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SYNOPSIS OF THE BIOLOGICAL DATA ON THE PACIFIC MACKEREL

Scomber japonicus Houttuyn

(Northeast Pacific)

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF COMMERCIAL FISHERIES

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By

DAVID KRAMER

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Synopsis of the Biological Data on the Pacific Mackerel, Scomber japonicus Houttuyn (Northeast Pacific)

By

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ABSTRACT

This synopsis attempts to bring together all knowledge extant on the identity (nomenclature, taxonomy, morphology), distribution, bionomics, life history, population, fishery, and protection and management of the Pacific mackerel.

INTRODUCTION

BCF (Bureau of Commercial Fisheries) has assigned the preparation of synopses on various economically important species to a number of its laboratories. Most of these synopses will be published in the U.S. Fish and Wildlife Service Circular series,[1] and will follow the format presented in "Preparation of synopses on the biology of species of living aquatic organisms," by H. Rosa Jr., Biology Branch, Department of Fisheries, Food and Agriculture Organization of the United Nations.

1 IDENTITY

1.1 Nomenclature

1.11 Valid name

Scomber japonicus Houttuyn.

1.12 Synonomy

Scomber japonicus Houttuyn (1782: 331). Japan.

Pneumatophorus japonicus (Houttuyn, 1782); Starks (1921: 222-223).

Scomber diego Ayres (1856: 101). Santa Barbara, Calif.

Pneumatophorus diego (Ayres) Jordan and Hubbs (1925: 221). California.

1.2 Taxonomy

1.21 Affinities

Phylum	Chordata
Class	Teleostomi
Order	Perciformes
Family	Scombridae

SCOMBER

Scomber Linnaeus

Scomber Artedi, in Linnaeus (1758: 297) (S. scombrus Linnaeus).

Cordylus Gronow (1854: 163) (Scomber scombrus L.).

Pneumatophorus Jordan and Gilbert (1883: 593) (as subgenus). Starks (1921: 222-223).

Matsui (1967) separated the mackerels into two genera, Scomber and Rastrelliger, and cited differences in 14 characters, chief of which were the presence in Scomber of vomerine and palatine teeth (lacking in Rastrelliger) and a well-developed anal fin spine (lacking in adult Rastrelliger). Other differences included: the hypohyal nearly as long as or longer than

[1] One synopsis, written by MacGregor, has appeared in the U.S. Fish and Wildlife Service Special Scientific Report--Fisheries series.

epihyal in Scomber, but less than one-third as long as the epihyal in Rastrelliger; 12 to 28 first dorsal fin interneurals in Scomber, 11 (rarely 10) in Rastrelliger; the first haemal spine somewhat flattened and bent backward in Scomber but flattened with the middle hooked and the distal part nearly vertically directed in Rastrelliger.

Matsui recognized only three species of mackerels with 31 vertebrae and 5 finlets in the genus Scomber (including Pneumatophorus). These include S. scombrus Linnaeus, S. japonicus Houttuyn, and S. australasicus Cuvier. S. scombrus differs from the others in having more heavily ossified bones, in having no swim bladder, and in having the first haemal spine anterior to the first interhaemal bone. He saw no reason for recognizing Pneumatophorus for the other two species. He summarized 12 characters for comparison of the three species, the most distinguishing of which, other than the absence of a swim bladder in scombrus, is the number and arrangement of the interneurals under the first dorsal fin--21 to 28 in S. scombrus, 15 to 21 in S. australasicus, and 12 to 15 in S. japonicus. He showed these arrangements by a representative diagram in his figure 7.

used are blue mackerel, greenback mackerel, striped mackerel, and American mackerel.

1.3 Morphology

1.31 External morphology

Dorsal IX-I, 9 to 13-IV to VI; anal I-I, 9 to 11-IV to VI; pectoral 17 to 19; caudal 17; pelvic I, 5; first dorsal fin rather high, received entirely into a groove when depressed, widely separated from the much lower second dorsal; scales small, easily lost; two very small keels on each side of the caudal peduncle. Color: dark green to blue above with metallic reflections shading into iridescent silvery on the sides and below; a series of about 30 wavy, dark streaks run vertically down the back to just below the lateral line (fig. 1).

Matsui (1967) differentiated three populations of S. japonicus in the temperate zones of the Pacific Ocean and the west and east Atlantic Ocean (table 1).

The Pacific mackerel off the coast of North America are not known to mix with any of the other populations designated above. Racial differences were investigated in this group by Fry and Roedel (1949) in tagging experiments--

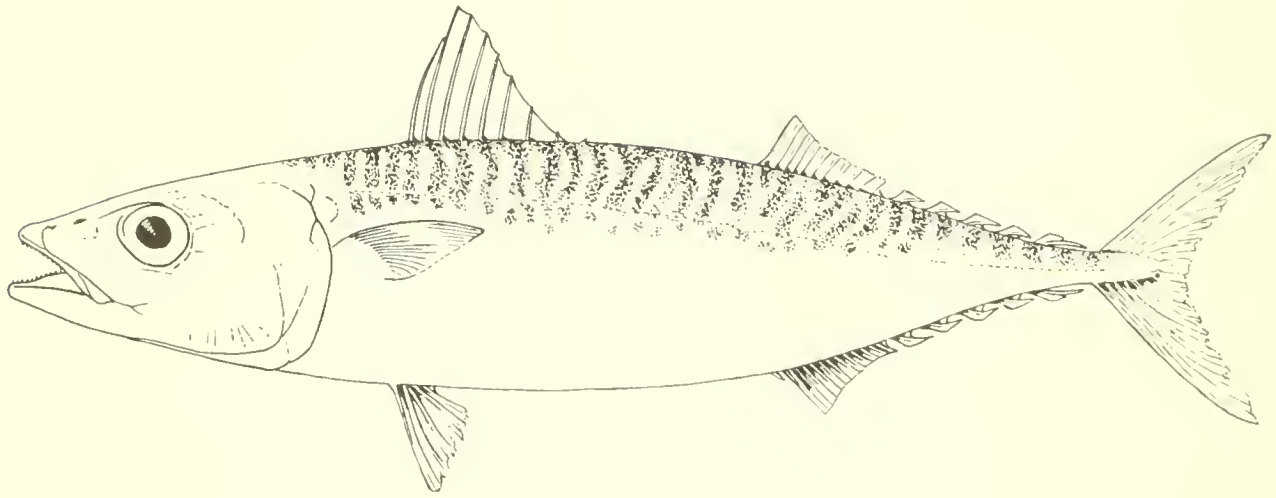

Figure 1.--Scomber japonicus (= Pneumatophorus diego) Houttuyn (adapted from frontispiece, Fitch, 1951).

1.22 Taxonomic status

See above.

1.23 Subspecies

See above.

1.24 Standard common names

The name officially sanctioned by the State of California for purposes of keeping records is Pacific mackerel. Other names variously

see 3.51 below--and by Roedel (1952) in a racial study.

For the racial study, Roedel examined specimens from six geographic regions: British Columbia, southern California, northern Baja California (Soledad Bay), central Baja California (Sebastian Vizcaino Bay), the Cape San Lucas region including sections of the Pacific and Gulf coasts of the peninsula, and the Gulf of California.

Table 1.--Difference Between populations of S. japonicus (table 7 of Matsui, 1967)

	Pacific	W Atlantic	E Atlantic
Pigment pattern on belly	Usually unmarked or only lightly marked	Usually clearly marked by a number of fairly large spots; sometimes by broken wavy lines; occasionally unmarked	Usually clearly marked by broken, wavy lines; sometimes by thicker lines that almost resemble spotting; occasionally unmarked
Mandibular and premaxillary teeth	Lightly crenulated	Strongly crenulated	Strongly crenulated
Scales	Smaller than those of Atlantic	Larger than those of Pacific population	Similar to W Atlantic
Gill rakers on lower 1st arch (on individuals 80 mm. SL or greater)	25-29	25-29	29-35
Distribution	China, Korea, Japan-Bonin Is.; Coast of Calif., Baja Calif., Gulf of Calif.-Chile	Massachusetts-Venezuela; Argentina	Mediterranean; Azores-Gulf of Guinea; Capetown

Four physical characteristics were selected for detailed study. Three were related to the initial position of vertebral structures: the haemal arch, the haemal brace either single or paired, and the paired haemal brace; and the fourth to the head length relative to fork length.

Statistical analyses gave evidence of five populations, each region, with the exception of British Columbia and California, being separable in some degree from adjoining regions. Tag returns, however, demonstrated that a portion of Vizcaino fish eventually reached California waters. The Cape San Lucas material differed radically in all respects from the northern regions and was separable from Gulf of California fish except in regard to the initial position of the haemal arch.

1.32 Cytomorphology

No data available.

1.33 Protein specificity

No data available.

2 DISTRIBUTION

2.1 Total area

The Pacific mackerel in the northeast Pacific Ocean has ranged from southeast Alaska (Rounsefell and Dahlgren, 1934) to Banderas Bay, Mexico (Fitch[2]).

The natural regions[3] of the oceans inhabited by this mackerel thus included northwest American coastal waters (4.2.4), San Francisco waters (4.5.2), California waters (4.6.3), and west Mexican waters (4.6.4). Now, as determined from populations of larvae, its range may extend only as far north as Point Conception, Calif.,[4] south along the coast and into all of the Gulf of California (Kramer, 1960). The offshore extent of the population is as far as 200 nautical miles (370 km.) off northern Baja California, and about 200 nautical miles (370 km.) off central Baja California, with the greatest numbers of larvae concentrated off upper and central Baja California (fig. 2). Data from two cruises in 1956 into the Gulf of California by the CalCOFI (California Cooperative Oceanic Fisheries Investigations) in February (Ahlstrom, 1956) and April (unpublished) showed that the populations of larvae in either of these months exceeded by far the total population of larvae in 1956 in the entire CalCOFI area for the whole year of surveys on the outer coast. Furthermore, although the CalCOFI data for the outer coast showed that Pacific mackerel larvae extend only as far south as Cape San Lucas, the data

[2] John E. Fitch, California Department of Fish and Game, Terminal Island, Calif., by correspondence.

[3] For definition of these regions, see Rosa, H. Jr., Preparation of synopses on the biology of species of living aquatic organisms. Biology Branch, FAO Fisheries Division.

[4] Recent reports of repeated traces of Pacific mackerel with jack mackerel taken off Pt. Sur, Calif.--by correspondence, Richard Parrish, California Department of Fish and Game, Hopkins Marine Station, Pacific Grove, Calif.

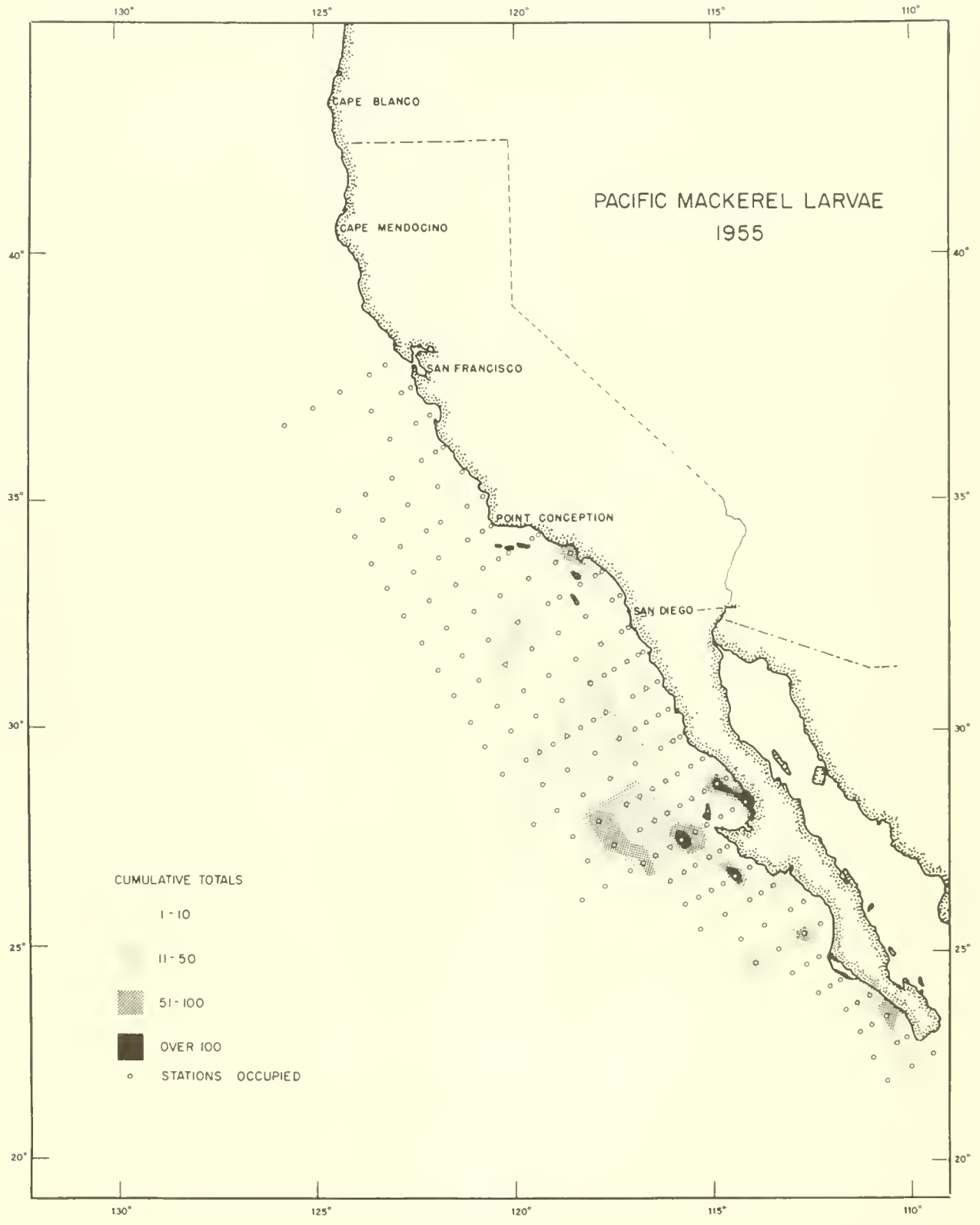

Figure 2.--Distribution and relative abundance of Pacific mackerel larvae in 1955 (fig. 20 of Kramer, 1960).

for the Gulf cruise in February 1956 showed very heavy concentrations of larvae off the mainland of Mexico not delimited by the southernmost extent of that cruise. The Gulf population, then (see 1.31 above) may extend as far as the limit of Banderas Bay defined by Fitch (see footnote 1), or farther.

2.2 Differential distribution

2.21 Spawn, larvae, and juveniles. See 2.1 above.

2.22 Adults

The adults occur in the same areas shown for the distributions of their larvae (also see 2.1), and farther north, at least to Pt. Sur, Calif. (see footnote 4).

2.3 Determinants of distribution changes

No data.

2.4 Hybridization

No evidence of hybridization.

3 BIONOMICS AND LIFE HISTORY

3.1 Reproduction

3.11 Sexuality

The Pacific mackerel is heterosexual with no evidence of sexual dimorphism.

3.12 Maturity

Fry (1936b) stated that mackerels, "... under 11-1/2 inches total length at the beginning of the spawning season will not spawn that season; some of the 12- and 12-1/2-inch fish and over three-fourths of the 13-inch fish will spawn. In terms of age--the yearling fish do not spawn whereas most of the 2-year-olds do." He stated further that these facts are true for mackerels in California waters but that some mackerels from the southern part of Baja California seem to mature at a smaller size.

3.13 Mating

Not observed but believed to be promiscuous.

3.14 Fertilization

External.

3.15 Gonads

Few data are available on the fecundity of the Pacific mackerel. MacGregor (1966) stated that this mackerel produces 304 eggs per gram of fish (based on counts for six specimens). One of these was collected off Avalon, Catalina Island, Calif. and another from San Hipolito Bay, Baja California. The remaining four were taken from a holding tank at the Scripps Institution of Oceanography, La Jolla, Calif. For want of better data, he included data from these four in his totals, although he was not sure of their validity. His data showed 309 and 220 eggs per gram of fish for the Avalon and San Hipolito specimens, respectively, and 141 to 457 eggs per gram of fish for the other four specimens.

3.16 Spawning

Studies of spawning of Pacific mackerel have been made off southern California and Baja California. Fry (1936b) stated that in 1936 Pacific mackerel spawned off southern California from late April or early May to August--the peak spawning was from May to early July. Kramer (1960), using larvae as indicators of spawning times, stated that spawning occurred in the same months from 1952 through 1956 on the surveys of the CalCOFI. He stated further that there was some variation in peak spawning times in different regions--April through July off southern California and northern Baja California and March through August off central Baja California. Ahlstrom (1959a, text table 10) showed that the peak of spawning in 1957 off central Baja California occurred from June through October and that the numbers of larvae off northern Baja California indicated a possible peak in April and May. Ahlstrom (manuscript[5]) showed that numbers of larvae in 1958 indicated peak spawning in March through July off southern California and northern Baja California and about August and September off central Baja California. He showed that in 1959 abundance of larvae was very low but that a spawning peak was indicated off southern California and northern Baja California in June and July and off central Baja California from June through September.

3.17 Spawn

The Pacific mackerel egg is pelagic and spherical. The egg and the embryonic development were described from live material by Fry (1936a) and Orton (1953). Kramer (1960) described the egg and embryonic development in greater detail from preserved material, from very early stages to hatching (figs. 3 and 4, table 2). Because of the various similarities of Pacific mackerel eggs to those of the jack mackerel, Trachurus symmetricus and the Pacific hake, Merluccius productus, with which they might be collected, Kramer compared the three as shown in table 2. The sizes of Pacific mackerel eggs shown in this table are averages and may vary according to time as noted by Fry (1936a) who concluded that eggs found at the beginning of the spawning season were larger than those found at the end of the season.

[5] Ahlstrom, Elbert H., BCF Fishery-Oceanography Center, La Jolla, Calif. Sardine eggs and larvae and other fish larvae off the Pacific coast, 1958-60.

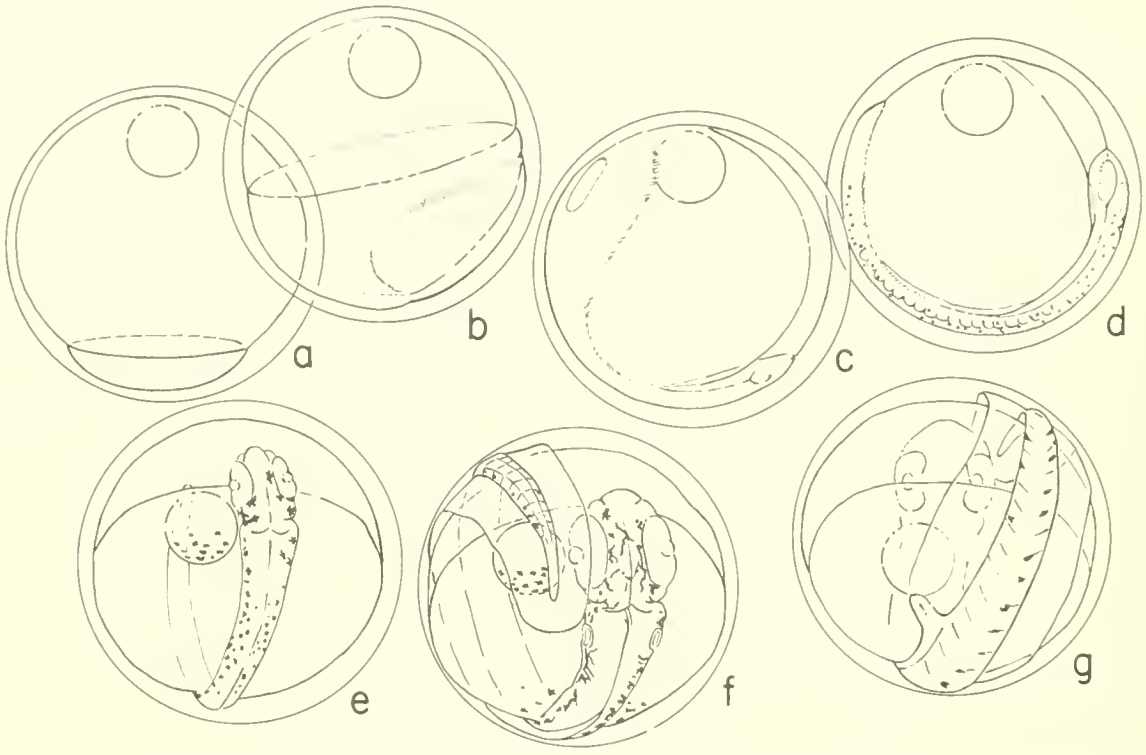

Figure 3.--Development of the egg of the Pacific mackerel, Scomber japonicus (= Pneumatophorus diego): a, b, and c, early embryonic development, c being the early stage immediately before blastopore closure; d, middle-stage, just after blastopore closure; e, middle-stage, dorsal view of head and pectoral region, tail separated from yolk-sac; f, late-stage, tail reaching to head; g, same as f, viewed from opposite pole (adapted from drawing of Mattson, fig. 1 of Kramer, 1960).

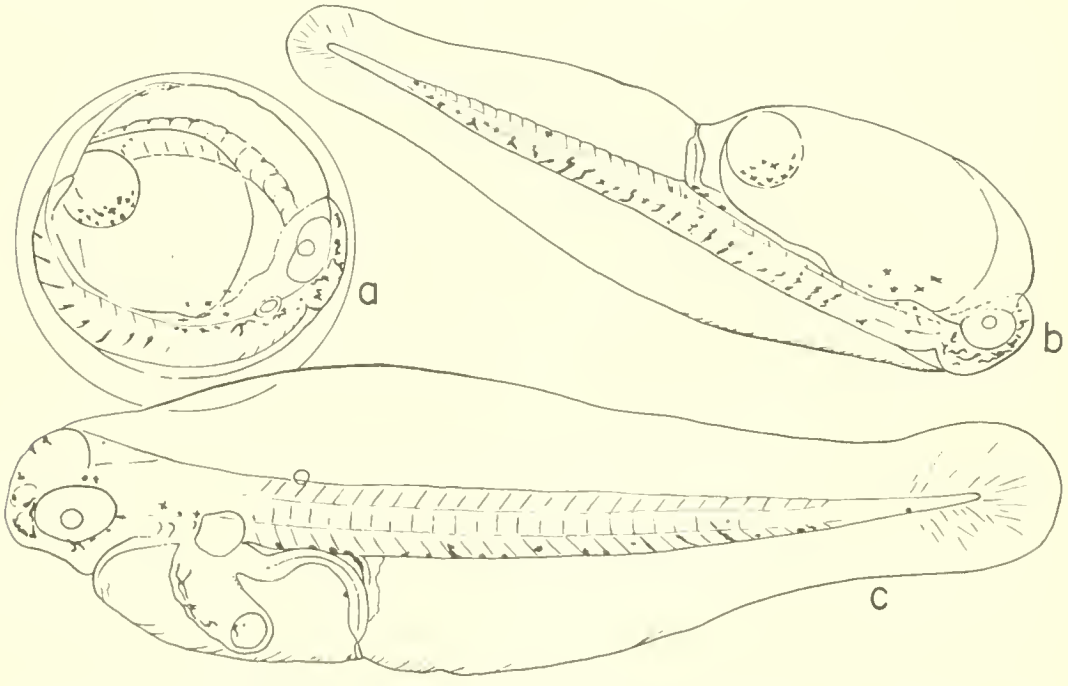

Figure 4.--Late-stage egg and yolk-sac larvae of the Pacific mackerel, Scomber japonicus (= Pneumatophorus diego): a, egg immediately before hatching; b, yolk-sac larva, 3.3 mm. long, just after hatching; c, yolk sac larva, 3.5 mm. long, with yolk about two-thirds absorbed (adapted from drawing by Mattson, fig. 2 of Kramer, 1960).

Table 2.--Characters used to distinguish eggs and newly hatched larvae of the Pacific mackerel, jack mackerel, and hake (table 2 of Kramer, 1960)

Item	Pacific mackerel	Jack mackerel[1]	Hake[1]
EGG			
Size	1.06 to 1.14 mm.	0.96 to 1.02 mm.	1.07 to 1.18 mm.
Oil globule	0.26 to 0.27 mm. Off center from polar axis.	Single--0.25 mm. On center on polar axis.	Single--0.30 mm. Off center from polar axis.
Yolk	Clear--magnification shows tiny vacuoles throughout yolk mass.[2]	Segmented.	Clear.
Perivitelline space	Narrower than either hake or jack mackerel--about 0.02 mm. wide.[3]	Moderate (0.09 mm. wide).	Moderate (0.06 mm. wide).
Pigmentation:			
Yolk	On yolk near pectoral region.	None.	On yolk near head.
Embryo	Dorsal pigment first one line head to tail; splits laterally to two dorsal lines when tail grows away from yolk; before hatching head becomes fairly heavily pigmented and body pigment begins ventral migration.	Dorsal pigment extends most of length of embryo; ventral pigment occurs behind anus; pigment seldom occurs forward of the eyes.	Dorsal pigmentation continuous in middle-stage eggs; separates into patches in later-stage eggs.
Number of myomeres	31	24	51 to 54.
YOLK-SAC LARVAE			
Size	3.0 to 3.5 mm.	2.07 mm.	2.4 mm.
Pigmentation	Some dorsal pigment; most pigment migrating ventrally.	Dorsal and ventral retained.	Collects in patches.
Oil globule	In rear of yolk-sac.	Under head in forward portion of yolk-sac.	In rear of yolk-sac.

[1]Ahlstrom and Counts (1955). [2]The same noted in hake eggs. [3]Fry (1936a).

In studies of vertical distributions Ahlstrom (1959b, table 8) showed, on the basis of collections at one station, that Pacific mackerel eggs may be distributed from the surface to as deep as 176 m. Most eggs in that series were taken between the surface and about 23 m. deep; abundance fell off sharply below that level.

3.2 Preadult phase

3.21 Embryonic phase. See 3.17 above.

3.22 Larvae phase.

Data on yolk-sac larvae are included in the same table as those on the embryonic phase (see 3.17 above) because the hatching stage closely resembles the latest embryonic stage. Kramer (1960) described the larvae (figs. 4, 5 and 6) in series from yolk-sac stage through 16.5 mm. and added further data on other specimens 18.9, 26.4, 30.0, and 66.6 mm. long. Detailed descriptions were given on changes in pigmentation, changes in body form, and sequences of ossification of various bony systems. Subsequent to the yolk-sac stage pigmentation increases in large, circular spots on top of the head, in two elongated patches on the dorsal surface of the body, in a vertical line on the base of the tail, in a line on the posterior part of the lateral line, in ventral area from the anus to the tail, and in two or three spots on the ventral surface of the gut. This pigmentation disappears in late-stage larvae.

Size on size regressions of body parts on standard length were expressed as straight line relations (fitted by least squares). Rates of increase are constant in relation to standard length for the head length, distance from snout to anus, and distances from snout to first

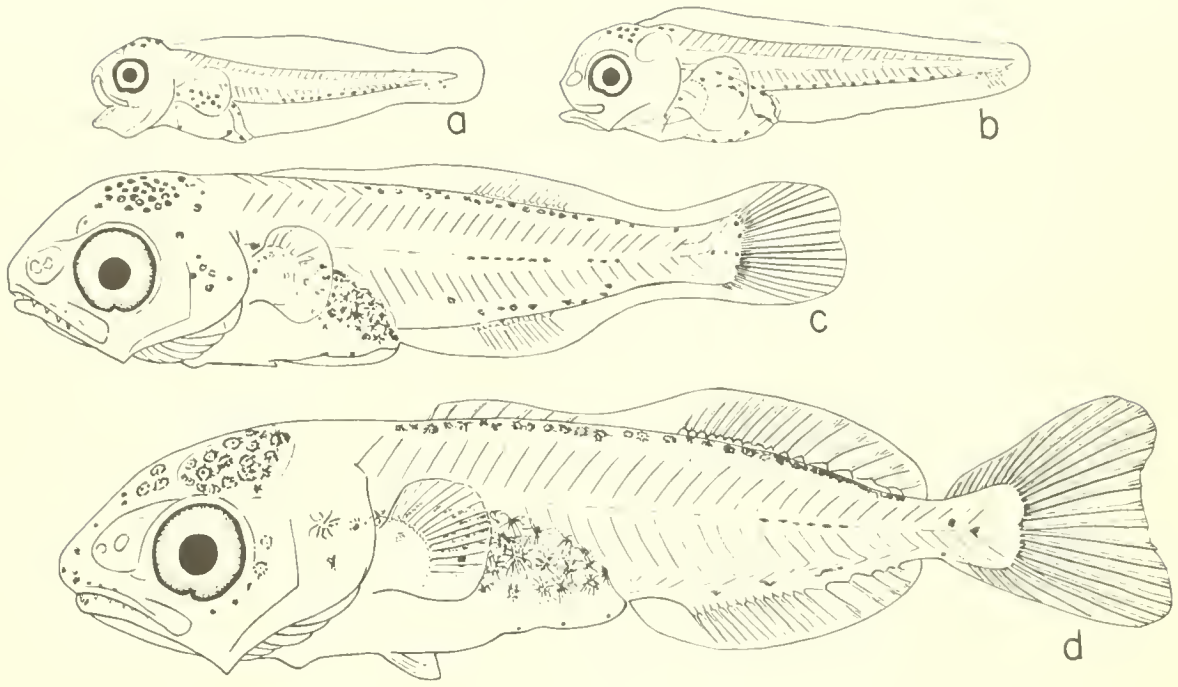

Figure 5.--Development of the larva of the Pacific mackerel, Scomber japonicus (= Pneumatophorus diego): a, larva 4.0 mm. long; b, larva 5.0 mm. long; c, larva 7.8 mm. long; d, larva 10.5 mm. long (adapted from drawing by Mattson, fig. 3 of Kramer, 1960).

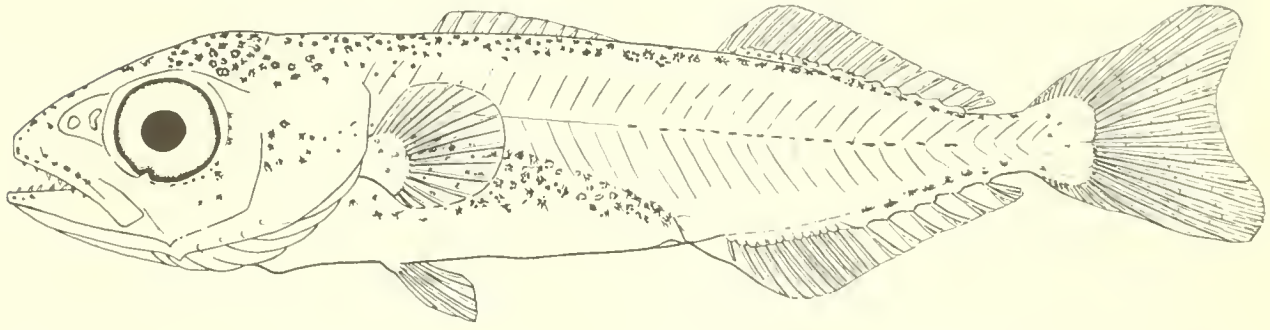

Figure 6.--Late larva of the Pacific mackerel, Scomber japonicus (= Pneumatophorus diego), 16.5 mm. long (adapted from drawing by Mattson, fig. 4 of Kramer, 1960).

dorsal and second dorsal fins. The body depth in early-stage larvae increases at a rate twice that of later stage larvae.

In Pacific mackerel, the order of first appearance of the fins is as follows: larval pectorals (without rays), caudal, pectorals (with rays), anal and second dorsal fins simultaneously, anal and dorsal finlets simultaneously, first dorsal, and ventrals. The development and appearance of the caudal keels were discussed in detail because of the occasional misconception that they are pseudofins with rays; each keel is made up of a series of scales assembled linearly on a complex curve.

Kramer (1960) further described the ossification and formation of the vertebral column and its parts for centra, urostyle, hypurals and epurals, vertebral arches and spines, ribs, epipleurals, zygapophyses, and parapophyses. Development of the fin and finlet interspinal systems were described with particular emphasis on the individual parts of the interspinal bones; especially the continuity of the interneural system between the first and second dorsal fins and the complex structures forming the dorsal slot of the first dorsal fin.

For Pacific mackerel larvae collected from 1953-57, the change in abundance from 3.00 to

4.00 mm. long was 39.5 percent, 17.8 percent at 5.00 mm., 6.7 percent at 6.75 mm., and 2.9 percent at 7.75 mm. The rapid decrease in abundance after 7.5 mm. is assumed to be masked by the ability of the larvae to escape capture by swimming away from the mouth of the collecting net.

3.23 Adolescent phase

In 1966 several hundred Pacific mackerel were hatched from eggs and reared to preadult stages at the Fishery-Oceanography Center. At about age 2 months several in this batch were accidentally killed in their tank. Eight of these were X-rayed and measured; their lengths ranged from 35 to 77 mm.

Nothing is known about juvenile Pacific mackerel in the sea. Their behavior in aquarium tanks indicates that they are particulate feeders on live or "dead" animal food--even prepared food--taking live or frozen brine shrimp, cut bait, fish or squid, and prepared trout food. The last was the least digestible; undigested material was voided shortly after feeding.

3.3 Adult phase

3.31 Longevity

Most of the fish taken commercially are less than 6 years old; most are 0, 1, 2 and 3 years old. Occasionally large mackerel appear in the catch. Fitch (1952) reported that the oldest Pacific mackerel aged was 11 years. Fitch (1956) reported that fish over 8 years old were rare and that 6-year-olds were becoming very uncommon.

3.32 Hardiness

No data on hardiness in ocean environment. Mackerel held in aquaria do best in circular plastic-lined tanks.

3.33 Competitors

No data except that since they are often caught with jack mackerel, they may compete with that species.

3.34 Predators

Not studied except for predation by man.

3.35 Parasites, diseases, injuries and abnormalities

No data for fish in ocean environment. In captivity these fish eventually develop hyperplasia (cancer-like growths) on the skin in the head region.

3.4 Nutrition and growth

3.41 Feeding

Pacific mackerel feed at any time of day. They can be caught at night by chumming under lights. They are particulate feeders.

3.42 Food

Fry (1936b) stated that this mackerel has a tremendous appetite and shows very little discrimination in its feeding. Any animal matter alive or dead is acceptable for food. He reported that the fish takes fish or squid several inches long, as well as small animals such as copepods or other free-swimming crustaceans. He stated that in general they feed on one kind of food at a time--for example, copepods, anchovies, or squid, but not mixtures of these. (See 3.23 for feeding in aquaria.)

3.43 Growth rate

When 2 years old, Pacific mackerel are about 12 inches (305 mm.) long and weigh about 3/4 pound (340)--Fitch, 1951. The relation of weight, length, and age are shown in figure 7.

Fry (1936b) listed the following approximate weights and lengths (in ounces and inches) and called them "rough averages":

Weight		Length	
Ounces	Gr.	Inches	mm.
1	28	6.50	165
2	57	7.75	197
4	113	9.50	241
8	227	11.75	298
16	453	14.50	368
24	680	16.25	413
32	907	17.75	451
40	1134	18.75	476

Condition factors (table 3) were derived from data for 137 mackerel presented by Fitch (1951, table 14) and from the data of G. O. Schumann (unpublished) on 139 of 340 mackerel hatched and reared at this laboratory, according to the formula: $K = \frac{\text{weight} \times 10^7}{\text{fork length}^3}$, where weight is in grams and length is in millimeters.

Hatanaka and Takahashi (1956) captured and held in captivity, for feeding experiments, a number of Japanese mackerel for which I calculated the condition factors. The factors for their specimens, when caught, were higher than the ocean specimens of comparable sizes shown in table 3.

3.44 Metabolism

No data.

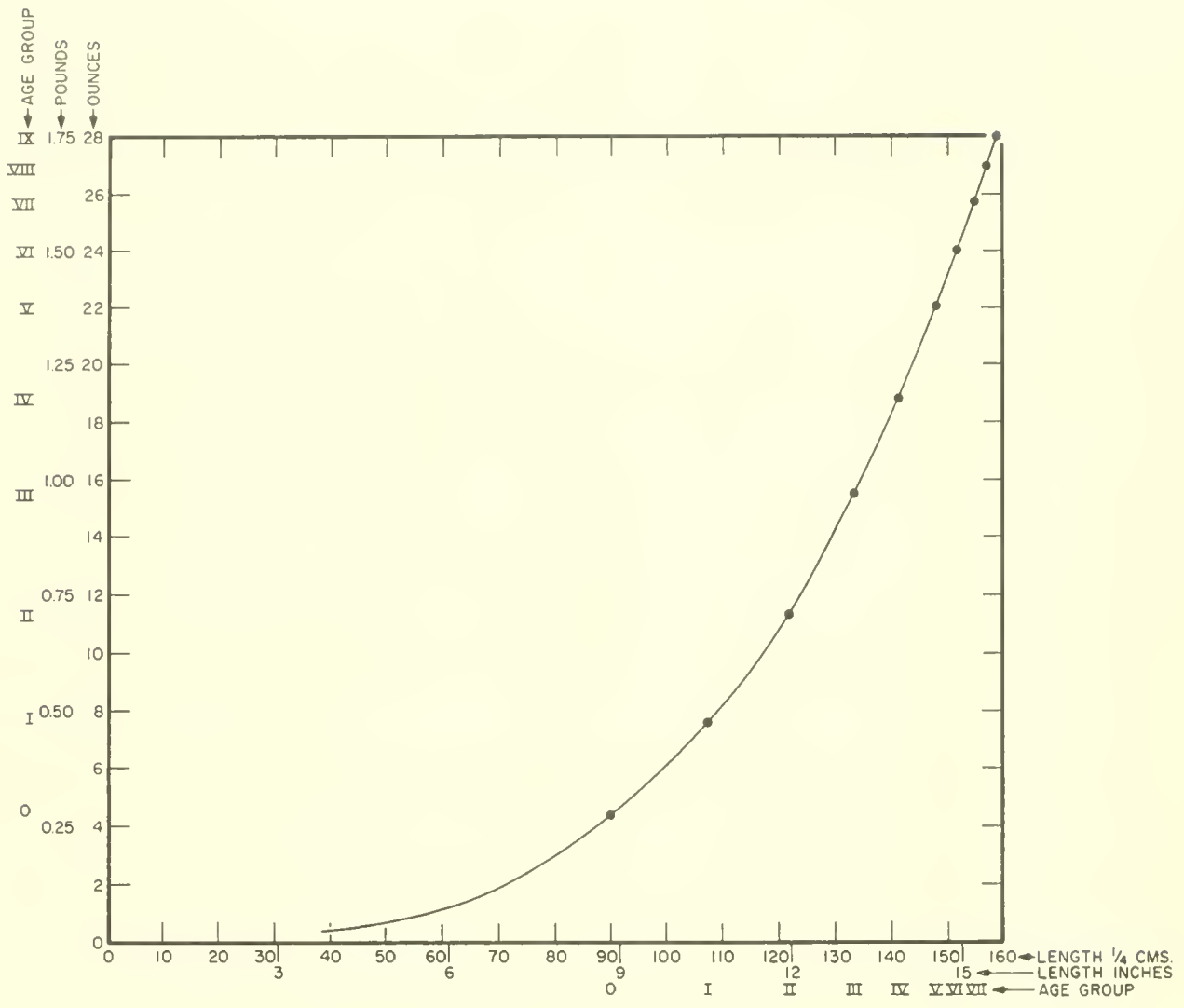

Figure 7.--Weight-length-age relation for Pacific mackerel (fig. 15 of Fitch, 1951).

3.5 Behavior

3.51 Migrations and local movements

The California Division of Fish and Game (Fry and Roedel, 1949) devised a tagging program in 1935, intensified it in 1940-41, and concluded it in 1943. Mackerel were tagged at several localities in central and southern California and as far south as Magdelena Bay, Baja California.

The Fisheries Research Board of Canada also tagged a few fish off the Oregon coast near the Columbia River.

Tag returns showed that the fish migrated throughout the region covered by the tagging program. One of the fish tagged off Oregon was caught again off southern California. Fish tagged off central California were recovered in large numbers at Los Angeles and Newport Beach canneries, and one was caught at San Diego and another at Ensenada, Baja California. Mackerel tagged off southern California were recaptured at Monterey and San Francisco. Fish tagged at northern and central Baja California were recovered at San Diego, Newport Beach, Los Angeles, Monterey and San Francisco, Calif. No fish tagged south of San Roque Bay, Baja California, were recovered.

3.52 Schooling

The Pacific mackerel schools by size. It is found in pure schools and mixed schools with jack mackerel and Pacific sardine.

Table 3.--Condition factors of ocean and laboratory-reared specimens of Pacific mackerel

Ocean specimens[1]				Laboratory reared specimens[2]			
Number of fish	Body length range	Condition factor		Number of fish	Body length range	Condition factor	
		Mean	Range			Mean	Range
	mm.				mm.		
7	85-100	82.5	81.6- 83.5	--	--	--	--
10	101-125	89.0	84.7- 92.5	--	--	--	--
10	126-150	96.1	92.8- 99.5	1	149	108.9	108.9
10	151-175	100.3	98.9-101.1	10	164-175	113.2	94.9-153.8
10	176-200	100.0	98.6-101.4	50	177-200	125.3	112.9-148.8
10	201-225	103.6	101.6-105.1	60	201-222	127.8	110.6-148.8
10	226-250	104.3	103.7-105.2	8	226-245	133.5	123.3-144.9
10	251-275	107.3	104.3-111.6	--	--	--	--
10	276-300	115.5	112.9-117.9	--	--	--	--
10	301-325	120.8	118.4-123.1	--	--	--	--
10	326-350	124.3	123.5-125.0	--	--	--	--
10	351-375	122.9	121.9-124.3	--	--	--	--
10	376-400	126.0	123.9-127.5	--	--	--	--
10	401-425	125.0	122.2-126.4	--	--	--	--

[1]From Fitch (1951).
[2]Reared at BCF Fishery-Oceanography Center, La Jolla, Calif. Hatched June 20, 1966, died December 28, 1966.

3.53 Response to stimuli

Pacific mackerel are attracted to nightlights, either as a response to the lights or to the food attracted by the lights.

4 POPULATION

4.1 Structure

4.11 Sex ratio

Unpublished data from the California Department of Fish and Game assumes a 50-50 ratio of male to female (see footnote 4).

4.12 Age composition

See 3.31.

One-year-old fish do not spawn, but most 2-year-olds and all older fish do (see 3.12).

4.13 Size composition

The length composition of the catch for each age group for the seasons 1939-40 through 1963-64 was as follows:

Range of length (mm.) by age group

0	I	II	III	IV
168-332	218-385	235-392	278-405	282-400

V	VI	VII	VIII	IX
315-410	332-422	330-430	362-425	385-415

Fish at 7 years (6+) were collected in the 1964-65 to 1966-67 seasons.

4.2 Abundance and density (of population)

No data available.

4.3 Natality and recruitment

No data available.

4.4 Mortality and morbidity

From analysis of tagging results, Fitch (1952) calculated that the mortality rate for the Pacific mackerel was between 74 and 78 percent per year for the seasons 1940-41 through 1942-43 (Fitch, 1952). He stated further that in age studies mortality rates for fish 2 years of age and older were calculated for two 5-year periods, 1938-42 and 1943-47. For the first, the rate was calculated at 48 percent between ages 2 and 3, 62 percent between 3 and 4, and 70 percent between 4 and 5. For the second period the rate increased to 55, 77, and 80 percent per year for 2-, 3-, and 4-year-old fish.

4.5 Dynamics of population (as a whole)

No data available.

4.6 The population in the community and the ecosystem

No data available.

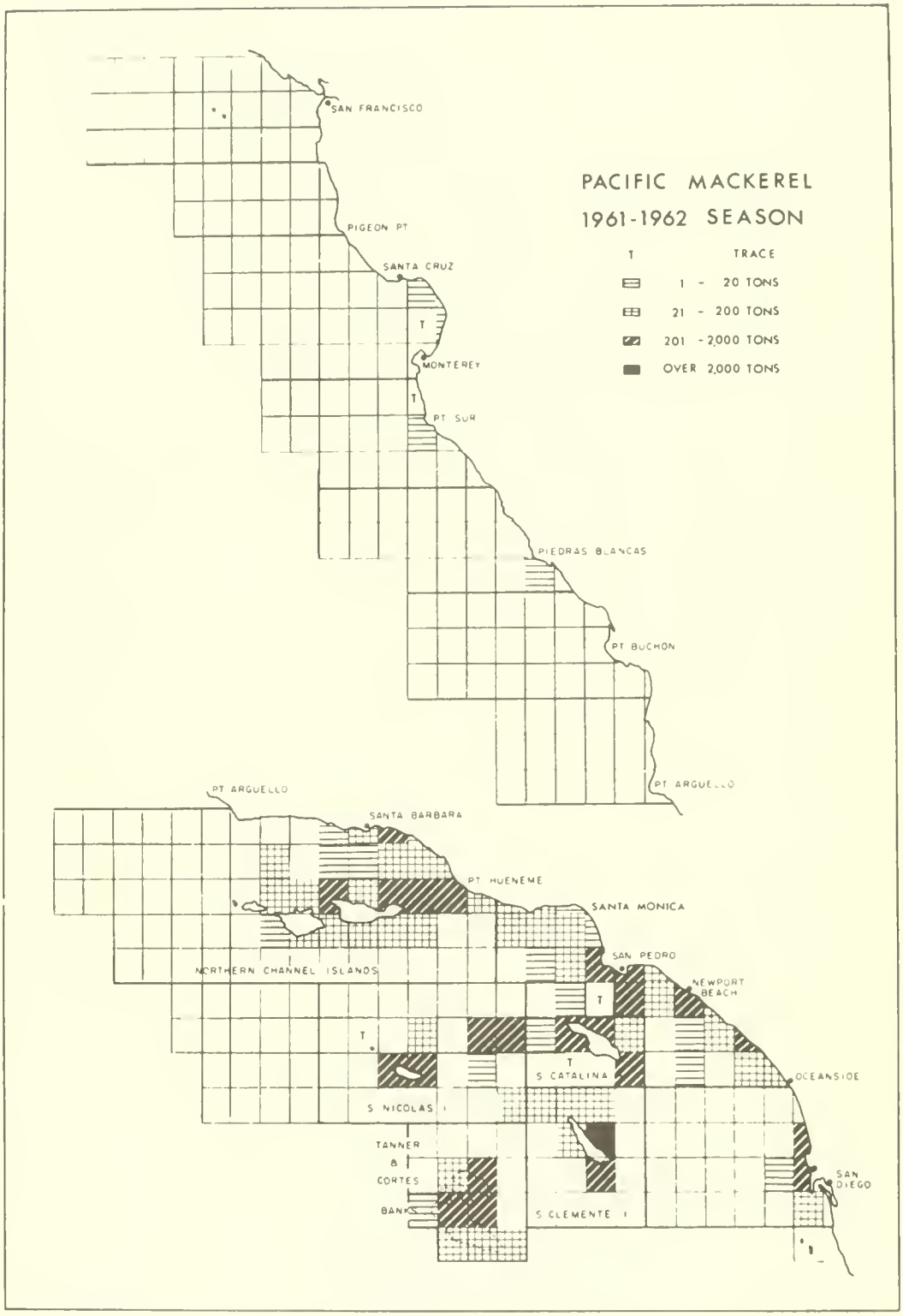

Figure 8A.--Catch locations for Pacific mackerel for the season 1961-62 (fig. 1 of Messersmith and Hyatt, 1965).

5 FISHERY

5.1 Fishing equipment

5.11 Gears

Pacific mackerel are caught commercially chiefly by roundhaul gear (purse seines and lampara nets); catch by other gear is mostly by scoop, a large commercial dip net (Messersmith and Hyatt, 1965).

Changes in types of gear and boats were described by Croker (1933, 1938) in his accounts of the mackerel fishery and by Scofield (1951) in his descriptions of the types and designs of purse seines and other roundhaul nets.

Every type of gear has been used in this fishery--set lines, handlines, pole lines, gill nets, trammel nets, lampara nets, ring nets, purse seines, and scoop nets--depending on demand, availability, and man's efficiency. The fish are located by such means as sightings of schools from boats and airplanes and use of electronic sounding gears.

5.12 Boats

As with gear, the fishery has increased its efficiency by changing the types and sizes of its boats, which range from skiffs, dories, and small power boats, 30 to 50 feet (9 - 15 m.) long to round haul boats, 50 to 85 feet (15 - 26 m.) long that use ring nets and purse seines. The small boats may use different gear at different seasons, depending on the behavior of the fish and sizes of schools.

5.2 Fishing areas

5.21 General geographic distribution

The Pacific mackerel fishery does not extend over the fish's entire range (see 2.1). The fishery is limited largely to the area off southern California (4.6.3) but some fishing extends as far north as Monterey (4.5.2)--fig. 8. Some mackerel, usually small amounts, are caught off Baja California (4.6.3) by the California fleets (see 5.43 for catch). Mexican landings are shown in table 4.

5.22 Geographic ranges

See 5.21.

5.23 Depth ranges

No data available.

5.24 Conditions of the grounds

No data available.

5.3 Fishing seasons

No regulation governs the season for Pacific mackerel. The State of California has established a statistical season, May to April, because the species is taken chiefly during the fall and winter.

5.4 Fishing operations and results

5.41 Effort and intensity

No data available.

5.42 Selectivity

This is determined primarily by the fishermen according to their identification of species, school size, and size of fish. Often there is no selectivity because of the occurrence of this species in mixed schools with jack mackerel and Pacific sardine.

5.43 Catches

Table 4 and figure 9 show the Pacific mackerel landings for the years 1926-66. Table 4 includes data on mixed landings as recorded for jack mackerel and Pacific mackerel for 1916-25.

6 PROTECTION AND MANAGEMENT

6.1 Regulatory (legislative) measures

6.11 Limitation or reduction of total catch.

There are no limitations on catch of Pacific mackerel.

6.12 Protection of portions of population.

Protections of certain portions, particularly small fish, have been suggested by the California Department of Fish and Game in order to prevent the exploitation of the young stocks.

Parrish and Blunt (manuscript [6]), in reporting on management efforts, stated that, ". . . evidence showing diminishing numbers of older, mature fish in the catch and a dependence upon individual strong year-classes lead to enactment of an 11 inch minimum size limit with 25 percent allowance by number for undersized fish effective December 1, 1947. The size limit was lowered to 8 inches from August 1, 1948 to July 31, 1949. Other than closures to purse seining around Santa Catalina Island, within 3 miles of the Orange County coast, and in Santa Monica Bay, no other restrictions have been enacted which might limit

[6] Richard H. Parrish and C. E. Blunt, California Department of Fish and Game, Terminal Island, Calif. "The Pacific mackerel fishery: a summary of biological knowledge and the current status of the resource."

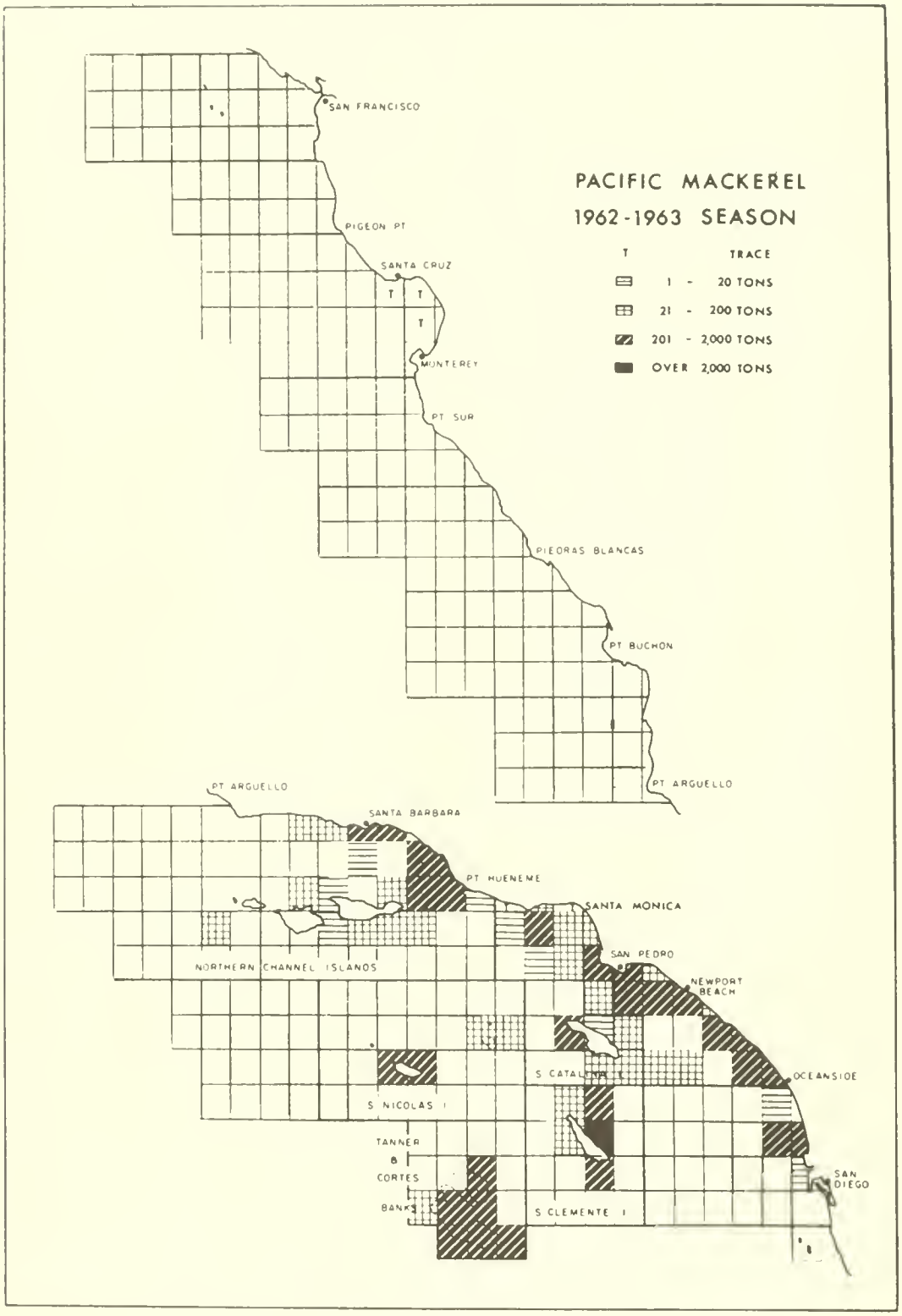

Figure 8B.--Catch locations for Pacific mackerel for the season 1962-63 (fig. 2 of Messersmith and Hyatt, 1965).

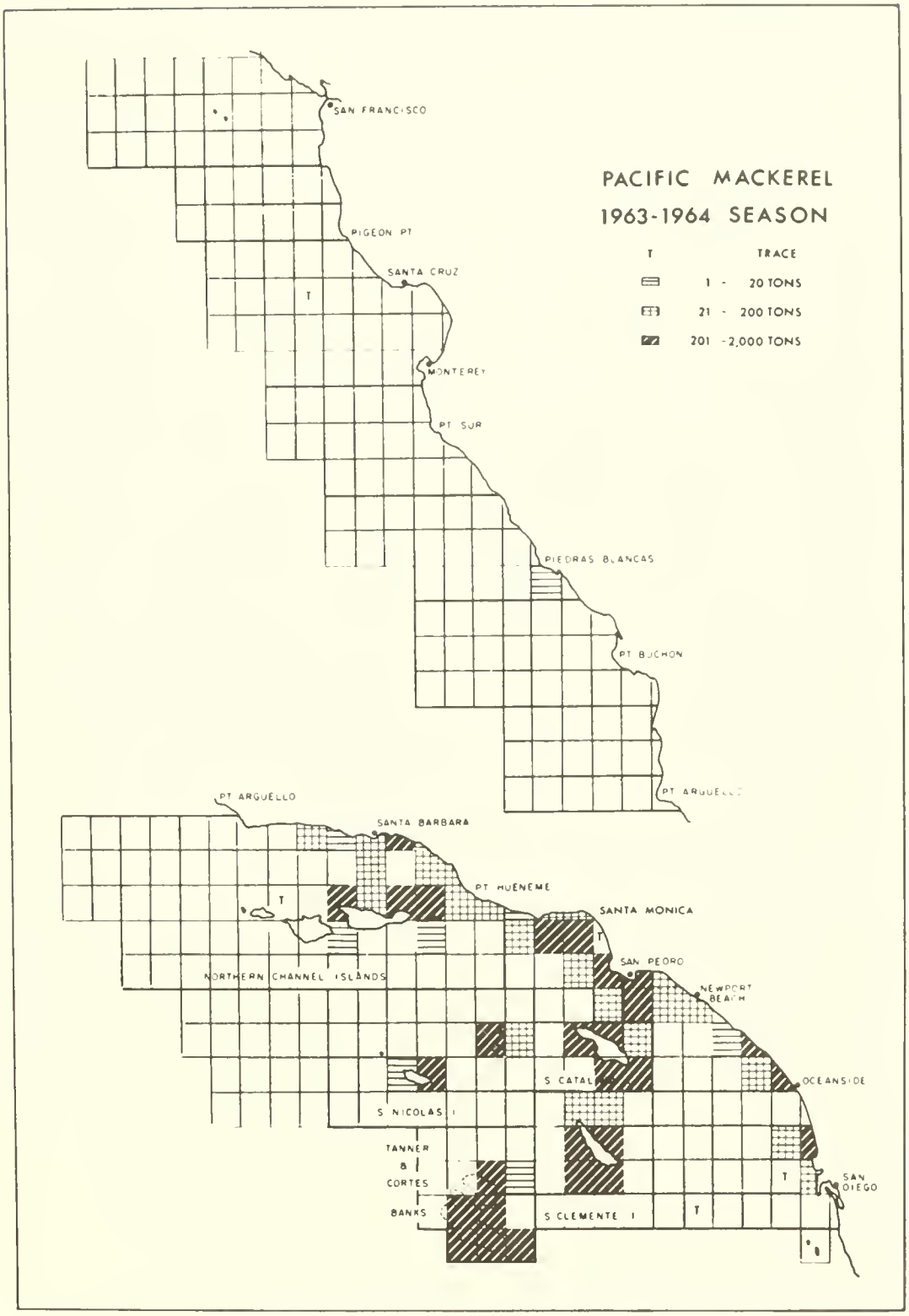

Figure 8C.--Catch locations for Pacific mackerel for the season 1963-64 (fig. 3 of Messersmith and Hyatt, 1965).

Table 4.--Pacific mackerel landings in California[1] (see fig. 9) and Baja California, Mexico, 1926-66

Year	California landings from			Baja California landings[2]	
	California waters	Water south of state	Total	Pacific mackerel	Pacific and jack mackerel[3]
	Tons	Tons	Tons	Tons	Tons
1926	1,805	7	1,812	--	--
1927	2,364	6	2,370	--	--
1928	17,626	5	17,631	--	--
1929	28,987	1	28,988	--	--
1930	8,266	--	8,266	--	--
1931	7,127	--	7,127	--	--
1932	6,237	--	6,237	--	--
1933	34,807	--	34,807	--	--
1934	56,791	133	56,924	--	--
1935	72,633	581	73,214	--	--
1936	49,414	857	50,271	--	--
1937	30,416	52	30,468	--	--
1938	39,923	1	39,924	--	--
1939	40,455	(4)	40,455	--	--
1940	60,252	--	60,252	--	--
1941	39,084	--	39,084	--	--
1942	26,266	11	26,277	--	--
1943	37,625	7	37,607	--	--
1944	41,828	(4)	41,828	--	--
1945	26,858	--	26,858	--	--
1946	26,938	--	26,938	--	1,081
1947	23,239	--	23,239	--	2,661
1948	19,693	--	19,693	--	470
1949	24,886	--	24,886	--	2,366
1950	16,325	--	16,325	--	3,602
1951	16,759	--	16,759	--	2,491
1952	10,302	--	10,302	--	1,911
1953	3,751	--	3,751	--	1,703
1954	12,516	180	12,696	4,984	--
1955	11,655	(4)	11,655	10,499	--
1956	25,006	--	25,006	13,025	--
1957	31,002	--	31,022	--	16,271
1958	13,817	7	13,824	--	1,154
1959	18,801	--	18,801	--	512
1960	18,404	(4)	18,404	--	2,531
1961	22,055	--	22,055	6,141	--
1962	24,289	(4)	24,289	3,424	--
1963	20,121	(4)	20,121	11,443	--
1964	13,414	(4)	13,414	9,608	--
1965	3,525	(4)	3,525	9,356	--
1966	--	--	2,258	5,416	--

[1]Landings of Pacific and jack mackerel were not recorded separately in 1916-25. Combined landings (tons) were: 1916, 557; 1917, 1673; 1918, 2003; 1919, 1327; 1920, 1499; 1921, 1457; 1922, 1233; 1923, 1777; 1924, 1614; and 1925, 1753.

[2]No data previous to 1946.

[3]No attempt made to separate species. When statistics indicated composition of a capture (two or more species) equal percentage representation was given each species.

[4]Less than one ton.

the Pacific mackerel catch. . . ." They further reported a recommendation by the California Department of Fish and Game for a bag limit on Pacific mackerel which was not implemented.

6.2 Control or alteration of physical features of the environment

None.

6.3 Control or alteration of chemical features of the environment

None.

6.4 Control or alteration of biological features of the environment

None.

6.5 Artificial stocking.

None.

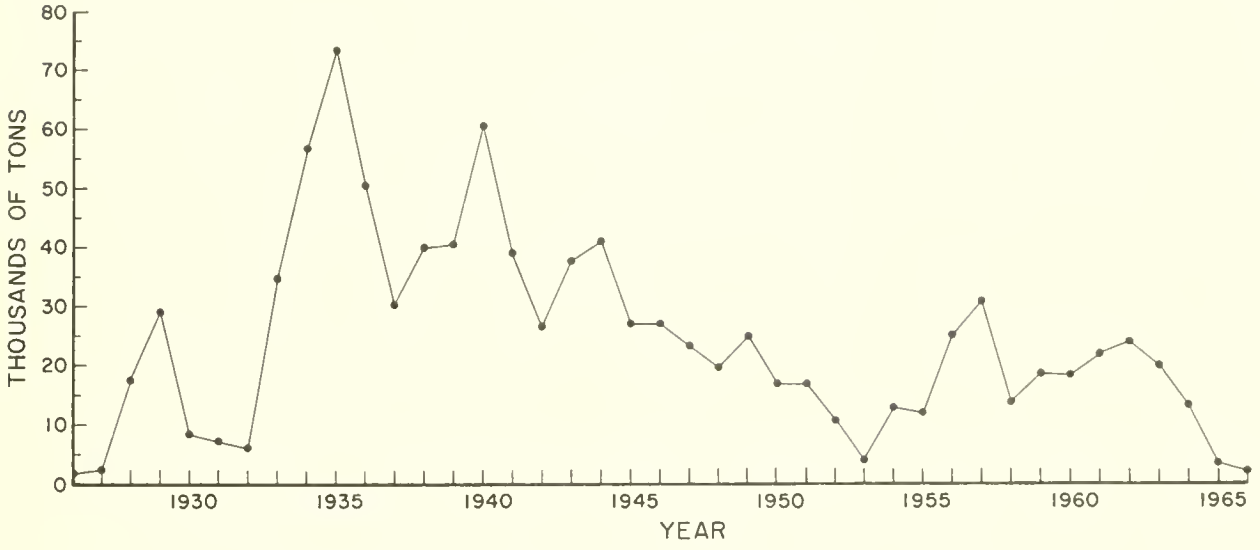

Figure 9.--Landings of Pacific mackerel in California, 1926-66 (See Table 4).

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