OVARIAN DEVELOPMENT AND FECUNDITY OF FIVE SPECIES OF CALIFORNIA CURRENT FISHES

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ABSTRACT

Four different types of ovarian development in five species of fishes are described. The size distribution of the developing eggs suggests that Pacific herring, *Clupea pallasii,* spawns one batch of eggs during its spawning season; *Vinciguerria lucetia* and Pacific saury, *Cololabis saira,* spawn more than once. The data for jack mackerel, *Trachurus symmetricus,* and Pacific mackerel, *Scomber japonicus,* proved to be inconclusive. The average number of eggs per gram of fish in a spawning batch was *V. Lucetia,* 456; *S. japonicus,* 264; *C. pallasii,* 277; *T. symmetricus,* 109; *C. saira,* 22.

INTRODUCTION

One objective of the California Cooperative Fisheries Investigations (CalCOFI) is to estimate the biomasses of species of California Current fishes from censuses of eggs and larvae of these species. Among data necessary to make such estimates are the number of eggs spawned by the females of each species during the spawning season. This is the product of the number of eggs spawned at each spawning and the number of spawnings per season. Five species of California Current fishes were investigated with respect to types of ovarian development.

The Pacific saury, *Cololabis saira,* is found in the temperate North Pacific from Asia to North America. There is a commercial fishery for saury in the northwestern Pacific, but there is no American fishery. It is important prey species for the albacore, *Thunnus alalunga,* in the North Pacific accounting for 50% or more by volume of the albacore diet (McHugh, 1952; Graham, 1959; Iversen, 1962).

The jack mackerel, *Trachurus symmetricus,* is a commercially important fish in California. The catch reached a peak of 73,000 tons in 1952. Since then this has declined to about 24,000 to 30,000 tons (1968–72). The jack mackerel also is taken from time to time in the sport fishery.

The Pacific mackerel, *Scomber japonicus,* was a commercially important fish in California. In 1935, the catch peaked at 73,000 tons. The catch declined to 600 to 3,500 tons (1965–69), and a moratorium on commercial fishing was declared in 1970. In spite of the decline in commercial catch, the Pacific mackerel has remained an important sport fish for commercial partyboat sports fishermen in southern California.

Vinciguerria lucetia an isospondylid fish of the family Gonostomatidae, is one of the most abundant pelagic fishes taken as larvae in the eastern North Pacific Ocean by CalCOFI. In 1955–57, it was the fourth most abundant fish larva found in CalCOFI net tows. This species accounted for 6.2% of the total larvae taken (Ahlstrom, 1959), ranking only behind northern anchovy, *Engraulis mordax* (33.4%), Pacific hake, *Merluccius productus* (18.5%), and rockfishes, *Sebastes* spp. (7.5%). At the present time no fishery exists for this species.

Unlike the above three groups, *V. lucetia* larvae are more abundant in the southernmost part of the CalCOFI survey area and in the last half of the year, an area and time of reduced coverage by CalCOFI cruises in the three years 1955–57. Ahlstrom and Counts (1958) estimated the number of *V. lucetia* larvae in the CalCOFI survey area between 25° and 37° N latitude at 19.5×10^{12} in 1951, and 19.0×10^{12} in 1952. In addition, *V. lucetia* has a very extensive range outside of the CalCOFI area in the Pacific, Indian, and Atlantic Oceans.

Although it has no direct commercial value, *V. lucetia* is believed to be a significant item in the diets of valuable commercial and game fishes (Ahlstrom and Counts, 1958).

Pacific herring, *Clupea pallasii,* has no commercial or sportsfishing importance in southern California although it is an important commercial species farther to the north. It is included in this study because it illustrates a type of ovarian development different from those of the other four species of fish.

MATERIALS AND METHODS

Fish were obtained from various CalCOFI collections. They were measured and weighed. Gonads were weighed to the nearest milligram and preserved in 3% formalin. Samples of ova were removed from developing ovaries, weighed, and spread with a drop of glycerin on a lined microscope slide. A second slide was lightly taped to the first slide as a cover.

Each slide was projected on a white-surfaced table at a magnification of 50× using a projector designed for scale reading. The diameters of enough yolked ova were measured to determine their size distribution. Additional ova from weighted samples were counted using either the projector or a binocular microscope to obtain an estimate of the number of ova in the ovary.

SPAWNING SEASONS

When the percent spawning by month is averaged over a number of years (Figure 1), we can obtain a general idea of when the spawning will probably occur. But in individual years the spawning is more concentrated in time, and the time of peak spawning may be much later or earlier than indicated by averaged data for several years.

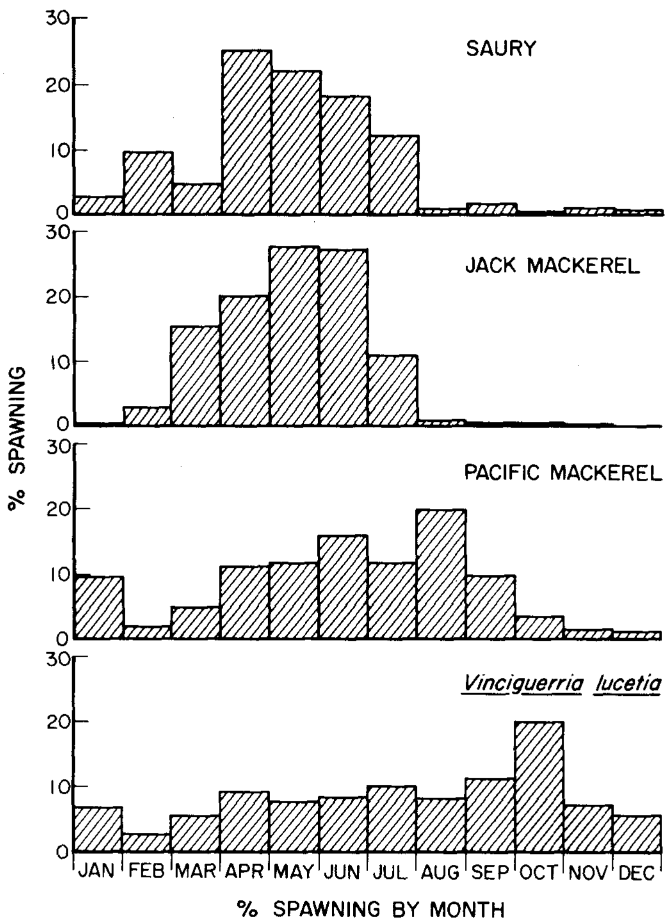

FIGURE 1. Average percent spawning by month. (A) Pacific saury based on standard haul totals of eggs for the years 1950 through 1959. (B) Jack mackerel based on standard haul totals of larvae for the years 1950 through 1959. (C) Pacific mackerel based on standard haul totals of larvae for the years 1951 through 1959. (D) *Vinciguerria lucetia* based on estimates of larval abundance for the years 1951 and 1952.

Pacific Saury

During the decade 1950–59, the 6 month periods of February through July accounted for 91% of the saury spawning (Figure 1A) as indicated by numbers of eggs taken in CalCOFI nets. But, in the individual years, the month of heaviest saury spawning occurred as early as February or as late as July, and an average of 63% of the spawning occurred in the 2 peak spawning months.

Jack Mackerel

Over the same time period, February through July accounted for 99% of the jack mackerel spawning as measured by the presence of larvae in CalCOFI net tows (Figure 1B). The month of heaviest spawning varied from March to as late as July, and an average of 66% of the spawning occurred in the 2 months of heaviest spawning in individual years.

Pacific Mackerel

During the 9 years 1951–59, the 6 months, April through September accounted for 79% of the Pacific mackerel spawning as measured by numbers of larvae taken in CalCOFI nets (Figure 1C). Heaviest spawning occurred as early as January to as late as August. An average of 54% of the spawning occurred in the 2 months of heaviest spawning in individual years.

Vinciguerria lucetia

Based on the numbers of larvae taken in CalCOFI net tows during the 2 years 1951–52, the 6 months May through October, accounted for 65% of *V. lucetia* spawning (Figure 1D). The peak spawning month in both years was October, but only 33% of the spawning took place in the two heaviest spawning months of these 2 years.

V. lucetia and Pacific mackerel have a more southerly distribution than saury and jack mackerel, and they may spawn earlier in the year to the south of the area regularly sampled by CalCOFI.

Pacific Herring

The Pacific herring has a very short spawning season in mid-winter in San Diego Bay, which is the southern limit of its spawning range on the west coast of North America. The demersal eggs of herring are not taken in CalCOFI surveys, but data are included here because these fish illustrate a fourth type of ovarian development.

RESULTS

The two mackerels have similar ovarian development. In immature female fish or in those

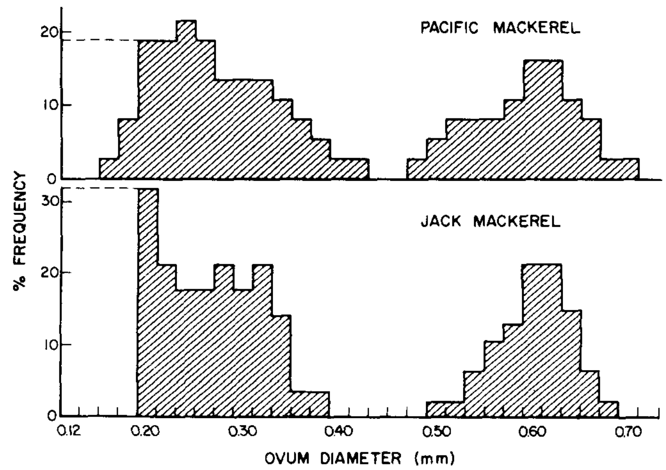

FIGURE 2. Frequency distribution of diameters of yolked eggs in the ovaries of (A) Pacific mackerel, and (B) jack mackerel.

with resting phase ovaries, only transparent eggs less than 0.20 mm in diameter are present. In the earliest stages of development, some of these eggs increase in size and become opaque as yolk material forms within the eggs.

A portion of these yolked eggs continues to grow and eventually forms a second distinct size group (Figure 2). The length of time that the opaque eggs are held at the prespawning stage may be prolonged until external conditions, such as water temperature, are suitable for spawning. Just before the onset of spawning these advanced eggs absorb water, roughly doubling their volume, and become translucent. A perivitelline space is formed enlarging the eggs even more.

Ahlstrom and Ball (1954) state that spawned jack mackerel eggs are 0.90 to 1.08 mm in diameter with a perivitelline space of 0.09 mm and yolk diameters of 0.68 to 0.88 mm (volume 0.16 to 0.26 mm^3). Two jack mackerel in the samples that I examined contained eggs of this size (Table 1).

According to Kramer (1960) freshly spawned Pacific mackerel eggs are 1.06 to 1.14 mm diameter with a perivitelline space of 0.02 mm. Yolk diameters range from 1.02 to 1.10 mm diameter (volume 0.55 to 0.70 mm^3).

The largest eggs (yolk diameters) found in Pacific mackerel ovary samples ranged from 0.57 to 0.77 mm in diameter except for two specimens which contained translucent eggs in the 1.06 to 1.14 mm range. One of these fish appeared to be partly spawned, and the eggs were not counted. The other contained both the large translucent eggs and smaller opaque eggs in the 0.50 to 0.74 mm range. These smaller eggs were found only in the anterior third of the ovary away from the oviduct. An estimate of the opaque eggs in this size group was 130 per gram of fish while the translucent eggs numbered 115 per gram of fish. The total number of eggs per gram of fish was 245, which is lower than the 378 and 319 eggs per gram of fish in the two prespawning females from the same sample. The opaque eggs in the ovaries of this fish were undoubtedly part of the same spawning batch as the translucent eggs but had not yet absorbed water. I have found the same conditions in the ovaries of sardines taken from a school that was actively spawning.

The number of advanced eggs averaged 109 per gram of fish for the 30 jack mackerel examined (Table 1). However, for the 15 smaller fish (217 to 258 mm fork length), the number of eggs was only 66 per gram of fish, while for the 15 larger fish, 438 to 554 mm, it was 152 eggs per gram of fish.

TABLE 1

Fecundity Data for 30 Jack Mackerel, *Thachurus symmetricus*.

Specimen number*	Fork length (mm)	Weight (grams)	Condition factor	Ovary weight (grams)	Gonad index	Advanced eggs		
						Size range (mm)	Number (thousands)	Number per gram of fish
1	217	109	106	2.2	2.0	.60–.77	5.1	47
2	225	124	109	2.1	1.7	.57–.67	5.2	42
3	225	116	102	3.3	2.8	.57–.70	10.3	89
4	230	139	114	3.5	2.5	.57–.70	9.9	71
5	230	136	112	3.4	2.5	.47–.63	9.9	73
6	232	122	98	2.1	1.7	.53–.70	.8	7
7	232	132	106	3.1	2.3	.50–.67	7.6	57
8	233	139	110	2.8	2.0	.57–.67	3.4	25
9	236	139	106	3.8	2.7	.57–.67	8.9	64
10	237	135	101	3.5	2.6	.50–.67	7.9	57
11	238	167	124	5.6	3.4	.53–.70	20.1	121
12	242	168	119	2.4	1.4	.57–.67	1.6	10
13	243	154	107	4.8	3.1	.53–.70	18.4	119
14	252	178	111	3.8	2.1	.47–.60	13.9	73
15	258	200	116	7.4	3.7	.57–.77	26.4	132
16	438	907	108	27.6	3.0	.47–.63	94.6	104
17	470	1149	111	59.5	5.2	.53–.70	263.	229
18	483	1214	104	48.1	4.0	.50–.67	236.	194
19	499	1382	111	49.9	3.6	.50–.67	246.	178
20	508	1410	108	50.6	3.6	.50–.70	199.	141
21	516	1416	103	52.3	3.7	.50–.70	150.	106
22	525	1547	107	59.2	3.8	.50–.67	251.	162
23	536	1443	94	40.4	2.8	.50–.67	173.	120
24	536	1802	117	62.3	3.5	.53–.70	226.	125
25	538	1772	114	72.2	4.1	.53–.70	314.	177
26	540	1722	109	120.0	7.0	.80–.90	159.	92
27	543	1718	107	141.8	8.3	.73–.97	192.	112
28	545	1636	101	83.6	5.1	.50–.70	437.	267
29	551	1793	107	65.5	3.7	.50–.63	251.	140
30	554	1785	105	70.9	4.0	.50–.70	245.	137

* Specimens number 1–15 were taken 95 miles west of San Diego, May 25, 1970; number 16–17, 265 miles west of San Diego, May 7, 1969; number 18–25, 90 miles west southwest of San Diego, June 22, 1970; number 26–30, 6 miles west of San Diego, May 27, 1970. Condition factor equals weight of fish times 10^7 divided by fork length cubed. Gonad index equals gonad weight × 100 divided by fish weight.

TABLE 2

Fecundity data for 18 Pacific Mackerel, *Scomber japonicus*.

Specimen number*	Fork length (mm)	Weight (grams)	Condition factor	Ovary weight (grams)	Gonad index	Advanced eggs		
						Size range (mm)	Number (thousands)	Number per gram of fish
1	273	267	131	6.7	2.5	.44–.60	37.7	141
2	280	358	163	33.3	9.3	.48–.66	163.7	457
3	291	286	116	10.2	3.6	.42–.58	63.1	220
4	314	362	117	21.9	6.0	.48–.70	136.8	378
5	326	375	108	17.0	4.5	.44–.64	119.8	319
6	343	475	118	30.4	6.4	.50–.74	146.6	309
7	328	471	133	35.4	7.5		132.1	281
8	328	493	140	30.7	6.2		127.4	258
9	333	509	138	22.7	4.5	.50–.67	123.7	243
10	335	501	133	26.5	5.3	.60–.73	96.3	192
11	341	545	137	27.0	5.0	.53–.73	104.7	192
12	341	573	145	36.5	6.4	.57–.77	235.0	410
13	342	545	136	36.8	6.8		152.8	280
14	345	541	132	28.0	5.2	.53–.70	116.0	214
15	346	555	134	33.4	6.0		127.4	230
16	350	573	134	23.0	4.0	.53–.67	93.5	163
17	353	602	137	36.0	6.0	.50–.67	181.8	302
18	379	727	134	34.5	4.7		112.6	155

* Specimens number 1–2 were taken in the San Diego area, June 9, 1960; number 3, Hipolito Bay, August 11, 1958; numbers 4–5, San Diego area, June 14, 1957; number 6, Santa Catalina Island, June 5, 1957; number 7–8, 25° 44′ N, 113° 08′ W, January 11, 1970. Condition factor equals weight of fish times 10^7 divided by fork length cubed. Gonad index equals gonad weight × 100 divided by fish weight.

The number of advanced eggs averaged 264 per gram of fish for 18 Pacific mackerel (Table 2). There were no apparent changes in the number of eggs per gram of fish over the fork length range of 273 to 379 mm.

During the period of development through spawning, there was no indication of the formation and growth of a second mode of eggs from the mass of smaller yolked and non yolked eggs for either species of mackerel. The ratio of numbers of small yolked eggs to numbers of advanced eggs was 1.5:1.0 for the Pacific mackerel and 1.6:1.0 for the jack mackerel.

The ovaries of immature *V. lucetia* contain only transparent ova less than 0.20 mm diameter. As the ovary develops, a mode of dark yolked eggs is formed (Figure 3A). All of the eggs in this mode continue to grow until they are about 0.48 mm diameter at which time a second mode of dark yolked ova about equal in number to the advanced eggs is formed (Figure 3B, C, D, and E). This secondary mode of opaque eggs is present in fish that contain advanced translucent eggs (Figure 3F, G, and H) but shows little growth until after the advanced eggs have been spawned. This apparent lack of growth in the secondary mode probably results from the very rapid

TABLE 3

Fecundity Data for 16 *Vinciguerria lucetia*.

Specimen number*	Standard length (mm)	Weight (grams)	Condition factor	Ovary weight (grams)	Gonad index	Advanced eggs		
						Size range (mm)	Number	Number per gram of fish
1	34	0.375	95	0.009	2.4	.40–.56	040	107
2	36	0.443	95	0.034	7.7	.52–.66	209	472
3	37	0.475	94	0.014	2.9	.30–.42	177	373
4	38	0.439	80	0.018	4.1	.36–.48	158	360
5	39	0.498	84	0.028	5.6	.54–.70	170	341
6	39	0.521	88	0.014	2.7	.38–.50	157	301
7	40	0.546	85	0.018	3.3	.30–.38	229	419
8	40	0.575	90	0.021	3.7	.38–.46	196	341
9	41	0.602	87	0.021	3.5	.36–.44	189	314
10	42	0.692	93	0.046	6.6	.50–.66	308	445
11	43	0.670	84	0.025	3.7	.22–.36	350	522
12	43	0.693	87	0.037	5.3	.54–.68	191	276
13	44	0.642	75	0.028	4.4	.36–.50	206	321
14	46	0.846	87	0.074	8.7	.54–.70	357	422
15	56	1.448	82	0.086	5.9	.32–.42	1,515	1046
16	56	1.678	96	0.092	5.5	.24–.44	2,064	1230

* Specimens number 1–14 were taken at Guadalupe Island, May 25, 1952; numbers 15–16, 25° 29′ N, 115° 24′ W, August 10, 1953. Condition factor equals weight of fish times 10^7 divided by standard length cubed. Gonad index equals gonad weight × 100 divided by fish weight.

growth of the advanced eggs owing to water absorption.

Ahlstrom and Counts (1958) give the diameter of the newly spawned *V. lucetia* egg as 0.58 to 0.74 mm. However, they found that the size of the egg was related to water temperature. Eggs taken in water with a temperature of 16° C averaged 0.72 mm diameter. With increasing temperature, eggs became progressively smaller and averaged only 0.60 mm diameter in water at 28° C.

The 14 specimens of *V. lucetia* taken at Guadalupe Island (29° N lat) ranged in standard length from 34 to 46 mm and averaged 358 advanced eggs per gram of fish (range 107 to 522). The two specimens taken at CalCOFI Station 130.60 (25° 29½′ N lat) were both 56 mm standard length and contained 1,046 and 1,230 eggs per gram of fish (Table 3) or about three times as many eggs per gram of fish as the smaller fish.

Although these two fish were taken farther to the south (and in August) than the 14 fish taken at Guadalupe Island (in May) when the water

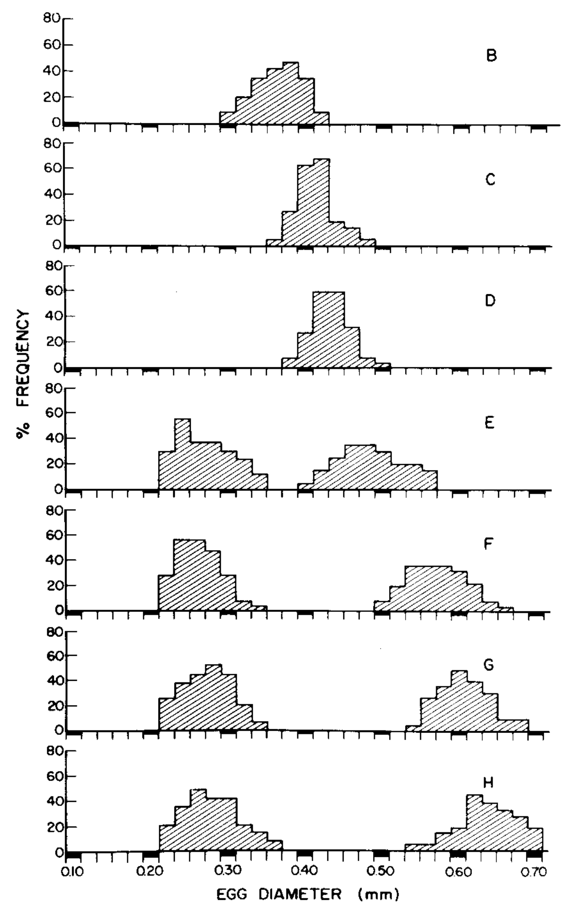

FIGURE 3. Frequency distributions of diameters of yolked eggs in the ovaries of *Vinciguerria lucetia.* (A, B, C, and D) Only the developing mode of yolked eggs (and small nonyolked eggs less than 0.20 mm in diameter) are present during earlier stages of development. (E, F, G, and H) As the advanced eggs develop a second size mode of eggs about equal in number to the advanced mode develops. This second mode of yolked eggs shows little growth as the advanced mode develops to the translucent spawning stage (H).

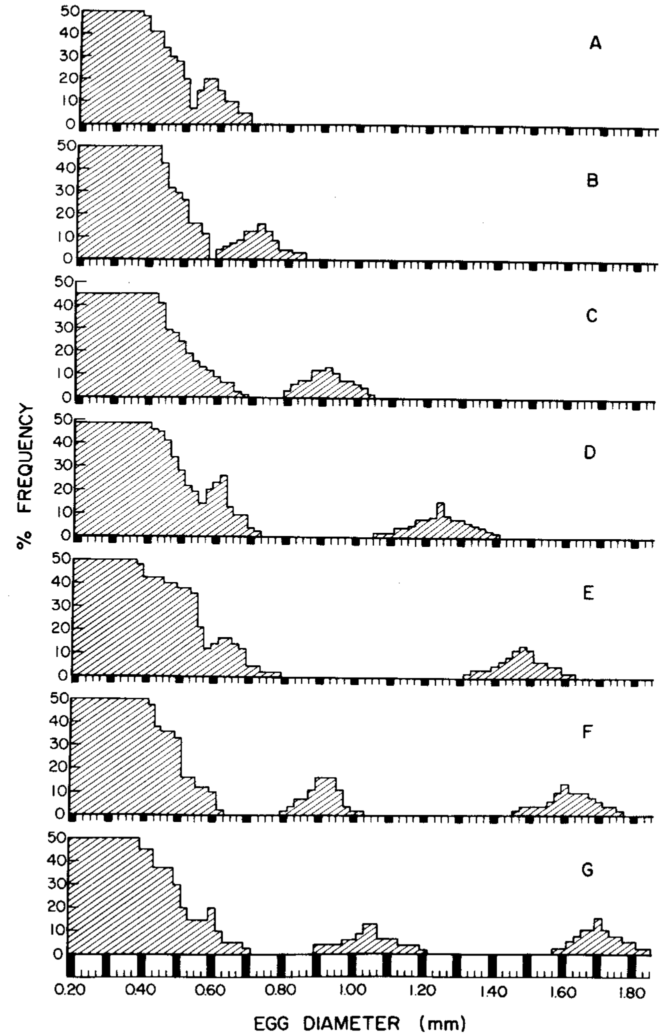

FIGURE 4. Frequency distribution of diameters of yolked eggs in the ovaries of the Pacific saury. At all stages of development a numerous mode of very small yolked eggs is present. (A, B, and C) The smaller group of eggs to be spawned becomes separated from these very small yolked eggs by size during their early development. (D, E) A second mode of eggs about equal in number to the advanced mode begins to develop as the advanced eggs increase in size, and (F, G) becomes completely differentiated by size from the mass of small yolked eggs as the advanced eggs continue to grow and eventually become translucent.

temperature was undoubtedly higher, the size difference in spawned eggs related to temperature cannot account for the great difference in fecundity. Probably the fecundity increases more rapidly proportionately to weight as the fish grows. This seems to be true also of the jack mackerel.

Pacific saury ovaries are elongate and cylindrical. In the immature ovaries of female fish the ova are transparent and less than 0.20 mm diameter. As the fish matures the ova increase in size and darken with yolk formation.

A group of these eggs becomes a distinct size mode and continues to increase in size (Figure 4A, B, and C). As these advanced eggs continue to grow, a second mode becomes distinguishable from the mass

TABLE 4

Fecundity Data for 16 Pacific Sauries, *Cololabis saira*.

Specimen number*	Standard length (mm)	Weight (grams)	Condition factor	Ovary weight (grams)	Gonad index	Advanced eggs		
						Size range (mm)	Number	Number per gram of fish
1	191	27.9	41	0.76	2.7	0.84–1.04	813	29
2	220	46.7	44	2.09	4.5	1.04–1.38	1314	28
3	247	69.9	46	6.63	9.5	1.34–1.74	2188	31
4	252	76.7	48	2.25	2.9	0.82–0.96	1761	23
5	269	88.7	46	6.31	7.1	1.34–1.60	2209	25
6	195	30.4	41	0.96	3.1	1.14–1.64	686	23
7	198	32.3	42	1.13	3.5	1.04–1.42	724	22
8	199	31.6	40	0.59	1.9	0.80–1.04	657	21
9	202	32.0	39	0.88	2.7	0.96–1.26	520	16
10	202	34.3	42	1.38	4.0	1.08–1.38	1016	30
11	203	35.4	42	1.94	5.5	1.48–1.90	(523)**	(15)**
12	207	36.1	41	0.68	1.9	0.76–1.24	542	15
13	208	37.2	41	2.11	5.7	1.56–1.90	(411)**	(11)**
14	184	25.0	40	0.40	1.6	0.82–1.16	225	9
15	215	47.0	47	2.07	4.4	1.58–1.84	(211)**	(4)**
16	281	100.1	45	3.20	3.2	1.50–1.88	1142	11

* Specimen number 1 was taken 100 miles south of San Diego, January 18, 1954; numbers 2–5, off Point Loma, San Diego, February 20, 1950; numbers 6–13; Sebastián Viscaíno Bay, March 8, 1954; numbers 14–15, Sebastián Viscaíno Bay, March 8, 1954; number 16, Cortes Bank, October 3, 1949. Condition factor equals weight of fish times 10^7 divided by standard length cubed. Gonad index equals gonad weight × 100 divided by fish weight.
** Partly spawned.

of smaller opaque eggs (Figure 4D, E). This second mode also becomes a distinct size mode as the first group of eggs approaches maturity (Figure 4F, G). The first mode becomes translucent at 1.50 to 1.90 mm diameter.

When the eggs absorb water and become translucent, they are expelled into the lumen of the cylinder-like ovary. The eggs are held together in a string by sticky filaments at this point. They are spawned in this condition, although the eggs break off into shorter strings during spawning activities.

For 13 Pacific sauries the number of eggs per gram of fish averaged 22 (Table 4; excluding the three fish that were partly spawned). The number of eggs in an advanced mode was approximately equal to the number in a distinct second mode when it was present. The number of small opaque eggs averaged 10 times as many as were in the advanced mode and ranged widely from 3 times to 16 times as many.

Five female Pacific herring taken from San Diego Bay were in prespawning condition. The ovaries of each of these fish contained small transparent eggs less than 0.20 mm diameter and one group of large yolked eggs (Table 5). There were no small or intermediate sized, yolked eggs.

DISCUSSION

Some inferences may be drawn from the size distributions of eggs in the ovaries of fishes. It is generally agreed that the herring spawns only one batch of eggs, and in herring containing advanced eggs, this group is the only group of yolked eggs in the ovary. Observations of spawning and the relatively short spawning season in any one locality tend to confirm this conclusion.

The ovaries of most species of maturing marine fishes, however, appear to contain distributions of egg sizes somewhat similar to those of the two mackerels. There is some controversy among investigators as to whether only the advanced group of yolked eggs or all yolked eggs are spawned during one spawning season.

TABLE 5

Fecundity Data for Five Pacific Herring, *Clupea pallasii*.

Specimen number*	Standard length (mm)	Weight (grams)	Condition factor	Ovary weight (grams)	Gonad index	Advanced eggs		
						Size range (mm)	Number	Number per gram of fish
1	153	53	148	9.27	18.5	1.14–1.36	8,463	160
2	166	75	164	14.65	19.5	1.02–1.24	18,168	242
3	168	67	141	15.97	23.8	1.16–1.38	16,621	248
4	168	84	177	20.15	24.0	1.12–1.30	20,600	245
5	169	87	180	26.96	31.0	1.24–1.50	20,918	240

* Five specimens were taken from San Diego Bay, January 1956. Condition factor equals weight of fish times 10^7 divided by standard length cubed. Gonad index equals gonad weight × 100 divided by fish weight.

The most generally held assumption seems to be that because the small eggs do form yolk, they will continue to develop and eventually be spawned as secondary and tertiary spawning batches. But, as the ovarian development of *V. lucetia* demonstrates, a discrete secondary spawning batch of eggs can readily develop directly from the nonyolked oocytes. The lengthy spawning season of this species and the fact that the secondary mode develops during the growth of the advanced mode and approximately equals it in the number of ova present are evidence that *V. lucetia* spawns more than once during the spawning season.

Ovary development of the Pacific saury resembles that of most marine fishes in that a large group of oocytes develop into small, yolked eggs, and from this group a smaller number of eggs continue to increase in size and develop into a spawning batch. The saury differs from most other species in that a discrete secondary batch of eggs about equal in number to the advanced group begins to develop before the advanced group is spawned. Further evidence of multiple spawning in this species is demonstrated in saury #4 (Table 4) which, in addition to the advanced group of eggs 0.82 to 0.96 mm in diameter, contained two large eggs aproximately 1.80 mm in diameter remaining from a previous spawning.

The California grunion, *Leuresthes tennuis,* which spawns on the beaches of southern California and Baja California during the nighttime high tides accompanying the new and full moons is known to be a multiple spawner. This species has a distribution of eggs in the ovaries very similar to that of the saury. In the ovaries of a female grunion (134 mm standard length, 23½ grams) I found 12 large eggs 1.5 to 1.6 mm in diameter remaining from a previous spawning, a discrete group of 1,775 advanced eggs 0.68 to 0.90 mm in diameter, and 5,680 smaller, yolked eggs 0.20 to 0.64 mm in diameter. The larger eggs in this latter group were begining to form a discrete size mode.

Two other atherinids, the topsmelt, *atherinops affinis,* and the jack smelt, *Atherinopsis californiensis,* also have this type of egg distribution in the developing ovaries. Clark (1929) reports finding a few ripe eggs in the lumen of the ovaries of jack smelt that contained developing modes of eggs indicating multiple spawning.

For species of fishes having size distributions of eggs in the ovaries similar to the mackerels, there is no good evidence for multiple spawning. When a few large eggs indicating previous spawning are present in the ovaries, the distribution of small, yolked eggs is much as it is when the advanced mode of eggs is present in the ovaries. No discrete size mode is present indicating that some of the small eggs have developed a new spawning group. Atresia of the smaller eggs is often evident, but until it becomes widespread, the eggs may be classified as developing merely because they contain yolk. The evidence for multiple spawning in species having this kind of ovarian egg size distribution is inconclusive.

SUMMARY

The five species of fishes reported on here illustrate four types of ovarian development. These four types are distinguished by the numbers and size distribution of yolked eggs present in the developing ovaries. The ovaries of all five species contained small transparent eggs containing no yolk material and less than 0.20 mm in diameter.

The prespawning ovaries of the herring contained only these small transparent eggs and the advanced eggs. The prespawning ovaries of *V. lucetia* contained an intermediate mode of developing yolked eggs in addition to the advanced group. The prespawning ovaries of the two mackerels contained a group of small, yolked eggs that is a size continuation of the smaller, nonyolked eggs in addition to the advanced eggs, but there was no intermediate mode of developing eggs. The prespawning ovaries of the Pacific saury contained small, intermediate, and large opaque eggs.

The ratios of small to intermediate to large, yolked eggs for the five species was:

Pacific herring	0.0:0.0:1.0
V. lucetia	0.0:1.0:1.0
Pacific mackerel	1.5:0.0:1.0
jack mackerel	1.6:0.0:1.0
Pacific saury	10.0:1.0:1.0

The data indicate Pacific herring spawn one batch of eggs each season, while Pacific saury and *V. lucetia* spawn more than once. The data for Pacific mackerel and the jack mackerel are inconclusive on this point.

The average number of eggs in the advanced mode per gram of adult female fish was:

Species	Number of fish	Eggs per gram of fish
V. lucetia	16	456
Pacific mackerel	18	264
Pacific herring	5	227
jack mackerel	30	109
Pacific saury	13	22

However, the number of eggs per gram of fish varied considerably. Small fish tended to have much lower relative numbers of eggs than larger fish. This was especially true in *V. lucetia* where 14 small specimens averaged 358 eggs per gram of fish while two large specimens averaged 1,138 eggs per gram of fish, and in the jack mackerel where 15 smaller specimens averaged 66 eggs per gram of fish while 15 larger specimens averaged 152 eggs per gram of fish.

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