CHARACTERS USEFUL IN IDENTIFICATION OF PELAGIC MARINE FISH EGGS

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ABSTRACT

Characters of importance in identifying pelagic marine fish eggs can be divided into two categories: characters independent of the embryo and characters associated with the developing embryo. Characters independent of the embryo would include egg shape, egg size, character of chorion, character of yolk, presence or absence of oil globules, and width of perivitelline space.

Planktonic marine fish eggs are usually globular in shape and range in size between 0.5 and 5.5 mm. We estimate that over 40% of the kinds of pelagic eggs are under 1.0 mm in diameter, 30% are between 1.0 and 1.5 mm, 15% are between 1.5 and 2.0 mm, and that about 14% are over 2.0 mm in diameter.

The chorion is usually smooth, but can be variously ornamented (polygonal network, spines, swellings, etc.). The perivitelline space is usually narrow but is wide in eggs of some primitive teleost groups (Anguilliformes and many clupeids). The yolk can be segmented or homogeneous. Oil globules range in number from none or one to many. About 25% of pelagic fish eggs lack an oil globule, 15% have two to many oil globules, and 60% have a single oil globule.

Characters associated with embryos would include pigment patterns, number of myomeres, length of gut, type of fin fold, position of heart, state of development at blastopore closure and at hatching, shape of yolk sac on late-stage eggs and newly hatched larvæ, position of oil globule(s) in the yolk sac, and special embryonic characters such as the elongated fin rays that form in trachipteroid eggs.

RESUMEN

Los caracteres importantes para la identificación de huevecillos de peces marinos pelágicos pueden ser divididos en dos categorías: carácteres independientes del embrión, y carácteres asociados con el embrión en desarrollo. Los carácteres independientes del embrión incluirían la forma del huevecillo, el tamaño del huevecillo, el carácter del corión, el carácter del vitelo, la presencia o ausencia de gotas oleosas, y la anchura del espacio perivitelino.

Huevecillos de peces marinos planctónicos son generalmente de forma globular y varían en tamaño entre 0.5 y 5.5 mm. Calculamos que más de 40% de los tipos de huevecillos pelágicos son menos de 1.0 mm de diámetro, el 30% son de entre 1.0 y 1.5 mm, el 15% son de entre 1.5 y 2.0 mm, y alrededor del 14% son de más de 2.0 mm de diámetro.

El corión es normalmente suave, pero puede estar distintamente ornamentado (red poligonal, espinas, inflaciones, etc.). El espacio perivitelino es normalmente estrecho, pero es ancho en los huevecillos de algunos grupos primitivos de teleósteos (anguiliformes y muchos clupéidos). El vitelo puede ser segmentado u homogéneo. Gotas oleosas varían en número desde ninguna hasta una o varias. Como 25% de los huevecillos de peces pelágicos carecen de la gota oleosa, el 15% tienen de dos a varias gotas oleosas, y el 60% tienen una sola gota oleosa.

Los carácteres asociados con embriones incluirían patrones de pigmentación, número de miómeros, longitud del intestino, tipo de pliegue de la aleta, posición del corazón, estado de desarrollo en el cierre del blastoporo y el tiempo de eclosión, la forma del saco vitelino en la última fase de los huevecillos y las larvas recién eclosionadas, la posición de la(s) gota(s) oleosa(s) en el saco vitelino, y carácteres embriónicos especiales tales como las rayas de aleta elongadas que se forman en huevecillos traquípteros.

INTRODUCTION

Oviparous marine teleosts extrude their eggs in a variety of ways. Many inshore species have demersal eggs, which are often attached to rocks, shells, or seaweed. Some build nests, and eggs are guarded by the male during incubation. Some demersal eggs are initially released in the pelagic zone, fertilized, and then sink. The chorions of these eggs are characteristically mucilaginous, permitting eggs to cling to bottom objects or to each other. Pelagic spawners usually produce separate isolated eggs, but the eggs of some species can be aggregated in various ways. They may be aggregated into large gelatinous masses or balloons (as in most scorpænid genera, and in the ophidiid genus *Brotula*) or can be spawned in gelatinous ribbon-like sheets (*Lophius antennarius*). Another method of aggregation is attachment of eggs to each other by filaments, a form of aggregation found in most exocœtoid fishes and in many atherinid fishes. In our experience except for eggs of the scomberesocid fish, *Cololabis saira*, aggregated eggs are seldom taken in plankton hauls. The number and arrangement of chorionic fila-

ments can differ strikingly among species and genera of exocœtoid fishes and provide useful characters for identification.

We are primarily interested in identifying pelagic eggs that are collected on ichthyoplankton surveys for the purpose of determining distribution and spawning biomass of target species. There are numerous contributions that describe pelagic eggs of marine fishes in order to facilitate their identification in plankton collections. The majority of such contributions are based on rearing artifically fertilized eggs from known parents or rearing mixtures of eggs collected in plankton hauls through both the embryonic and larval periods to sizes that can be positively identified. Other contributors have used the historical method of identifying eggs collected in ichthyoplankton surveys by working backwards from late-stage larvæ or juveniles that can be positively identified to earlier stage larvæ and ultimately to yolk-sac larvæ and eggs.

SUMMARY OF CHARACTERS

Plates 1 and 2

The characters of importance in identification of pelagic marine eggs are the following;

1) *egg shape*: spherical or otherwise;
2) *egg size*: pelagic marine fish eggs range in size from ca 0.5 to ca 5.5 mm;
3) *chorion*: ornamented or smooth, type of ornamentation, thickness;
4) *inner membrane*: presence or absence and location within egg;
5) *yolk*: segmented or homogeneous, nature of segmentation;
6) *perivitelline space*: width;
7) *oil globules*: number and size;
8) *embryonic characters*: state of development at blastopore closure, sequence of appearance and changes in pigmentation, pigment pattern at hatching, stage of development on late-stage embryos of various anatomical features such as eyes, mouth, fins, digestive tract, position of anus, and heart.

DESCRIPTION OF CHARACTERS

Egg Shape

Planktonic eggs are predominantly spherical, but there are some interesting exceptions. The engraulids afford the most striking exceptions; the eggs of most anchovies are ellipsoidal. The eggs of several species of engraulids approach the globular shape (*Thryssa mystax*, Delsman 1931; *Anchoa mitchilli*, Kuntz 1914; and *Setapinna phasa*, Jones and Menon 1952). Delsman (1931) described eggs of several species of *Stolephorus* that had a terminal knob at one end of the chorion. Planktonic eggs
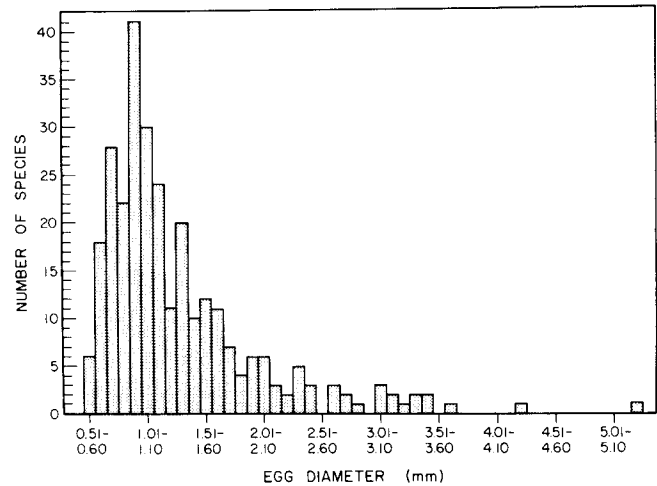

Figure 1. Frequency of egg diameter for 288 species with pelagic eggs, compiled from Mito (1961-63), Marinaro (1971), Robertson (1975), Russell (1976) and original data.

of some marine fishes in other families are not truly spherical but rather are somewhat off-round, as in the scomberesocid, *Scomberesox saurus* (Ahlstrom 1972) and in several ostraciontid species (Watson and Leis 1974; Plate 1).

Egg Size

Pelagic fish eggs range from 0.5 mm in diameter to about 5.5 mm (Figure 1). Among the smallest marine fish eggs are those of certain bothid flatfishes and labrids, whereas the eggs of the pleuronectid flatfish, *Reinhardtius hippoglossoides* (4.0 to 4.5 mm size range), and a muraenid eel from the Mediterranean (ca 5.5 mm) are the largest known. The majority of pelagic fish eggs are in the size range 0.6 to 1.6 mm. In some fishes, larger sized eggs result from the possession of a wide perivitelline space, as for example in some clupeids, most Anguilliformes, some stomiatoid fishes, and the pleuronectid flatfish genus *Hippoglossoides* (Plate 2). The yolk mass within some large eggs may be no larger than in eggs of less than 1.5-mm diameter that have a narrow perivitelline space. Some fishes that spawn larger sized eggs with the yolk mass almost filling the egg would include several pleuronectid flatfishes, most trachipteroid fishes, most exocœtoids that spawn separate pelagic eggs, various tetraodontiform fishes that spawn pelagic eggs, several argentinoid fishes, and some trichiurids and uranoscopids. This list could be made moderately extensive but, even so, would probably not include more than 10% of the kinds of pelagic marine fish eggs.

Chorion

The outermost structure of the egg is variously called the egg capsule, egg shell, vitelline membrane, egg membrane, or chorion. Although most fish eggs have smooth unornamented chorions, it can be variously and sometimes elaborately ornamented in some species. Such ornamentation can occur in several orders, including the

Salmoniformes, Myctophiformes, Gadiformes, Pleuro-nectiformes, Atheriniformes, Gobiesociformes, and Clupeiformes (Rass 1972). In some species where the chorion appears to be smooth and unornamented, a careful inspection, especially under higher magnification, shows the chorion to be striated or wrinkled. This is particularly true of the egg membranes of a number of pleuronectid flatfishes, which have striations or reticulations.

The ornamentation of the chorion can be limited or extensive. It can consist simply of a single protuberance or swelling, or a cluster of pustules or swellings surrounding the micropyle (Plate 1). Mito (1963b) shows several types of flatfish eggs that possess a single swelling or protuberance, and Watson and Leis (1974) illustrate an egg with a more complicated protuberance that they also assigned to a flatfish. Eggs of ostraciontids are known to have a patch of pustules on the chorion surrounding the micropyle (Watson and Leis 1974).

Of those eggs with extensive chorion ornamentation, the most widespread type consists of a honeycomb-like polygonal network formed at the outer surface of the egg membrane (Plates 1 and 2). Usually the network is hexagonal, but in some species the polygons can have 4, 5, or 7 sides intermixed with the usual 6-sided pattern. The diameters of the polygons range for example from 0.015 in *Chirocentrus dorab* (Delsman 1923) to 0.18-0.24 mm in the soleid, *Aesopia cornuta* (Mito 1963b). The pattern is well shown on scanning electronmicrographs of the pleuronectid genus *Pleuronichthys* and the synodontid genus *Synodus*, two genera that are phylogenetically remote (Sumida et al. 1979). On eggs of the macrurid genus *Coelorhynchus*, the network is removed from the chorion itself and attached to it by a series of posts (Sanzo 1933). In the distinctive egg of the sternoptychid, *Maurolicus muelleri*, the chorion is divided into a number of hexagonal facets, the junctions of which protrude as spine-like structures (Mito 1961a).

Another less common type of ornamentation on the chorion of pelagic fish eggs is spination. Spines can be relatively simple such as are found on the eggs of several exocoetids that spawn separate pelagic eggs, or they can be rather complex spine-like structures such as the ornamentation found on several types of eggs referred to the Myctophiformes (Plate 1).

Only a few of the pelagic, separate exocoetid eggs have been confidently assigned to species. Identified eggs would include eggs of two species of *Oxyporhamphus* with quite short spines distributed over the chorion and two species of *Cheilopogon*, which have fewer but somewhat longer and thinner spine-like filaments (Plate 1).

Delsman (1938) described two types of eggs that had strikingly ornamented chorions, which he referred to the Myctophoidea. The chorions are covered with short, trifid spines. On one type of egg the appendages are made up of three planes intersecting each other at an angle of 120° and ending in a point. In a second type of egg, the trifid spine-like structures end bluntly in a small hollow pit. Other eggs similar to Delsman's second type have been described from Japanese waters (Mito 1961a) and

from Hawaii (Watson and Leis 1974; Plates 1 and 2).

Instead of having ornamentation on the outer surface of the chorion, eggs of fishes belonging to the salmoniform suborder Argentinoidei have pustules or swellings on the inner surface of the chorion. The pustulation can be quite marked, as in the eggs of *Microstoma* or *Nansenia*, or hardly evident, as in eggs of some bathylagid smelts.

Inner Egg Membrane

Most pelagic fish eggs lack a free inner egg membrane. The presence of an inner egg membrane occurs, for example, in eggs of some anguilliform fishes (Mito 1961a shows several example; Plate 2), in some clupeiform fishes (Delsman 1926), and in some fishes of the suborder Stomiatoidei (Sanzo 1931b; Ahlstrom and Counts 1958). The inner membrane can be quite firm, as in eggs of *Chauliodus sloani* (Mito 1961a), or it can be thin and irregular in outline, as in eggs of *Vinciguerra lucetia* (Ahlstrom and Counts 1958). In the latter, the inner membrane lies close to the chorion. In the egg of *Chauliodus sloani*, which has a wide perivitelline space, the inner membrane is much closer to the embryo, and in the egg of *Argyropelicus hemigymnus* it adheres in places to the yolk (Sanzo 1931b).

Yolk

The yolk mass dominates the newly spawned fish egg and is usually translucent and unpigmented. The yolk is segmented in eggs of most "primitive" teleosts but is homogeneous in the majority of eggs of "higher" teleosts (Plates 1 and 2). Segmented yolk is found in some of the latter group (principally among the perciforms and pleuronectiforms) at the end of the embryonic period. In addition to the character of segmented versus homogeneous yolk, the shape of the yolk sac, particularly in late-stage eggs or new-hatched larvae, is a useful character. Also the presence of pigmentation and its characteristic distribution may help in identification.

Segmentation of the yolk can range from coarse to fine. Delsman found the type of segmentation to be an important character for distinguishing the eggs of clupeoids. He found the yolk to be finely segmented in eggs of *Dussumieria hasseltii* (Delsman 1925), moderately fine in eggs of most species of *Ilisha* (Delsman 1932), and coarsely segmented in eggs of *Anodontostoma chacunda* (Delsman 1926).

Segmentation of the yolk among eggs of a given species can be quite variable. Ahlstrom and Counts (1958) commented on the variability observed in eggs of the stomiatoid *Vinciguerria lucetia*, especially noticeable in early-stage eggs. The yolk in some eggs was nearly homogeneous, in others partly segmented, and in still others completely segmented into globules.
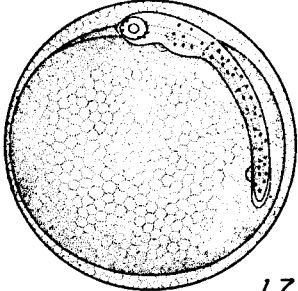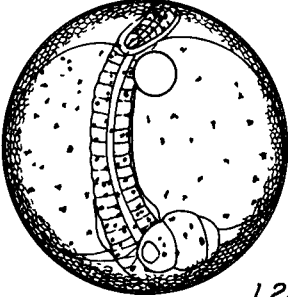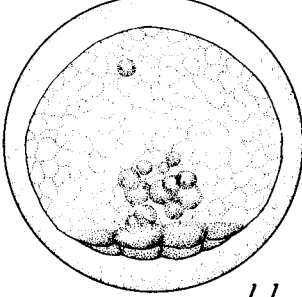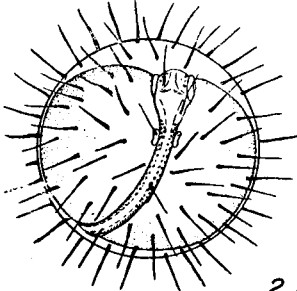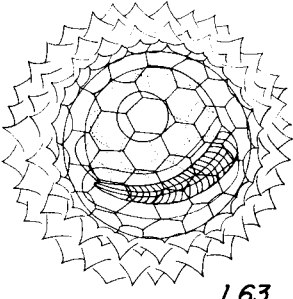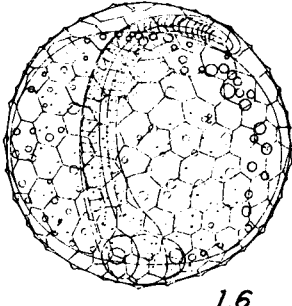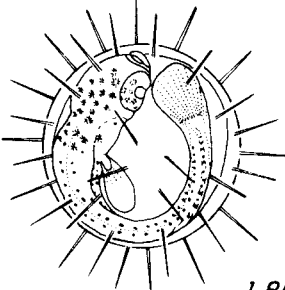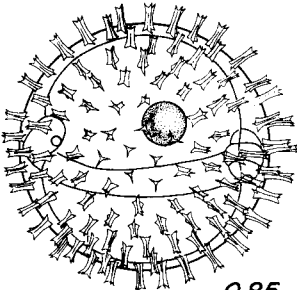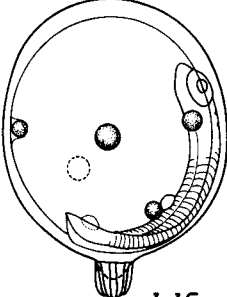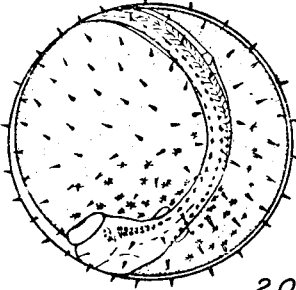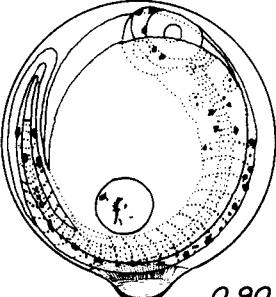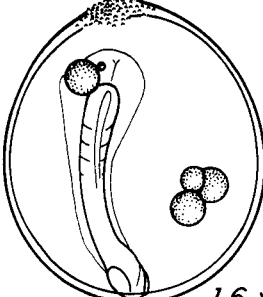
In some "higher" teleosts the segmentation is confined to the periphery of the yolk, as in eggs of various soleids (see Russell 1976). In others, for example the carangid, *Trachurus symmetricus*, where segmentation becomes rather complete, it can progress from little or no segmentation in newly spawned eggs to rather complete segmentation in late-stage eggs (Ahlstrom and Ball 1954).

Explanation of Plates

Captions under each plate indicate the species and the diameter or dimensions of the egg in mm.

Plate 1

Uranoscopus scaber, from Dekhnik (1973).
Pleuronichthys cornutus, from Mito (1963b).
Leuroglossus stilbius, from Ahlstrom (1969).
Cheilopogon nigricans, from Parin and Gorbunova (1964).
Maurolicus muelleri, from Mito (1961a).
Aesopia cornuta, from Mito (1963b).
Cheilopogon katoptron, from Kovalevskaya (1965).
Myctophiform, from Watson and Leis (1974).
Pleuronectiform, from Watson and Leis (1974).
Oxyporhamphus meristocystis, from Parin and Gorbunova (1964).
Ceratacanthus cirrus, from Sanzo (1939).
Ostraciontid, from Watson and Leis (1974).

TYPES OF ORNAMENTATION ON CHORIONS OF PELAGIC MARINE FISH EGGS

O OIL GLOBULE	1 OIL GLOBULE	2 OR MORE OIL GLOBULES
1.7 *Uranoscopus scaber*	*1.22* *Pleuronichthys cornutus*	*1.1* *Leuroglossus stilbius*
2.1 *Cheilopogon nigricans*	*1.63* *Maurolicus muelleri*	*1.6* *Aesopia cornuta*
1.85 *Cheilopogon katoptron*	*0.85* *Myctophiform*	*1.15 x 1.25* *Pleuronectiform*
2.0 *Oxyporhamphus meristocystis*	*0.90* *Centracanthus cirrus*	*1.6 x 1.9* *Ostraciodontid*

Plate 2

Synodus lucioceps, original.
Microstoma microstoma, from Sanzo (1931a).
Myctophiform, from Mito (1961a).
Muraena helena, from Grassi (1913).
Sardinops sagax, from Mito (1961a).
Anguillid, from Mito (1961a).
Etrumeus acuminatus, original.
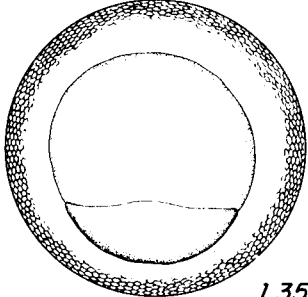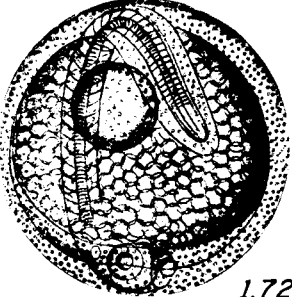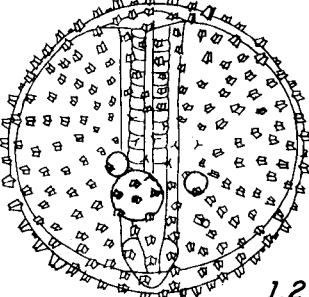*Trachurus symmetricus,* from Ahlstrom and Ball (1954).
Soleid, from Mito (1963b).
Glyptocephalus zachirus, original.
Merluccius productus, from Ahlstrom and Counts (1955).
Prionotus carolinus, from Kuntz and Radcliffe (1917).
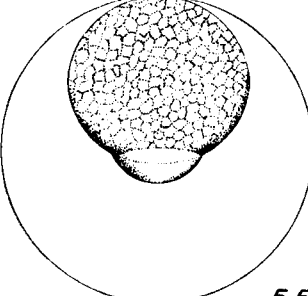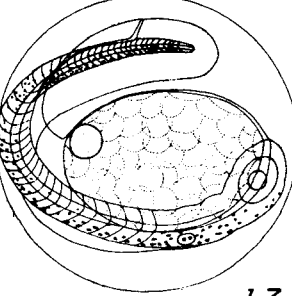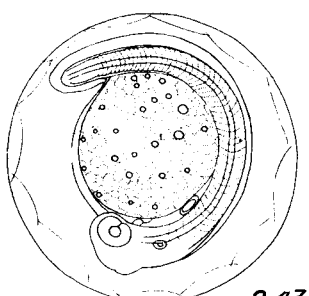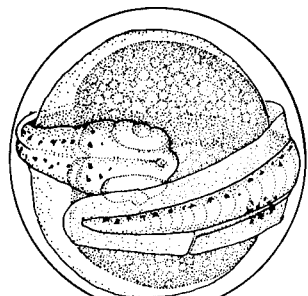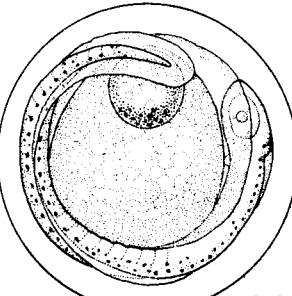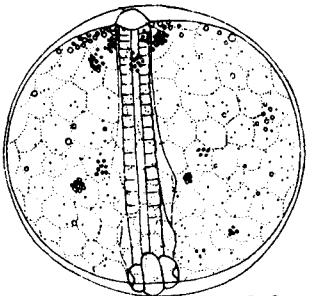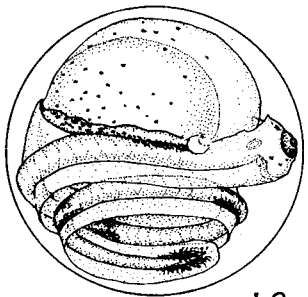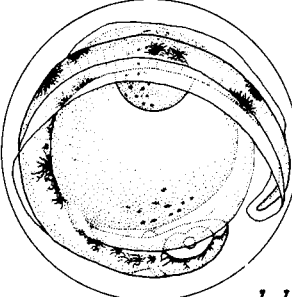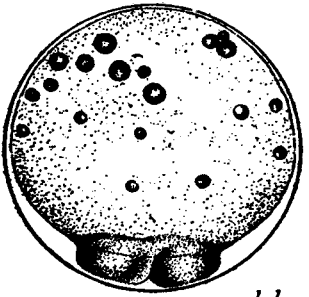
VARIETY OF PATTERNS IN PELAGIC MARINE FISH EGGS

		0 OIL GLOBULE	1 OIL GLOBULE	2 OR MORE OIL GLOBULES
SCULPTURED CHORION		*1.35* Synodus lucioceps	*1.72* Microstoma microstoma	*1.2* Myctophiform
SMOOTH CHORION	WIDE PERIVITELLINE SPACE	*5.5* Muraena helena	*1.7* Sardinops sagax	*2.43* Anguillid
	NARROW PERIVITELLINE SPACE — SEGMENTED YOLK	*1.35* Etrumeus acuminatus	*1.0* Trachurus symmetricus	*1.6* Soleid
	NARROW PERIVITELLINE SPACE — UNSEGMENTED YOLK	*1.9* Glyptocephalus zachirus	*1.1* Merluccius productus	*1.1* Prionotus carolinus

Perivitelline Space

In the majority of pelagic fish eggs the perivitelline space is narrow; however, eggs with a wide perivitelline space are the basic type among eels, are common among clupeiform fishes, and are encountered in stomiatoid fishes (Plate 2). All of these examples are "primitive" teleosts whose eggs have regularly segmented yolk. Fishes with homogeneous yolk seldom have a wide perivitelline space. A well-known exception is the flatfish genus *Hippoglossoides*, whose several species have pelagic eggs with a wide perivitelline space (Pertseva-Ostroumova 1955). The eggs of the striped bass, *Morone saxatilis*, also have a wide perivitelline space; however, this species enters estuaries or rivers to spawn, and the eggs are semi-buoyant.

When first spawned, even those pelagic fish eggs that ultimately develop a wide perivitelline space have little or no perivitelline space. In the Pacific sardine, *Sardinops caeruleus*, Miller (1952) found that the perivitelline space was small or nonexistant at time of extrusion from the female. The perivitelline space was almost completely formed within 2 hours after fertilization as a result of hydration. Egg diameter increased from 1.15 mm at fertilization to 1.64 mm after 2 hours, to the maximum diameter of 1.83 mm at 10 hours after fertilization. Since a fully formed perivitelline space requires some time to develop, its absence in recently spawned eggs can be misleading. In species that will ultimately develop a wide perivitelline space, it is helpful to give the diameter before and after hydration. Also in eggs with a wide perivitelline space, the diameter of the yolk mass is a useful measurement.

Oil Globule

For identifying pelagic marine fish eggs, perhaps no character is more important than the number of oil globules. Examples of species that lack oil globules in their yolk are known for many teleost orders, although for some of the orders, known examples are limited to one or a few species. Major families in which the eggs of all or many species lack an oil globule would include the Engraulidæ, Synodontidæ, Gadidæ, and Pleuronectidæ. Two other commonly occurring groups whose eggs lack an oil globule are the Trachipteroidei and Exocoetoidei.

Examples of pelagic eggs with multiple oil globules are known for at least seven orders. Multiple oil globules occur most frequently in anguilliform eels, bathylagid smelts, soleid and cynoglossid flatfishes, and in tetraodontiform fishes. The number of multiple oil globules can range from few (less than 10) to many (more than 50). The largest numbers occur in eggs of some soleid flatfishes. When numerous, oil globules tend to aggregate into clusters, and the pattern of distribution of the oil globules within the yolk mass can be useful in egg identification. In bathylagid smelts, the oil globules undergo remarkable migrations during embryonic development (Ahlstrom 1969).

The most common kind of pelagic fish egg is that with a single oil globule. This is true, for example, in most perciform families, in several families of flatfishes, and in many gadoids, stomiatoids, and clupeoids. A compilation of data from Mito (1961-63), Marinaro (1971), Robertson (1975), Russell (1976), and our California Cooperative Oceanic Fisheries Investigations (CalCOFI) area shows that for a total of 515 species, 24.5% lacked an oil globule, 60.1% had one oil globule, and 15.3% had multiple oil globules (Table 1). In eggs with a single oil globule, it usually lies at the vegetal pole opposite to the blastodisc and developing embryo. The single oil globules can range in size from < 0.10 mm to > 1.0 mm. The oil globule in formaldehyde-preserved pelagic eggs is usually colorless or faintly yellowish or reddish.

In eggs having a single oil globule, the position of the oil globule in the yolk sac can be of diagnostic value. The usual position of the oil globule is in the rear of the yolk sac; however, in a moderate number of families it is far forward in the yolk sac, as for example in labrids, most carangids, mullids, and lethrinids. In some genera the position of the oil globule can vary from species to species. Thus, two species of *Sphyraena* have the oil globule in a forward position (*S. pinguis* in Shojima et al. 1957; *S. borealis* in Houde 1972), and two species of *Sphyraena* have the oil globule in the rear of the yolk sac. (*S. sphyraena* in Vialli 1956; *S. argentea* in Orton 1955). In some species the oil globule is in an intermediate position or slightly forward. Several examples drawn from three families are serranids such as *Serranus cabrilla* (Raffaele 1888) and *Lateolabrax japonicus* (Mito 1963a); clupeids such as *Konosirus punctatus* (Uchida et al. 1958), *Harengula pensacolae* (Gorbunova and Zvyagina 1975) and *Brevoortia smithi* (Houde and Swanson 1975); and argentinids such as *Argentina silus* (Schmidt 1906) and *Nansenia oblita* (Sanzo 1931a).

Embryonic Characters

We have found it helpful to divide embryonic development in the egg into three stages: early (fertilization to blastopore closure), middle (from blastopore closure to the time that the separating tail begins to curve laterally away from the embryonic axis), and late (from the time that the tail is curved away from the embryonic axis to the time of hatching).

In eggs of some fishes the embryo is undergoing organogenesis prior to blastopore closure, whereas in others the embryo is relatively undifferentiated at closure of the blastopore. For example, in the Pacific hake, *Merluccius productus*, when the embryonic shield has enveloped approximately three-fourths of the yolk, the embryo has a discernible eye. Just before blastopore closure, 10 to 13 myomeres are visible behind the head of the developing embryo (Ahlstrom and Counts 1955). Similarly, in the jack mackerel, *Trachurus symmetricus*, the myomeres

TABLE 1
Frequency of Character Combinations in Pelagic Marine Fish Eggs.

| | Oil Globules | | | | | | All categories | |
| | 0 | | 1 | | 2 or more | | | |
	No.	%	No.	%	No.	%	No.	%
Ornamented chorion	23	4.5	18	3.5	11	2.1	52	10.1
Chorion smooth								
Wide perivitelline space	15	2.9	12	2.3	17	3.3	44	8.5
Segmented yolk, narrow								
perivitelline space	15	2.9	62	12.0	11	2.1	88	17.0
Homogeneous yolk, narrow								
perivitelline space	73	14.2	218	42.3	40	7.8	331	64.3
Total all categories	126	24.5	310	60.1	79	15.3	515	99.9

appear behind the head and the optic vesicles form shortly before blastopore closure (Ahlstrom and Ball 1954). In contrast, in argentinoid smelts the embryo is a simple undifferentiated ridge at blastopore closure.

In late-stage eggs a suite of characters can be used, including the shape of the developing embryo, its myomere count, the position of the anus on the body, and the nature of the finfold. Pigmentation usually begins forming on middle-stage eggs and reaches its fullest development on later stage eggs. In many kinds of eggs there is a sequence of changes in pigmentation during embryonic development. The pigment pattern may be confined to the embryo itself, or it can be developed over part or all of the yolk sac and may extend out into the finfolds. Also, it may be variously developed in relation to the oil globule if present. The ·melanophores originate from the neural crest region and usually first appear along the dorsal and dorso-lateral surfaces of the embryo. In many species the embryonic pigment at hatching is aligned along the dorsal margins of the body, often extending from the head to the end of the notochord.

For the majority of marine fishes with pelagic eggs, the yolk-sac stage is a period of rearrangement (migration) of melanophores from the predominant dorsal position on newly hatched larvae to their predominantly ventral position on late yolk-sac larvae. Some species, however, begin or even complete the migration and rearrangement of body melanophores before hatching. The mackerel, *Scomber japonicus*, furnishes an example where the downward movement of the dorso-lateral row of melanophores commences on late-stage embryos (Kramer 1960). Examples of species that reach a more advanced, although still intermediate, phase of rearrangement of melanophores on late-stage embryos are bonito, *Sarda lineolata* (Orton 1953); Pacific hake, *Merluccius productus* (Ahlstrom and Counts 1955); and cod, *Gadus morhua* (Fridgeirsson 1978). Several groups of fishes complete the rearrangement of pigment in the late-stage pelagic eggs, and the pattern is similar to that found in yolk-sac larvae and on into the preflexion larval stage. A few examples are the carangid, *Seriola quinqueradiata*

(Mito 1961b); stromateoids from several families (Ahlstrom et al. 1976); *Trachipterus* sp. (Mito 1961b); and the cynoglossid, *Areliscus trigrammus* (Fujita and Takita (1965). A variant of this is found in species that develop heavy pigment over the head and body of their embryos and retain such heavy pigmentation during the yolk-sac stage and larval period. Various flatfishes develop heavily pigmented embryos as, for example, in all species of *Pleuronichthys* (Sumida et al. 1979), in *Hypsopsetta* (Eldridge 1975), in *Scophthalmus rhombus* (Ehrenbaum 1905-1909), and in *Verasper variagatus* (Mito 1963b). Examples from other groups are *Coryphaena hippurus* (Mito 1961b), *Cololabis saira* (Hatanaka 1956), *Zeus faber* (Dehknik 1973), and *Mugil auratus* (Dehknik 1973).

Some pelagic eggs lack melanophores on late-stage embryos or at best have a few inconspicuous melanophores. Embryos and newly hatched larvae of engraulids lack melanophores. When melanophores become visible later in the yolk-sac stage, they already are ventral in position, lying along the gut and on the ventral margin of the tail. It is assumed that the pigment cells in Engraulidae migrate as in the Clupeidae but pigment formation is delayed until cells have reached more or less permanent locations. Other examples of fishes with this type of melanophore migration are two species of *Girella* (Orton 1953; Uchida et al. 1958); the Pacific halibut, *Hippoglossus stenolepis* (Thompson and Van Cleve 1936; Pertseva-Ostroumova 1961); the argentinid, *Argentina silus* (Schmidt 1906), and several synodontids (Mito 1961a).

Although larvae of some groups develop specialized larval characters such as elongated fin rays and head spination, such characters are seldom developed on embryos. A striking exception is the development of elongated elaborate dorsal and pelvic fin rays in embryos of trachipteroids. Another such character is the pair of appendages that develop during the embryonic period on the head of *Champsodon* spp. (Mito 1960, 1962).

The size and state of development at hatching is related to egg diameter for eggs with a narrow perivitelline space and to yolk size for those with a wide perivitelline space. The length of a larva at hatching is usually 2.5-3.0 times the diameter of the egg. Larvae hatching from small eggs are usually underdeveloped in that they lack a functional mouth, pigment in the eyes, and fins of any sort. Other organs are similarly underdeveloped. Larvae hatching from large eggs usually are much better developed. The eyes can be pigmented, the mouth formed, and the larval pectoral fins developed. In eggs of flying fishes, flexion of the caudal fin precedes hatching, and in some species of the group the other fins are well developed before hatching. An interesting exception to the correlation of large egg size and advanced development before hatching is found in *Argentina silus* (Schmidt 1906). This species has a large egg (ca 3.0-3.5 mm), an enormous oil

globule (0.95-1.18 mm), and lacks a perivitelline space in early-stage eggs. At hatching, the yolk-sac larva of *S. silus* is as underdeveloped as in those species that hatch from eggs in the 0.6-1.0-mm size range. The eyes are unpigmented, the mouth undeveloped, and the pectoral fins lacking.

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