ADDITIONAL DATA ON THE SPAWNING OF THE HAKE

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ABSTRACT

In January 1970 samples of hake were taken off southern and central Baja California to study fecundity. In the southern area female hake as small as 130 mm standard length contained developing eggs, and all females longer than 140 mm contained such eggs. There is a marked cline in size at first maturity of hake along the Pacific Coast (hake in the Pacific Northwest exceed 400 mm before reaching maturity). Seventeen female hake 130 to 202 mm long taken in the southern area contained from 3,400 to 19,500 eggs or 229 per gram of fish; 11 females 222 to 305 mm from the central area contained from 3,500 to 110,000 eggs or 243 per gram of fish. In previously published data 22 female hake 346 to 688 mm from northern Baja California contained from 33,000 to 496,000 eggs or 192 eggs per gram of fish. There are no significant differences in fecundity among the three areas. The hake spawns once a year with over 98% of the spawning taking place between January and April.

In 1966, I published data on the fecundity of 22 female hake taken off northern Baja California. In 1970, additional samples of hake were obtained from central and southern Baja California to determine if there were geographic differences in hake fecundity in the offshore waters of Baja California.

The hake samples taken off southern and central Baja California in January contained prespawning females from which estimates of fecundity were obtained.

The hake from northern Baja California for which fecundity data have been published (MacGregor, 1966) appear to be identical to those taken off southern and northern California, while those taken farther to the south are different with respect to growth rate and size at first maturity and, in fact, have been described as a different species (Ginsberg, 1954).

The female hake for which fecundity determinations were made were taken by trawl from the research vessel *David Starr Jordan*. Station J-45-13 at lat 26°07′ N, long 113°07′ W was sampled January 11, 1970. Station J-45-27 at lat 28°44′ N, long 115°15′ W was sampled January 16, 1970. Methods for estimating fecundity of the samples were essentially the same as used previously (MacGregor, 1966).

Previous data on hake fecundity (MacGregor, 1966) were obtained from samples taken by the research vessel *John N. Cobb* (Berry and Perkins, 1966). Station C-58-23 at lat 31°49′ N, long 117°53′ W was sampled March 21, 1963. Station C-58-29 at lat 29°46′ N, long 116°01′ W was sampled March 23, 1963. Station C-58-31 at lat 29°35′ N, long 116°00′ W was sampled March 25, 1963.

FECUNDITY

The range for fecundity data for samples J-45-13 (Table 1) and J-45-27 (Table 2) compare with *Cobb* 1963 samples (MacGregor, 1966) as follows:

	J-45-13	*J-45-27*	Cobb *1963*
Standard length (mm)	130 to 202	222 to 305	346 to 688
Weight (g)	22.1 to 57.0	88.0 to 221.0	300 to 2,750
Gonad weight (g)	0.928 to 4.002	3.279 to 22.710	13.1 to 196.8
Advanced eggs	3,419 to 19,564	3,496 to 110,017	33,000 to 496,000
Eggs per gram of fish	141 to 343	38 to 498	83 to 556

There is no overlap in the ranges of standard length and fish weight of the samples from the three localities. The number of advanced eggs in the ovaries tends to increase with size of fish both within and between samples. However, because of the great variation in the numbers of advanced eggs among the individual fish, there is considerable overlap in gonad weight and numbers of advanced eggs between successive samples.

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TABLE 1.—Fecundity data for 17 female hake taken at Station J-45-13 (lat 26°07′ N, long 113°07′ W) January 11, 1970.

Standard length	Weight	Gonad weight	Gonad index	Advanced eggs		Eggs per gram of fish
				Size range	Number	
mm	*g*	*g*		*mm*		
130	22.1	0.928	4.2	0.50-0.67	3,419	155
131	23.3	1.345	5.8	.57- .73	7,049	303
135	25.2	1.320	5.2	.57- .77	3,564	141
137	22.4	1.518	6.8	.50- .67	6,469	289
137	29.3	1.795	6.1	.53- .70	7,139	244
138	24.8	0.987	4.0	.53- .70	4,048	163
140	28.8	1.350	4.7	.53- .70	4,956	172
140	34.5	2.241	6.6	.57- .77	7,926	230
141	30.5	1.222	4.0	.50- .70	4,534	149
150	21.2	1.198	5.7	.53- .73	4,257	201
150	37.1	2.481	6.7	.53- .73	10,864	293
160	31.5	1.875	6.0	.53- .73	6,447	205
162	30.3	1.957	6.5	.57- .73	7,633	252
170	32.3	2.000	6.2	.50- .70	8,741	271
172	37.7	1.863	4.9	.47- .70	10,731	285
174	37.7	2.000	5.3	.50- .70	7,559	201
202	57.0	4.002	7.0	.50- .67	19,564	343

TABLE 2.—Fecundity data for 11 female hake taken at Station J-45-27 (lat 28°44′ N, long 115°15′ W) January 16, 1970.

Standard length	Weight	Gonad weight	Gonad index	Advanced eggs		Eggs per gram of fish
				Size range	Number	
mm	*g*	*g*		*mm*		
222	100	8.663	9.7	0.50-0.67	29,399	294
230	88	7.011	8.0	.50- .73	23,253	264
233	104	8.488	8.2	.60- .77	29,450	347
238	91	3.279	3.6	.57- .73	3,496	38
245	105	6.292	6.0	.50- .70	17,511	168
247	120	5.956	5.0	.60- .80	18,264	152
252	110	9.341	8.5	.53- .77	43,014	391
268	147	5.308	3.6	.60- .80	13,747	94
275	146	11.860	8.2	.57- .83	38,959	286
287	176	12.972	7.4	.67- .83	24,877	141
305	221	22.710	10.3	.57- .80	110,017	498

The mean number of advanced eggs per gram of fish is 229 for sample J-45-13, 243 for sample J-45-27, and 192 for the *Cobb* 1963 samples. Owing to the great range of individual values in each of the samples, there is no significance in the differences between the means. The mean for the 50 fish in the three samples is 216 eggs per gram of fish. The standard error of the mean is 15 eggs or about 7%. In spite of some rather low fecundities, the distribution of eggs per gram of fish approximates a normal distribution indicating that these low counts are within the limits of expected variation.

Eggs/gram	*Percent frequency*
< 50	2
100	24
200	38
300	30
400	2
500	2
>550	2

The low counts apparently did not result from partial spawning of the advanced mode because they were found in fish that were not yet ripe.

RATIOS

To obtain estimates of the numbers of advanced eggs in the hake ovary, first about 100 yolked eggs in the sample were measured in order to delimit the distributions of advanced- and small-yolked eggs. Then the additional advanced-yolked eggs in the weighed sample were counted. An estimate of the numbers of small eggs was obtained from the ratio of large to small eggs in the measured frequency distribution, but because this estimate is based on relatively few eggs it is less accurate than the estimates of advanced eggs. Estimates of the numbers of small eggs per gram of fish ranged from

33 to 766 and averaged 248. This compares with 38 to 556 with an average of 216 for the advanced eggs for all samples.

The correlation obtained by MacGregor (1966) between percentage of eggs in the advanced mode and advanced eggs per gram of fish has no mathematical significance because both variables are related. Actually there is no relation between the number of advanced eggs and the number of small eggs. Ovaries containing either high or low numbers of advanced eggs per gram of fish may contain either high or low numbers of small-yolked eggs. However, the conclusion that the great variation in the ratios of large to small eggs makes multiple spawning unlikely seems to be valid.

Of 366,093 hake larvae taken on monthly cruises in the 6 years 1951 through 1956, 87% were taken in January, February, and March, 11.5% in April, and the remaining 1.5% in the remaining 8 months. Several large samples of hake taken off California in April 1970 showed that the advanced eggs were no longer present in the ovaries of the females while the smaller yolked eggs were. Because there is no evidence of further egg development in the ovaries and no evidence of heavy spawning subsequent to April in the plankton, we must assume that these small-yolked eggs are resorbed following spawning of the advanced mode.

SIZE AT FIRST MATURITY

One hundred thirty-six hake from sample J-45-13 (southern Baja California) were examined for stage of sexual maturity. Eighty hake from sample J-45-27 (central Baja California) and an additional seven hake taken in 1961 near Cedros Island (central Baja California) were also examined (Table 3).

In sample J-45-13 the largest immature male was 127 mm in length, and the largest immature female 138 mm. The smallest maturing male was 119 mm, and the smallest maturing female 125 mm. All males 129 mm and longer and all females 140 mm and longer were maturing.

In sample J-45-27 the range of fish length was not as good for determining size at first maturity. The smallest maturing male was 137 mm long, and it appeared that all males 159 mm and longer were mature. The smallest mature female was 222 mm in length, and all females of this length and longer were maturing. However, on the basis of the 1961 sample it appears that all females were maturing at some length between 202 and 222 mm.

It is difficult to determine the size at first maturity for hake off northern Baja California and California because very few fish of suitable size, taken during the spawning season, were available. For off-season hake the gonad index may

TABLE 3.—Size at first maturity. Southern Baja California, sample J-45-13, lat 27°07′ N, long 113°07′ W, January 11, 1970. Central Baja California (Cedros Island area), sample J-45-27, lat 28°44′ N, long 115°15′ W, January 16, 1970, and sample B-6111-3, Cedros Island, November 25, 1961. Males judged mature or immature by size and appearance of testes. Females judged immature if largest eggs in ovary were 0.20 mm or less in diameter (not yolked); probably maturing if maximum egg diameter was 0.23 to 0.47 mm; mature if maximum egg diameter was 0.50 mm or larger. Immature, not sexed: gonads not developed enough so that sex can be determined by gross examination.

Sample	Males			Females				Not sexed	
	Standard length	Immature	Mature	Standard length	Maximum egg diameter (mm)			Standard length	Immature
					0-0.10	0.30-0.47	0.50-0.77		
	mm			mm				mm	
J-45-13	119-127	6	6	122-124	6	0	0	100-118	19
				125-128	8	1	0		
	129-166	0	50	130-138	9	4	6		
				140-202	0	0	21		
					Maximum egg diameter (mm)				
					0-0.20	0.37	0.67-0.83		
J-45-27	137-140	1	1	172-197	3	0	0	120-138	42
	159-307	0	21	222-228	0	1	1		
				230-305	0	0	10		
B-6111-3				236	0	0	1	148-202	6

indicate maturity. Generally, hake with gonad indices of less than 0.5 (i.e., the gonad weight is less than 0.5% of the fish weight) do not contain yolked eggs in their ovaries. There is no yolk in eggs up to 0.20 mm diameter, and fish containing such eggs a few months before or after the spawning season may be considered immature. Eggs in an ovary having a gonad index of 0.8 have a maximum diameter of about 0.34 mm and at a gonad index of 1.5, about 0.43 mm maximum diameter. The eggs generally are not large enough to count (over 0.65 mm diameter for the largest eggs in the ovary) until the gonad index is about 3.5, and then only for fish having a fecundity of less than 100 eggs per gram of fish. If we apply the same criterion (a gonad index of less than 0.5 as indicating an immature fish) to the males, we can roughly estimate the size at maturity for off-season hake.

Applying this criterion of maturity to a number of miscellaneous hake samples taken in the off-season for spawning off northern Baja California and southern California, it appears that all males 285 mm and longer and all females 340 mm and longer were mature.

Best (1963) estimated that all hake, both males and females, taken off northern California were mature at 400 mm total length (about 360 mm standard length). The length at which all fish are mature could be somewhat less as he had a limited number of smaller fish in his samples.

Nelson and Larkins (1970) found that all fish of 450 mm total length (about 405 mm standard length) were mature in the Pacific Northwest. Apparently they also had few smaller fish to work with, and the length at which all fish are mature could be somewhat less.

DISCUSSION

The mean number of eggs per gram of fish was not significantly different among the three samples, J-45-13, J-45-27, and *Cobb* 1963. These three samples were taken in widely separated localities, and although they were similar with respect to relative fecundity, questions have been raised as to the distinctness of the north Pacific hake with respect to race or even species.

Ginsberg (1954) assigned the north Pacific hake to two species based on morphometric and meristic characters. His descriptions were based on 12 specimens of *Merluccius productus* taken off Washington, Oregon, and California, as far south as San Diego, and eight specimens of *M. angustimanus* taken in the Gulf of Panama, the Gulf of California, off the Pacific Coast of Baja California, and off Del Mar, Calif.

Ahlstrom and Counts (1955) could find no evidence of more than one species of hake in their extensive collections of eggs and larvae taken between San Francisco and the southern tip of Baja California. All of the small fish that had fully developed dorsal and anal fins had fin ray counts that fell within the range of *M. productus* but outside of the range of *M. angustimanus* as given by Ginsberg.

F. H. Berry (unpublished data) studied numerous additional specimens of hake from Baja California and California. He concluded that *M. productus* and *M. angustimanus* were the same species and the differences in meristic and morphometric characters, used by Ginsberg to separate the species represented a latitudinal cline.

There was certainly a marked cline in size at maturity for the hake used in this study, especially when these data are compared with data given by other authors. The size at which all fish were mature was as follows:

	Sex	*Standard length*
Southern Baja California	males	129 mm
	females	140 mm
Central Baja California	males	159 mm
	females	202-222 mm
Northern Baja California and southern California	males	285 mm
	females	340 mm
Northern California (Best, 1963)	both	360 mm
Pacific Northwest (Nelson and Larkins, 1970)	both	405 mm

The differences between areas are so great that the roughness of some of the estimates does not affect the conclusion that these differences are very real.

The distribution and growth patterns of the European hake, *M. merluccius*, is similar to that of *M. productus* in many ways. The European hake ranges from Norway to at least Mauritania in Africa (Hart, 1948) while *M: productus*

ranges from Alaska to at least the southern tip of Baja California. Both species grow to much larger sizes in the northern parts of their ranges, but are much smaller in their southern ranges. *M. merluccius* in the Mediterranean Sea is smaller than the north Atlantic form, and both the southern Baja California and African coasts apparently produce dwarf races of their respective hake species.

Most recent information from the Guinean Trawling Survey (Williams, 1968) shows that there are continuous populations of hake from Norway to South Africa. However, the hake taken off the west coast of Africa are ascribed to several species other than *M. merluccius*. The West African hake, *M. polli* and unidentified *M.* spp. were taken throughout the survey area from the Gambia border to the Congo. The Senegal hake *M. senegalensis* was taken in the northern areas between the Gambia border and southern Liberia with one questionable record from Nigeria, and the South African hake *M. capensis* was taken in the southern areas between Cameroun and the Congo. A sample of 50 *M. senegalensis* averaged 26.3 cm total length (range 18 to 27), and a sample of *M. polli* averaged 41.7 cm total length (range 35 to 49).

SUMMARY

The north Pacific hake, *Merluccius productus*, ranges from Alaska to at least southern Baja California.

The fecundity of individual hake varied greatly off Baja California and southern California, but there was no significant difference in average fecundity among the samples taken from widely separated sampling stations in this area. Estimates of the number of advanced eggs contained in 50 prespawning hake averaged 216 eggs per gram of fish.

Average size at first maturity for female hake varied from 133 mm standard length off southern Baja California to about 340 mm off northern Baja California and southern California. Males appeared to mature at smaller sizes 128 mm in the south to 285 mm in the north.

LITERATURE CITED

AHLSTROM, E. H., AND R. C. COUNTS.
1955. Eggs and larvae of the Pacific hake, *Merluccius productus*. U.S. Fish Wildl. Serv., Fish. Bull. 56: 295-329.

BERRY, F. H., AND H. C. PERKINS.
1966. Survey of pelagic fishes of the California Current area. U.S. Fish Wildl. Serv., Fish. Bull. 65: 625-682.

BEST, E. A.
1963. Contribution to the biology of the Pacific hake, *Merluccius productus* (Ayres). Calif. Coop. Oceanic Fish. Invest., Rep. 9: 51-56.

GINSBERG, I.
1954. Whitings on the coasts of the American continents. U.S. Fish Wildl. Serv., Fish. Bull. 56: 187-208.

HART, T. J.
1948. The distribution and biology of hake. Biol. Rev. (Cambridge) 23: 62-80.

MACGREGOR, J. S.
1966. Fecundity of the Pacific hake, *Merluccius productus* (Ayres). Calif. Fish Game 52: 111-116.

NELSON, M. O., AND H. A. LARKINS.
1970. Distribution and biology of Pacific hake: A synopsis. *In* Pacific hake, p. 23-33. U.S. Fish Wildl. Serv., Circ. 332.

WILLIAMS, F.
1968. Report on the Guinean Trawling Survey. Volume I. General report. Organisation of African Unity, Scientific, Technical and Research Commission, Lagos, Nigeria. OAU/STRC Publ. 99, 828 p.