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MESOPELAGIC AND BATHYPELAGIC FISHES IN THE CALIFORNIA CURRENT REGION

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The title of my talk "Mesopelagic and Bathypelagic Fishes" was assigned by the convenors of this symposium. I prefer to call the fishes that I will talk about "deep-sea pelagic fishes"; most are mesopelagic, some are bathypelagic, and a few are epipelagic. The word "deep" of deep-sea refers more particularly to the depth of the bottom, rather than the depth at which the fishes are distributed. Stated realistically, I am talking about all the small pelagic fishes not covered by the other speakers.

Most of my information is derived from CalCOFI surveys carried out over an 18-year period. As you know, fish eggs and larvae are sampled by quantitative plankton hauls. Standard CalCOFI plankton hauls sample a relatively shallow depth zone—from the surface to about 76.5 fathoms (140 meters) on the average. Recently, the depth of the hauls was increased to about 114.8 fathoms (210 meters)—the depth also sampled on EASTROPAC cruises, currently underway.

If I were dealing with adults exclusively, the depths sampled would be much too shallow to obtain meaningful information on mesopelagic and bathypelagic fishes. It is fortunate, consequently, that most of these fishes spawn either in the upper mixed layer or in the layer immediately below the thermocline, where the larvae become available to the CalCOFI sampling gear.

In a previous CalCOFI Symposium, I discussed the "Kinds and Abundance of Fishes in the California Current Region Based on Egg and Larval Surveys" (Ahlstrom 1965). In that presentation, I listed the 25 most abundant kinds of larvae obtained in each of 4 years, 1955–58. In those years larvae of deep-sea pelagic fishes made up 14 or 15 of the 25 most abundant kinds. A similar relation held in the 2 succeeding years: 17 kinds of deep-sea pelagic fishes were among the top 25 in 1959 and 15 kinds in 1960.

I will use data from these 6 years in my discussion of deep-sea pelagic fishes because they were collected during cruises spaced at approximately monthly intervals, and constitute our best series of data on the relative abundance of fish larvae. From 1961 through 1965, CalCOFI cruises were made at 3-month intervals; data on fish larvae from these cruises are similar to those derived from the earlier years but are less reliable because of the smaller number of surveys per year. In addition, the earlier series of years (1955–60) is particularly interesting because it included periods of contrasting oceanographic conditions; water temperatures over much of the CalCOFI area in 1956 were the lowest encountered during CalCOFI surveys, whereas they were markedly higher than average during 1958 and 1959.

Based on abundance of larvae, deep-sea pelagic fishes are predominantly of three kinds—myctophid lanternfishes, gonostomatid lightfishes, and deep-sea smelts of the family Bathylagidae. Larvae of these three families usually make up over 90% of the larvae of deep-sea pelagic fishes taken on CalCOFI surveys. The other 10%, however, constitute a very interesting and diverse group of fishes, including such bizarre kinds as hatchetfish, viperfish, and anglerfishes.

I have prepared a series of tables that will permit us to fit the "deep-sea pelagic fishes" into the total fish picture as determined from surveys of larvae; to look at the contributions, by family, of all the deep-sea pelagic fishes that occurred with any frequency in our larval collections; and then to look more closely at the kinds of larvae we take of myctophid lanternfishes, gonostomatid lightfishes, and deep-sea smelts of the families Bathylagidae and Argentinidae.

The values given in the tables, unless otherwise noted, are standard haul summations. The larvae taken in each collection are standarized to the number of larvae under 10 square meters of sea surface. The two essential pieces of information needed in deriving a standardization factor for the oblique planton hauls are (1) an estimate of the amount of water strained during a haul (based on revolutions registered by a current meter fastened in the mouth of the net), and (2) information on the depth stratum sampled (determined from length of towing cable payed out and the cosine of the angle of stray of the towing cable from the vertical). A standard haul total for a cruise is simply the summation of the standardized values for all stations occupied; the yearly total for a species is a summation of monthly cruise totals.

Larvae of deep-sea pelagic fishes made up about 20% to over 40% of the larvae obtained on CalCOFI survey cruises during 1955–60 (Tables 1 and 2). They represented a number of faunal groups: some are subarctic-temperate water forms, some are tropical-subtropical forms, and some are oceanic forms. The contribution of subarctic-temperate species tends to be largest during colder-than-average years, whereas tropical-subtropical and oceanic spe-

cies occur in largest numbers during warmer-than-average years. The tenfold change in relative abundance of gonostomatid larvae—from 2.6% of the total larvae in 1956 to 26.0% in 1959—largely reflects changes in abundance related to water temperature. The bathylagid smelts exhibit a threefold range in relative abundance, whereas the contribution of myctophid larvae is less variable from year to year (9.1% to 14.3% of the total). The larvae of all other deep-sea pelagic fishes constitute 1.0% to 1.85% of the larvae taken on CalCOFI surveys.

It should be noted that the CalCOFI collections are not typical of oceanic waters generally. They are dominated by the larvae of two species—northern anchovy, *Engraulis mordax*, and Pacific hake, *Merluccius productus*, which usually make up 45% to 60% the larvae—whereas deep-sea fishes are the dominant forms over vast expanses of the world's oceans.

TABLE 1

RELATIVE ABUNDANCE OF LARVAE OF THE MAJOR FAMILIES OF FISHES IN THE CALIFORNIA CURRENT REGION OFF CALIFORNIA AND BAJA CALIFORNIA DURING 1955–60

(Standard haul summations)

Family	Year					
	1955	1956	1957	1958	1959	1960
Epipelagic and bottom fishes						
Engraulidae	151,192	134,926	146,628	205,871	206,876	292,401
Clupeidae	14,181	15,934	10,384	12,228	5,983	9,081
Carangidae	13,282	8,330	20,402	6,547	4,558	5,584
Scombridae	1,956	1,784	2,280	1,455	970	1,464
Gadidae	61,377	89,861	78,291	58,364	17,662	33,022
Scorpaenidae	32,512	32,676	37,416	24,072	11,656	15,533
Bothidae	20,761	24,007	16,346	7,171	4,775	7,445
Pleuronectidae	2,121	2,786	2,101	993	705	706
Other	7,247	13,964	16,207	8,644	11,241	12,204
Subtotal	304,629	324,268	330,055	325,345	264,426	377,440
Deep-sea pelagic fishes (mostly mesopelagic and bathypelagic)						
Myctophidae	34,620	42,625	60,136	49,590	67,373	52,584
Gonostomatidae	14,297	10,672	58,075	60,710	122,073	37,121
Bathylagidae	19,690	23,019	37,006	13,618	10,623	32,762
Other	5,662	7,556	8,277	6,755	5,961	5,073
Subtotal	74,269	83,872	163,494	130,673	206,030	127,540
Total—all categories	[1]378,898	408,140	493,549	456,018	470,456	504,980

[1] Totals for 1955 include multiple occupancies of pattern off Southern California during September and November, but exclude Norpac.

TABLE 2

PERCENTAGE CONTRIBUTION OF LARVAE OF THE MAJOR FAMILIES OF FISHES IN THE CALIFORNIA CURRENT REGION OFF CALIFORNIA AND BAJA CALIFORNIA DURING 1955–60

Family	Year					
	1955	1956	1957	1958	1959	1960
Epipelagic and bottom fishes						
Engraulidae	39.9	33.1	29.7	45.1	44.0	57.9
Clupeidae	3.7	3.9	2.1	2.7	1.3	1.8
Carangidae	3.5	2.0	4.1	1.4	1.0	1.1
Scorpaenidae	8.6	8.0	7.6	5.3	2.5	3.1
Gadidae	16.2	22.0	15.9	12.8	3.7	6.5
Scombridae	0.5	0.4	0.5	0.3	0.2	0.3
Bothidae	5.5	5.9	3.3	1.6	1.0	1.5
Pleuronectidae	0.6	0.7	0.4	0.2	0.1	0.1
Other	1.9	3.4	3.2	1.9	2.4	2.4
Subtotal	80.4	79.4	66.8	71.3	56.2	74.7
Deep-sea pelagic fishes (mostly mesopelagic and bathypelagic)						
Bathylagidae	5.2	5.6	7.5	3.0	2.3	6.5
Gonostomatidae	3.8	2.6	11.8	13.3	26.0	7.4
Myctophidae	9.1	10.5	12.2	10.9	14.3	10.4
Other	1.5	1.9	1.7	1.5	1.2	1.0
Subtotal	19.6	20.6	33.2	28.7	43.8	25.3
Total—all categories	100.0	100.0	100.0	100.0	100.0	100.0

Table 3 summarizes, by family, the contributions of all deep-sea pelagic fishes that enter significantly into the CalCOFI catches. Twenty families are included, plus the ordinal grouping of "eel leptocephali." Families that made significant contributions, in addition to the Myctophidae, Gonostomatidae, and Bathylagidae discussed above, include the Agrentinidae, Melamphaidae, Centrolophidae, Tetragonuridae, Stomiatidae, and Paralepididae. The "other" category in Table 3, although not large in number of specimens, contains larvae from at least as many families as those separately listed.

The relative abundance of different kinds of myctophid larvae in the California Current region during 1955–60 is summarized in Table 4. The tabulation is given by species for all commonly occurring larvae except *Hygophum* spp., which includes larvae of *H. atratum* and *H. reinhardti; although Hygophum* larvae can be identified to species, we have not done so routinely when identifying and enumerating larvae of this genus. Sixteen genera are represented in this tabulation, and 4 more of sporadic occurrence *(Benthosema, Centrobranchus, Electorna,* and *Lepidophanes)* are included in the "other" category. Hence, 20 genera of myctophids are represented in the collection of larval fishes from the California Current region. A number of these are common to abundant and three (*Triphoturus mexicanus, Stenobrachius leucopsarus,* and *Diogenichthys laternatus*) consistently rank among the top 12 kinds of larvae.

The myctophids in the California Current region belong to several faunal assemblages. *Stenobrachius leucopsarus* and *Tarletonbeania crenularis* are subarctic-temperate species which are at the southern end of their range in the CalCOFI area. *Diogenichthys laternatus* is a tropical lanternfish that is collected as far north as central Baja California in all years and off southern California in warmer-than-average years. *Ceratoscopelus townsendi* is a widely distributed, offshore oceanic form that occurs in the outer part of the CalCOFI station grid. All of these species have a much more extensive distribution than is encompassed in the CalCOFI surveys. The oceanic distribution of *Triphoturus mexicanus,* the most abundant myctophid in CalCOFI collections, is perhaps as completely encompassed as any by the CalCOFI surveys. Larvae of this species are abundant off Baja California and in the Gulf of California.

We have had a deep interest in lanternfish larvae of the California Current region since the initiation of the CalCOFI surveys some 18 years ago, and at long last Dr. H. Geoffrey Moser and I are in the midst of preparing descriptions of their early life history stages. Larval studies can make a definite contribution to the understanding of relationships among genera and species in some fish families; the myctophids are an outstanding example. There are good larval characters, at the generic level, for all genera that occur in the California Current region. The 20 genera off California and Baja California whose larvae we can identify, represent two-thirds of all genera currently recognized in this family. Consequently, the information we are accumulating on myctophids off California will aid in the identification of myctophid larvae from other areas and other oceans.

The gonostomatid light fishes are represented in the CalCOFI collection by five genera: *Vinciguerria,*

TABLE 3

RELATIVE ABUNDANCE OF LARVAE OF THE PRINCIPAL FAMILIES OF DEEP-SEA FISHES (MOSTLY MESOPELAGIC AND BATHYPELAGIC) IN THE CALIFORNIA CURRENT REGION OFF CALIFORNIA AND BAJA CALIFORNIA DURING 1955–60

(Standard haul summations)

Family	Year					
	1955	1956	1957	1958	1959	1960
Argentinidae	1,277	1,603	1,852	690	359	527
Bathylagidae	19,690	23,019	37,006	13,618	10,623	32,762
Gonostomatidae	14,297	10,672	58,075	60,710	122,073	37,121
Sternoptychidae	186	181	269	324	326	203
Astronesthidae	0	37	0	227	16	14
Chauliodontidae	254	350	195	285	241	210
Idiacanthidae	35	66	87	147	126	291
Melanostomiatidae	47	32	158	113	105	90
Malacosteidae	15	6	43	36	34	20
Stomiatidae	411	81	271	1,188	824	621
Myctophidae	34,620	42,625	60,136	49,590	67,373	52,584
Paralepididae	324	366	452	689	633	586
Scopelarchidae	113	89	199	170	335	227
Melamphaeidae	773	1,051	1,328	1,259	1,095	793
Eel leptocephali	16	68	134	247	255	52
Bregmacerotidae	36	0	706	218	52	104
Trachipteridae	76	84	98	107	34	94
Trichiuridae	110	389	332	97	311	365
Chiasmodontidae	97	46	222	280	240	133
Centrolophidae	1,386	898	768	431	405	407
Tetragonuridae	490	2,154	708	60	107	92
Other	16	55	455	187	463	244
Total	74,269	83,872	163,494	130,673	206,030	127,540

Cyclothone, Ichthyococcus, Diplophos, and (infrequently) *Danaphos* (Table 5). Most gonostomatid larvae—88.5 to 96.6% in 1955–60—belong to one species, *Vinciguerria lucetia;* it may be the most abundant fish in the temperate and tropical waters of the eastern Pacific Ocean. We have described the development of this species from egg to adult (Ahlstrom and Counts 1958). Two other species of *Vinciguerria*—*V. nimbaria* and *V. poweriae*—occur in offshore oceanic waters, and have been sampled on the few cruises when our coverage extended seaward beyond California Current waters into the oceanic water mass. We obtained excellent information on the distribution of these two species on the portion of the "Norpac" survey of the North Pacific Ocean made by CalCOFI vessels (between 20° N.–45° N. lat. and offshore to 150° W. long.), in 1955.

The abundance of larvae of *V. lucetia* is variable in the CalCOFI area, depending on water temperatures: The number collected ranged from 9,800 in 1956, a cold year, to 118,000 in 1959, a warm year. In the latter year, *Vinciguerria* made up 25% of all fish larvae and was outranked only by the northern anchovy. Yet we sampled only the fringe of the distribution of *Vinciguerria lucetia,* as will be evident when I discuss later the results of EASTROPAC I, the multi-vessel cruise of the eastern tropical Pacific.

Although five or possibly six species of *Cyclothone* are taken in the CalCOFI area, only two are common, *C. signata* and *C. acclinidens. Cyclothone* larvae are also more abundant during warmer-than-average years than during cold years—3,840 were taken in 1959 as compared to 810 in 1956.

The Bathylagidae is the third family of deep-sea pelagic fishes that is common in the CalCOFI collections. We take larvae of six species of bathylagid smelts, but only three are abundant (Table 5). The most abundant species, *Leuroglossus stilbius,* is taken throughout the length of the CalCOFI pattern, and also in the Gulf of California. It usually ranks about fifth in abundance, surpassed only by larvae of northern anchovy, Pacific hake, rockfish (*Sebastodes* spp.), and *Vinciguerria.* Most larvae of the deep-sea smelts are distributed below the thermocline—not in the upper mixed layer—and thus have a distribution similar to that of hake larvae. Larvae of *Bathylagus ochotensis* seldom rank higher than 15th. It is a subarctic form that has a widespread distribution in the North Pacific; we sample only the southern extent of its distribution. *Bathylagus wesethi* is a subtropical species that occurs between central California and southern Baja California; the CalCOFI station grid may encompass much of its distribution. The three less common species of Bathylagidae in the CalCOFI collections are *Bathylagus pacificus, B. milleri,* and *B. nigrigenys;* the first two are subarctic forms and the last is a tropical species that is sometimes taken in the CalCOFI area off southern Baja California.

Four species of argentinid smelts occur in the CalCOFI area—*Argentina sialis, Microstoma microstoma,* and two species of *Nansenia* (Table 5). Only *Argentina* has occurred in numbers large enough to rank among the top 25 kinds of larvae, and then only in some years.

I mentioned previously that the deep-sea pelagic fishes are more dominant in offshore waters than in

TABLE 4

RELATIVE ABUNDANCE OF LARVAE OF MYCTOPHID LANTERNFISHES IN THE CALIFORNIA CURRENT REGION OFF CALIFORNIA AND BAJA CALIFORNIA, 1955–60

(Standard haul summations)

Species	Year					
	1955	1956	1957	1958	1959	1960
Ceratoscopelus townsendi	446	221	2,598	1,446	4,457	1,564
Diaphus spp.	1,022	3,562	713	605	722	703
Diogenichthys atlanticus	699	747	780	641	634	704
Diogenichthys laternatus	4,774	3,158	11,603	7,020	6,425	3,678
Diogenichthys sp.[1]	21	24	235	157	496	506
Gonichthys tenuiculus	141	60	466	742	803	208
Hygophum spp.[2]	400	223	795	998	1,250	854
Lampadena urophaos	38	--	--	338	996	323
Lampanyctus regalis	95	82	124	92	197	58
Lampanyctus ritteri	1,986	1,924	2,789	3,127	2,424	1,990
Lampanyctus spp.[3]	487	310	732	989	1,369	1,140
Loweina rara	44	23	27	22	28	27
Myctophum nitidulum	53	88	122	230	400	148
Notolychnus valdiviae	8	12	0	2	12	54
Notoscopelus resplendens	100	4	156	119	524	331
Protomyctophum crockeri	1,824	1,852	1,415	1,824	2,045	1,979
Stenobrachius leucopsarus	7,453	15,125	16,808	11,880	7,224	11,977
Symbolophorus californiense	656	462	1,645	1,280	1,115	602
Tarletonbeania crenularis	999	3,352	1,570	526	777	1,730
Triphoturus mexicanus	13,160	10,802	16,207	16,604	33,871	22,106
Other[4]	214	594	1,351	948	1,604	1,902
Total	34,620	42,625	60,136	49,590	67,373	52,584

[1] Small specimens of *D. atlanticus* and *D. laternatus,* which cannot be identified to species with certainty.
[2] *Hygophum atratum* and *H. reinhardti* (combined).
[3] *Lampanyctus* spp. includes larvae of *L. idostigma* and several other species.
[4] Includes disintegrated specimens that could be identified with certainty only to the family level.

TABLE 5

RELATIVE ABUNDANCE OF LARVAE OF GONOSTOMATID LIGHTFISH AND OF DEEP-SEA SMELTS OF THE FAMILIES BATHLAGIDAE AND ARGENTINIDAE IN THE CALIFORNIA CURRENT REGION OFF CALIFORNIA AND BAJA CALIFORNIA DURING 1955–60

(Standard haul summations)

	Year					
	1955	1956	1957	1958	1959	1960
Family Gonostomatidae						
Vinciguerria lucetia	12,658	9,832	55,114	57,424	117,959	35,041
Cyclothone spp.	1,532	814	2,880	2,921	3,844	1,974
Ichthyococcus spp.	106	13	69	139	122	26
Diplophos	0	9	12	218	126	68
Other	1	4	0	8	22	12
Total	14,297	10,672	58,075	60,710	122,073	37,121
Family Bathylagidae						
Leuroglossus stilbius	15,114	18,620	29,506	4,859	7,597	29,795
Bathylagus ochotensis	1,301	2,231	1,078	1,550	545	1,671
Bathylagus wesethi	3,245	2,146	6,347	7,033	2,386	1,207
Other	30	22	75	176	95	89
Total	19,690	23,019	37,006	13,618	10,623	32,762
Family Argentinidae						
Argentina sialis	877	1,288	1,400	276	101	249
Microstoma microstoma	92	81	56	105	107	64
Nansenia spp.	308	234	396	309	151	214
Total	1,277	1,603	1,852	690	359	527

the California Current region. This dominance was most evident when we identified and counted the larvae taken on Norpac, the first comprehensive survey of the North Pacific Ocean made during August 1955. The CalCOFI agencies used four vessels on Norpac to cover the extensive area between 20° N. and 45° N. lat. and offshore to 150° W. long. Myctophids made up 46.7% of the larvae and gonostomatids 34.8%. *Vinciguerria* (three species) was the most abundant genus, contributing 24.4% of the larvae; *Ceratoscopelus townsendi* was the most abundant myctophid, contributing 11.2% of the larvae. Three other genera contributed over 5% of the total larvae: *Cyclothone* (10.0%), *Triphoturus* (9.5%), and *Diogenichthys* (5.5%). The dominance of the myctophids and gonostomatids is typical of offshore oceanic waters in other parts of the world, such as the eastern tropical Pacific and the Indian Ocean. When I examined collections of larvae from the International Indian Ocean Expedition at the Indian Ocean Biological Centre at Ernakulam, India (while appraising the potential of the larval fish collection there), I found that collections of fish larvae from the oceanic zone contained 47.6% myctophids and 30.5% gonostomatids — percentages similar to those found on Norpac.

I have examined the fish larvae obtained on the first EASTROPAC cruise, made by four vessels during February and March 1967. Myctophid larvae made up 47.2% of the larvae obtained, gonostomatid larvae (including the allied hatchetfish of the Sternoptychidae), 29.2%, and bathylagid larvae, 5.1%.

As mentioned above, myctophid larvae can be reliably identified to genus, even when the species composition is not completely known. Eighteen genera were commonly represented in the EASTROPAC collections. One species far outranked all others: *Diogenichthys laternatus* contributed 26.7% of the total larvae collected on EASTROPAC. It proved to be even more numerous than the larvae of the gonostomatid light fish, *Vinciguerria lucetia*, which made up 19.7%. Larvae of only two species of Bathylagidae were present in EASTROPAC collections—*Bathylagus nigrigenys* (3.1% of the total) and *Leuroglossus tranus* (2.0%).

I believe that I have shown that the deep-sea pelagic fishes are a very large resource, indeed. The fish larvae in all parts of oceanic province that I have investigated have been dominated by two families of deep-sea fishes—myctophids and gonostomatids. This vast oceanic province makes up at least 80%, and perhaps as much as 90% of the area of the oceans. The deep-sea pelagic fishes must represent a huge biomass.

Myctophids and gonostomatids fill an exceedingly important ecological role as forage fishes. They serve as a vital link between the zooplankton community and the larger predator fishes, including tunas and billfishes.

Can we harvest this resource directly? Perhaps, but I am not sanguine about the prospects. My reservations are based on several considerations. Foremost is the problem of fish size: most common myctophids and gonostomatids may be too small to be of commercial value. The two most abundant fishes in the eastern tropical Pacific, on the basis of their abundance as larvae—*Diogenichthys laternatus* and *Vinciguerria lucetia*—are only 1 to 2 inches (25 to 50 mm) long as mature adults. The myctophid that was taken most commonly (as juvenile and adult) in the micronekton collections made with the Blackburn micronekton net on EASTROPAC, *Notolychnus valdiviae*, is only an

inch long at maturity. Most species of the gonostomatid *Cyclothone* are even less substantial than *Vinciguerria,* being thin and short. The majority of myctophids are larger as adults than the two discussed above; most species attain a length of approximately 2 to 4 inches (50 to 100 mm) and a few are relative monsters, growing to 6 or even 8 inches (150 to 200 mm) long. The bathylagid and argentinid smelts attain a somewhat larger average size than myctophids or gonostomatids. Most bathylagids, as adults, are comparable in size to anchovies, and *Argentina* and *Nansenia* grow as large as the sardine.

Another important limitation is the fact that adults of deep-sea pelagic fishes are indeed "deep"-sea fishes. Unlike their larvae, most myctophid lanternfishes occur at depths of 200 to 400 fathoms during daylight and may or may not move to shallower depths at night (Paxton 1967). These fishes also are most common in oceanic waters at a considerable distance from land.

Still another prime limitation to harvesting the deep-sea pelagic fishes is their manner of distribution. Adult gonostomatids and myctophids seldom occur in dense schools—although there may be exceptions, such as the schools of the myctophid *Benthosema panamense* that have occasionally been taken as bait by tuna fishermen, or the schools of the myctophid *Ceratoscopelus* that have been observed in the North Atlantic.

As the use of submersible vessels increases, we could rapidly increase our knowledge of the distribution of deep-sea fishes, which are commonly observed during dives. We also may learn how to concentrate the fish in quantities large enough to harvest them economically. These developments are for the future. For the present the deep-sea pelagic fishes will continue to be curiosities, rather than hors d'oeuvres.

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