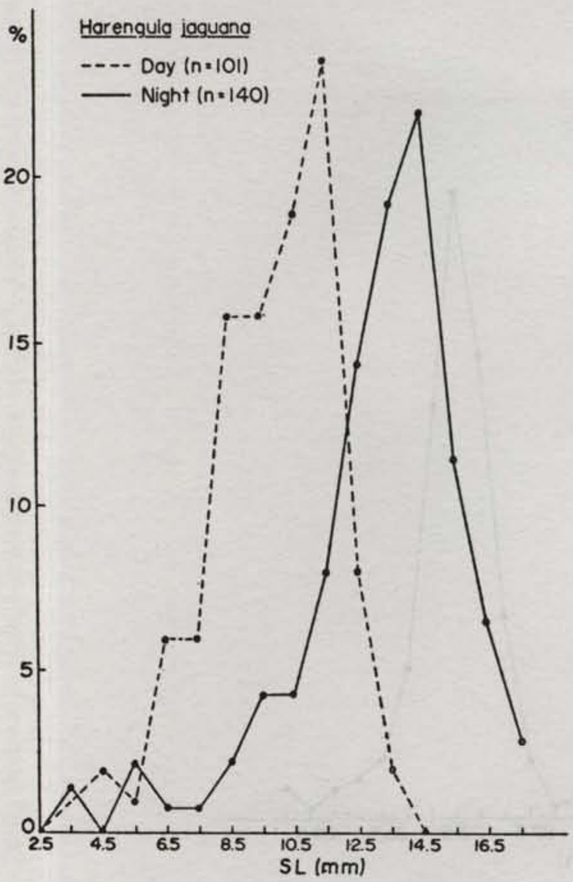

Fig. 3. Size frequency distribution of *Harengula jaguana* larvae, collected at night and day periods with neuston net during four survey cruises.

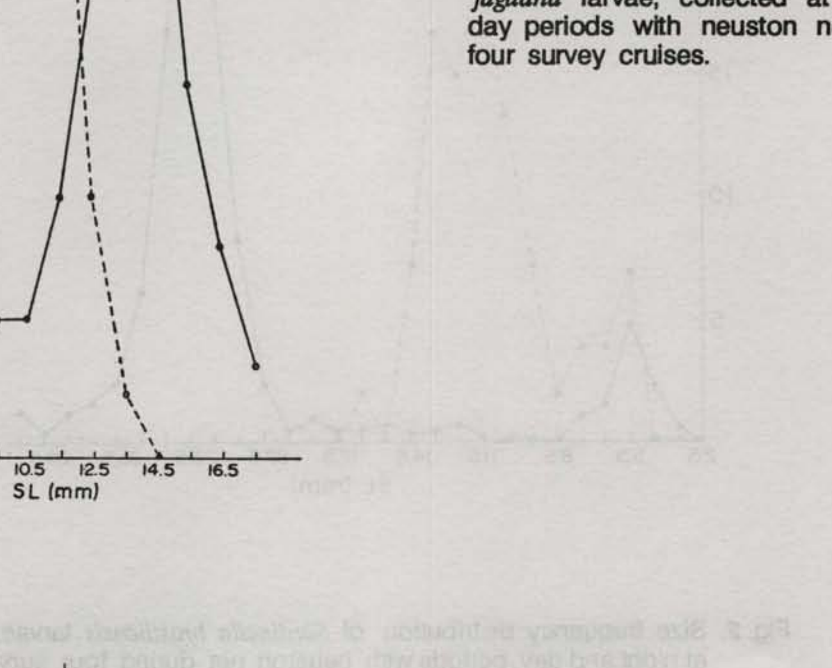

Fig. 4. Size frequency distribution of *Engraulis anchoita* larvae, collected at night and day periods with neuston net during four survey cruises.

Table 3. Number of larvae of two species (*S. brasiliensis* and *H. jaguna*) of the family Clupeidae collected during four cruises

CRUISE	BONGO NET					NEUSTON NET				
	Sample Number	*S. brasiliensis*	*H. jaguana*	Others	Total	Number Sample	*S. brasiliensis*	*H. jaguana*	Others	Total
Jan/1980	2633	36	3	0	39	2648	4	7	0	11
	2634	26	16	0	42	2649	3	19	0	22
	2640	8	16	8	32	2650	0	14	0	14
	2641	2	19	9	30	2651	9	3	2	14
	2642	2165	0	0	2165	2652	162	0	0	162
	2646	21	1	0	22	2653	127	0	0	127
	2647	18	0	0	18	2654	1128	0	0	1128
Jan/1981	2705	50	48	3	101	2741	1	30	0	31
	2723	286	1	0	287	2742	3	0	0	3
	2724	4	0	0	4	2743	2	0	0	2
	2725	18	0	0	18	2744	0	0	0	0
	2726	26	30	4	60	2745	3	61	0	64
Oct/1981	2796	0	0	0	0	2825	1	1	0	2
	2798	0	0	2	2	2827	0	0	0	0
	2802	2	1	0	3	2831	0	0	0	0
	2803	1	1	0	2	2832	0	0	0	0
	2804	1	3	1	5	2833	0	0	0	0
	2805	4	2	1	7	2834	0	0	0	0
	2807	0	2	0	2	2836	0	0	0	0
	2808	4	7	2	13	2837	0	0	0	0
	2809	1	1	0	2	2838	0	0	0	0
	2810	1	0	0	1	2839	0	0	0	0
	2811	1	1	0	2	2840	0	0	0	0
	2812	1	2	0	3	2841	2	0	0	2
Mar/1982	2842	1	4	0	5	2874	0	3	0	3
	2843	0	2	0	2	2875	0	5	1	6
	2846	1	0	0	1	2878	0	0	0	0
	2847	0	1	0	1	2879	0	2	0	2
	2848	9	0	0	9	2880	45	0	1	46
	2871	3	0	0	3	2903	0	0	0	0
	2872	8	7	0	15	2904	14	6	0	20
	2873	12	40	83*	135	2905	42	93	0	135
	TOTAL	2710	208	113	3031		1546	244	4	1794

(*) Older larvae identified as *Ophistonema oglinum*.

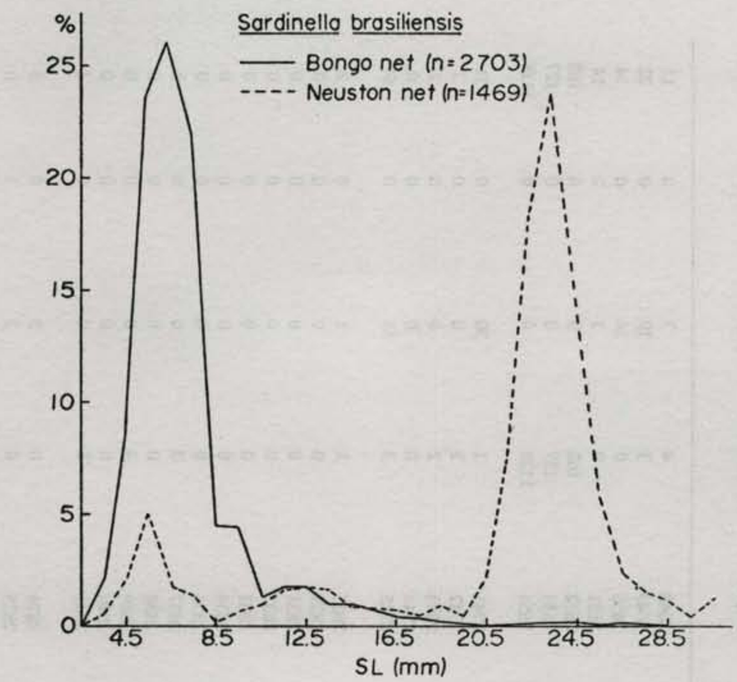

Fig. 5. Comparison of size frequency distribution of *Sardinella brasiliensis* larvae, collected with neuston and bongo nets during four survey cruises.

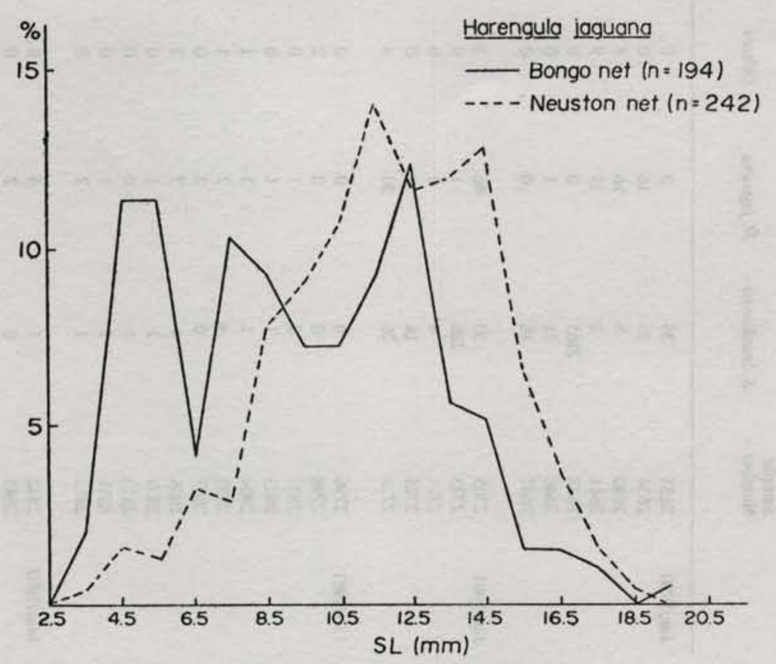

Fig. 6. Comparison of size frequency distribution of *Harengula jaguana* larvae, collected with neuston and bongo nets during four survey cruises.

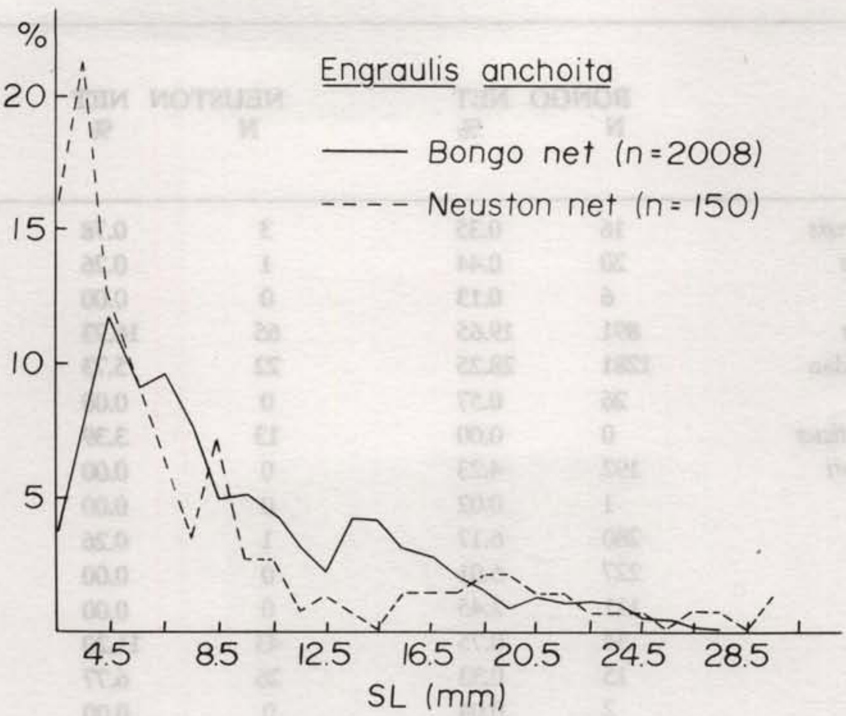

Fig. 7. Comparison of size frequency distribution of *Engraulis anchoita* larvae, collected with neuston and bongo nets during four survey cruises.

Discussion

Because of different sampling system (type of nets, towing time, filtered water volume, etc.), it was expected to obtain different larval abundances collected with two nets at the same stations. In fact, we obtained much more larvae in number and taxonomic groups with bongo net than with neuston net (Table 4 and 5). The similar kind of observation was made in the California Current region by Ahlstrom & Stevensen (1975) and they suggested the samples collected only at surface layer were less representative than those obtained with oblique haul. On the other hand, when these values are expressed in relative frequency, we can observe different tendency of dominant groups which show different vertical distribution patterns. For example, the group of mesopelagic fish larvae (Myctophidae and Gonostomatidae) predominated in samples taken with bongo net, while the families Mullidae and Gerreidae were more abundant in neuston net samples during the cruise of March 1982.

From the results presented in Tables 4 and 5, we can consider the families Mullidae, Mugilidae and Exocoetidae as euneustonic, as observed by Hempel & Weikert (1972), Zaitsev (1971), and Tully & ÓCéidigh (1989). However, when we compare the same families collected in different time of day with neuston net (Table 2), only Exocoetidae was real euneuston and other two families were facultative neuston which occurred mainly during day. We can also consider the families Gerreidae and Blenniidae as facultative neustonic groups, but Eldridge *et al.* (1978) considered the Gerreidae as belonging to euneustonic group.

Vertical distribution pattern may vary considerably within the same species according to sampling place. For example, Hempel & Weikert (1972) observed that the larvae of *Scomber scombrus* occurred in neustal during day in the North Sea, but they did occur in neustal during night in the Norwegian sea. In our samples, the species of the family Scombridae (*Auxis* sp, *Katsuwonus pelamis*, and other scombrids) occurred exclusively during night in neuston samples.

Table 4. Comparison of catches with bongo net and neuston net at a fixed station near Cabo Frio in October 1981

TAXON	BONGO NET N	BONGO NET %	NEUSTON NET N	NEUSTON NET %	TOTAL
Sardinella brasiliensis	16	0.35	3	0.78	19
Harengula jaguana	20	0.44	1	0.26	21
others Clupeidae	6	0.13	0	0.00	6
Engraulis anchoita	891	19.65	65	16.93	956
others Engraulididae	1281	28.25	22	5.73	1303
Saurida spp.	26	0.57	0	0.00	26
Bregmaceros atlanticus	0	0.00	13	3.39	13
Bregmaceros cantori	192	4.23	0	0.00	192
Scombridae	1	0.02	0	0.00	1
Carangidae	280	6.17	1	0.26	281
Serranidae	227	5.01	0	0.00	227
Sciaenidae	111	2.45	0	0.00	111
Gerreidae	34	0.75	43	11.20	77
Mullidae	15	0.33	26	6.77	41
Anguilliformes	2	0.04	0	0.00	2
Ophidiidae	97	2.14	6	1.56	103
Scorpaenidae	1	0.02	0	0.00	1
Triglidae	5	0.11	0	0.00	5
Balistidae	2	0.04	0	0.00	2
Trichiuridae	3	0.07	0	0.00	3
Blenniidae	95	2.09	90	23.44	185
Sphyraenidae	3	0.07	0	0.00	3
Tetraodontidae	1	0.02	0	0.00	1
Percophididae	3	0.07	0	0.00	3
Lophidae	2	0.04	3	0.78	5
Stromateidae	1	0.02	0	0.00	1
Gadidae	1	0.02	0	0.00	1
Mugilidae	4	0.09	34	8.85	38
Syngnatidae	49	1.08	0	0.00	49
Bothidae	287	6.33	1	0.26	288
Cynoglossidae	126	2.78	0	0.00	126
others Pleuronectiformes	44	0.97	0	0.00	44
Gobiidae	23	0.51	0	0.00	23
not identified	686	15.13	76	19.79	762
TOTAL	4535		384		4919

Table 5. Comparison of fish larvae taken with Bongo net and neuston net during the cruise of March 1982

TAXON	BONGO NET N	BONGO NET %	NEUSTON NET N	NEUSTON NET %	TOTAL
Sardinella brasiliensis	153	1.30	101	3.58	254
Harengula jaguana	94	0.80	109	3.87	203
others Clupeidae	0	0.00	2	0.07	2
Engraulis anchoita	1131	9.62	53	1.88	1184
others Engraulididae	113	0.96	39	1.38	152
Trachinocephalus myops	11	0.09	1	0.04	12
Synodus foetens	13	0.11	2	0.07	15
Saurida spp	91	0.77	0	0.00	91
Bregmaceros atlanticus	192	1.63	0	0.00	192
Bregmaceros cantori	131	1.11	0	0.00	131
Hygophum spp	86	0.73	0	0.00	86
outros Myctophidae	2808	23.88	41	1.45	2849
Maurolicus muelleri	1793	15.25	0	0.00	1793
others Gonostomatidae	893	7.59	2	0.07	895
others mesopelagics	406	3.45	1	0.04	407
Auxis spp	455	3.87	14	0.50	469
Katsuwonus pelamis	34	0.29	3	0.11	37
Thunnus spp	9	0.08	0	0.00	9
Euthynnus alletteratus	4	0.03	0	0.00	4
others Scombridae	159	1.35	4	0.14	163
Carangidae	162	1.38	25	0.89	187
Serranidae	26	0.22	14	0.50	40
Sciaenidae	12	0.10	6	0.21	18
Gerreidae	65	0.55	329	11.67	394
Mullidae	31	0.26	446	15.82	477
Anguilliformes	70	0.60	2	0.07	72
Paralepedidae	162	1.38	0	0.00	162
Ophidiidae	100	0.85	1	0.04	101
Scorpaenidae	61	0.52	0	0.00	61
Triglidae	39	0.33	0	0.00	39
Balistidae	8	0.07	14	0.50	22
Trichiuridae	87	0.74	1	0.04	88
Stomiatidae	34	0.29	0	0.00	34
Nomeidae	85	0.72	0	0.00	85
Blenniidae	11	0.09	81	2.87	92
Carapidae	5	0.04	0	0.00	5
Gempylidae	20	0.17	0	0.00	20
Sphyraenidae	12	0.10	0	0.00	12
Diodontidae	1	0.01	3	0.11	4
Exocoetidae	2	0.02	18	0.64	20
Tetraodontiformes	3	0.03	0	0.00	3
Apogonidae	1	0.01	0	0.00	1
Callionymidae	6	0.05	0	0.00	6
Holocentridae	1	0.01	1	0.04	2
Caproidae	3	0.03	0	0.00	3
Coryphaenidae	3	0.03	7	0.25	10
Mugilidae	7	0.06	54	1.91	61
Syngnatidae	1	0.01	2	0.07	3
Lutjanidae	0	0.00	1	0.04	1
Bothidae	411	3.50	6	0.21	417
Cynoglossidae	50	0.43	0	0.00	50
Gobiidae	94	0.80	0	0.00	94
Fistulariidae	2	0.02	0	0.00	2
Merlucciidae	9	0.08	0	0.00	9
Ogcocephalidae	1	0.01	0	0.00	1
not identified	1598	13.59	1437	50.96	3035
TOTAL	11759		2820		14579

Vertical distribution patterns of different size classes also showed considerable variation in some species (Blaxter & Hunter, 1982; Uotani, 1973; Hunter, 1976) and we can see the same tendency in Figure 5 in which larvae smaller than 19.5 mm SL of the *S. brasiliensis* were more abundant in midwater below the neustonic layer and juveniles larger than 20.0 mm SL were typically euneustonic. On the other hand, *E. anchoita* did not show such tendency, distributing in the same proportion in both layers. However, this result can be attributed to possible undersampling of *E. anchoita* juveniles due to aggregating behavior during this stage and there was a possibility of failing to catch a patch of juveniles during the cruises. For example, Hewitt (1981) discussed on distribution patterns and patchiness of larvae of *Engraulis mordax* and *Trachurus simmetricus* with different size. He demonstrated that newly hatched larvae of both species showed patchy distribution, but dispersing later with age. Posteriorly, they tended to aggregate again when they achieved juvenile stage.

Differences in catches with neuston net observed between night and day periods (Figs 2-4, Table 2) can be attributed to many factors. One of the possibilities is a diel vertical migration, as like proposed by Hempel & Weikert (1972) and Holdway & Maddock (1983a; b). Figure 2 seems to confirm this possibility, i.e. a presence of *S. brasiliensis* larvae ranging from 8.5 to 15.5 mm SL in day time and of juveniles ranging from 20.5 to 30.5 mm SL in night time. On the other hand, Figure 5 demonstrates that the sardine juveniles were not collected with bongo net in both periods at the same stations. Therefore, we can conclude that sardine juveniles were concentrated exclusively in surface layer (neustal).

Another important factors which influence on day/night catch ratio is avoidance of larger larvae from mouth opening during day (e.g. Bridger, 1956; Smith & Richardson, 1977). Ability of avoidance of fish larvae has a relation with developmental stage of visual system and swiming capacity. O'Conell (1981) observed that the photosensial system of *E. mordax* larva became functional when they grow to 4.0 mm SL, the *area temporalis* appeared with 5.0 mm SL and differentiation of rod-cell started to occur with10.0 mm SL. Hunter & Sanchez (1976) and Sandy & Blaxter (1980) showed that with a formation of rod-cell the larvae started vertical migration, showing higher activity.

Beside to development of visual organ, the swiming capacity is another important factor influencing on avoidance. Hunter (1972) observed the larvae of *E. mordax* could swim with cruising speed from 0.6 to 0.9 times of body length per second, but they could move rapidly with burst speed of 15 body length per second. This means the larva of 15 mm SL can dislocate more than 20 cm per second, resulting further ability of avoidance. In fact, the avoidance of *S. brasiliensis* larvae increased exponentially from the size of 19 mm SL (Matsuura, 1983, fig. 53). Therefore, the catches of large number of sardine juveniles with neuston net during night and absence of them during day can be explained by the influence of avoidance.

The results shown in Table 2 gives one more evidence on different diel migratory behaviors of fish larvae. Hempel & Weikert (1972) observed the diel vertical migration became more evident with an increase of size and age and it was related to feeding behavior. According to Zaitsev (1971) many epipelagic organisms do diel vertical migration and remain in deep layer during daytime and coming up to surface (0-5 cm) in nighttime. Kauffman *et al.* (1981) demonstrated a relation between vertical migration of Atherinidae larvae and feeding selectivity. These studies on vertical distribution of neustonic organisms suggest that the upper several centimeters of surface must be very poor in food organisms during daytime. Therefore, to explain most of fish larvae stay in this layer during daytime (Table 2), we must find another ecological reason, e.g. protection against predation. Zaitsev (*op. cit.*) described many cases of mimetism in neustonic organisms. Besides, to stay in upper several centimeters of surface implicates a high degree of adaptation to environmental conditions, principally to strong solar radiation. Analyzing the neustonic samples, we can notice that most of fish larvae have dark or almost blue color in their dorsal side and silver color in ventral side. Since only larvae of few species are specialized in this layer, there must be less competition on food organisms (Hartmann, 1970).

Mean density of neuston in the North Sea was 47 larvae 100 m^{-3} and 10 larvae 100 m^{-3} in subtropical North Atlantic (Hempel & Weikert, 1972). Tully & ÓCéidigh (1989) gave a value of 2-28 larvae 100 m^{-3} in the Galway Bay (Ireland). We made no estimation of water volume filtered by neuston net, but using the towing speed of 1.75 knots for 10 minutes and supposing the net cut upper 15 cm, we can estimate possible volume of water filtered at each station and obtained 24.3 m^3. Total number of fish larvae taken with neuston net was 4182 and mean number per station was 66.4 larvae. This was converted into mean density and we obtained 273 larvae 100 m^{-3}. When we compare this value with those observed in the Northwest Atlantic, our value is much higher than others. The reason of this high neuston density in the Brazilian waters was a occurrence of large number of sardine juveniles in night stations. Also we can point out a large number of Gerreidae, Mullidae and Engraulididae in neuston samples.

Our results on neuston net confirm the observation of Ahlstrom & Stevens (1975). For example, in some families, such as Mugilidae and Mullidae which tend to aggregate in surface layer, a neuston net is very useful to make quantitative study on distribution and abundance. In other case there occurs size selectivity of larvae as demonstrated with *S. brasiliensis* and a neuston net has a disadvantage in quantitative study of mortality and abundance. Still it can be used for sampling of larger larvae and juveniles which can be more efficiently collected with neuston net than with bongo net during night time.

Resumo

Larvas de peixes foram coletadas com rede de nêuston e rede bongô, na costa sudeste do Brasil, durante quatro cruzeiros oceanográficos (Jan/1980; Jan/1981; Out/1981; Mar/1982). São estudados os padrões de distribuição diária de larvas e problemas de amostragem. Numa comparação entre coletas de superfície e coletas oblíquas, observam-se diferenças

em composição, tanto em termos de espécies como de tamanho de larvas. Pode ser observada uma clara tendência de estratificação por composição de tamanho para *Sardinella brasiliensis* em que espécimes juvenis (> 19 mm) ocorreram preferencialmente na camada superficial. Estes juvenis também apresentaram maior capacidade de fuga da boca da rede durante o período diurno. A maioria dos táxons de ocorrência neustônica foi também capturada em camadas mais profundas, mas alguns grupos como Mugilidae, Mullidae e Gerreidae predomiram na camada superficial. A densidade do ictionêuston é mais elevada na nossa região do que a observada no Atlântico noroeste, e o número de larvas de peixes da coleta diuna com rede de nêuston excedeu o da coleta noturna.

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References

AHLSTROM, E. H. & STEVENS, E. 1975. Report of neuston (surface) collection made on an extended CalCOFI cruise during May 1972. CalCOFI Rept, *18*:167-180.

BAKUN, A. & PARRISH, R.H. 1990. Comparative studies of coastal pelagic fish reproductive habitats: the Brazilian sardine *(Sardinella aurita)*. J. Cons. perm. int. Explor. Mer, *46*:269-283.

BLAXTER, J.H.S. & HUNTER, J.R. 1982. The biology of the clupeid fishes. Adv. mar. Biol., *19*:1-223.

BROWN, D.M. & CHENG, L. 1981. New net for sampling the ocean surface. Mar. Ecol.-Prog. Ser., *5*: 225-227.

BRIDGER, J.P. 1956. On day and night variations in catches of fish larvae. J. Cons. perm. int. Explor. Mer, *22*(1):42-57.

CHAMPALBERT, G. 1980. Les peuplements de l'écosystéme neustonique. Océanis, *6*(2):205-211.

DAVID, P.M. 1965. The neuston net: a device for sampling the surface fauna of the ocean. J. mar. biol. Ass. U.K., *45*(2):313-320.

ELDRIDGE, P. J.; BERRY, F. H. & MILLER III, M. C., 1978. Diurnal variations in catches of selected species of ichthyoneuston by Boothbay neuston net off Charleston, South Carolina. Fishery Bull. natn. mar. Fish. Serv., U.S., *76*(1):295-297.

GRUBER, D.; AHLSTROM, E. H. & MULLIN, M. M., 1982. Distribution of ichthyoplankton in the Southern California Bight. Rept. Calif. coop. ocean. Fish. Invest., *23*:172-179.

HARTMANN, J. 1970. Juvenile saury pike *(Scomberesox saurus* Walb.), an example of ichthyoneuston. J. Cons. perm. int. Explor. Mer, *33* (2):245-255.

HEMPEL, G. & WEIKERT, H. 1972. The neuston of the subtropical and boreal Northeastern Atlantic Ocean, a review. Mar. Biol., *13*(1):70-88.

HEWITT, R. 1981. The value of pattern in the distribution of young fish. Rapp. P-v. Réun. Cons. perm. int. Explor. Mer., *178*:229-236.

HOLDWAY, P. & MADDOCK, L. 1983a. A comparative survey of neuston: geographical and temporal distribution patterns. Mar.Biol. *76*:263-270.

________ & ________ 1983b. Neustonic distributions. Mar. Biol., *77*:207-214.

HUNTER, J. R. 1972. Swimming and feeding behavior of larval anchovy *Engraulis mordax*. Fishery Bull., natn mar. Fish. Serv., U.S., *70*(3): 821-838.

________ 1976. Culture and growth of northern anchovy, *Engraulis mordax*, larvae. Fishery Bull., natn. mar. Fish. Serv., U.S., *74*(1):81-88.

________ & SANCHEZ, C. 1976. Diel changes in swim bladder infration of the larvae of the northern anchovy, *Engraulis mordax*. Fishery Bull., natn. mar. Fish. Serv., U.S., *76*(4):847-855.

JOHN, H.-CH. 1981. Ichthyoneuston of Cape Verde Archipelago. Rapp. P.-v. Réun. Cons. perm. int. Explor. Mer, *178*:237-239.

KAUFFMAN, T. A.; LINDSAY, J. & LEITHISER, R., 1981. Vertical distribution and food selection of larval atherinids. Rapp. P.-v. Réun. Cons. perm. int. Explor. Mer, *178*:342-343.

KRAMER, D.; KALIN, M. J.; STEVENS, E. G.; THAIKILL, J. R. & ZWEIFEL, J. R. 1972. Collecting and processing data on fish eggs and larvae in the California Current region. NOAA Tech. Rept., natn. mar. Fish. Serv. Circ., (370): 1-38.

LEVINTON, J. S. 1982. Marine ecology. New Jersey. Prentice-Hall. 526p.

MATSUO, Y.; NEMOTO, T. & MARUMO, R. 1976. A convertible neuston net for zooplankton. Bull. Plankt. Soc. Japan, *23*(1):26-30.

MATSUURA, M. 1983. Estudo comparativo das fases iniciais do ciclo de vida da sardinha-verdadeira, *Sardinella brasiliensis* e da sardinha-cascuda, *Harengula jaguana* (Pisces: Clupeidae) e nota sobre a dinâmica da população da sardinha-verdadeira na região sudeste do Brasil. Tese de livre-docência. Universidade de São Paulo, Instituto Oceanográfico. 150p. + tabs + figs.

O'CONELL, C. P. 1981. Development of organ systems in the northern anchovy, *Engraulis mordax* and other teleosts. Am. Zool., *21*:429-446.

POWLES, H. 1981. Distribution and movements of neustonic young of estuarine dependent (*Mugil* spp., *Pomatomus saltatrix*) and estuarine independent (*Coryphaena* spp.) fishes off the Southeastern United States. Rapp. P.-v. Réun. Cons. perm. int. Explor. Mer, *178*:207-209.

SAMEOTO, D. D. & JAROSZYMSKI, L. O. 1969. Otter surface sampler: a new neuston net. J. Fish. Res. Bd Can., *26*(8):2240-2244.

SANDY, J. M. & BLAXTER, J. H. S. 1980. A study of retinal development in larval herring and sole. J. mar. biol. Ass. U.K., *60*:59-71.

SCHRAM, T. A.; SVELLE, M. & OPSAHL, M. 1981. A new divided neuston sampler in two modifications: description, tests, and biological results. Sarsia, *66*(4):273-282.

SMITH, P.E. & RICHARDSON, S.L. 1977. Standard techniques for pelagic fish egg and larva surveys. FAO Fish. tech. Pap., (175):1-100.

TULLY, O. & ÓCÉIDIGH, P. 1989. The ichthyoneuton of Galway Bay (Ireland). I. The seasonal, diel and spatial distribution of larval, post-larval and juvenile fish. Mar. Biol., *101*(1):27-41.

UOTANI, I. 1973. Diurnal changes of gas bladder and behaviour of postlarval anchovy and other related species. Bull. japan. Soc. scient. Fish., *39*(8):867-876.

ZAITSEV, Yu. P. 1971. Marine neustonology; translated into English from Russian edition of 1970 by A. Mercado. Jerusalem, Israel Program for Scientific Translations. 207p.

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