REPORT OF NEUSTON (SURFACE) COLLECTIONS MADE ON AN EXTENDED CalCOFI CRUISE DURING MAY 1972

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ABSTRACT

This is the first report on neuston samples collected during CalCOFI cruises. Fortunately, Cruise 7205 covered an extensive area of the temperate north Pacific.

Some fish spend their young stages in surface waters or migrate into this zone diurnally, particularly at night. For these the neuston collections provide insights that cannot be observed in the standard oblique plankton collections. The neuston net samples some species in far greater numbers—the Pacific saury is a prime example—and so is an excellent tool for establishing distribution and relative abundances. The neuston net samples a higher proportion of large larvae of some species, the northern anchovy for example, than does the oblique net, and so may become a valuable tool in mortality determinations. Other genera in which the neuston net sampled larger larvae than are usually taken in the oblique net include *Sebastes, Anoplopoma,* and *Macrorhamphosus.* The neuston collections of oceanic fishes in the family Myctophidae demonstrate interesting behavioral pattern differences between its two subfamilies. In one subfamily, Myctophinae, only juveniles and adults were taken. In the subfamily Lampanyctinae only larvae were taken. This marked contrast in behavioral pattern of the two subfamilies is not evident in oblique hauls.

The comparison of the neuston and oblique plankton collections shows the neuston net to be a highly selective gear, sampling some species in much greater abundance than the oblique net but also sampling far fewer species than the oblique plankton net. The neuston net presents interesting potentialities when used in addition to the standard oblique net.

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INTRODUCTION

This is the first report on neuston net collections made on cruises of the California Cooperative Oceanic Fisheries Investigations (CalCOFI). The collections were taken on extended Cruise 7205 which covered the cardinal lines of the regular CalCOFI pattern from line 10 off Puget Sound to Line 150 off southern Baja California as well as the terminal line, line 157 below Cape San Lucas, Baja California, a north-south extent of 1,680 miles (48° to 20° N). In addition, extensive offshore coverage was achieved by adding eight lines of offshore stations west of the CalCOFI pattern along latitudes 20°, 24°, 27°, 31°, 35°, 39°, 42°, and 46° N, extending offshore usually to 145° W longitude (Figure 1). This coverage is almost as extensive as that obtained by CalCOFI vessels on the cooperative NORPAC Expedition of 1955. A total of 105 neuston hauls was obtained over the regular CalCOFI grid and 43 hauls on the eight offshore lines.

METHODS AND EQUIPMENT

The neuston net hauls were made simultaneously with the oblique plankton tows. This was achieved by launching the neuston net from a different winch located on the opposite side of the vessel simultaneously with the launching of the net assembly for the oblique hauls; it was retrieved at the same instant as the oblique tow. Speed of hauling was 1.5 to 2 knots. The duration of the haul averaged 21.5 minutes. Inasmuch as we wish to compare the catches made by the two types of hauls, neuston versus oblique, only those stations are included where both types of catches were made.

The neuston net used on this CalCOFI cruise was anything but sophisticated. A CalCOFI meter net frame (1.0 m diameter) was bent from round to ovoid, and a styrofoam float was fastened in either side of the mouth of the net. The floats maintained the net so that only about half of the mouth was under water. A standard CalCOFI net constructed of 505 micron mesh was utilized. It is estimated that the effective straining area at the mouth was about 0.3 m². As might be anticipated, the net performed consistently well in relatively calm seas, and less so in

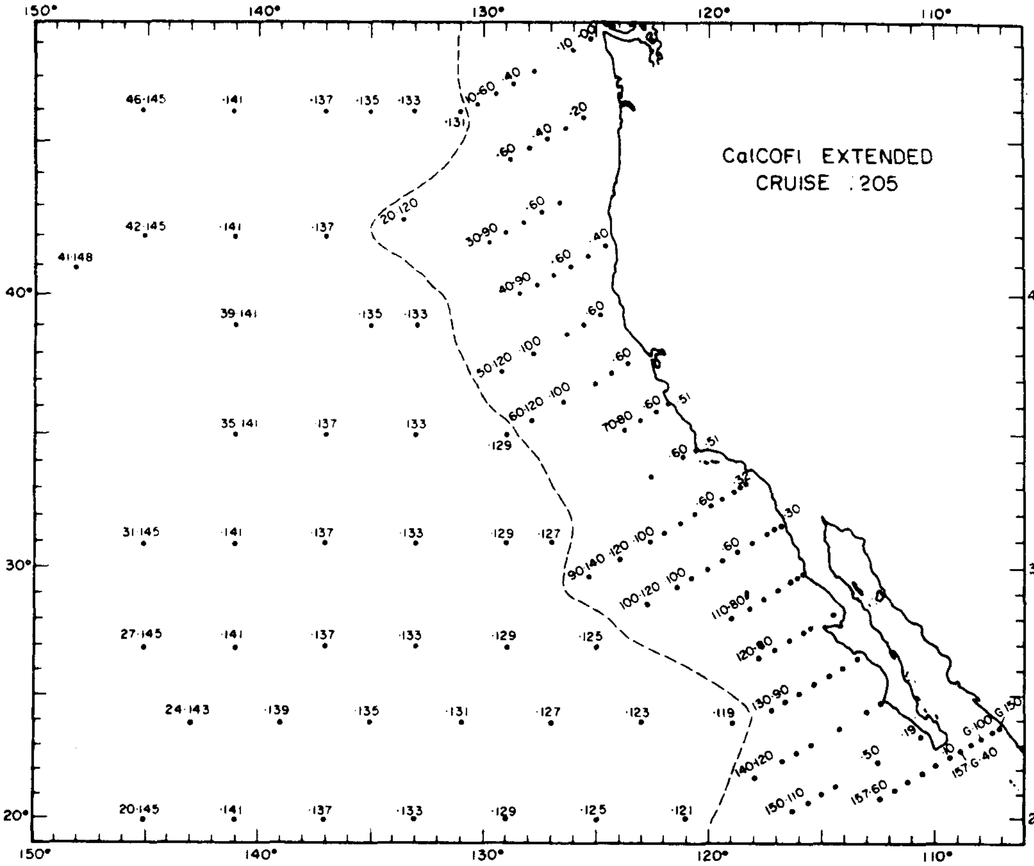

FIGURE 1. Station pattern for CalCOFI extended Cruise 7205.

more turbulent seas. The amount of water strained by the neuston net in moderate seas is estimated to be between 250 to 300 m^3. No current meter was used in the neuston net; however, a current meter was used in taking the simultaneous oblique haul, also utilizing a 505 micron mesh CalCOFI net. Information on distance traversed during each haul can be derived from this current meter's readings. The regular CalCOFI net was lowered to about 200 m depth (300 m of wire payed out) and retrieved at a uniform rate.

The regular CalCOFI cruises do not extend far enough offshore to completely delimit the spawning distribution of jack mackerel, *Trachurus symmetricus*, or of the Pacific saury, *Cololabis saira*. Eggs and larvae of these two species usually are at or near their peak abundance during May. Cruise 7205 was designed, in part, to more effectively sample the offshore distributions of these two species. As our results will demonstrate, the neuston net is a much more effective gear for sampling the larvae and juveniles of the Pacific saury than is our CalCOFI gear. Although both nets sampled eggs and larvae of jack mackerel, the CalCOFI oblique hauls obtained these in more collections.

RESULTS

Number of Specimens Taken

In the following discussion and throughout this presentation, we are dealing with actual counts of specimens taken in hauls. No attempt has been made to standardize the counts since there is no simple way to standardize counts from neuston hauls.

The number of fish larvae per collection in the neuston net ranged from zero to 1,039. Numbers of specimens per haul were grouped in six categories of abundance for both neuston and oblique hauls

TABLE 1

Summary for Six Abundance Categories of Number of Larvae per Collection for Neuston Hauls and Oblique CalCOFI Net Hauls on Extended CalCOFI Cruise 7205

Lines	Neuston net collections								Oblique net collections							
	Number larvae per haul								Number larvae per haul							
	0	1-10	11-50	51-100	101-1,000	over 1,000	Total	Average no/station	0	1-10	11-50	51-100	101-1,000	over 1,000	Total	Average no/station
Regular CalCOFI pattern																
10- 50	11	12	1	3	1	0	28	31.2	2	8	15	3	0	0	28	21.8
60-100	3	14	9	3	4	0	33	75.6	0	4	11	4	12	2	33	248.8
110-150	1	13	13	2	3	1	33	58.8	0	4	10	4	13	2	33	215.4
157	1	1	2	2	5	0	11	156.6	0	0	2	1	8	0	11	354.5
Subtotal	16	40	25	10	13	1	105	67.0	2	16	38	12	33	4	105	188.8
Offshore latitudinal lines																
46- 41	6	3	1	0	0	0	10	2.2	0	1	9	0	0	0	10	26.6
39- 31	2	3	5	2	1	0	13	33.4	0	1	3	3	6	0	13	78.5
27- 20	0	4	12	4	0	0	20	28.6	0	0	4	6	10	0	20	130.6
Subtotal	8	10	18	6	1	0	43	23.9	0	2	16	9	16	0	43	90.7
Total	24	50	43	16	14	1	148		2	18	54	21	49	4	148	
% of total whole numbers	16	34	29	11	9	1	100		1	12	37	14	33	3		

(Table 1). Fewer larvae were taken on the average in neuston hauls. Samples having zero to 10 larvae made up fully 50%; with zero hauls contributing 16%, hauls with one to 10 larvae, 34%. The contributions of other abundance categories was as follows: samples with 11 to 50 specimens, 29%, samples with 51 to 100 specimens, 11%, and samples with 101 or more, 10%.

In the oblique hauls, 50% had 50 or fewer larvae; with two zero hauls contributing slightly more than 1%, hauls with one to 10 larvae comprising 12% and hauls with 11 to 50 larvae, 37%. One-half of the oblique hauls contained 51 or more larvae, with 3% containing over 1,000 larvae, 33% with 101 to 1,000 larvae, and 14% with 51 to 100 larvae.

Fewer larvae were taken in the northern part of the survey area than elsewhere by both types of plankton hauls. Thus, on the upper five lines (10 to 50) of the regular CalCOFI grid, an average of only 22 larvae per haul was obtained in oblique hauls, whereas an average of fully 10 times as many larvae per haul was obtained from the remainder of the CalCOFI pattern.

The contrast in numbers between the two types of hauls was most pronounced on the two northern offshore latitudinal lines (along latitude 46° and 41°) where only 2.2 specimens per haul were taken by the neuston net as compared to 26.6 specimens per haul in oblique collections. Over the regular CalCOFI pattern, the average catch in the neuston hauls was approximately one-third that taken in oblique hauls, and was somewhat less than one-third in offshore stations.

Kinds of Larvae Taken

Regular CalCOFI Stations (Lines 10 to 157)

Neuston net hauls. The neuston net at stations of the regular CalCOFI grid caught 7,031 larvae-juveniles belonging to 51 categories (Table 2). Of these, two were Clupeiformes, three Stomiatoidei, 10 Myctophidae, three Scomberesocidae-Exocoetidae, six Scorpaeniformes, four Pleuronectiformes, 16 Perciformes, and seven others. Absent from the neuston collections were larvae of Argentinoidei, Myctophiformes other than Myctophidae, and Melamphaidae. Taken exclusively in the neuston hauls were larvae- juveniles of *Anoplopoma fimbria* (468 specimens in seven hauls), *Macrorhamphosus gracilis* (43 specimens in seven hauls), and *Opisthonema* sp. (149 larvae in three hauls). The average number of larvae per haul was 67.0.

In the neuston hauls 10 categories (six species, four genera) contributed 91.4% of the total, as follows: *Engraulis mordax*, 43.3%; *Cololabis saira*, 15.6%; *Oxyporhampus micropterus*, 11.2%; *Anoplopoma fimbria*, 6.7%; *Tarletonbeania crenularis*, 4.2%; *Oligoplites* sp. 3.6%; *Opisthonema* sp., 2.1%; *Sebastes* sp., 1.9%; *Vinciguerria lucetia*, 1.9%, and *Auxis* sp., 0.9%.

Oblique net hauls. Almost 2.5 times as many kinds of larvae were taken in the oblique hauls as in neuston hauls made over the regular CalCOFI grid of stations; 123 categories as compared to 51 (Table 2). The breakdown of the kinds of larvae taken in regular hauls was as follows: two Clupeiformes, 10 Argentinoidei, 10 Stomiatoidei, 26 Myctophidae, 12 other Myctophiformes, five Anguilliformes, three Scomberesocidae-Exocoetidae, five Gadiformes, three Melamphaidae, 12 Pleuronectiformes, seven Scorpaeniformes, 22 Perciformes, and six others. The average number of larvae per haul was 188.8.

In the oblique hauls, 10 categories (eight species, two genera) contributed 87.1% of the larvae obtained, as follows: *Engraulis mordax*, 53.8%;

TABLE 2

Comparisons of Catches of Neuston Net and Oblique CalCOFI Net at 105 Stations Over the Regular CalCOFI Pattern on Cruise 7205

	Neuston				Oblique			
	Occurrences	Number Specimens	Stage	Size Range (mm)	Occurrences	Number Specimens	Stage	Size Range (mm)
Clupeidae:								
Opisthonema sp.	3	149	L	3.0–15.0	0	0	..	0
Engraulidae:								
Engraulis mordax	25	3,041	L	2.5–31.0	36	10,671	L	2.0–20.5
Bathylagidae:								
Leuroglossus stilbius	0	0	..	..	20	128	L-J	2.3–19.0
Bathylagus nigrigenys	0	0	..	..	8	45	L	2.5–10.0
Bathylagus ochotensis	0	0	..	..	25	70	L-J	4.9–27.5
Bathylagus wesethi	0	0	..	..	15	189	L	2.5–18.0
Sternoptychidae:								
Cyclothone spp.	0	0	..	..	12	68	L	3.3–13.5
Vinciguerria lucetia	7	136	L	2.0–15.5	35	3,162	L	2.0–19.0
Myctophidae:								
Ceratoscopelus townsendi	0	0	..	..	10	90	L	2.0–12.0
Diaphus spp.	2	4	L	4.2– 5.2	14	79	L	2.5– 6.6
		1	L	*5.8*				
Diogenichthys laternatus	2	1	J-A	19.5	7	673	L	1.8–10.4
Gonichthys tenuiculum	11	41	J-A	14.5–57.5	9	48	L	2.0– 6.7
Hygophum atratum	4	50	J-A	14.5–57.5	16	123	L	1.8–13.5
Lampadena urophaos	2	17	L	5.0– 6.5	4	18	L	2.9– 8.9
Lampanyctus spp.	1	2	L	3.4, 4.0	60	222	L	2.0–14.0
Myctophum nitidulum	1	1	J-A	35.0	1	1	L	4.0
Protomyctophum crockeri	0	0	..	..	40	102	L	2.5–19.0
Stenobrachius leucopsarus	3	4	L	3.5–13.2	40	277	L	2.5–14.0
Symbolophorus californiensis	3	3	J-A	39.5–71.0	14	81	L	2.9–12.5
Tarletonbeania crenularis	12	296	J-A	20.5–67.0	31	130	L	3.3–18.0
Triphoturus mexicanus	0	0	..	..	37	355	L	1.5– 9.4
Other myctophids incl unident	4	5	..	..	9*	128	..	..
Scomberesocidae:								
Cololabis saira	49	1,095	L-J	5.0–57.0	5	8	L	5.6–14.0
Exocoetidae:								
Oxyporhamphus micropterus	8	785	L	3.5–15.0	3	6	L	4.3– 6.5
Others	12	107	L-J	3.2–20.5	0	0	..	..
Merlucciidae:								
Merluccius productus	2	2	L	4.0, 14.5	15	75	L	2.0–16.5
Bregmacerotidae:								
Bregmaceros bathymaster	1	7	L	2.3– 4.0	6	957	L	2.4–11.5
Melamphaidae:								
Melamphaes spp.	0	0	..	..	22	44	L	2.4–20.5
Macrorhamphosidae:								
Macrorhamphosus gracilis	4	43	L-J	8.0–25.5	0	0	..	..
Sphyraenidae:								
Sphyraena sp.	1	31	L	2.5– 5.0	1	119	L	2.3– 4.9
Polynemidae:								
Polydactylus sp.	1	13	L	4.0–13.5	1	5	L	2.0– 3.0
Mugilidae:								
Mugil sp.	7	53	L-J	3.5–19.0	1	1	L-J	19.0
Carangidae:								
Trachurus symmetricus	5	43	L	2.5– 3.5	20	450	L	1.5–15.0
Oligoplites sp.	1	253	L	3.0– 8.5	1	15	L	2.8– 4.3
Coryphaenidae:								
Coryphaena sp.	3	3	L	4.2–15.0	2	4	L	3.0– 5.2
Scombridae:								
Auxis sp.	3	60	L	2.5–11.0	5	93	L	2.0– 5.9
Blenniidae:								
Hypsoblennius sp.	4	6	L	6.6–12.0	1	1	L	3.4
Scorpaenidae:								
Sebastes spp.	15	137	L-J	3.0–33.5	37	307	L-J	3.1–17.0
Cottidae:								
Scorpaenichthys marmoratus	2	6	L	7.0–11.0	0	0	..	..
Anoplopomatidae:								
Anoplopoma fimbria	7	468	L	9.0–32.5	0	0	..	..
Hexagrammidae:								
Hexagrammos sp.	4	5	L-J	12.0–31.0	0	0	..	..
Oxylebius pictus	2	4	L	2.7– 8.9	0	0	..	..
Pleuronectidae:								
Pleuronichthys sp.	2	3	L	5.8– 9.0	3	3	L	2.6– 7.0
Bothidae:								
Citharichthys sp.	3	3	L	3.2– 5.1	8	36	L	2.5–33.5
Paralichthys californicus	2	2	L	7.8, 7.9	1	5	L	2.2– 2.9
Other identified:	18	102	..	..	89*	640	..	..
Unidentified:	5	36	..	..	..	304	..	..
Disintegrated:	6	13	..	..	..	88	..	..
TOTAL	105	7,031	..	..	105	19,823	..	..

* Indicates number of categories included rather than number of occurrences.

TABLE 3

Comparison of Catches of Neuston Net and Oblique CalCOFI Net at 43 Stations Spaced Along Six Offshore Latitudinal Lines on Cruise 7205.

	Neuston				Oblique			
	Occurrences	Number Specimens	Stage	Size Range (mm)	Occurrences	Number Specimens	Stage	Size Range (mm)
Bathylagidae:								
Bathylagus spp.	0	0	--	--	13	50	L	3.7-18.5
Sternoptychidae:								
Cyclothone spp.	2	3	L	2.0- 6.5	32	232	L	2.0-16.0
Diplophos taenia	1	1	L	6.0	6	8	L	4.8-43.5
Sternoptyx sp.	0	0	--	--	23	157	L	2.1- 9.6
Vinciguerria spp.	3	6	L; J-A	7.0-40.0	27	823	L	2.1-19.5
Other	0	0	--	--	10*	107	--	--
Malacosteidae:								
Aristostomias sp.	3	7	L	17.5-42.0	4	8	L	6.1-27.5
Melanostomiidae:								
Bathophilus sp.	5	7	L	4.0-28.0	5	6	L	4.4-26.0
Eustomias sp.	2	2	L	6.0-16.0	0	0	--	--
Stomiatoidei:								
Other	0	0	--	--	8	91	--	--
Myctophidae:								
Bolinichthys sp.	6	38	L	4.3-12.0	9	22	L	2.7- 8.9
Ceratoscopelus spp.	5	46	L	3.2-15.0	30	567	L	1.8-17.0
Diaphus spp.	1	1	L	3.7	17	54	L	2.3- 9.2
Diogenichthys spp.	0	0	--	--	25	250	L	2.0-11.0
Electrona rissoi	0	0	--	--	12	37	L	2.6- 7.5
Gonichthys tenuiculus	2	5	J-A	23.5-46.0	0	0	--	--
Hygophum spp.	1	6	J-A	13.5-22.0	20	84	L	2.4-11.5
Lampadena urophaos	7	144	L	3.5-17.0	16	63	L	2.2-12.5
Lampanyctus spp.	5	6	L	3.5-13.5	36	238	L	2.0- 8.0
Loweina rara	1	1	J-A	24.0	5	7	L	2.9- 8.6
Myctophum nitidulum	1	1	J-A	20.0	18	41	L	2.3- 9.6
Notolychnus valdiviae	0	0	--	--	19	90	L	2.0- 8.7
Notoscopelus resplendens	0	0	--	--	17	86	L	2.3-15.5
Protomyctophum spp.	0	0	--	--	13	35	L	2.5-17.2
Symbolophorus spp.	0	0	--	--	20	77	L	3.2-15.5
Stenobrachius leucopsarus	2	2	L	3.4, 10.0	8	95	L	3.0- 9.0
Taaningichthys minimus	14	142	L	4.5-20.0	3	3	L	4.7- 9.4
Tarletonbeania crenularis	0	0	--	--	8	29	L	5.0-18.0
Triphoturus spp.	0	0	--	--	9	34	L	2.9-11.6
Other	4	10	L, J	3.0-16.5	9*	78	L	2.5-12.0
Paralepididae:								
Several kinds	0	0	--	--	25	49	L	3.0-45.0
Scopelarchidae:								
Scopelarchus spp.	0	0	--	--	12	24	L	3.8-29.0
Scomberesocidae:								
Cololabis saira	25	347	L-J	4.5-71.0	1	1	J-A	82.0
Cololabis adocetus	6	158	L-J	4.6-49.0	0	0	--	--
Exocoetidae:								
Several kinds	12	64	L-J	4.0-20.5	0	0	--	--
Bregmacerotidae:								
Bregmaceros spp.	0	0	--	--	12	39	L	1.9-19.2
Melamphaidae:								
Several kinds	0	0	--	--	26	88	L	1.8-17.0
Percicthyidae:								
Howella sp.	0	0	--	--	7	25	L	2.3- 4.1
Bramidae:								
Brama japonica	0	0	--	--	4	9	L	3.0- 6.4
Coryphaenidae:								
Coryphaena sp.	2	2	L	11.0-18.0	1	1	L	4.3
Gempylidae—Trichiuridae:								
Several kinds	0	0	--	--	13	19	L	2.1-17.5
Carangidae:								
Trachurus symmetricus	1	18	L	1.7- 3.5	5	62	L	2.0- 4.5
Naucrates ductor	2	2	L	9.5, 10.5	0	0	--	--
Scorpaenidae:								
Sebastes spp.	1	1	L	12.0	1	4	L	7.0-11.5
Ceratiodei:								
Five families	0	0	--	--	5*	10	L	2.2- 5.0
Other identified:	0	0	--	--	20*	44	--	--
Unidentified:	3	3	--	--	27	92	--	--
Disintegrated:	3	4	--	--	21	59	--	--
TOTAL	43	1,027		--	43	3,899		--

* Indicates number of categories included rather than number of occurrences.

Vinciguerria lucetia, 16.0%; *Bregmaceros bathymaster*, 4.8%; *Diogenichthys laternatus*, 3.4%; *Trachurus symmetricus*, 2.3%; *Triphoturus mexicanus*, 1.8%; *Sebastes* spp., 1.5%; *Stenobrachius leucopsarus*, 1.4%; *Lampanyctus* spp., 1.1%; and *Bathylagus wesethi*, 1.0%.

Offshore Latitudinal Lines

Neuston net hauls. In the offshore collections, only 24 kinds of larvae-juveniles were taken in the neuston net hauls (Table 3); of these five were Stomiatoidei, 11 Myctophidae, three Scomberesocidae-Exocoetidae, one Scorpaeniformes (*Sebastes* sp.), and three Perciformes (*Trachurus symmetricus*, *Naucrates ductor*, and *Coryphaena* sp.). The catches were dominated by larvae-juveniles of Scomberesocidae-Exocoetidae and larvae of Myctophidae, which combined contributed 94.5% of the specimens. Two scomberesocids and four myctophids contributed 85.2% of the total, as follows: *Cololabis saira*, 33.8%; *C. adocetus*, 15.4%; *Lampadena urophaos*, 14.0%; *Taaningichthys minimus*, 13.8%; *Ceratoscopelus* sp. (*townsendi*-complex), 4.5%; and *Bolinichthys* sp., 3.7%. The average number of larvae per haul was 23.9.

Oblique net hauls. Markedly more kinds of fish larvae were taken in the oblique plankton hauls made on the offshore latitudinal lines. They were grouped into 85 categories, of which 16 were Stomiatoidei, five Argentinoidei, 24 Myctophidae, 11 other Myctophiformes, four Melamphaidae, 11 oceanic Perciformes, five Ceratiodei, and nine others. The absence of some of these groups from neuston collections, such as the Argentinoidei was anticipated since the larvae were known to occur in or below the thermocline. However, the complete absence from neuston hauls of all myctophiform groups except Myctophidae was not anticipated. Among the myctophiform groups not sampled by the neuston net are the Paralepididae, Scopelarchidae, Scopelosauridae, and Evermannellidae. In the oblique hauls in the offshore area the Myctophidae contributed 48.5%; the Stomiatoidei, 36.7%; Argentinoidei, 1.4%; other Myctophiformes, 2.2%; Melamphaidae, 2.3%; oceanic Perciformes, 3.2%; and all others, 5.7%. The average number of larvae per haul was 90.7.

SPECIES

Inasmuch as we know a great deal about the kinds of larvae taken in our oblique hauls, and very little about the catches from surface neuston nets, we plan to orientate our discussions to the latter. The species or groups we will discuss in some detail are the following: northern anchovy, *Engraulis mordax*, eggs and larvae; Pacific saury, *Cololabis saira*, eggs and larvae-juveniles; jack mackerel, *Trachurus symmetricus*, eggs and larvae; sablefish, *Anoplopoma fimbria*, larvae; rockfish, *Sebastes* spp., larvae; slender snipefish, *Macrorhamphosus gracilis*, larvae-juveniles; myctophid lanternfishes, larvae-juveniles.

Anchovy (Eggs and Larvae), *Engraulis mordax* Girard

Anchovy eggs were taken in 13 neuston net hauls and in '7 oblique plankton hauls at comparable stations (Figure 2). However, the total number of eggs collected was greater in the neuston hauls; 4,529 as compared to 2,741. Studies on vertical distribution of anchovy eggs (Ahlstrom, 1959; Ahlstrom et al., 1958) indicated a variable depth distribution within the upper mi~ed layer from haul-to-haul, sometimes with largest concentrations near the surface, sometimes not.

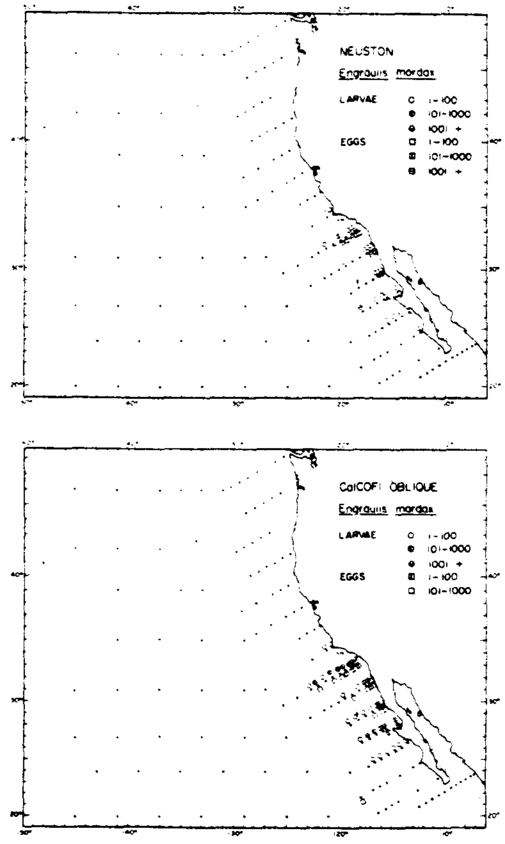

FIGURE 2. Distribution and relative abundance of eggs and larvae of the northern anchovy, *Engraulis mordax*, taken in neuston hauls (upper) and CalCOFI oblique hauls (lower) on Cruise 7205.

We have made two simple assumptions to facilitate comparison of numbers of eggs taken in the two types of hauls, both using 505 micra meshes. First we assumed that the neuston haul strained approximately 30% as much water as the standard oblique haul, and second that anchovy eggs were distributed between the surface and 60 m deep, hence for the oblique hauls which averaged approximately 200 m depth, the net was in water containing anchovy eggs during 30% of the time duration of the haul. If these assumptions are acceptable, the original counts from the two nets should be roughly comparable. The comparisons indicate higher concentrations of eggs near the surface in better than half of the hauls containing 40 or more eggs in either net.

Anchovy larvae were taken in 25 neuston net collections; they were obtained in oblique net hauls made at all of these stations, and at 11 additional stations on which both types of hauls were taken.

As indicated above, it was estimated that the neuston net strained approximately 30% as much water as the obliquely drawn net. The neuston net also collected about 30% as many anchovy larvae as the oblique net. However, anchovy larvae were probably collected during 30% to 50% of the time duration of the oblique haul, because they were seldom deeper than 100 m and usually shallower. Hence, less larvae were taken by the neuston net per unit volume of water strained than by the oblique net while sampling the depth stratum over which anchovy larvae were distributed.

A different segment of the anchovy larvae population was sampled at the surface in neuston net hauls than in the complete depth distribution of anchovy larvae sampled by the oblique plankton hauls (Table 4). Only about 2.5% as many small larvae, 2.0 to 6.0 mm, were taken in neuston hauls as in oblique plankton hauls. Conversely, only 2.5% as many large larvae, 14.5 mm and larger, were taken in the oblique hauls as in the neuston net hauls. These are striking differences. Obviously, larger anchovy larvae tend to congregate in the surface layer. The oblique net collected more larvae of all size categories between 2.0 and 10.0 mm, whereas the neuston net collected more larvae of all size categories, 10.5 mm and longer (Figure 3).

TABLE 4

Extended Cruise 7205, Anchovy Larvae, by Size Category, Taken in Neuston Net Hauls and Regular Plankton Hauls at the Same Stations

Size Category	Neuston	Regular Plankton
2.0	0	88
2.5	1	529
3.0	11	1809
3.5	15	1242
4.0	29	851
4.5	29	598
5.0	41	516
5.5	21	419
6.0	15	437
6.5	32	345
7.0	45	422
7.5	58	349
8.0	131	559
8.5	139	424
9.0	227	402
9.5	171	231
10.0	186	235
10.5	182	152
11.0	182	99
11.5	210	57
12.0	178	39
12.5	159	26
13.0	170	16
13.5	120	12
14.0	118	8
14.5	108	1
15.0	75	5
15.5	67	1
16.0	51	1
16.5	33	
17.25	58	2
18.25	37	1
19.25	27	1
20.25	11	
21.25	5	
22.25	2	
23.25	3	
24.25	4	
..		
28.25	1	
..		
31.25	1	
Dis.	88	788
Total	3,041	10,665

Pacific Saury (Eggs and Larvae), *Cololabis saira* (Brevoort)

The eggs of the Pacific saury are irregularly ovoid in shape, with a cluster of attachment filaments at one pole and a single median filament. The eggs often are found attached to cables or ropes of gear left suspended in the water (i.e. drogues, buoys, nets, etc.). The eggs are sometimes found attached to larger invertebrates, especially salps.

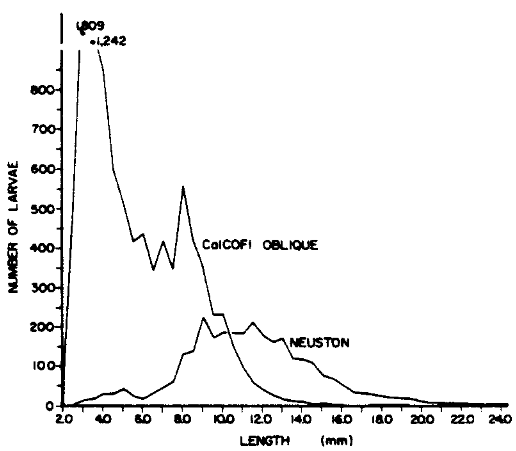

FIGURE 3. Size composition of larvae of northern anchovy, *Engraulis mordax*, in neuston collections versus CalCOFI oblique collections for all stations occupied in Cruise 7205.

The saury egg develops slowly; we lack precise information on rate of development as related to temperature, but it is about 10 days at room temperature for eggs kept in a finger bowl (Smith, Ahlstrom and Casey, 1970).

Despite the fact that saury eggs are spawned in large clusters, the eggs tend to fragment into small clusters (two to 10 eggs) or into individual eggs. Most saury eggs taken in plankton hauls are either individually separate or in small clusters.

Saury eggs were taken in 15 neuston net hauls, all from the regular CalCOFI pattern. Six of the hauls contained a single egg, seven hauls contained two to 10 eggs, one haul had 89 eggs, and one haul contained a very large group of approximately 3,000 eggs. The latter is one of the larger clusters of saury eggs that has been taken in a net haul. Only a single stage of development was observed in the eggs examined

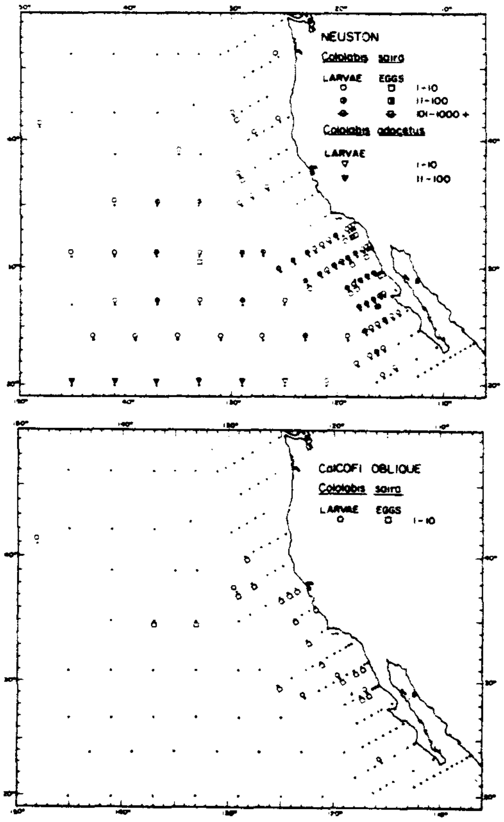

FIGURE 4. Distribution and relative abundance of eggs and larvae of Pacific saury, *Cololabis saira*, taken in neuston hauls (upper) and CalCOFI oblique hauls (lower). Larvae of *Cololabis adocetus* taken only in neuston hauls (upper) on Cruise 7205.

from this cluster, and similarly for the sample containing 89 eggs. In two of the samples with small numbers of eggs, two developmental stages were represented, hence these contained eggs spawned on two different nights.

Saury eggs were taken in 18 oblique net hauls of which 16 were from the regular CalCOFI grid and two from offshore (Figure 4). No collections contained more than seven eggs and 11 collections contained but a single egg, hence large clusters of eggs were lacking. Of the seven collections with two or more eggs, four contained eggs with two stages of development, representing two days' spawning.

Saury eggs appear to be equally well (or poorly) collected by both types of gear; approximately 10% of the neuston hauls contained saury eggs, compared to circa 12% for oblique hauls.

Saury larvae-juveniles present quite a different picture. Larvae-juveniles of saury were taken in 74 of the 148 stations occupied with neuston gear on Cruise 7205, i.e., in 50% of the stations occupied; whereas these stages were obtained in only six oblique hauls, i.e., in 4% of the stations occupied. This is a dramatic difference.

Sampling with the neuston gear is even better than one would conclude from the above figure of 50% positive hauls. In the northern part of the survey pattern it was too early in the year for full saury spawning—rather spawning was just commencing in the waters off Washington and Oregon. Likewise, in the southern part of the pattern, particularly inshore off southern Baja California, we did not get saury spawning because this was beyond the southern limit of saury spawning. In the intermediate area—off northern Baja California and southern California, sauries were sampled at most stations occupied.

In addition to Pacific saury, *Cololabis saira*, there is a small tropical saury, *C. adocetus* Bohlke, in the eastern North Pacific. The dwarf species was taken at all stations occupied between 20.125 to 20.145 inclusive on the southernmost offshore line along 20° N latitude. The best method of distinguishing between these two species is by number of vertebrae. Specimens of *C. adocetus* had 56 to 58 vertebrae in contrast to those of *C. saira* which had 63 to 68. The young stages of the two species are remarkably similar in appearance otherwise. The caudal peduncle character given by Ueyanagi and Doi (1971) for distinguishing between specimens of the two species could not be consistently applied to our specimens. The positioning of the last finlet of the dorsal and anal fins in relation to the caudal fin was too similar on some specimens of both species to be a reliable character. Hence we relied on vertebrae counts made from radiographs for positive identifications.

Obviously the neuston net is a highly effective gear for sampling larvae-juveniles of saury, which live exclusively near the surface. The distributional pattern we obtained from neuston hauls on extended

Cruise 7205, including the sharp separation of the two species of *Cololabis*, was much better than the composite pattern based on positive hauls for saury larvae-juveniles from all previous offshore CalCOFI cruises.

Jack Mackerel (Eggs and Larvae), *Trachurus symmetricus* (Ayres)

The offshore distribution of eggs and larvae of the jack mackerel, *Trachurus symmetricus*, was seldom completely circumscribed on our regular CalCOFI cruises (Ahlstrom, 1969). One of the objectives of extended Cruise 7205 was to obtain information on the offshore distribution of eggs and larvae of this species. Farris (1961) showed that May was usually the peak month for eggs and June for larvae of *Trachurus symmetricus*.

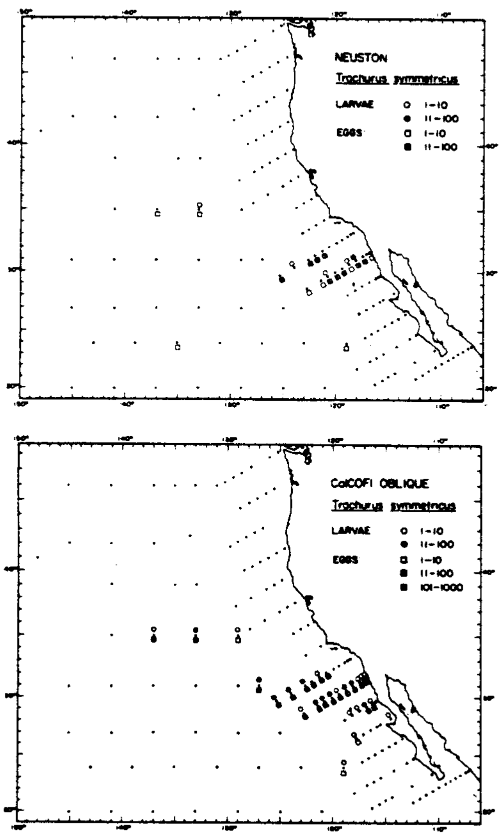

FIGURE 5. Distribution and relative abundance of eggs and larvae of jack mackerel, *Trachurus symmetricus*, taken in neuston hauls (upper) and CalCOFI oblique hauls (lower).

Although jack mackerel eggs and larvae were taken in both types of plankton hauls (Figure 5), the eggs and larvae occurred in more oblique hauls than in neuston net hauls. This was particularly true of the larvae; jack mackerel larvae were taken in only six neuston net hauls as compared to 25 oblique hauls. Moreover, only small jack mackerel larvae, 1.7 to 3.5 mm, were taken in the neuston collections; whereas, larvae up to 15.0 mm were taken in the oblique hauls. Hence, larger larvae of jack mackerel do not congregate near the surface as do those of the northern anchovy. Jack mackerel eggs, however, are collected relatively well in surface neuston hauls—occurring in 16 hauls as compared to 23 oblique hauls. Jack mackerel eggs previously had been found in some abundance near the surface (Ahlstrom, 1959; Bieri, 1961), hence their presence in the neuston net hauls was not unexpected.

Sablefish (Larvae), *Anoplopoma fimbria* (Pallas)

Larvae of the sablefish were taken in seven collections with most specimens taken at station 20.20 (Figure 6). A size series of 443 specimens, 9.0 to 33.0 mm, was obtained at this station. No specimens of sablefish larvae were taken in oblique plankton hauls on Cruise 7205. The large collection of sablefish from station 20.20 contained more specimens than the aggregate of all specimens collected previously in oblique hauls on CalCOFI cruises. A complete size series was available from this one haul—which we have used for illustrations (Figure 7). The larvae are slender, heavily pigmented and develop strikingly large, but distinctively pigmented pectoral fins. Brock (1940) called attention to the large pigmented pectoral fins, one-third the standard length, that

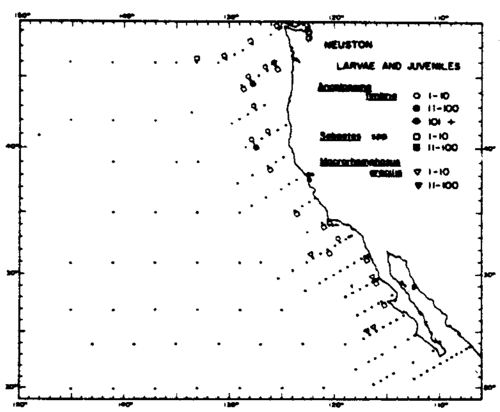

FIGURE 6. Distribution and relative abundance of larvae and early juveniles of the sablefish, *Anoplopoma fimbria*; rockfishes, *Sebastes* spp.; and slender snipefish, *Macrorhamphosus gracilis*, in neuston collections on Cruise 7205.

ANOPLOPOMA FIMBRIA

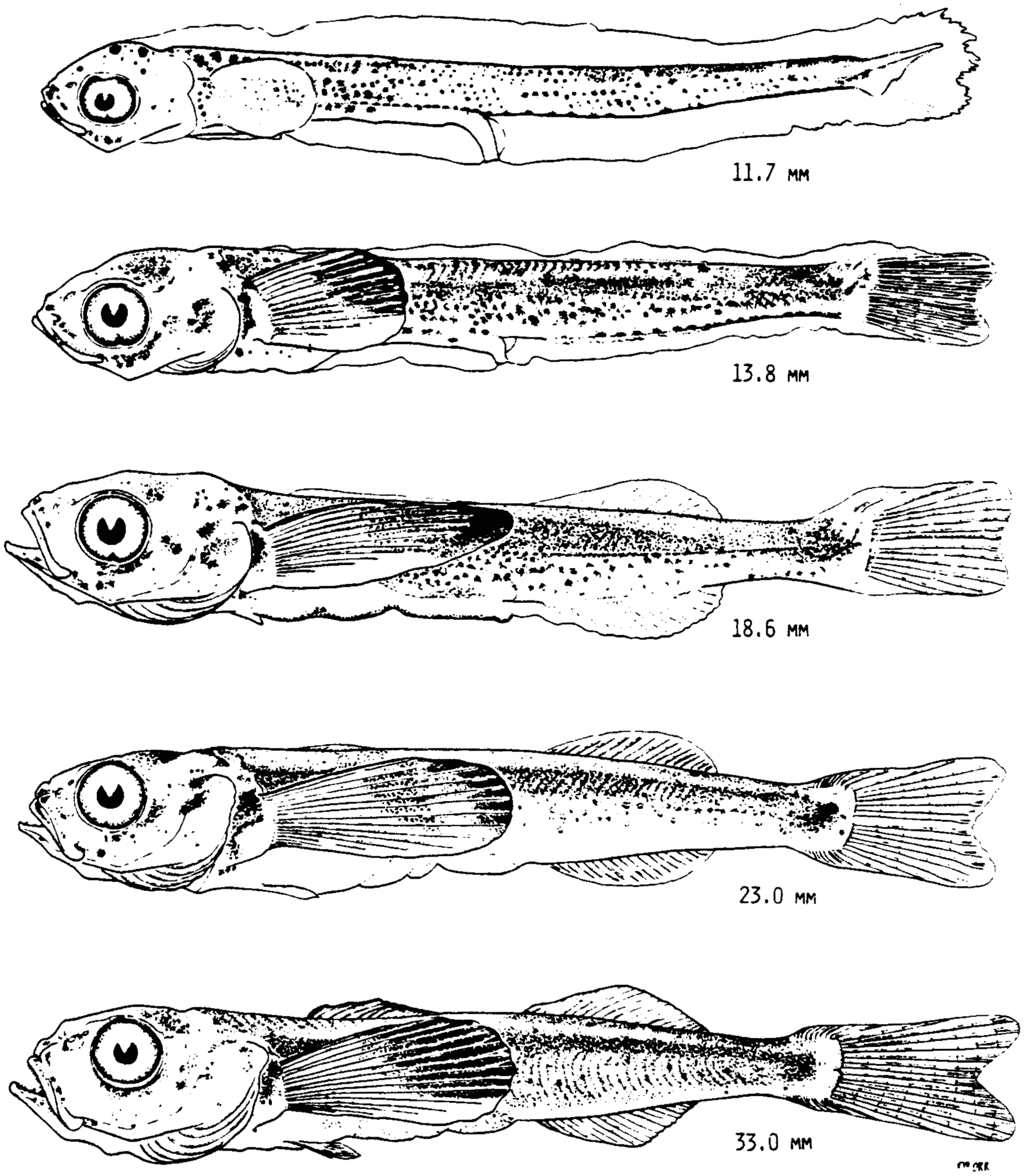

FIGURE 7. Larval developmental series of sablefish, *Anoplopoma fimbria*, based on neuston collections made at CalCOFI station 7205-20.20. Measurement given under figures are standard length.

develop on late-stage larvae of sablefish. Kobayashi (1957) described a larval series, with illustrations of five specimens, 11.3 to 30.2 mm total length. Our specimens are similarly shaped, but more heavily pigmented on the back and particularly more heavily pigmented on the outer margins of the pectoral fins.

Rockfish (Larvae), *Sebastes* spp.

Rockfish larvae were taken in 16 neuston collections (Figure 5). the two largest collections were obtained at stations 20.50 (60 specimens 8.5 to 15.0 mm) and 40.80 (48 specimens 14.5 to 31.0 mm). The latter collection, especially, contained larger sized specimens, seldom obtained in oblique plankton hauls. Rockfish larvae were taken in 38 oblique plankton hauls; the number of specimens per collection ranged from one to 55. The difference in size composition of the specimens taken by the two types of gear is quite dramatic. Of the 138 specimens taken in neuston collections, only 16 were 10.0 mm or less in standard length, 78 were in the size range of 10.1 to 20.0 mm, and 44 were 20.1 to 33.5 mm. In contrast, 298 of the 308 specimens taken in oblique hauls were 10.0 mm or less in body length and only 10 specimens were larger than 10.0 mm, i.e., 10.1 to 17.0 mm. Obviously larger size specimens of rockfish still in the pelagic stage do tend to congregate at the surface. Most rockfish in the neuston hauls appear to be a single species; although specimens could not be identified with certainty, *Sebastes alatus* is a possibility.

Slender Snipefish (Larvae-Juveniles), *Macrorhamphosus gracilis* (Lowe)

Larvae of this species are occasionally taken in CalCOFI collections. Specimens were obtained in four neuston collections (Figure 5); with most specimens in the collection taken at station 130.80, where 38 specimens ranging in length from 8.0 to 17.5 mm were caught. This is another instance in which the neuston collections contained both more specimens and larger sizes than were taken in oblique hauls. As Fitch and Lavenberg (1968) recorded, this species is a schooling fish usually occurring in small schools of 50 to 100 individuals, but on one occasion off southern California, fishermen set on a school estimated to contain 40 to 50 tons. No material of this species was obtained in the oblique plankton hauls made on extended Cruise 7205.

Family Myctophidae

The early developmental stages of myctophids are sharply separable into two groups, those that have narrow-eyed larvae and those that have round-eyed larvae. The myctophids in the first group belong to the subfamily Myctophinae, those in the second group to the subfamily Lampanyctinae (Paxton, 1972; Moser and Ahlstrom, 1972, 1974).

The family Myctophidae was well represented in neuston net collections, inasmuch as larvae and/or juvenile-adults were obtained for 15 genera—eight in the subfamily Myctophinae, seven in the subfamily Lampanyctinae. Equal numbers of specimens were obtained of each subfamily in neuston hauls, 407 as compared to 407. What was completely unanticipated was that all specimens except one of Myctophinae taken in neuston hauls were juvenile-adults, whereas all specimens of Lampanyctinae were exclusively larvae.

Subfamily Myctophinae

As noted above, all specimens of this subfamily taken in surface neuston collections, save for one larva, were juvenile-adults, including recently transformed specimens, belonging to eight genera. In contrast, the collections of this subfamily from oblique plankton hauls contained only larvae, save for one juvenile of *Diogenichthys atlanticus*. Larval material was obtained of the eight genera sampled in neuston hauls, and of two additional genera (*Protomyctophum* and *Electrona*). Hence, for members of this subfamily the two types of gear sampled different developmental stages.

Most material of this subfamily in neuston collections was obtained over the regular CalCOFI grid—393 of 407 specimens. In contrast, larvae of this subfamily were slightly more abundant in the offshore grid of stations in oblique plankton hauls, the average number per collection was 14 in the offshore grid, 12 over the regular CalCOFI grid.

The several kinds of juvenile-adult myctophids of the subfamily Myctophinae taken in neuston net hauls belong to species that commonly have been dipnetted under working lights of our research vessels while on station.

The four genera of myctophids known collectively as the slendertails are among the lanternfishes that are known to occur at the surface. The most common species of slendertails in the neuston net hauls was *Tarletonbeania crenularis* (Figure 8, upper); 296 specimens, 20.5 to 67.0 mm standard length were obtained from 12 hauls, preponderantly from the northern part of the regular CalCOFI pattern, i.e. lines 10 to 30 off Washington and Oregon. Its southern counterpart, *Gonichthys tenuiculus*, was taken in 13 collections from the southern part of the CalCOFI pattern, but in lesser abundance (Figure 8, upper), 46 specimens total, 14.5 to 57.5 mm standard length. Only single specimens of early juveniles were obtained of the other two genera of slendertails, a 24.0 mm specimen of *Loweina rara*, and a 16.5 mm specimen of *Centrobranchus choerocephalus*.

Among other Myctophinae lanternfishes only juveniles of *Hygophum atratum* were taken in any abundance in neuston hauls—56 specimens, 13.5 to 47.5 mm standard length from six stations off central and southern Baja California.

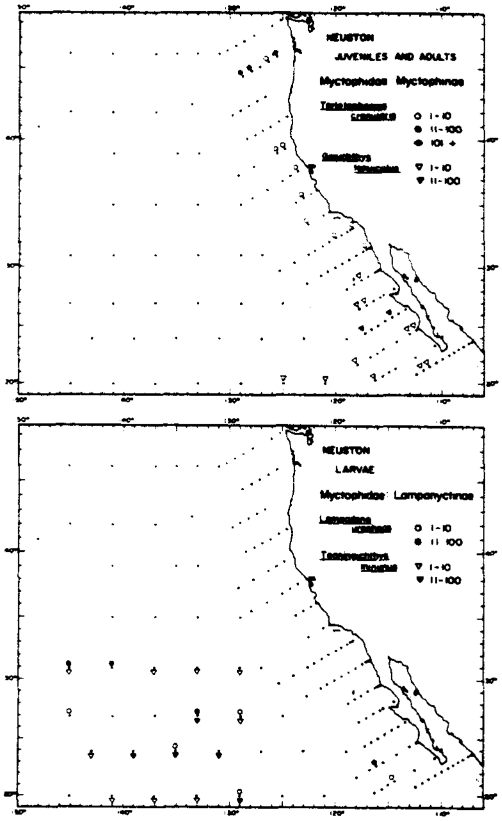

FIGURE 8. Upper—Distribution and relative abundance of juveniles and adults in two slendertails, *Tarletonbeania crenularis* and *Gonichthys tenuiculus* (Family Myctophidae, Subfamily Myctophinae). Lower—Distribution and relative abundance of larvae of two lanternfishes *Lampadena urophaos* and *Taaningichthys minimus* (Family Myctophidae, Subfamily Lampanyctinae).

Subfamily Lampanyctinae

Only larvae of lanternfishes of this subfamily, not juvenile-adults, were taken in neuston net hauls. The material from oblique plankton hauls consisted predominantly of larvae, together with a few juvenile-adult specimens. There is little relation between the kinds and relative abundance of myctophid larvae sampled by the two kinds of gear.

Only three kinds of lampanyctine larvae were taken at all commonly in neuston net hauls: *Taaningichthys minimus, Lampadena urophaos,* and *Bolinichtys* sp. In addition, four kinds were taken infrequently: *Ceratoscopelus* sp., *Diaphus* sp., *Lampanyctus* sp., and *Stenobrachius leucopsarus.*

Larvae of *T. minimus* furnish a prime example of a species taken in markedly greater abundance in neuston collections. Larvae of this species, ranging from 4.0 to 20.0 mm long, were obtained at 14 neuston stations, averaging 10 larvae per positive haul (Figure 8, lower). In oblique plankton hauls a total of three specimens, 3.0 to 9.0 mm long, was obtained in as many hauls. It should be noted that the size range sampled in neuston hauls is from early stage larvae to larvae about ready to metamorphose, i.e., all sizes of larvae of this species occur in the surface layer sampled by the neuston net. Adults of this species occur predominantly at depths between 450 and 500 m, and do not appear to perform daily vertical migration (Davy, 1972). Even so, the adults probably do migrate to the upper mixed layer to spawn; otherwise there is no obvious mechanism for the larvae to get to the surface layer from the depths at which the adults live.

Larvae of *L. urophaos* and *Bolinichthys* sp. were taken in larger numbers per collection in neuston hauls, but occurred in more than twice as many oblique hauls as neuston. A total of 162 specimens of *L. urophaos* larvae was taken in nine neuston collections, an average of 18 specimens per positive haul (Figure 8, lower). Larvae of this species were taken in 20 oblique hauls, but in lesser abundance—averaging only four specimens per positive haul.

Larvae of *Bolinichthys* sp. were taken in 13 oblique hauls as compared to six neuston hauls; however, the latter yielded 38 larvae as compared to a total count of 28 for oblique hauls.

For all other categories of lampanyctine lanternfishes, the oblique hauls obtained decidely more larvae in more collections. Several examples follow.

Larvae of *Ceratoscopelus* sp. were taken in five neuston hauls for a total count of 38, whereas larvae of *Ceratoscopelus* sp. occurred in 40 oblique hauls for a total count of 657.

Larvae of *Stenobrachius leucopsarus* were taken in five neuston hauls (total of six specimens) as compared to 48 oblique hauls in which 372 specimens were obtained. For the other two kinds of lampanyctine larvae taken in neuston hauls, *Diaphus* had three occurrences for a total of five specimens, and *Lampanyctus* had six occurrences for a total of eight as compared to 31 occurrences and 133 specimens of *Diaphus* and 96 occurrences and 460 specimens of *Lampanyctus* in oblique hauls.

Although larvae of *Triphoturus mexicanus* and *T. nigrescens* were not taken in neuston hauls, they occurred in 46 oblique hauls, contributing 460 specimens.

DISCUSSION

Most kinds of fishes taken commonly in the CalCOFI neuston collections or species closely related to these have been taken in other areas in neuston hauls (Hempel and Weikert, 1972; Nellen, 1973). For example, there is a striking similarity between the forms taken in neuston hauls in the vicinity of the Meteor Seamount in the eastern Atlantic (Nellen, 1973). The four most common kinds were *Scomberesox saurus*, the Atlantic equivalent of the Pacific saury, 57.3% of total; *Macrorhamphosus* sp., 36.2%; *Gonichthys cocco*, 3%; *Taaningichthys* sp., 0.6% for a composite total of 97.1%.

Advantages and Disadvantages of Neuston Net Collections

We propose to give a brief summary of the advantages and disadvantages of neuston net collections. For fishes that congregate near the surface at any stage in their early development—from eggs, larvae, to juvenile stages the neuston net is a good gear for establishing areal distribution and even relative abundance. For example, the distribution of the Pacific saury, based on neuston net hauls on Cruise 7205, provided a more coherent distributional pattern than was obtained from composite oblique plankton hauls records from a number of previous CalCOFI cruises. Furthermore, the distribution of the small tropical saury, *Cololabis adocetus*, could be sharply delimited from that of the Pacific saury, *C. saira*. The sablefish, *Anoplopoma fimbria*, was markedly more abundant in neuston net hauls and a larger size range of specimens was sampled than have been taken in oblique hauls. The lanternfish, *Taaningichthys minimus*, appears to prefer the surface layer at all stages of larval development.

For some kinds of fishes, larger sized specimens are taken in neuston hauls than in oblique hauls. A number of examples were given in the preceding discussions. For example, strikingly more larger anchovy larvae were taken in neuston hauls than in oblique; the size composition of rockfishes, *Sebastes* spp. taken by the two types of hauls also was markedly different, with larger sized specimens predominating in the neuston hauls. However, larvae of jack mackerel, *Trachurus symmetricus* proved an exception in that only small larvae were taken in neuston hauls, compared to a larger size range of larvae in oblique hauls. For some fishes, a different developmental stage was sampled by the neuston haul; thus, only juvenile-adult material of myctophine lanternfishes was taken in neuston hauls, whereas the complete size range of larvae of these lanternfishes was obtained in oblique hauls.

The marked difference in size composition of anchovy larvae in the neuston hauls as compared to standard oblique hauls points up the fact that the neuston hauls collect a disproportionate number of larger larvae while markedly undersampling the smaller sizes. What are the implications of these differences with regard to mortality estimates? A first reaction is that the neuston sample is a highly biased one, of dubious value for mortality studies. But the neuston haul does provide a much larger sample of anchovy larvae in the size range of 14 mm and larger—sizes that are poorly sampled in oblique hauls. On reconsideration, why not take advantage of this fact. If additional work with neuston hauls shows that the larger sized larvae of anchovies are consistently sampled by the neuston net from station to station and cruise to cruise, then this net could be used to provide estimates of changes in relative abundance of larger anchovy larvae from year to year—information essential for evaluating success of survival of cohorts of anchovies.

Although some species are sampled more abundantly in neuston hauls, the reverse is also true. Many kinds of larvae common in oblique hauls are rare or lacking in neuston collections. This net alone will not provide a representative sample of the fish larvae in a survey area. It should not be regarded as a primary tool, but a supplementary one with intriguing potentials.

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