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The Northern Anchovy (Engraulis Mordax) And Its Fishery 1965–1968

By
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and a Staff of Associates
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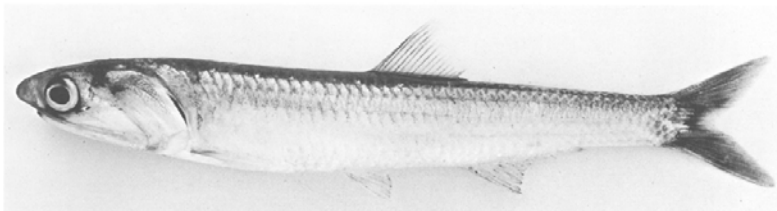

FRONTISPIECE—Northern anchovy (*Engraulis mordax* Girard, 1854). *Photograph by Jack W. Schott.*

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ABSTRACT

In 1964 scientists of the California Department of Fish and Game, the U.S. Bureau of Commercial Fisheries, and the University of California proposed an ecological experiment to assist the return of the Pacific sardine (Sardinops caeruleus) by imposing pressure on its chief natural competitor, the northern anchovy (Engraulis mordax) . Bitter controversy followed but in late 1965 the California Fish and Game Commission authorized a closely regulated anchovy reduction fishery. The controversy did not cease, but a modest fishery with a 75,000 ton quota was initiated.

Reduction landings during the 1965–66, 1966–67, and 1967–68 seasons were 16,800, 37,600 and 6,500 short tons, respectively. Landings were from an anchovy population conservatively estimated as between 4 and 5 million tons, 50% of which occurs off California, and consequently do not reflect a lack of abundance but low processor demand as dictated by declining world fishmeal prices. Landings were primarily by purse seiners operating in Monterey Bay and the inshore waters off southern California. Three-year-olds were dominant in central California landings and 2-year-olds in southern California. One-year-olds were most representative of the southern California live bait catch.

Both otoliths and scales from over 1,100 anchovies were used to compare two age-determination methods. The percent of agreement between individual age assignments was high and there were no significant differences in the resulting age compositions. Anchovy scales are caducous while otoliths are rarely unobtainable or deformed. Otoliths are therefore recommended for age determination of anchovies because they yield results comparable to scales and are more available.

During a 3-year period beginning in March 1966 nearly 381,000 anchovies were tagged and 1,080 were recovered on magnets installed in reduction plants. Recoveries demonstrate that anchovies can and do move considerable distances and between major fishing grounds in a short period of time. Anchovies from central California contribute to the southern California fishery and anchovies released off southern California were caught off central California and Ensenada, Baja California, Mexico.

A limited term live-bait sampling study determined that considerable manpower is required if the estimates are to be statistically significant. Since zero and 1-year-old fish are co-dominant in the live-bait fishery intensive sampling of this fishery may be useful for detecting changes in year-class strength and recruitment to the southern California commercial reduction fishery.

1. A REVIEW OF THE CALIFORNIA ANCHOVY FISHERY AND RESULTS OF THE 1965–66 AND 1966–67 REDUCTION SEASONS

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1.1. INTRODUCTION

The northern anchovy (Engraulis mordax Girard) has become the subject of spirited controversy among special interest groups concerned with fisheries during the past few years. This controversy revolves around: (i) recommendations by State, University and Federal marine scientists that large quantities of anchovies be harvested (Ahlstrom, et al., 1967*a, b*); (ii) requests by the fishing industry for reduction quotas; and (iii) unyielding opposition to such proposals by sport fishermen who require anchovies for live bait and chum. The controversy is intensified because the anchovy is important as forage for fishes of interest to sportfishermen, and because of the history of the over-harvested Pacific sardine (Sardinops caeruleus) resource (Murphy, 1966).

The purpose of this paper is to review briefly the fishery prior to November 1965, the events leading to an anchovy fishery for reduction, the research program established by the Department of Fish and Game to assist in the management of the anchovy resource, and to discuss the fishery during the 1965–66 and 1966–67 reduction seasons. The fishery data reported are not conclusive, but are intended to serve as a basis for future comparisons to indicate the effects of increased exploitation on a now relatively unexploited anchovy stock(s). All weight records are in short tons.

1.2. ACKNOWLEDGMENTS

I wish to express my sincere thanks to Robson A. Collins, James E. Hardwick, Russell H. Wickwire and Richard Wood who as members of the anchovy project collected and tabulated much of the data on which the fishery portion of this paper is based, and to John L. Baxter, California Department of Fish and Game, for his encouragement and editorial comments.

1.3. FISHERY PRIOR TO NOVEMBER 1965

Reliable records of commercial landings used for human consumption, dead bait, feeding in fish hatcheries and mink farms, and reduction to oil and meal date from 1916. From 1916 through 1921 annual landings averaged only 504.5 tons; most of the catch was for reduction to oil and meal (Phillips, 1949). In 1919 a law was passed prohibiting the reduction of whole fish except under permit. The law was strengthened

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in 1921 resulting in reduced landings averaging 159 tons for the next 17 years. During the period 1939 through 1946 landings averaged 1,454 tons.

In 1946 the scarcity of sardines caused processors to begin canning anchovies in quantity and in 1947 the catch jumped six-fold to 9,470 tons. The landing capacity of the fishing boats exceeded the canning needs of plants and excess deliveries were diverted to reduction plants.

TABLE 1

Commercial and Live Bait Catch of Anchovies in California, 1939–1967

(In short tons)

Year	Commercial Catch	Live Bait Catch*	Total	Percent Live Bait
1939	1,074	1,503	2,577	58.3
1940	3,159	2,006	5,165	38.8
1941	2,053	1,588	3,641	43.6
1942	847	258	1,105	23.4
1943	785	No live bait records obtained during World War II		
1944	1,946			
1945	808			
1946	961	2,748	3,709	74.1
1947	9,470	2,854	12,324	23.2
1948	5,418	3,586	9,004	39.8
1949	1,661	2,777	4,438	62.6
1950	2,439	3,824	6,263	61.1
1951	3,477	5,142	8,619	59.7
1952	27,891	6,810	34,701	19.6
1953	42,918	6,392	49,310	13.0
1954	21,205	6,686	27,891	24.0
1955	22,346	6,126	28,472	21.5
1956	28,460	6,332	34,792	18.2
1957	20,274	4,110	24,384	16.9
1958	5,798	4,236	10,034	42.2
1959	3,587	4,738	8,325	56.9
1960	2,529	4,658	7,187	64.8
1961	3,856	5,912	9,768	60.5
1962	1,382	6,167	7,549	81.7
1963	2,285	4,442	6,727	66.0
1964	2,488	5,191	7,679	67.6
1965	2,867	6,148	9,015	68.2
1966	31,140	6,691	37,831	17.7
1967	34,805	5,387	40,192	13.4

* Live bait catch figures are minimum figures taken from California Fish and Game Catch Bulletins as reported by most live-bait fishermen.

TABLE 1

Commercial and Live Bait Catch of Anchovies in California, 1939–1967

(In short tons)

In order to lower the amount of anchovies being reduced, the California Fish and Game Commission passed a regulation that required each processor place a high proportion of each ton of anchovies in cans (Clark and Phillips, 1952). With the temporary resurgence of the sardine population through 1951, anchovy canning declined. With the collapse of the sardine fishery in 1952, anchovy landings increased to 27,891 tons and 42,918 tons in 1953. Due to economic conditions, presumably low consumer acceptance of the canned product, landings declined to 19,400 tons in 1957 and 5,200 tons in 1958. Landings did not again exceed 5,000 tons until 1966 when, for the first time in over 40 years, anchovies were fished solely for reduction purposes.

Anchovies are very important in California as live and dead bait. Records of the live bait catch were initiated in 1939 and, except during World War II, have been submitted voluntarily ever since. These records account for most of the catch but are not complete since some operators do not submit records. When records were first initiated live bait landings were 1,074 tons and accounted for 58% of the statewide anchovy catch (Table 1). Since 1950 anchovy live-bait landings have fluctuated between 3,800 and 6,800 tons, averaging 5,570 tons for the past 5 years (1963 through 1967).

1.4. EVENTS CULMINATING IN AN ANCHOVY FISHERY FOR REDUCTION

The November 12, 1965 decision of the California Fish and Game Commission authorizing the present reduction fishery for anchovies was not capricious, but was arrived at after several months of consideration. As early as 1942 and each year since 1961 central California reduction plant owners have requested the Commission to issue anchovy reduction permits.

On January 28, 1949, the Commission adopted a policy opposing the "issuance of reduction permits for whole herring or anchovies." Since then, industry has made numerous attempts to have the policy changed, either by the California Legislature or through the Commission.

On March 6, 1964, the California Cooperative Oceanic Fisheries Investigations (CalCOFI) Committee[2] presented a series of papers concerning the anchovy to the California Marine Research Committee (MRC). The papers included anchovy population estimates and a proposal for an ecological experiment to assist the return of the sardine by simultaneously reducing fishing pressure on the sardine and imposing pressure on the sardine's chief natural competitor, the anchovy. The proposed experiment, "Requirements for Understanding the Impact of a New Fishery in the California Current System," (Ahlstrom et al, 1967*a*) was a long-range program consisting of three phases. Phase 1 called for a controlled anchovy harvest of 200,000 tons throughout the principal range of the population with approximately 35% in California waters (emended to 35% north of lat. 31° N). This phase was to have an annual quota for a period of approximately 3 years. Phase 2 called for adjusting the quotas and their areal distribution on the basis of the findings during Phase 1. Phase 3 had the ultimate objective of restoring the predecline balance between sardines and anchovies and maximizing the harvest of both species consistent with all uses. It was noted that if both the sardine fishery and competition from anchovies are affecting the sardine population, and if the objective was to bring back the sardine in the shortest possible time there should be fishing on anchovies and a complete moratorium on sardine fishing. At the time of this proposal the total

[2] The CalCOFI Committee is composed of four members; three are the scientific leaders of the MRC-associated programs of the major cooperating agencies and one represents the MRC. In 1964 they were E. H. Ahlstrom, U.S. Bureau Comm. Fish.; J. L. Baxter, CDFG; J. D. Isaacs, Univ. of Calif.; and G. I. Murphy, Coordinator for MRC. P. M. Roedel has acted in Dr. Murphy's place since 1966. Dr. A. R. Longhurst replaced Dr. Ahlstrom in 1967.

spawning biomass of anchovies was estimated to be between 1.8 and 2.25 million tons based on egg and larva data available through 1958 (Table 2).

TABLE 2

Anchovy Population Estimates,[1] Source of Estimate and Reference

Year of Estimate	Adult Biomass (Million short tons)	Estimated by	Reference
1940–41	1.3	G. Murphy	Murphy, 1965
1952	2.3	G. Murphy	Murphy, 1965
1955	3.6	G. Murphy	Murphy, 1965
1955–57	Mean 1.5	J. S. MacGregor	MacGregor, 1964
1955–57	Mean 1.0	J. Radovich	Radovich, 1965*a*
1955–57	Mean 2.0	G. Murphy	Radovich, 1965*b*
1957–59	Mean 4.8	G. Murphy	Murphy, 1965
1958	1.8 to 2.25	E. H. Ahlstrom	Ahlstrom, 1966*b*
1962–66	4.0 to 5.0	CalCOFI Committee	Ahlstrom, et al 1967*a* Roedel, 1967
1964–66*	3.2 to 4.0	J. Radovich	Baxter, 1966
1964–66*	4.0 to 5.0	MRO scientists	Baxter, 1966
1964	2.5 to 5.0	J. Radovich	Radovich, 1965*c*
1965	4.5 to 5.6	E. H. Ahlstrom	Ahlstrom, 1966*b*

[1] Based on egg and larva data compiled by United States Bureau of Commercial Fisheries.
* 1966 data incomplete and preliminary.

TABLE 2

Anchovy Population Estimates, Source of Estimate and Reference

During April 1965, Assembly Bill 2756 was introduced in the California Assembly. This bill would have allowed landing and reduction of 115,000 tons of anchovy by specified classes of vessels during the 28½-month period January 1, 1966 through May 15, 1968. The bill was passed by both houses of the Legislature, but was pocket vetoed by the Governor on two grounds: (i) the purposes of the bill could be legally accomplished by administrative action, and thus the bill was not needed; and (ii) the limited entry features of the bill were of questionable constitutionality and might involve the State Government in costly litigation (Chapman, 1967). Opposition to AB 2756 by organized sportsmen's groups was so intense that the Governor's office received over 35,000 letters in opposition, more than for any other measure considered during the 1965 legislative session. The Governor then requested the Commission to reconsider allotting permits for reduction fishing.

After hearing considerable testimony from all interested parties, including the California Department of Fish and Game's recommendation for approval, the Fish and Game Commission adopted (August 27, 1965) the following new policy concerning the reduction of anchovies: "It is the policy of the Fish and Game Commission that: 1. The anchovy resource shall be managed on a scientific basis, with regulations sufficiently flexible to allow corrective action to be taken at any time the Commission deems necessary; 2. The existing uses of anchovy shall be protected; and 3. The Commission shall give consideration to the issuance of anchovy reduction permits when the scientific evidence indicates that the resource will not be endangered."

After the Commission adopted the above policy the Department proposed regulations which would allow the taking of 15,000 and 100,000 tons of anchovies north and south of Point Conception respectively. The proposal included setting of seasons, the mandatory use of log books, and the northward extension of the statutory ban on fishing within 3 miles of the mainland shore from south of Point Mugu to south of Point Conception. Action on this proposal was scheduled for October 1, 1965. The Department also proposed a tagging and monitoring project to be initiated in the event a reduction fishery was authorized.

During the October 1 meeting the Fish and Game Commission expressed the opinion that effective scientific management of the sardine and anchovy resources required that full regulatory authority over both species be delegated to one body. It therefore adopted a resolution requesting the California Legislature to recognize these problems and to assist it by providing immediate legislation declaring a moratorium on the taking of sardines so that it could proceed with the proper scientific studies in a systematic manner, and to delegate management responsibility for both sardines and anchovies to the Commission. Responsibility was to include the control of the take and/or regulation for all purposes. The Commission felt that since the Legislature was going into emergency session it could take up the matter and therefore postponed further action on the take of anchovies for reduction purposes. When the Legislature failed to act on the resolution the Commission decided to proceed with the matter of an anchovy reduction fishery at its November 12, 1965 meeting.

At this meeting the Commission listened to considerable testimony by all interested parties before adopting regulations governing an experimental fishery to take and use 75,000 tons of anchovies by a reduction process. The regulations were adopted with the following preamble: "It is the intent of the Fish and Game Commission that an experimental fishery be initiated for the take of anchovies for use by a reduction process; the Fish and Game Commission wishes to make clear that the experimental fishery for reduction purposes may be terminated at any time that the Commission finds that the existing uses of anchovy are jeopardized or that the resource is endangered; . . ." Thus the anchovy reduction fishery began. Commission action, much of the testimony, and the adopted regulations are a matter of public record (California Fish and Game Commission, 1965).

The 1965–66 regulations governing the take of anchovies for reduction are summarized as follows:

1. Season: October 15, 1965 through April 30, 1966.
2. Permit Areas and Quotas:
   a. Northern Permit Area (North of Pt. Conception) 10,000 tons.
   b. Southern Permit Area (south of Pt. Conception) 65,000 tons distributed over four zones (Figure 1). No fishing within 3 miles of the mainland shore, a northward extension from Point Mugu of the statutory requirement.
3. Size limit: Minimum 5 inches total length with an undersized allowance of 25 percent, by weight, of all anchovies in the load (a statutory law reiterated).
4. Fishing operations:
   a. Vessel identification numbers required on side of vessel (a statutory law).
   b. Daily record of fishing on forms provided by the Department of Fish and Game.

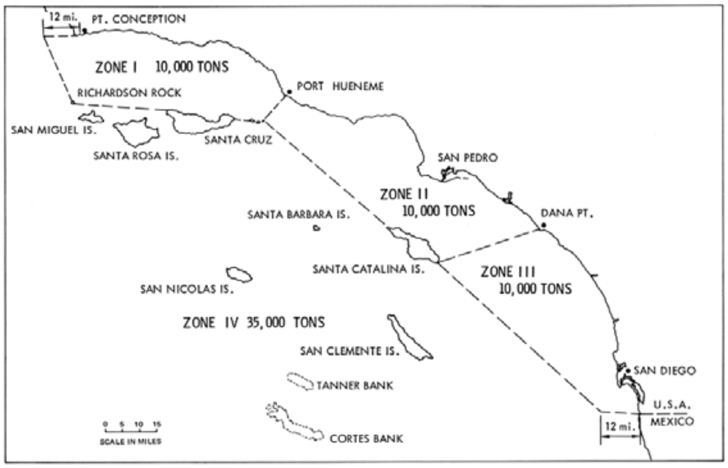


FIGURE 1. Anchovy reduction quota and zones for the Southern Permit Area, 15 October 1965 through 30 April 1966 and 1 October 1966 through 30 April 1967.

FIGURE 1. ***Anchovy reduction quota and zones for the Southern Permit Area, 15 October 1965 through 30 April 1966 and 1 October 1966 through 30 April 1967.***

5. Administration:

a. Five-day notice of zone closure when approaching quota.

b. All permits can be suspended on 48 hours notice by Commission determination of depletion of species, waste, or deterioration of fish.

Reduction permits for the 1965–66 season were issued to:

Santa Cruz Canning Co., Moss Landing
Hovden Food Products Corp., Monterey
J. D. Packing Co., Oxnard
Westgate-California Corp., California Marine Curing and Packing Co., Terminal Island
Van Camp Seafood Co., Terminal Island
Star-Kist Foods, Inc., Terminal Island
Pan Pacific Fisheries, C.H.B. Foods, Inc., Terminal Island
Westgate-California Corp., San Diego
Del Monte Fishing Co., Pacific Rendering Plant, San Francisco

In August 1966, the Fish and Game Commission again considered testimony by interested parties before adopting regulations for a second season. The adopted regulations were similar in most respects to those of 1965–66 and agreed with the recommendations of the Department of Fish and Game. They are recorded in the Commission minutes as is much of the testimony (California Fish and Game Commission, 1966). Amended provisions of the regulations were as follows: (i) season lengthened to October 1, 1966 through April 30, 1967; (ii) time requirement for notification of zone closure reduced from 5 days to 48 hours; and (iii) vessel operators desiring to take anchovies for reduction purposes in the southern permit area were required to file a declaration of intent. All companies that received permits in 1965, except Del Monte Fishing Co., applied for and received permits for the 1966–67 season. Permits are issued only to applicants who have complete reduction plants in operating condition. No fee is charged for the permits and they are not transferable.

1.5. DEPARTMENT OF FISH AND GAME ANCHOVY RESEARCH PROGRAM

When the Commission authorized the anchovy reduction fishery, the Department of Fish and Game initiated a project responsible for monitoring the fishery and conducting any biological studies on the anchovy necessary for resource management.

Project objectives included determination of migratory habits, estimates of population size and mortality rates, catch locations, catch per unit of effort, number and pounds of anchovies landed, the age-composition of the catch, and other fishery statistics. Initial efforts were directed toward tagging and tag recovery, and fishery monitoring of the commercial reduction and live bait fisheries.

In addition to studies of the fishery, the Department conducts oceanic surveys of adult and juvenile fishes that contribute considerably to the knowledge of anchovy abundance, habits and distribution. These are year-around-surveys of all surface and mid-depth resources between central California and Magdalena Bay, Baja California and as far as 80 miles offshore. They are made by operating an echo sounder over a predetermined course and identifying schools by their characteristic echo trace supplemented with mid-water trawl catches. These surveys are made possible through funding provided by Public Law 88–309, the Federal Aid for Commercial Fisheries Research and Development Act (Bartlett Bill).

The impartial analysis of all these data, and data from cooperating agencies, can provide a scientific basis for the wise multiple use of the anchovy resource for live and dead bait, forage for predator fishes, human consumption and pet food, as a protein supplement to the diet of livestock and poultry, and various other commercial products.

1.5.1. Tag and Tag Recovery

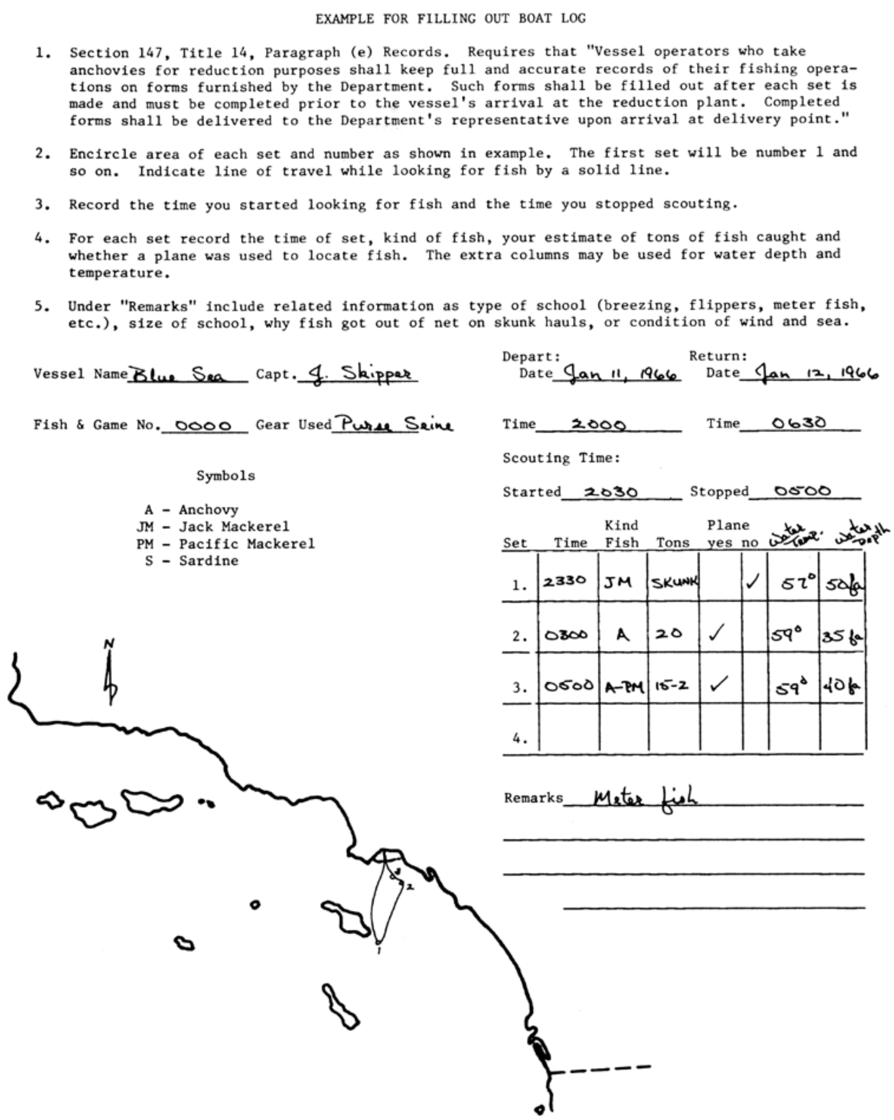
Tagging studies have met with considerable success. During the period March 14, 1966 through January 31, 1968, 224,566 anchovies were tagged with internal tags, and 530 were tags recovered (Wood and Collins, 1969). Tags are recovered on permanent magnets placed in the final stages of the reduction process. This method of recovery precludes assigning tags to individual vessels and specific recapture localities. Recoveries can be assigned only to major fishing areas such as Monterey, southern California, or Ensenada, Baja California, Mexico. This method is excellent for determining movements between major fishing areas, but cannot be used for determining local movements. A magnet system to correct this deficiency was installed but has not yet been tested under production conditions. Tag recoveries have demonstrated that anchovies move considerable distances, and between major fishing grounds (Messersmith, 1967; Messersmith, et al., 1969; and Haugen, et al., 1969). Fish from as far away as San Francisco Bay and San Diego contribute to the Monterey fishery and fish from Monterey Bay reach southern California. The magnitude of these migrations cannot be determined as yet.

1.5.2. Fishery Monitoring

The principal methods of collecting statistics to monitor the anchovy fishery are fishing logs and interviews, landing records ("pink tickets") and fish sampling.

Fishing logs (Figures [2] and [3]) are used to determine the vital statistics relating to the catch and effort of the fishing fleet. Log books are assigned to fishing boat skippers who complete the logs at the end of each trip. The fleet's normal procedure is to sail in the evening, fish all night and deliver their catch the following morning. Each time the skipper sets the net he records the time of day, the estimated catch in tons, and whether or not an airplane assisted in locating fish, and marks on the chart portion of the fishing log the area where the set(s) was made. From these data we can determine the number and size of vessels, and several vital catch statistics, including catch per hour, area of catch, and catch per set.

Logs are required of all skippers who land anchovies for reduction and are submitted voluntarily by most of those who land anchovies for canning. For the period October 15, 1965 through April 30, 1967 log data were obtained for 93% of the total commercial anchovy landings for reduction and non-reduction purposes. Catch per effort analyses are based only on those logs with complete data and therefore do not include all landings (Tables 3 and 4). Effort is defined as the elapsed



EXAMPLE FOR FILLING OUT BOAT LOG

1. Section 147, Title 14, Paragraph (e) Records. Requires that "Vessel operators who take anchovies for reduction purposes shall keep full and accurate records of their fishing operations on forms furnished by the Department. Such forms shall be filled out after each set is made and must be completed prior to the vessel's arrival at the reduction plant. Completed forms shall be delivered to the Department's representative upon arrival at delivery point."

2. Encircle area of each set and number as shown in example. The first set will be number 1 and so on. Indicate line of travel while looking for fish by a solid line.

3. Record the time you started looking for fish and the time you stopped scouting.

4. For each set record the time of set, kind of fish, your estimate of tons of fish caught and whether a plane was used to locate fish. The extra columns may be used for water depth and temperature.

5. Under "Remarks" include related information as type of school (breezing, flippers, meter fish, etc.), size of school, why fish got out of net on skunk hauls, or condition of wind and sea.

Vessel Name Blue Sea Capt. J. Skipper

Depart: Date Jan 11, 1966 Return: Date Jan 12, 1966

Fish & Game No. 0000 Gear Used Purse Seine

Time 2000 Time 0630

Scouting Time:

Started 2030 Stopped 0500

Symbols

A – Anchovy
JM – Jack Mackerel
PM – Pacific Mackerel
S – Sardine

Set	Time	Kind Fish	Tons	Plane yes	Plane no	water temp.	water depth
1.	2330	JM	SKUNK		✓	57°	50fa
2.	0300	A	20	✓		59°	35 fa
3.	0500	A-PM	15-2	✓		59°	40 fa
4.							

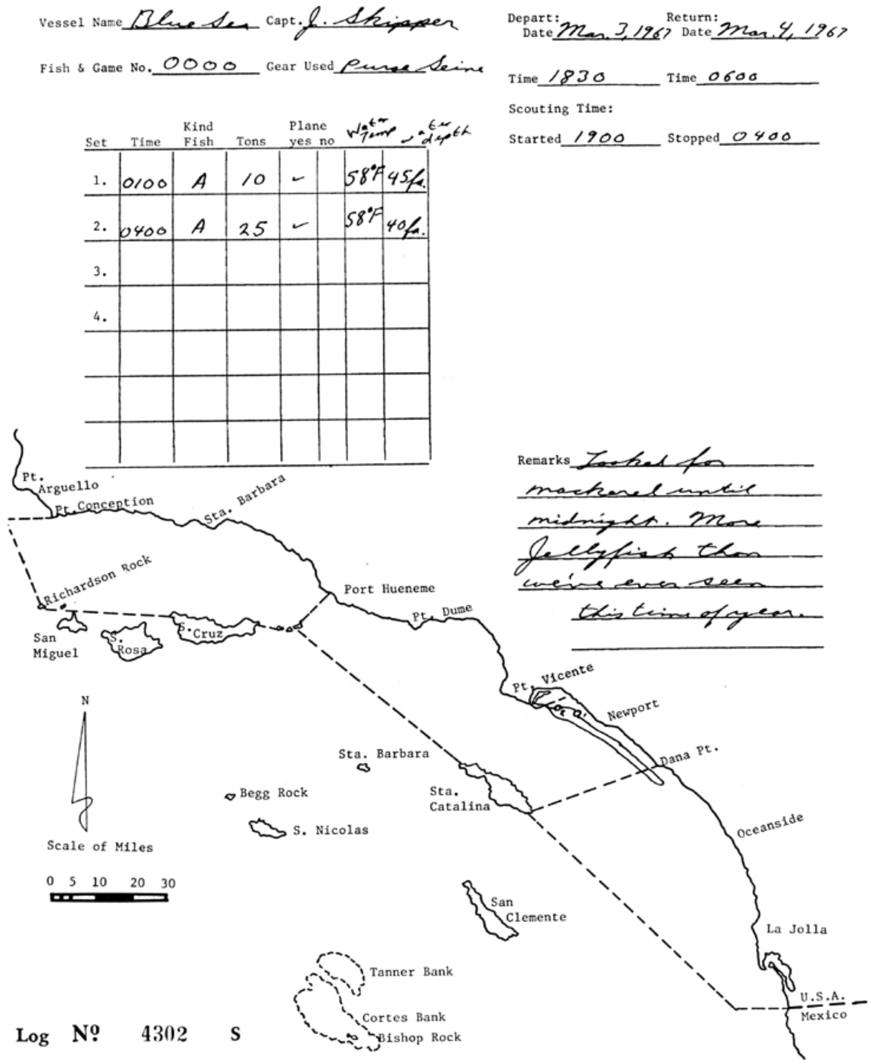
Remarks Meter fish

FIGURE 2. Instructions for completing fishing logs. *Photograph by Jack W. Schott.*

FIGURE 2. ***Instructions for completing fishing logs.*** *Photograph by Jack W. Schott*

time between inception of scouting and the completion (or start) of the last set.

In addition to monitoring the fishery via logs a sampling program was initiated to estimate the year-class composition of the catch in pounds and numbers. During the 1965–66 season vessels to be sampled were selected according to area of fishing since the fleet tended to congregate in one or two areas on any given day. Samples consisted of 50 fish selected at random. We measured the lengths of all 50 and obtained


Vessel Name Blue Sea Capt. J. Skipper

Depart: Date Mar. 3, 1967 Return: Date Mar. 4, 1967

Fish & Game No. 0000 Gear Used Purse Seine

Time 1830 Time 0600

Scouting Time:

Started 1900 Stopped 0400

Set	Time	Kind Fish	Tons	Plane yes	Plane no	Water Temp	depth
1.	0100	A	10	✓		58°F	45fa.
2.	0400	A	25	✓		58°F	40fa.
3.							
4.							

Remarks Looked for mackerel until midnight. More Jellyfish than we've ever seen this time of year.

Log Nº 4302 S

FIGURE 3. Completed fishing log. ***Photograph by Jack W. Schott.***

FIGURE 3. ***Completed fishing log.*** *Photograph by Jack W. Schott.*

individual weights, sex, state of female maturity, and scales and otoliths for age determination from 10. At the start of the 1966–67 anchovy reduction season, sampling procedures were changed extensively, reflecting knowledge gained during the first season. The new program called for obtaining 20 random samples for every 5,000 tons of fish landed in southern California. Each ton (within the 5,000) from which a sample was to be drawn was determined from a table of random numbers, as was the part of the load to be sampled. Samples consisted of two 500g (1.1 pound) clusters, each divided into two equal parts. All the fish

TABLE 3

Monthly Anchovy Landings * During 1965–66 Reduction Season—Short Tons

	October	November	December	January	February	March	April	Total
REDUCTION								
Northern Permit Area 10,000 Ton Quota	----	43.3	127.3	44.3	----	118.9	41.5 (9.2)	375.3 (9.2)
Southern Permit Area 65,000 Ton Quota								
Zone I 10,000 Ton Quota	----	----	----	623.5 (15.4)	34.3	145.2 (13.4)	832.4	1,635.4 (28.8)
Zone II 10,000 Ton Quota	----	----	----	1,019.1 (13.3)	1,485.2 (15.9)	4,740.8 (51.0)	5,160.9 (102.0)	12,406.0 (182.2)
Zone III 10,000 Ton Quota	----	----	----	----	----	917.8	55.1	972.9
Zone IV 35,000 Ton Quota	----	----	----	452.7	707.7 (74.8)	239.9	45.7 (37.7)	1,446.0 (112.5)
Unknown	----	----	----	6.9 (6.9)	----	----	----	6.9 (6.9)
Area Total	----	----	----	2,102.2 (35.6)	2,227.2 (90.7)	6,043.7 (64.4)	6,094.1 (139.6)	16,467.2 (330.3)
REDUCTION TOTAL	----	43.3	127.3	2,146.5 (35.6)	2,227.2 (90.7)	6,162.6 (64.4)	6,135.6 (148.9)	16,842.5 (339.6)
NON-REDUCTION								
Northern Permit Area	571.5 (571.5)	127.8 (127.8)	42.5 (22.5)	104.4 (32.2)	15.8	108.4 (37.4)	141.9 (106.9)	1,112.3 (898.3)
Southern Permit Area	16.6 (16.6)	11.0 (11.0)	17.6 (17.6)	43.2 (43.2)	64.6 (47.3)	97.1 (93.1)	113.6 (103.6)	363.7 (332.4)
NON-REDUCTION TOTAL	588.1 (588.1)	138.8 (138.8)	60.1 (40.1)	147.6 (75.4)	80.4 (47.3)	205.5 (130.5)	255.5 (210.5)	1,476.0 (1,230.7)
TOTAL ALL USES	588.1	182.1	187.4	2,294.1	2,307.6	6,368.1	6,391.1	18,318.5

* Portion in parentheses not suitable for catch-effort analysis.

TABLE 3

Monthly Anchovy Landings During 1965–66 Reduction Season—Short Tons

TABLE 4

Monthly Anchovy Landings * During 1966–67 Reduction Season—Short Tons

	October	November	December	January	February	March	April	Total
REDUCTION								
Northern Permit Area 10,000 Ton Quota	2,452.6 (147.3)	1,263.8 (22.5)	1,714.4 (3.8)	1,539.8	221.9	354.8	473.2	8,020.5 (173.6)
Southern Permit Area 65,000 Ton Quota								
Zone I 10,000 Ton Quota	----	85.0	616.3	1,992.2	968.3 (72.9)	316.7	----	3,978.5 (72.9)
Zone II 10,000 Ton Quota	----	----	584.3	2,130.0 (15.4)	2,858.5 (20.3)	2,599.3	1,881.0	10,053.1 (35.7)
Zone III 10,000 Ton Quota	----	----	5.6	255.5	498.4	486.5	571.7	1,817.7
Zone IV 35,000 Ton Quota	----	1,026.6	2,920.3	5,361.6 (16.0)	2,287.1	1,984.8 (4.5)	157.9	13,738.3 (20.5)
Unknown	6.8 (6.8)	----	----	----	----	----	----	6.8 (6.8)
Area Total	6.8 (6.8)	1,111.6	4,126.5	9,739.3 (31.4)	6,612.3 (93.2)	5,387.3 (4.5)	2,610.6	29,594.4 (135.9)
REDUCTION TOTAL	2,459.4 (154.1)	2,375.4 (22.5)	5,840.9 (3.8)	11,279.1 (31.4)	6,834.2 (93.2)	5,742.1 (4.5)	3,083.8	37,614.9 (309.5)
NON-REDUCTION								
Northern Permit Area	630.4 (33.0)	320.7 (123.2)	300.7 (17.7)	18.2 (18.2)	30.0	139.0 (9.0)	10.9 (10.9)	1,467.9 (212.9)
Southern Permit Area	61.9 (61.9)	55.4 (55.4)	54.8 (23.8)	92.7 (92.7)	138.4 (138.4)	125.5 (125.5)	77.5 (77.5)	606.2 (575.2)
NON-REDUCTION TOTAL	701.3 (95.8)	385.1 (178.6)	355.5 (41.5)	110.9 (110.9)	168.4 (138.4)	264.5 (134.5)	88.4 (88.4)	2,074.1 (788.1)
TOTAL ALL USES	3,160.7	2,760.5	6,196.4	11,390.0	7,002.6	6,006.6	3,172.2	39,689.0

* Portion in parentheses not suitable for catch-effort analysis.

TABLE 4
Monthly Anchovy Landings During 1966–67 Reduction Season—Short Tons

in one part were measured only; from the remainder we obtained length, individual weight, sex, state of female maturity, and scales and otoliths for age determination. State of maturity during both seasons was determined by a method defined by Hjort (1910).

During the 1966–67 season central California sampling procedures differed from those for southern California in that 2,000g (4.4 pounds) were collected on alternate days from the two reduction plants in Monterey Bay; 1,000g (2.2 pounds) were retained for processing. A 200g (0.44 pounds) subsample, from the 1,000g was obtained for complete processing, as in southern California, while for the remaining 800g (1.76 pounds), only length measurements were taken.

1.6. THE FISHERY

1.6.1. 1965–66 Season (October 15, 1965 through April 30, 1966)

The problems inherent in the development of a new fishery began cropping up soon after anchovy reduction permits were received by the processors (November 22, 1965). A price for fish had to be negotiated, purse seines had to be purchased, some reduction equipment was not fully dependable, and processors in general were concerned about the economic soundness of the venture. In short, it had been 8 years since anchovies were taken in quantity (never under such stringent administrative controls) and nearly everyone in the fishing industry was wary.

Some believe that this fishery could be the salvation of California's pelagic wetfish fleet and it is fitting that the first reduction landings were in Monterey at the last remaining plant on John Steinbeck's famous "Cannery Row." The fish were large but the oil yield was low and interest waned. A price dispute curtailed all fishing until January 10 when negotiating parties finally agreed to a price of $20 per ton. Prior to the settlement only about 170 tons were landed, therefore for all practical purposes the new fishery did not start until January 10, 1966.

The present fishery is conducted in two distinct geographical areas, Monterey Bay and southern California. Each has its own fishing fleet and method of operating. Both use purse seine and lampara nets exclusively. The former are more effective and cost $10,000 to $15,000 each.

1.6.1.1. Northern Permit Area

This area's 10,000 ton reduction quota was never approached for two reasons, lack of processor interest attributed to low oil yield and the difficulty of catching fish. Anchovies tended to be scarce and in water too deep for the nets used in the area. Total landings for the reduction season were 1,488 tons of which 375 were for reduction (Table 3). Except for 43 tons caught off Point Sur, all were caught in Monterey Bay (Figure 4) .

The Monterey fleet consisted of seven vessels that made at least one delivery; four purse seiners and three lampara vessels. The lampara nets are used by small vessels of 13 to 30 gross registered tons (GRT), and usually cannot catch anchovies when the water depth is over 20 fathoms. The GRT of the purse seiners was 52, 54 and 102.

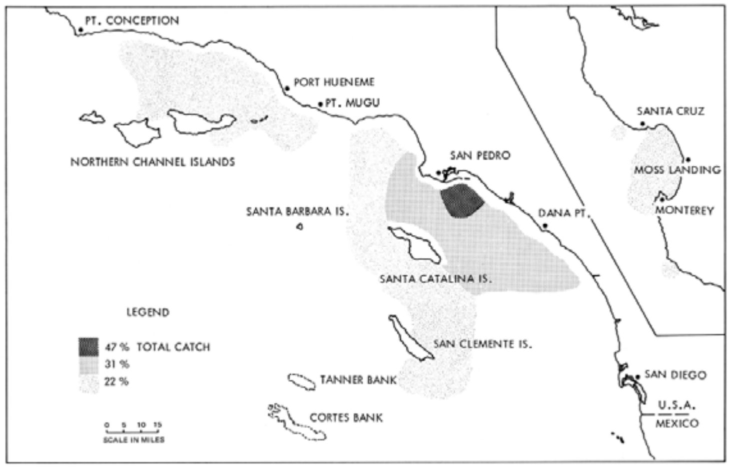


FIGURE 4. Anchovy reduction fishing catch areas, 15 October 1965 through 30 April 1966.

*FIGURE 4. **Anchovy reduction fishing catch areas, 15 October 1965 through 30 April 1966.***

1.6.1.2. Southern Permit Area

Reduction fishing off southern California began in January in the Santa Cruz Basin and San Pedro Channel areas. In February all effort shifted to the San Pedro Channel where the fleet remained until April 26, when the 10,000 ton quota was reached and that area (Zone II, Figure 1) was closed to fishing. The fleet consisted of 24 vessels which operated at least temporarily (Table 5). Eighteen made more than six deliveries while the remainder made as few as one. During January, 3 purse seiners and 13 lampara boats caught fish. By the close of the season 12 pure seiners and 7 lampara boats were active; 4 of the original lampara boats had converted to purse seines; 1 lampara boat had sunk and 1 seiner had run aground.

TABLE 5

Data Concerning Gear and Vessel Length and Gross Registered Tons of the Southern California Anchovy Fleet

	Lampara	Lampara Converted to Purse Seine	Purse Seine
1965–66 Season			
Number Vessels	11	4	9
Length			
Mean	47.4	46.2	69.4
Median	47	41	71
Range	35–58	40–62	69.4
Gross Registered Tons			
Mean	35.4	38	99
Median	30	29	98
Range	14–60	22–73	36–135
1966–67 Season			
Number Vessels	4	0	25
Length			
Mean	38.2	--	63.3
Median	38	--	65
Range	34–42	--	40–79
Gross Registered Tons			
Mean	21.5	--	74.8
Median	21	--	73
Range	14–30	--	22–135

TABLE 5

Data Concerning Gear and Vessel Length and Gross Registered Tons of the Southern California Anchovy Fleet

As the season progressed, several important events took place concurrently; anchovies became more available close to the fleet's home port of San Pedro, the weather improved, and many boats acquired better gear.

During March and especially April the daily landings of the fleet frequently exceeded the reduction capacity of individual plants. To avoid the many problems caused by too many fish the processors placed the vessels on daily limits. Despite this, during the last 4 days of fishing following the Department's announcement that the San Pedro zone (Zone II) would close, 16 vessels with a combined capacity of about 1,100 tons landed 3,470.8 tons from this area at the rate of 12.6 tons per hour. In comparison the catch per unit of effort for January through April was 5.8, 6.1, 6.9, and 9.2 tons per hour respectively (Table 6).

Vessels that worked with airplanes were nearly twice as successful as those that did not (Table 7). Purse seiners caught approximately three times as many fish as did lampara vessels and were twice as effective in terms of catch per hour (Table 6).

Final reduction landings for southern California were 16,467 tons of a 65,000 ton quota. Catches by zone were: Zone I—1,635 tons, Zone II—12,406 tons, Zone III—973 tons, and Zone IV—1,446 tons (Figure 1 and Table 3). The origin of 7 tons was unknown.

TABLE 6

Catch and Catch Per Hour * by Area and Gear, 1965–66 Season

	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Total
Northern Permit Area							
Purse Seine							
Tons	43.34	136.03	116.50	15.75	171.64	56.50	539.76
Hours	5.00	18.00	39.00	2.00	51.00	15.50	130.50
Tons/Hour	8.67	7.56	2.99	7.88	3.36	3.64	4.14
Lampara							
Tons	--	11.25	--	--	18.25	10.75	40.25
Hours	--	2.00	--	--	12.50	3.00	17.50
Tons/Hour	--	5.62	--	--	1.46	3.58	2.30
Total							
Tons	43.34	147.28	116.50	15.75	189.89	67.25	580.01
Hours	5.00	20.00	39.00	2.00	63.50	18.50	148.00
Tons/Hour	8.67	7.36	2.99	7.88	2.99	3.64	3.92
Southern Permit Area							
Purse Seine							
Tons	--	--	1,374.30	1,601.87	4,365.18	5,117.39	12,458.74
Hours	--	--	158.00	211.75	527.25	488.00	1,385.00
Tons/Hour	--	--	8.70	7.56	8.28	10.49	9.00
Lampara							
Tons	--	--	692.20	551.87	1,618.16	847.09	3,709.32
Hours	--	--	198.75	143.00	341.50	163.50	846.75
Tons/Hour	--	--	3.48	3.86	4.74	5.18	4.38
Total							
Tons	--	--	2,066.50	2,153.74	5,983.34	5,964.48	16,168.06
Hours	--	--	356.75	354.75	868.75	651.50	2,231.75
Tons/Hour	--	--	5.79	6.07	6.89	9.16	7.24
Statewide							
Purse Seine							
Tons	43.34	136.03	1,490.80	1,617.62	4,536.82	5,173.89	12,998.50
Hours	5.00	18.00	197.00	213.75	578.25	503.50	1,515.50
Tons/Hour	8.67	7.56	7.57	7.57	7.85	10.28	8.58
Lampara							
Tons	--	11.25	692.20	551.87	1,636.41	857.84	3,749.57
Hours	--	2.00	198.75	143.00	354.00	166.50	864.25
Tons/Hour	--	5.63	3.48	3.86	4.62	5.15	4.34
Total							
Tons	43.34	147.28	2,183.00	2,169.49	6,173.23	6,031.73	16,748.07
Hours	5.00	20.00	395.75	356.75	932.25	670.00	2,379.75
Tons/Hour	8.67	7.36	5.52	6.08	6.62	9.00	7.04

* Based on scouting time to last set and excluding landings with no effort data (Table 3).

TABLE 6

Catch and Catch Per Hour by Area and Gear, 1965–66 Season

TABLE 7

Catch and Catch-Effort * by Airplane Use, Area, and Season

	1965–66 Season		1966–67 Season	
	Tons	Tons/Hour	Tons	Tons/Hour
Northern Permit Area				
With Airplane	61.0	7.63	----	----
Without Airplane	500.0	3.73	9,011.3	9.13
Unknown	19.0	3.17	90.5	5.49
Total	580.0	3.92	9,101.8	4.89
Southern Permit Area				
With Airplane	10,149.2	9.09	18,123.7	6.99
Without Airplane	5,768.9	5.84	10,416.8	5.64
Unknown	250.0	4.24	949.0	4.62
Total	16,168.1	7.25	29,489.5	6.35
Statewide				
With Airplane	10,210.2	8.56	18,123.7	6.99
Without Airplane	6,268.9	5.59	19,428.1	6.86
Unknown	269.0	4.14	1,039.5	4.69
Total	16,748.1	7.04	38,591.3	6.84

* Based on scouting time to last set and excluding landings with no effort data (Tables 3 and 4).

TABLE 7

Catch and Catch-Effort by Airplane Use, Area, and Season

1.6.2. 1966–67 Season (October 1, 1966 to April 30, 1967)

1.6.2.1. Northern Permit Area

During the season all reduction fishing in this permit area occurred in Monterey Bay. Fishing began October 4 with anchovies close to shore in water less than 20 fathoms deep and therefore vulnerable to the lampara fleet as well as to purse seiners. To keep the fishermen from exceeding plant reduction capacities the processors imposed daily limits of 10 to 20 tons for lamparas and 30 tons for the seiners. One plant soon lowered delivery limits for the lamparas and seiners to 8 and 16 tons respectively. These limits were continually adjusted according to the availability of fish (the more available the fish the lower the limit and vice versa) and according to the needs or interest of the processors.

During the season the fleet consisted of 3 purse seiners and 15 lampara vessels, only one of which made less than eight deliveries. The average registered gross tonnage for the small lampara vessels was 14 tons compared to 65 tons for the purse seiners. Approximately two-thirds of the lampara catch was by vessels which do not put their catch on their own boat but use lighters, a remnant of the past, which they tow to and from the fishing grounds (Figures 5 and 6). The lighters used by four vessels at Moss Landing can carry up to 25 tons of anchovies, the one at Montery can carry 12.

The small lamparas normally cannot catch fish in water over 20 fathoms deep. In Monterey Bay this restricts them to within 4 to 6 miles of the beach in the southern and northern halves of the bay respectively. This condition is the same noted during the late 1940's

FIGURE 5. Monterey Bay lampara vessel with a 25-ton capacity lighter.

FIGURE 5. ***Monterey Bay lampara vessel with a 25-ton capacity lighter.***

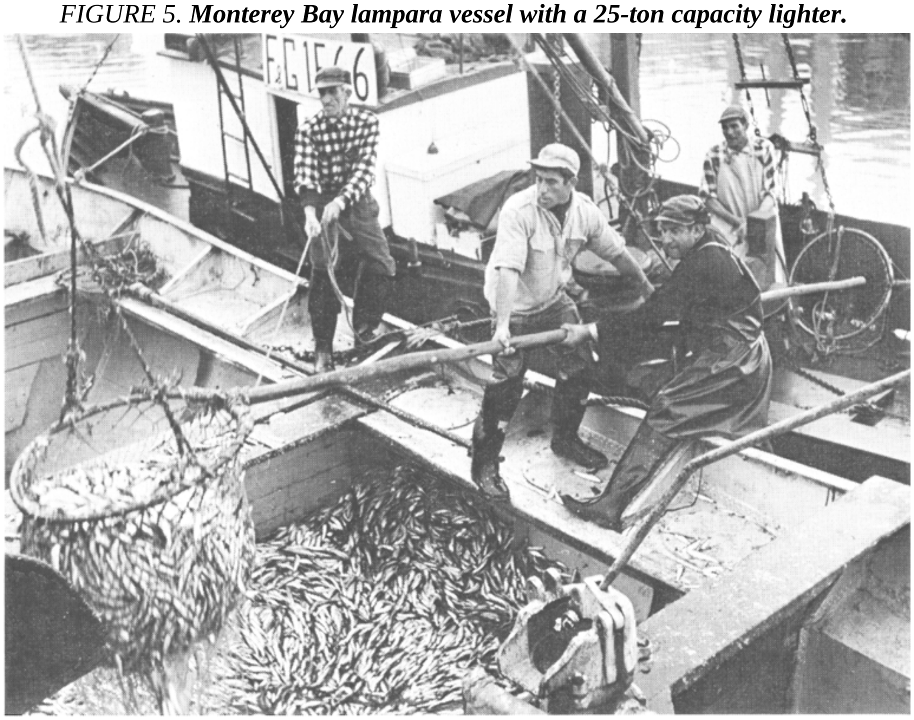


FIGURE 6. Unloading the lighter shown in Figure 5.

FIGURE 6. ***Unloading the lighter shown in Figure 5.***

TABLE 8

Catch and Catch Per Hour * by Area and Gear, 1966–67 Season

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Total
Northern Permit Area								
Purse Seine								
Tons	1,065.01	834.51	1,993.57	1,539.79	251.88	437.00	424.75	6,546.51
Hours	100.75	71.00	137.25	149.00	34.00	49.50	48.75	590.25
Tons/Hour	10.57	11.75	14.52	10.33	7.41	8.83	8.71	11.09
Lampara								
Tons	1,845.78	613.31	--	--	--	47.75	48.50	2,555.34
Hours	304.50	71.00	--	--	--	14.50	23.00	413.00
Tons/Hour	6.06	8.64	--	--	--	3.29	2.11	6.19
Total								
Tons	2,910.79	1,447.82	1,993.57	1,539.79	251.88	484.75	473.25	9,101.85
Hours	405.25	142.00	137.25	149.00	34.00	64.00	71.75	1,003.25
Tons/Hour	7.18	10.20	14.52	10.33	7.41	7.57	6.60	9.07
Southern Permit Area								
Purse Seine								
Tons	--	1,111.61	4,151.88	9,624.68	6,497.81	5,359.90	2,610.52	29,356.40
Hours	--	53.75	271.25	1,140.75	1,229.25	1,469.75	443.00	4,607.75
Tons/Hour	--	20.68	15.31	8.44	5.28	3.65	5.90	6.37
Lampara								
Tons	--	--	5.65	83.21	21.25	23.03	--	133.14
Hours	--	--	4.00	26.00	3.00	1.50	--	34.50
Tons/Hour	--	--	1.41	3.20	7.08	15.35	--	3.86
Total								
Tons	--	1,111.61	4,157.53	9,707.89	6,519.06	5,382.93	2,610.52	29,489.54
Hours	--	53.75	275.25	1,166.75	1,232.25	1,471.25	443.00	4,642.25
Tons/Hour	--	20.68	15.10	8.32	5.29	3.66	5.89	6.35

TABLE 8

Catch and Catch Per Hour by Area and Gear, 1966–67 Season

Statewide								
Purse Seine								
Tons	1,065.01	1,946.12	6,145.45	11,164.47	6,749.69	5,796.90	3,035.27	35,902.91
Hours	100.75	124.75	408.50	1,289.75	1,263.25	1,519.25	491.75	5,198.00
Tons/Hour	10.57	15.60	15.04	8.66	5.34	3.82	6.17	6.91
Lampara								
Tons	1,845.78	613.31	5.65	83.21	21.25	70.78	48.50	2,688.48
Hours	304.50	71.00	4.00	26.00	3.00	16.00	23.00	447.50
Tons/Hour	6.06	8.64	1.41	3.20	7.08	4.42	2.11	6.01
Total								
Tons	2,910.79	2,559.43	6,151.10	11,247.68	6,770.94	5,867.68	3,083.77	38,591.39
Hours	405.25	195.75	412.50	1,315.75	1,266.25	1,535.25	514.75	5,645.50
Tons/Hour	7.18	13.07	14.91	8.55	5.35	3.82	5.99	6.84

* Based on scouting time to start of last set and excluding landings with no effort data (Table 4).

TABLE 8—Cont'd.

by Clark and Phillips (1952) who reported "Five to six miles offshore is usually as far out as catches of anchovies are made."

After December 24 rough weather and the failure of anchovies to school in water shallower than 20 fathoms eliminated the lampara vessels from the fishery. They didn't resume fishing until March 20 when anchovies again moved into shallow water.

Northern permit area canneries processed 9,488 tons of anchovies, 8,021 tons for reduction (Table 4). Purse seiners caught 6,547 tons @ 11.1 tons per hour and the lamparas caught 2,555 tons @ 6.2 tons per hour (Table 8). No effort data were available for 386 tons.

1.6.2.2. Southern Permit Area

A price dispute curtailed fishing until November 9 when a Port Hueneme purse seiner began catching anchovies in the outer Santa Barbara Passage and around Santa Cruz Island; no other vessels fished until December 14. On December 20, 15 purse seiners made deliveries and by January 16 the fleet was at full strength. During the season, 29 vessels made at least 1 delivery, while 23 made more than 11; one boat made 50 deliveries. In January the fleet consisted of 22 seiners and 4 lampara vessels. At season's end there were 18 seiners and no lamparas. The seiners had a mean GRT of 75, mean length of 65 feet, and a catch rate of 6.4 tons per hour (Tables 5 and 8). The decrease in average length and GRT compared to the 1965–66 purse seine fleet reflects the conversion from lampara nets to purse seine nets. All vessels were slightly more successful when working with airplanes (Table 7).

The southern California fishery first developed around Anacapa Island, although a few seiners, particularly the smaller vessels, made catches near Santa Barbara and Santa Catalina Islands. The center of fishing effort began to shift from Anacapa Island toward San Pedro in mid-January. By February 13, nearly all fishing effort was concentrated in the San Pedro Channel, off San Pedro, where it remained until that zone (Zone II, Figure 1) was closed on April 16.

Landings from around Anacapa Island and the San Pedro Channel accounted for 62% of the total southern California catch of 29,594 tons for reduction (Figure 7) . The season catch rate of 6.4 tons per hour was 0.8 tons per hour less than during the 1965–66 season, probably because the quota in Zone II was reached before anchovies concentrated in that zone and because of poor fishing in March caused by rough weather and failure of anchovies to form tight schools.

The 23 most active vessels in the fleet had a combined carrying capacity of about 1,800 short tons. This fleet averaged 11 deliveries per fishing day with a maximum of 21. The delivery capacity of 11 vessels is more than the five active southern California reduction plants can process (50 tons per hour) during a normal work day. This is especially true when reduction facilities are needed to process offal from tuna, bonito, or mackerel canning. To control the amount of anchovies landed the processors placed the fishing vessels on limits during much of the season thus effectively reducing the fleet's average daily landings by about one-third.

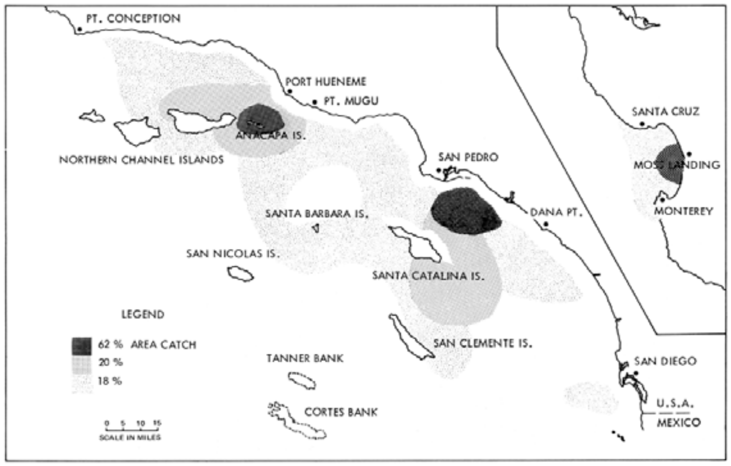


FIGURE 7. Anchovy reduction fishing catch areas, 1 October 1966 through 30 April 1967.

FIGURE 7. ***Anchovy reduction fishing catch areas, 1 October 1966 through 30 April 1967.***

1.7. FISHING SUCCESS OF PURSE SEINE AND LAMPARA NETS

Catch per hour can be used as an indicator of the relative fishing power of the two gear types, but is not suitable for exact comparison since the vessels, crews, areas of fishing, and months of greatest effort are not always directly comparable. However, since data suitable for comparing gear success are available for a few vessels it is useful to examine here the fishing success of the two gear types.

The comparison is limited to the catch, effort, and catch per hour of vessels that fished in the same areas during the same period of each month (Table 9). The vessels were divided into two groups: (i) five that used lampara gear only, and (ii) three that fished half of the time with lampara gear and half with purse seine nets. Vessels in the two groups had a similar average registered gross tonnage (44.4 for lamparas and 41.0 for lampara-seiners) and average vessel length (52 feet for lamparas and 48 feet for lampara-seiners). Data for vessels that used purse seines only are not presented because these vessels are considerably larger.

TABLE 9

Catch Statistics for Groups of Vessels Using Pure Seine or Lampara Gear and Fishing in the Same Area in the Same Time Period of the 1965–66 Season

	Lampara Gear Only		Vessels That Converted From Lampara Gear (Period A) To Purse Seine Gear (Period B)	
	Period A	Period B	Period A	Period B
January 12–26				
Tons	366.86	--	152.65	--
Hours*	89.75	--	34.50	--
Tons/Hour	4.09	--	4.42	--
February 16–24				
Tons	252.56	--	214.04	--
Hours*	78.50	--	44.50	--
Tons/Hour	3.22	--	4.81	--
March 14–18				
Tons	307.24	--	129.25	--
Hours*	80.50	--	27.50	--
Tons/Hour	3.82	--	4.70	--
March 20–30				
Tons	--	901.60	--	224.27
Hours*	--	190.25	--	33.50
Tons/Hour	--	4.74	--	6.69
April 21–26				
Tons	--	558.88	--	731.75
Hours*	--	84.75	--	77.75
Tons/Hour	--	6.59	--	9.41
Unweighted Total				
Tons	926.66	1,460.48	495.94	956.02
Hours*	248.75	275.00	106.50	111.25
Tons/Hour	3.73	5.31	4.66	8.59
Weighted Total				
Tons	1,113	1,133	1,393	1,610
Hours*	300	200	300	200
Tons/Hour	3.71	5.66	4.64	8.05

* Based on scouting time to last set.

TABLE 9

Catch Statistics for Groups of Vessels Using Pure Seine or Lampara Gear and Fishing in the Same Area in the Same Time Period of the 1965–66 Season

The unweighted data indicate that anchovies became more available as the season progressed (Table 9). When the data for vessels that used lampara gear only were weighted to equal effort (100 hours) in each monthly period, the catch per hour showed an increase of 53% from 3.71 tons per hour to 5.66 tons per hour between the earlier and later parts of the season. This increase is accepted as a measure of increased fish availability since no other parameter, such as vessels, crew, or gear was changed. Weighted data for vessels that converted during the season from lampara to purse seine gear indicate a catch of 4.64 tons per hour when fishing with lampara gear and 8.05 with purse seine gear. A 53% increase in catch per hour would be expected because of the increased availability of fish, hence these vessels would have been expected to show a catch per hour of 7.10 tons if they had not converted. The 13% difference between the expected 7.10 tons per hour and the actual 8.05 tons per hour is attributed to the change in gear.

1.8. ECONOMICS

The anchovy reduction fishery started at a time when the price of fish meal, one of the two main products of anchovy reduction, reached a peak of $210 per ton for a 65% protein guarantee product, the highest it had been since 1949. Meal prices then started a steady decline to $137 per ton at the end of the report period. The price for oil remained steady at about 50¢ per gallon.

During both seasons fishermen received $20 per ton for anchovies. Plant operators paid an additional $2.00 per ton privilege tax plus harbor fees. On the average 5.5 tons of whole anchovies will produce 1 ton of meal and 5 to 140 gallons of oil.

Oil analyses (conducted by the U.S. Bureau of Commercial Fisheries Technology Laboratory, Terminal Island, California) of samples taken during various months of the year revealed that the oil content of anchovies fluctuated between 15 and 45 gallons per ton of fish in the Monterey area and between 5 and 30 gallons per ton off southern California. These laboratory extractions are about 50–60% (and at low oil yields 80%) higher than the reduction plants' yield. Oil content drops from January through April and into May, paralleling the period of highest spawning activity, jumps to a high level in early summer, and remains high until December or January.

1.9. DISCUSSION

1.9.1. Northern Permit Area

During 1965–66 and 1966–67 seasons the area's anchovy fishery was conducted in and around Monterey Bay. All landings were made at two processing plants, one in Monterey and one in Moss Landing. About 67% of the landings were made during October through December and 86% during October through January. Low oil yield in February, March and April resulted in lower fishing effort. Fishing effort in the late months of the 1966–67 season was reportedly an attempt to improve the seasons' landings under the theory that if the quota was not approached no quota would be granted in the future.

In 1952, the year of greatest Monterey anchovy landings, 73% of the year's catch of 19,868 tons came from within 20 miles of San Francisco, 95% during October, November, and December. The remaining 27% was caught in Monterey Bay, 95% during June, July and August.

Examination of catch records for 1952 and for the 1966–67 reduction season reveal that anchovies have been caught in quantity during all months except December, February and March. Since the oil yield is highest during the July through December period, it would appear that the most economical time to conduct an anchovy reduction fishery in Monterey is from June through January, not October through April.

1.9.2. Southern Permit Area

When reporting the commercial catch for the seasons 1954–55 through 1956–57, Miller and Wolf (1958) stated that "through the past three seasons the commercial catch of anchovies in southern California has *not been limited by lack of fish*." (Emphasis added.) This statement is still true and in an attempt to foresee developments a comparison between the fishery during those years and now seems appropriate.

The fishery during the 1950's was characterized by: landings for human consumption in the absence of previously abundant sardines; catches exceeding 34,000 tons in 1953 and averaging 23,400 tons from 1953 through 1957; one zone which included all the area south of an east-west line through Point Mugu with 21,000- and 35,000-ton quotas from September 1955 to March 31, 1956 and from April 1, 1956 to March 31, 1957 respectively; prices paid the fishermen ranging from $42 per ton in 1953 and 1954 to $25–26 per son from 1955 through 1957; an anchovy spawning population in California waters of 300,000 to 600,000 tons based on larvae distribution (Ahlstrom, 1966*a*) and early population estimates (Table 2).

In contrast, characteristics of the fishery in 1965–66 and 1966–67 were: landings primarily for reduction; catches in the latter season totaling 30,000 tons of a 65,000 ton quota; the division of the area south of Point Conception into four fishing zones; a 7-month season designed not to conflict with the peak live bait season of June to September; price of fish never exceeding $20 per ton; an anchovy spawning population in California waters of approximately 2.5 million tons.

Analysis of catch records for 1953 through 1957 reveal that October, November, and December landings usually contributed the least to each seasons catch while February through May usually contributed the most. It is quite probable that these data only reflect the fact that the wetfish fleet is most active for more valuable mackerel during October through December and least active February through May. By contrast December 1966 landings of 4,181 tons accounted for nearly 14% of that seasons catch and is the greatest anchovy tonnage ever landed during any of the last 4 months of the year.

Fishery zones did not hamper fishing during the early months of the reduction season, but the closure of the most accessible zone after its quota was reached during the last month of each season definitely curtailed landings.

California Department of Fish and Game sea survey data for 1965, 1966, and 1967 reveal that over one million anchovy schools were present from San Diego to the Northern Channel Islands and offshore to

Cortes Bank and San Nicolas Island during April, May, and June (Baxter, 1968 and Kenneth F. Mais, pers. commun.). Except for April 1967 they were not abundant in a 20-mile wide coastal belt between San Diego and Oceanside. Inshore schools were more *numerous* in April and May than in June. (We do not yet know what this means in terms of biomass.) During October, 1966 the area south of a line from San Pedro to San Nicolas Island was practically devoid of anchovy schools; Cortes Bank was the lone exception.

Tag return data demonstrate that anchovies move considerable distances in a short time; in one instance at least 369 miles in 129 days (2.9 miles per day). Consequently fishery zones do not protect any segment of the population but rather serve only to distribute the areas of fishing. The effect of the zones has been to close the most productive area, close to home port, and reduce total landings.

The data indicate that the last 3 or 4 months of the year can *not* be expected to be good anchovy fishing months and that fishery zones not only distribute the area of catch but curtail landings, especially during the last months of the season. It can be argued that the present high anchovy population negates any analogy between what happened in the 1950's and what might be expected now.

1.10. REFERENCES

Ahlstrom, Elbert H. 1966a. Distribution and abundance of sardine and anchovy larvae in the California Current region off California, 1951–1965: A summary. U.S. Fish and Wild. Serv., Spec. Sci. Rept. Fish., (534) :1–71.

Ahlstrom, Elbert H. 1966b. Method of deriving our present estimate of abundance of the anchovy population. *In* Calif. Mar. Res. Comm. Minutes, 2–3 Aug. 1966, p. 13–15.

Ahlstrom, E. H., J. L. Baxter, J. D. Isaacs, and P. M. Roedel. 1967a. Report of the CalCOFI Committee. Calif. Mar. Res. Comm., Calif. Coop. Ocean. Fish. Invest. Rept., 11 :5–9.

Ahlstrom, E. H., J. L. Baxter, J. D. Isaacs, and P. M. Roedel. 1967b. CalCOFI Committee recommendation on the anchovy fishery. *In* Calif. Mar. Res. Comm., Minutes, 28 Feb. 1967, App. 4.

Baxter, J. L. 1966. Anchovy population size. Calif. Dept. Fish and Game MRO Ref. (66–21) :1–2.

Baxter, J. 1968. Agency reports, California Department of Fish and Game pelagic fish investigations. Calif. Mar. Res. Comm., Calif. Coop. Ocean. Fish. Invest. Rept., 12:10–13.

California Fish and Game Commission. 1965. Minutes, meeting of November 12, 1965. p. 12–17.

California Fish and Game Commission. 1966 Minutes meeting of August 26, 1966. p. 19–29.

Chapman, W. M. 1967. Statement of W. M. Chapman before the California Fish and Game Commission respecting the anchovy fishery, anchovy population size, biological research, impact of fishery on environment and sport fishery, and its regulation for maximum use and conservation of the resource. San Francisco, California, August 26, 1966. *In* Calif. Mar. Res. Comm., Minutes, 8 Aug. 1967. App. 2 :1–14.

Clark, Frances N. and Julius B. Phillips. 1952. The northern anchovy (Engraulis mordax mordas) in the California fishery. Calif. Fish and Game, 38(2) :189–207.

Haugen, Charles W., James D. Messersmith, and Russell H. Wickwire. 1969. Progress report on anchovy tagging off California and Baja California, March 1966 through May 1969. *In* The northern anchovy (Engraulis mordax) and its fishery (1965–1968. Calif. Dept. Fish and Game, Fish Bull., (147) : 75–89.

Hjort, Johan. 1910. Report on herring investigations until January, 1910, Cons. Perm. Int. Explor. Mer., Publ. Circonstance. (53) :35.

MacGregor, John S. 1964. Average biomass estimates for the years 1955–57. *In* Calif. Mar. Res. Comm., Minutes, 6 March 1964, Doc. 6.

Messersmith, J. D. 1967. tagged anchovies move from southern California to Monterey Bay. Calif. Fish and Game, 53(3) :209.

Messersmith, J. D., John L. Baxter, and Philip M. Roedel. 1969. The anchovy resources of the California Current Region off California and Baja California. Calif. Mar. Res. Comm., Calif. Coop. Ocean. Fish. Invest. Rept., 13 :32–38.

Miller, Daniel J., and Robert S. Wolf. 1958. Age and length composition of the northern anchovy catch off the coast of California in 1954–55, 1955–56, and 1956–57. *In* Age and length composition Pacific Coast catches sardines and Pacific mackerel 1955–56 and 1956–57 seasons and the northern anchovy 1954–55 through 1956–57 seasons. Calif. Dept. Fish and Game, Fish Bull., (106) :27–72.

Murphy, Garth I. 1965. Living resources off our shores. Calif. Mag. Comm., Agri. and Ind. Dec. 1965 :25–26.

Murphy, Garth I. 1966. Population biology of the Pacific sardine (Sardinops caerulea) . Calif. Acad. Sci., Proc., 4th ser., 34(1) :1–84.

Phillips, Julius B. 1949. Anchovy. *In* The commercial fish catch of California for the year 1947 with a historical review 1916–1947, Calif. Div. Fish and Game, Fish Bull., (74) :89–90.

Radovich, John. 1965a. Estimate of anchovy population size. *In* Calif. Mar. Res. Comm., Minutes, 11 May 1965, App. 5.

Radovich, John. 1965b. Review of the anchovy problem. *In* Calif. Fish and Game Comm., Minutes, 25 June 1965.

Radovich, John. 1965c. Remarks on anchovies. *In* Calif. Fish and Game Comm., Minutes, 12 Nov. 1965.

Roedel, Philip M. 1967. The role of the CalDOFI Committee in relation to the California anchovy fishery. Calif. Dept. Fish and Game, MRO Ref. (67–9) :1–8.

Wood, Richard and Robson A. Collins. 1969. First report of anchovy tagging in California. Calif. Fish and Game, 55(2) :141–148.

2. THE 1967–68 ANCHOVY REDUCTION FISHERY

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2.1. INTRODUCTION

This is the second report on the northern anchovy (Engraulis mordax) reduction fishery off the Pacific coast of California. The first report covered the 1965–66 and 1966–67 seasons (Messersmith, 1969).

On July 28, 1967 the California Fish and Game Commission authorized a third reduction fishing season to begin September 15, 1967 and end May 15, 1968. As in preceding years there were two permit areas: The Northern Permit Area, which includes all California waters north of a line extending west from Point Conception; and the Southern Permit Area, which includes all California waters south of this line. The number of zones within the Southern Permit Area was increased to five although the quota, 65,000 short tons, remained unchanged.

The purpose of this paper is to review the fishery and give some insight into the factors contributing to the failure of the catch to approach the authorized quota (Table 10). All weight records are reported in short tons.

2.2. ACKNOWLEDGMENTS

This paper would not have been possible without the cooperation of the numerous fishermen participating in the fishery. I also wish to thank Department of Fish and Game Patrol Captain Clifford Mattews and seasonal assistant Les Fischer for their aid in maintaining contact with the fishery at Port Hueneme. In Monterey Richard H. Parrish, Department of Fish and Game, and local processors provided immediate contact with the fishery.

2.3. FISHERY REGULATIONS

In response to a request by the California Fish and Game Commission, the Department of Fish and Game submitted its recommendations for a 1967–68 anchovy reduction season at the July 28, 1967 meeting of the Commission. The major Department recommendations were: a quota of 200,000 tons, 15,000 tons in the Northern Permit Area and 185,000 tons in the Southern Permit Area; two zones in the Southern Permit Area, one to include the area between Santa Catalina Island and the mainland and the other the remainder of the Southern Permit Area.

Industry asked for a 250,000 ton quota with no zones while sportsmen's groups urged the Commission to put an end to all anchovy reduction (Minutes of California Fish and Game Commission Meeting, April 7, 1967 and July 28, 1967). Major features of the regulations adopted (July 28, 1967) by the Commission included: A Northern Permit Area with a 10,000 ton quota; a Southern Permit Area (Figure 8) divided into five zones with a 5,000 ton quota in each of the 4 inshore zones and a 45,000 ton quota in the offshore zone; and a season of September 15 through May 15.

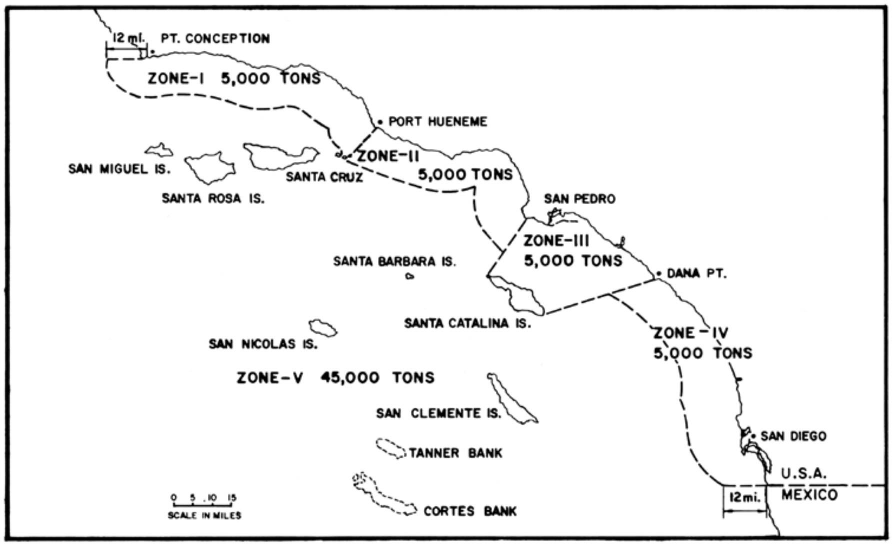

FIGURE 8. The Southern Permit Area illustrating the 5 zones and their respective quotas.

FIGURE 8. ***The Southern Permit Area illustrating the 5 zones and their respective quotas.***

The following processors applied for and were issued reduction permits on August 28 and 29:

Star-Kist Foods, Inc., Terminal Island
Santa Cruz Canning Co., Moss Landing
Hovden Food Products Corp., Monterey
J. D. Packing Co., Inc., Oxnard (Name changed to Universal Packers Corp., October 4, 1967)
Westgate-California Corp., California Marine Curing and Packing Co., Terminal Island
Westgate-California Corp., San Diego
Van Camp Sea Food Company, Terminal Island
Pan Pacific Fisheries, C.H.B. Foods, Inc., Terminal Island

2.4. FISHERY

2.4.1. Northern Permit Area

Northern Permit Area fishermen first delivered anchovies for reduction on October 2, after agreeing with processors to accept $17 per ton. On March 2 and 3 anchovies sold for only $16 per ton.

The 16 lampara vessels and 3 purse seiners operating took 2,080 tons during October (Table 10). By November 13, all but one of the lampara vessels had ceased operations. This was a result of rough weather, an abundance of sea lions on the fishing grounds, and a generally reduced availability of anchovies, particularly in water less than 20 fathoms deep. The sea lions presented a danger to fishermen

TABLE 10

Anchovy Landings in Tons—September 15, 1967 Through May 15, 1968

	Northern Permit Area			Southern Permit Area								
				Reduction								
	Reduction	Non-Reduction	Total	Zone I	Zone II	Zone III	Zone IV	Zone V	Total	Non-Reduction	Total	Season Total
1967												
October	2,080	261	2,341	77	44	--	--	411	532	80	612	2,953
November	816	146	962	--	43	--	--	192	235	55	290	1,252
December	1,745	42	1,787	--	--	--	--	--	--	42	42	1,829
1968												
January	757	92	849	--	--	--	--	--	--	147	147	996
February	28	--	28	65	--	--	--	--	65	83	148	176
March	45	94	139	--	--	--	--	--	--	78	78	217
April	183	235	418	--	--	20	--	--	20	107	127	545
May	--	2	2	--	--	--	--	--	--	59	59	61
Total	5,654	872	6,526	142	87	20	0	603	852	651	1,503	8,029

TABLE 10

Anchovy Landings in Tons—September 15, 1967 Through May 15, 1968

and were responsible for lost time, smaller catches and net damage. More than once fishermen reported a large male sea lion coming aboard a vessel or skiff and chasing crew members around the vessel. Two purse seiners continued to operate after November 13, when weather permitted, and a third purse seiner fished for anchovies when mackerel were not available.

Oil yield declined from 22 gallons per ton of raw fish on January 29 to 11 gallons per ton on February 5 and consequently processors quit accepting anchovies until late March. We know that processors were not willing to accept anchovies between February 5 and March 29 because of their low oil content; we do not know if anchovies were available to Northern Permit Area fishermen.

Data from the Department's Fisheries Resources Sea Survey Investigation indicate that anchovies were unavailable even if the processors had wanted them. The Survey found spawning anchovies in Monterey Bay during late February. It is the experience of the Sea Survey staff that anchovy schools spread out near the sea surface prior to and during spawning. When the cold water reached the surface, spawning ceased, and anchovies again formed schools vulnerable to roundhaul gear.

During the light-of-the-moon period beginning April 11, fishermen removed anchovy gear from their boats, some in preparation for squid fishing, and others to fish for salmon in Alaska. No anchovies were taken for reduction for the rest of the season which closed May 15, 1968.

As in the two previous seasons (Messersmith, 1969) purse seiners were more successful (10 tons per hour) than lampara vessels (4 tons per hour), and were also more successful (16 tons per hour) in December and January than in the fall or spring (7 tons per hour).

2.4.2. Southern Permit Area

When the season began on September 15, fishermen, boat owners, and processors were involved in price negotiations for tuna, bonito, and mackerel as well as for anchovies. Since anchovies are the least valuable, and the others appeared to be immediately available, anchovies received the lowest priority in the negotiations. On October 7 one vessel began delivering anchovies at Port Hueneme for $15 per ton, less $2 for trucking. On February 7 the price declined to $12 per ton, less $2 for trucking and the fishermen quit fishing two days later. Until that time a large concentration of anchovies had been available in Hueneme Canyon and around Anacapa Island. Anchovies were not again landed at Port Hueneme during the remainder of the reduction season, although the Department's Fisheries Resources Sea Survey April cruise found several large schools of spawned out anchovies in shallow water near Ventura.

San Pedro fishermen and boat owners agreed to accept $16 per ton for anchovies effective February 19. However, the only anchovies landed at San Pedro for reduction were 27 tons delivered by two purse seiners on April 8 when several large schools were found in the San Pedro Channel. The purse seiners had difficulty following them as the fish were moving rapidly and erratically. Large anchovies were not again reported in this area during the remainder of the season.

Department of Fish and Game survey cruises found fewer anchovy schools in the nearshore waters of southern California than in previous years. The January-February 1968 cruise detected only 296 schools during 980 miles of echo sounding. During the April-May cruise, adult anchovies were found farther seaward than during any previous cruise, with the bulk of the population 40 to 120 miles offshore in and beyond the San Nicolas Basin. A few large schools were found in shallow water near Ventura, the only place fishermen may have been able to fish them economically. Large quantities of juvenile anchovies were found within 10 miles of shore from northern Baja California to Newport Beach.

2.5. OIL AND MEAL PRICES

The primary purpose of Terminal Island reduction plants is to reduce the offal from tuna, bonito and mackerel canning. When this offal is mixed with anchovies and reduced the resultant meal and oil is sold as tuna-and-mackerel. The mixtures are of inferior quality to that of pure anchovy products and therefore bring lower prices.

Domestic anchovy meal prices are very stable but are reported irregularly. Therefore, I have presented Peruvian anchovy meal prices (Figure 9) as an index of the local meal market, since they rarely differ by as much as $10 per ton from the domestic product. Whereas during the 1966–67 season, when 37,615 tons were landed, meal sold for as much as $158 per ton. During the 1967–68 season prices were never higher than $140 per ton.

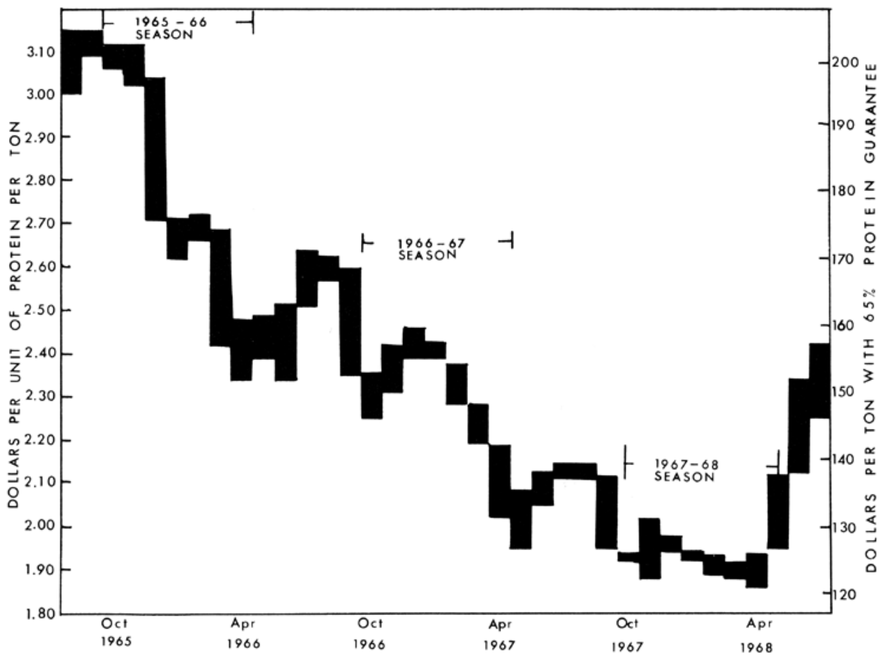

FIGURE 9. The monthly ranges of Peruvian anchovy meal prices at Los Angeles from August 1965 through July 1968. Data is based on the United States Bureau of Commercial Fisheries Market News Report.

FIGURE 9. ***The monthly ranges of Peruvian anchovy meal prices at Los Angeles from August 1965 through July 1968. Data is based on the United States Bureau of Commercial Fisheries Market News Report.***

Domestic tuna and mackerel oil prices ranged from 52 cents to 47 cents per gallon during the 1966–67 reduction season and 28 to 24 cents per gallon during the 1967–68 season.

2.6. DISCUSSION

In the Northern Permit Area processors imposed daily landing quotas of 15 to 20 tons for each lampara vessel and 30 to 40 tons for purse seiners. Such limits remained in effect from the first delivery on October 2 until late November after all but one lampara vessel had quit fishing. Regardless of these conditions the fishermen indicated, by their participation, that they thought anchovy fishing was profitable. The processors in the Northern Permit Area continued to place orders for anchovies until the oil yield dropped below 11 gallons per ton. Weather was the primary factor curtailing landings during November, December and January.

In the Southern Permit Area, where the oil yield seldom exceeds six gallons per ton, processors did not offer the fishermen as much as did Northern Permit Area processors. Boat owners expressed the opinion that they could make a profit at $16 per ton, provided no limits were placed on deliveries. Many crew members thought they could not make a decent living at that price, since they work on a profit sharing basis. Regardless, the prime factor inhibiting the fishery was the failure of adult anchovies to school within the inshore zones. A second factor which rivaled the first as a deterrent to fishing was the low price of fish meal.

2.7. REFERENCE

Messersmith, James D. 1969. A review of the California anchovy fishery and results of the 1965–66 and 1966–67 reduction season. *In* The northern anchovy (Engraulis mordax) and its fishery, 1965–1968. Calif. Dept. Fish and Game, Fish Bull., (147) : 6–32.

3. AGE DETERMINATION OF NORTHERN ANCHOVIES, ENGRAULIS MORDAX, FROM OTOLITHS[1]

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California Department of Fish and Game

3.1. INTRODUCTION

When the California Fish and Game Commission authorized an anchovy reduction fishery, in the fall of 1965, an expanded program of biological studies and fishery monitoring was undertaken by the Department of Fish and Game. Age determination, using scales to assess year-class composition, was an important part of this program. Scales have been used to determine the age of northern anchovies (Engraulis mordax) since the early 1950's (Clark and Phillips, 1952). The scale method was thoroughly investigated by Miller (1955), who found that it was valid, but subject to an unmeasurable degree of error. He concluded that "If the errors are consistent in degree from year to year or if they tend to be compensatory, the data may be used to measure variations in age composition and year class strength." The method worked quite well using material collected from the canning and live bait fisheries, and several large year-classes were followed for up to three years. These year-classes showed expected growth rates, lending confidence to the scale method.

With the start of a moderate reduction fishery certain drawbacks in the scale method of age determination became apparent. Fish are handled without regard to freshness and often spend 12 hours or more in the hold of a vessel, arriving at the unloading dock in various stages of decomposition. Since anchovy scales are caducous many samples contained a large proportion of fish without usable scales.

The large numbers of scales obtained for age analysis during the first two reduction seasons (1965–66 and 1966–67) were more than could be examined by the scale readers before the beginning of subsequent seasons. Streamlining the age determination system and increasing personnel reduced processing time somewhat, but the ages of some fish were still not established until over a year later.

For effective management, data from one season of fishing must be processed before the start of the next. The existing scale method was too slow and inefficient to accomplish this.

Otoliths, routinely used by the Department of Fish and Game for age determination of Pacific mackerel (Scomber japonicus) and jack mackerel (Trachurus symmetricus) , were suggested as an alternate for age determination of anchovies and as a solution to the problems encountered in the use of scales. A study on this use was begun in 1966. Its purposes were: i) To develop a technique for determining ages of anchovies

[1] This work was supported in part by Federal Aid to Commercial Fisheries Research and Development Act funds as Bartlett Project M63R4.

from their otoliths; ii) To verify that age determination from scales and otoliths are comparable; and iii) To delineate the relative advantages and disadvantages of each method.

3.2. ACKNOWLEDGMENTS

Many people participated in the data collection and analysis. Stephen J. Crooke, California Department of Fish and Game, collected some of the samples and participated in the initial otolith reading. The CalCOFI scale readers were Clarkson E. Blunt, Jr., James E. Hardwick and Alexander Petrovich of the California Department of Fish and Game and Makoto Kimura and John S. MacGregor of the U.S. Bureau of Commercial Fisheries, La Jolla. James D. Messersmith guided the study and offered advice and encouragement during preparation of the manuscript.

3.3. MATERIALS AND METHODS

3.3.1. Samples

During 1966 and 1967 we collected both otoliths and scales from each anchovy in each live-bait sample. Development of clear age determination criteria required using material from all months of the year, and from all ages of fish. For these reasons the otoliths and scales were taken from the live bait fishery in accordance with our regular sampling plan (Wood and Strachan, 1970). They consisted of samples of anchovies caught for sale as live bait at the ports of San Diego, Los Angeles-Long Beach, and Port Hueneme. Reduction fishery samples were available only during the first four months of the year, the period of ring formation in scales, and we suspected this was true for otoliths also. Assignment of ages to fish taken during this period is difficult and subject to a high degree of error (Miller, 1955).

3.3.2. Obtaining the Otoliths

The largest of three pair of otoliths, the sagittae, are used for age determination. They are found within the otic capsules that lie at the base of the posterior portion of the skull and can be obtained readily be removing the gill arches and breaking the skull on a line through the otic capsules (Figure 10) . Examination of the otolith location, and a little experimentation leads quickly to proficiency in extracting them. The otoliths are surrounded by a tissue sac, the sacculus, which must be removed before reading or storage. Gently rubbing the otolith in the palm of the hand removes this tissue readily; they then can be stored and allowed to dry overnight before reading.

Small gelatine capsules, such as those used for dispensing medicines, work quite well for storing otoliths if kept dry. The capsules are inexpensive, easy to obtain, and protect the otoliths from breaking. All capsules for one sample are stored in a single coin envelope labeled with the sample number and date of sampling (Figure 11) . Each capsule contains a number which relates it to the length, weight, sex, and state of maturity data of the fish from which the otolith was taken.

About 1,200 paired samples of scales and otoliths were suitable for this study. An additional 400 were unusable because the scales were either regenerated, or too few in number.

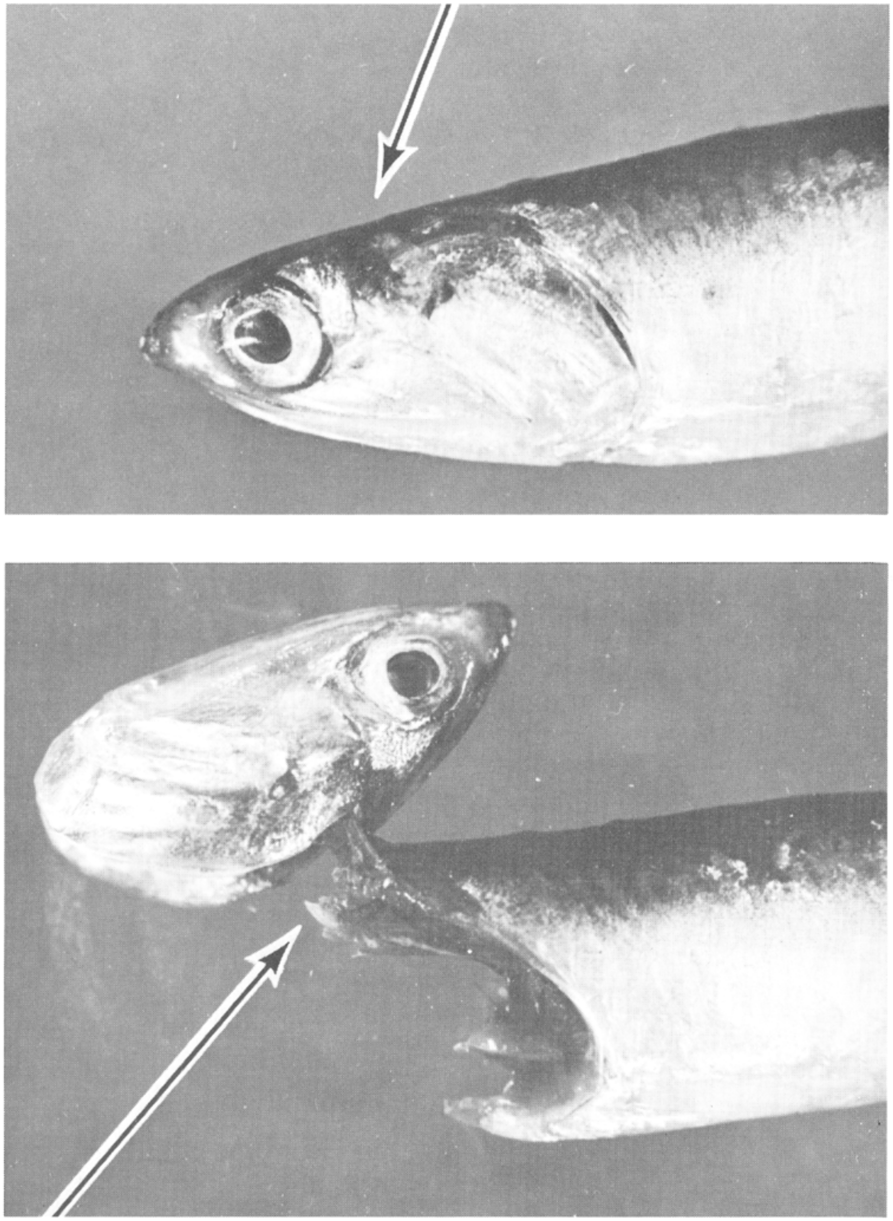

FIGURE 10. The arrow indicates the point at which the anchovy skull is broken in order to obtain its otoliths (upper photo). The skull is broken and an arrow points to the otolith protruding from the otic capsule (lower photo).

FIGURE 10. ***The arrow indicates the point at which the anchovy skull is broken in order to obtain its otoliths (upper photo). The skull is broken and an arrow points to the otolith protruding from the otic capsule (lower photo).***

3.3.3. Reading Criteria

For reading, the otoliths are immersed in about ¼-inch of water. Other mediums such as anise oil will work, but we found, as did Fitch (1951) with Pacific mackerel otoliths, that water is entirely satisfactory. Water has a clearing effect on otoliths and they will become completely transparent if submerged too long. This can be corrected by allowing them to dry for a few minutes. A dish with a black glass insert (Schott, 1965), or a black glass embryological staining dish help accentuate the rings by providing contrast.

Reading was done under a binocular microscope at a magnification of 10X to 20X. A beam of light, from a small microscope lamp, directed at the otoliths from a low angle is usually the best illumination. Light directed almost straight down helps to bring out the narrow rings of older fish when they are difficult to detect.

Since investigators have used a number of different terms to describe otolith structures the literature is very confusing. We have used the terminology set down by the International Commission for the Northwest

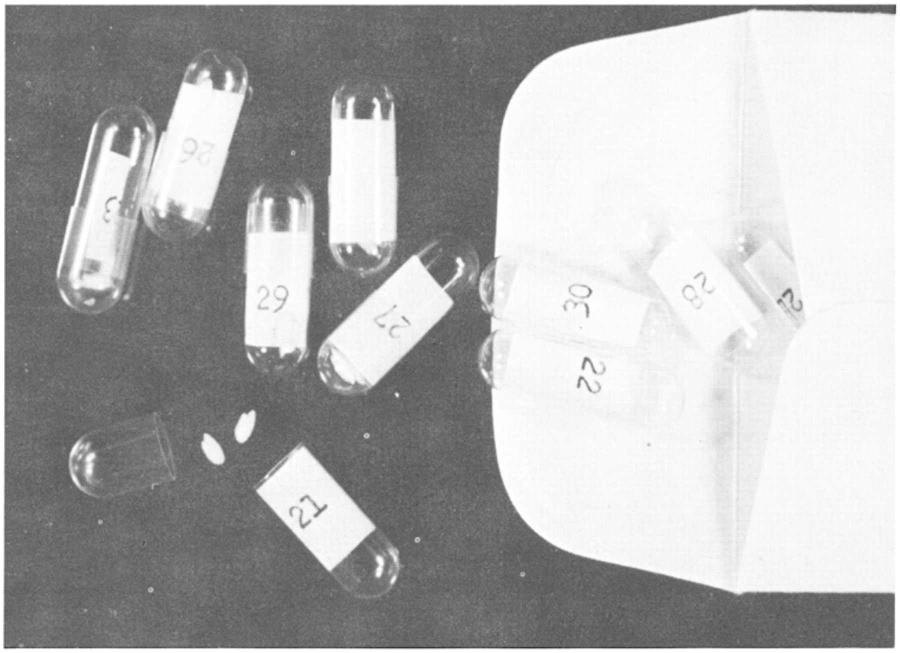

FIGURE 11. All the otoliths from one sample are stored in small gelatine capsules in a coin envelope.

FIGURE 11. ***All the otoliths from one sample are stored in small gelatine capsules in a coin envelope.***

Atlantic Fisheries (Jensen, 1965; Appendix A). These terms are quite clear and particularly adaptable to automatic data processing.

Examination of otoliths under magnification and reflected light reveal a central white opaque nucleus surrounded by alternating bands of translucent or hyaline, and white opaque material, termed zones (Figure 12) . If a dark background is used the hyaline zones appear dark. During the first few years of growth the white opaque zones are wider than the dark hyaline zones which separate them. The quantity of material laid down by older fish is so small that the opaque zones formed after the second or third year appear as thin white lines on a dark background.

Preliminary criteria for judging otolith rings were established using past experience with Pacific mackerel (Fitch, 1951) and Pacific sardines (Sardinops caeruleus) (Walford and Mosher, 1943) as a guide.

We now define a completed annual ring as the interface between an inner dark hyaline zone and an outer white opaque zone (Fitch, 1951; Chugunova, 1959). For age determination we count only completed rings, i.e. white opaque zones, excluding the nucleus. The type of growth evident on the margin of the otolith, opaque or hyaline, tells us how recently the last ring was formed. Since the anchovy reduction fishery is presently conducted during the period of ring formation the knowledge of how recently the last ring was formed is very important in year-class assignment. It is difficult to detect new opaque zones in older fish, because they are narrow. New growth is evident first at the dorsal edge and on the antirostrum (Figure 13) and this area must be carefully examined for newly formed zones. The rings on the majority of the ototliths we have examined are easily seen, and up to seven completed rings have been detected, the same maximum number detected on scales (Clark and Phillips, 1952). The photographs in Figures 14 and 15 have been chosen to represent typical otoliths from several different ages of anchovies. Zones laid down by the fish tend to decrease in width with increasing age, becoming quite narrow in older fish. This characteristic helps separate rings

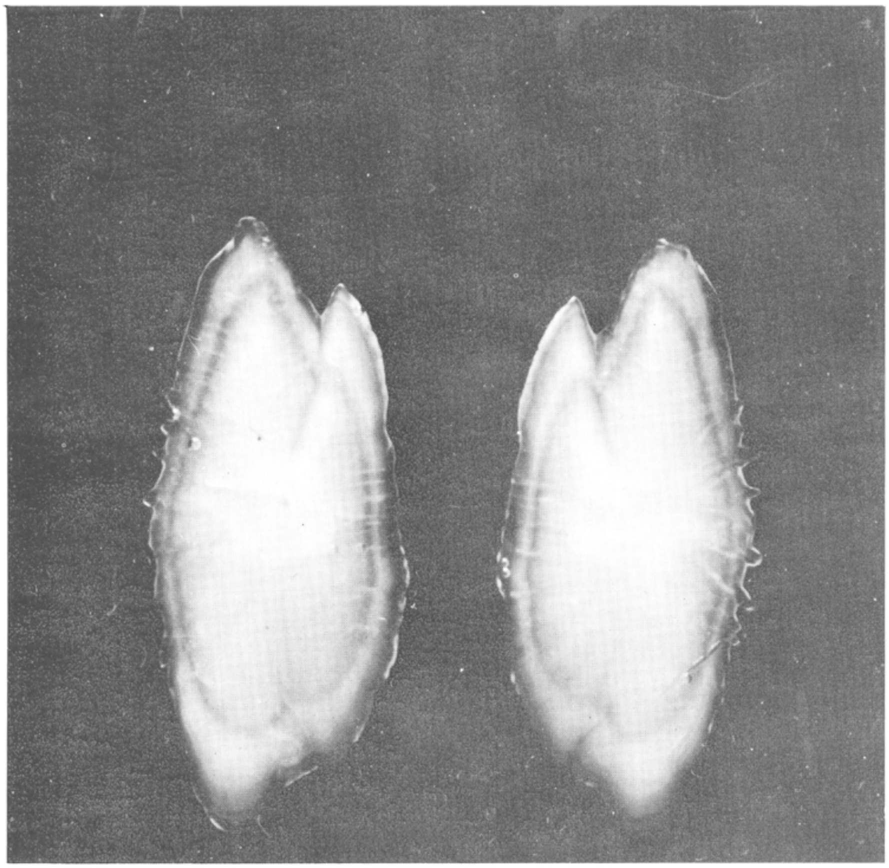

FIGURE 12. A typical otolith has alternating bands of white (opaque) and dark (hyaline) material. These bands are called zones. The anterior end is at the top and the dorsal edges toward the center. *Photograph by Jack W. Schott*

FIGURE 12. ***A typical otolith has alternating bands of white (opaque) and dark (hyaline) material. These bands are called zones. The anterior end is at the top and the dorsal edges toward the center.*** *Photograph by Jack W. Schott*

from spurious checks. We occasionally find spurious checks in fish taken from catches, and quite often in fish held in captivity. They appear as a ring which is quite narrow when compared to those interior and exterior to it, and may fail to be complete around the entire otolith (Figure 16) .

Occasionally we find otoliths of large size which appear completely opaque and so severly calcified that the zones are obscured (Figure 17) . These are unreadable and we omit them from our analysis. The lengths of these fish are distributed in the same manner as the aged fish, and less than 1% of the total had otoliths of this type. At other times one of the otoliths may be so deformed that an assignment of age must be based on a single otolith (Figure 18) . In all cases where an abnormal otolith was found the other appeared normal, and an age could be determined from it.

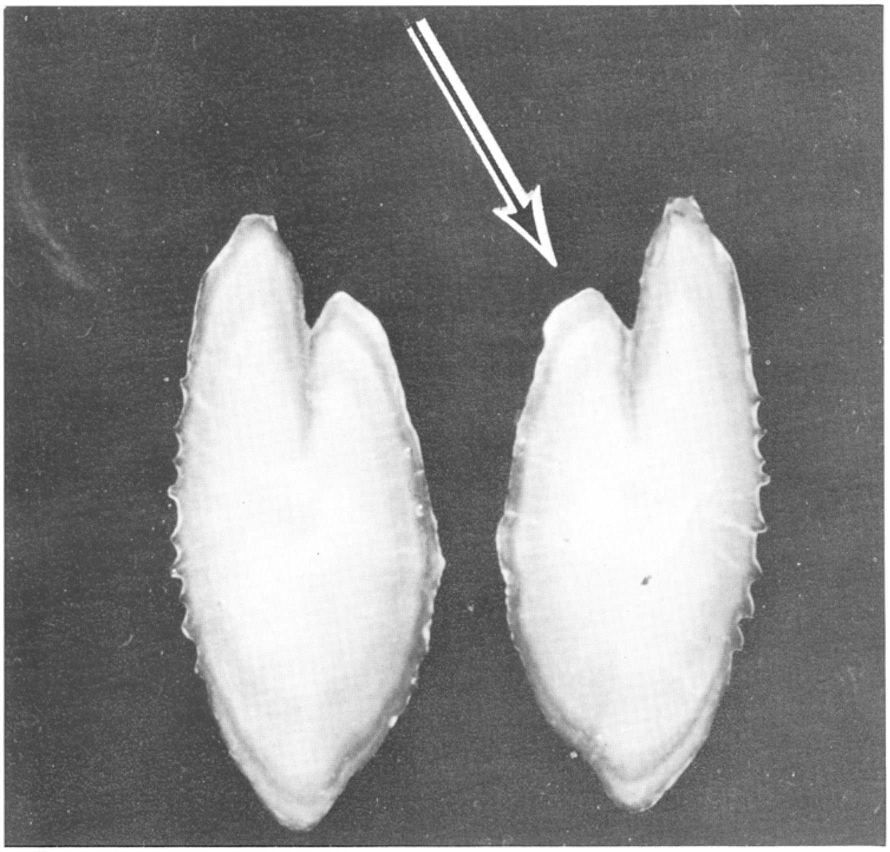

FIGURE 13. New rings can be detected first on the antirostrum (arrow) and dorsal edge of otolith. ***Photograph by Jack W. Schott.***

FIGURE 13. ***New rings can be detected first on the antirostrum (arrow) and dorsal edge of otolith.*** *Photograph by Jack W. Schott.*

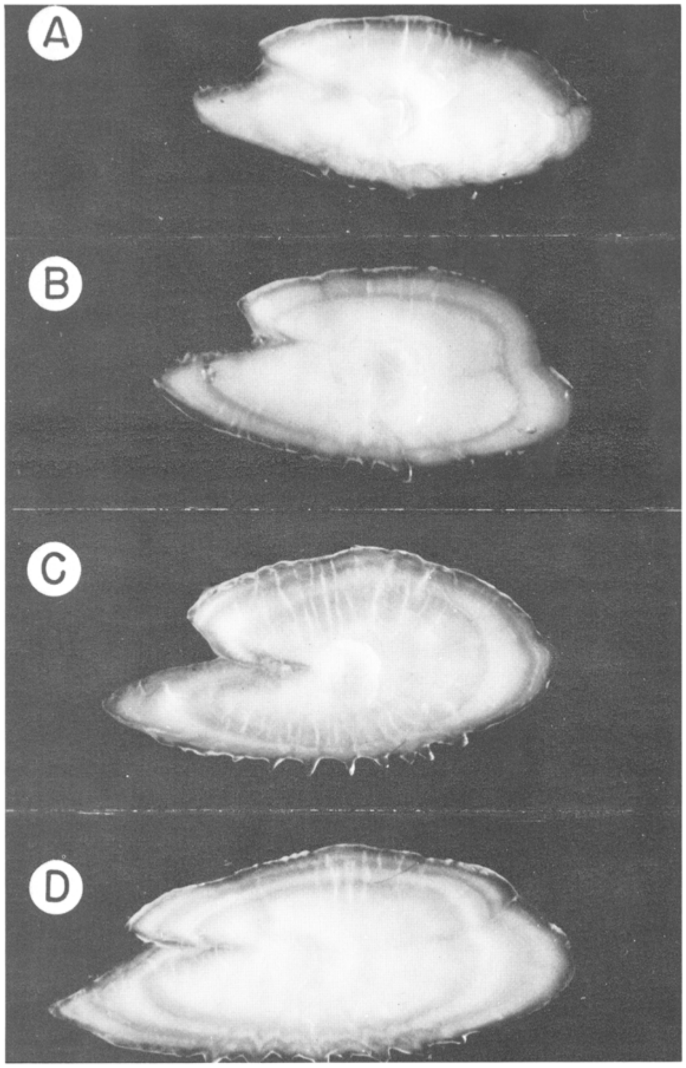

FIGURE 14. Examples of otoliths from: A. 90-mm male, age 0. Several checks can be seen; B. a 110-mm female, age I, this otolith has a hyaline edge and is about to form a second annulus; C. a 114-mm male, age II; and D. a 121-mm female, age II. Notice the relative size, and width of the hyaline margin of C and D. *Photograph by Jack W. Schott.*

FIGURE 14. ***Examples of otoliths from: A. 90-mm male, age 0. Several checks can be seen; B. a 110-mm female, age I, this otolith has a hyaline edge and is about to form a second annulus; C. a 114-mm male, age II; and D. a 121-mm female, age II. Notice the relative size, and width of the hyaline margin of C and D. Photograph by Jack W. Schott.***

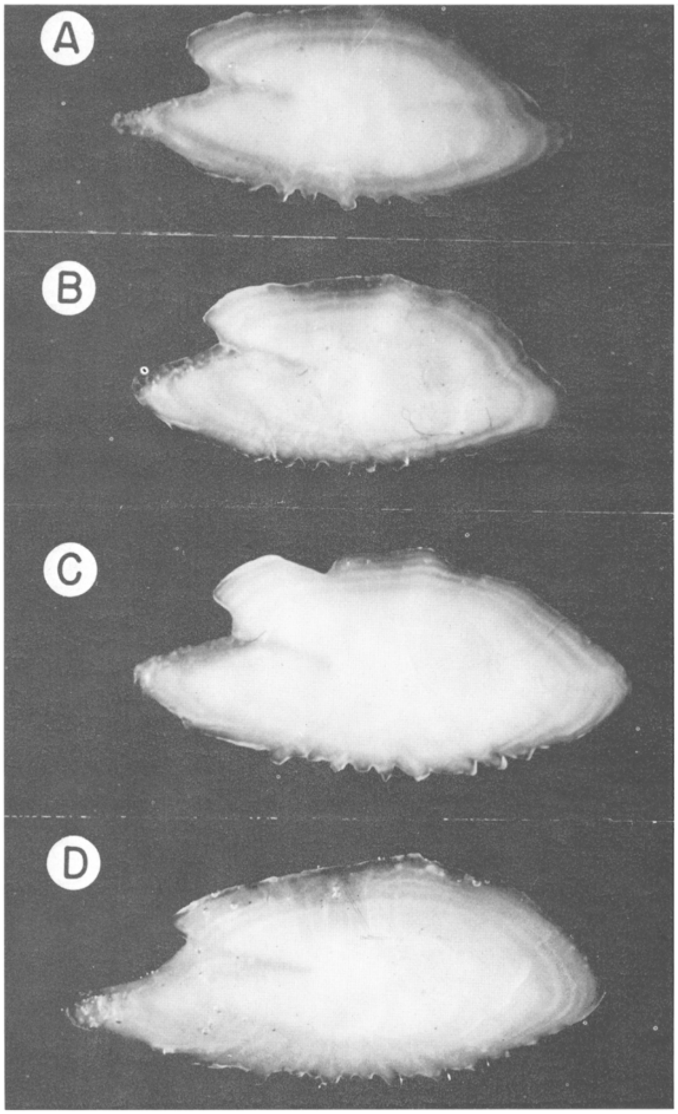

FIGURE 15. Otoliths from: A. a 128-mm female, age III; B. a 129-mm male, age IV, the last two rings are narrow and can be seen on the dorsal edge; C. a 138-mm female, age V; D. a 144-mm female, age VI. *Photograph by Jack W. Schott.*

FIGURE 15. ***Otoliths from: A. a 128-mm female, age III; B. a 129-mm male, age IV, the last two rings are narrow and can be seen on the dorsal edge; C. a 138-mm female, age V; D. a 144-mm female, age VI.*** *Photograph by Jack W. Schott.*

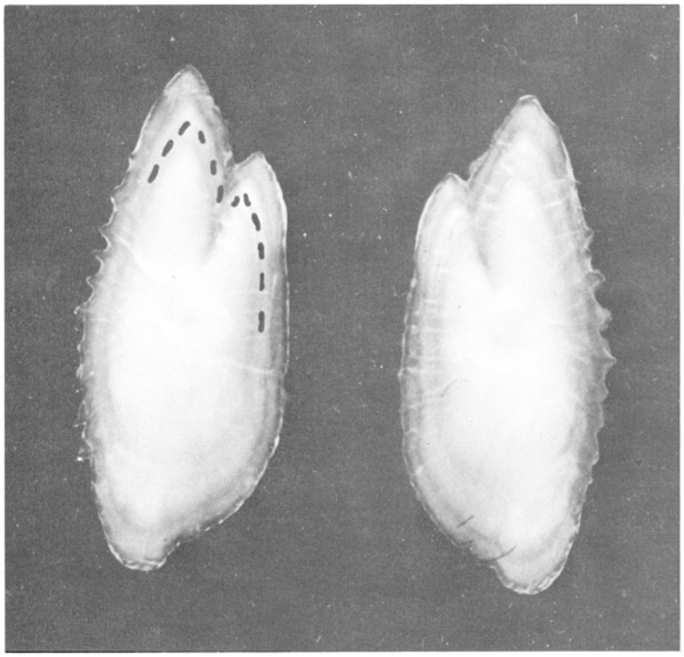

FIGURE 16. Checks in rings such as the one in the second opaque zone, may lead to false age if they are not recognized. *Photograph by Jack W. Schott.*

FIGURE 16. ***Checks in rings such as the one in the second opaque zone, may lead to false age if they are not recognized.*** *Photograph by Jack W. Schott.*

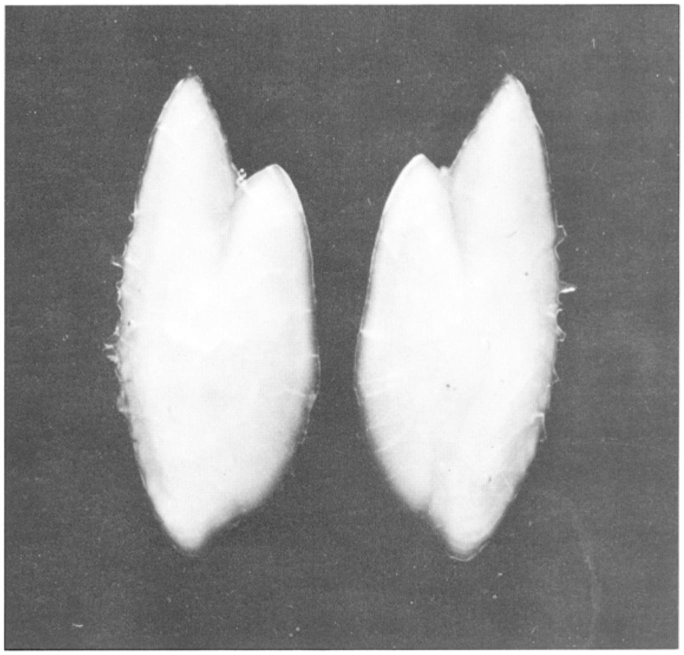

FIGURE 17. An otolith unreadable due to calcification. One or more rings may be obscured. *Photograph by Jack W. Schott.*

FIGURE 17. **An otolith unreadable due to calcification. One or more rings may be obscured.** *Photograph by Jack W. Schott.*

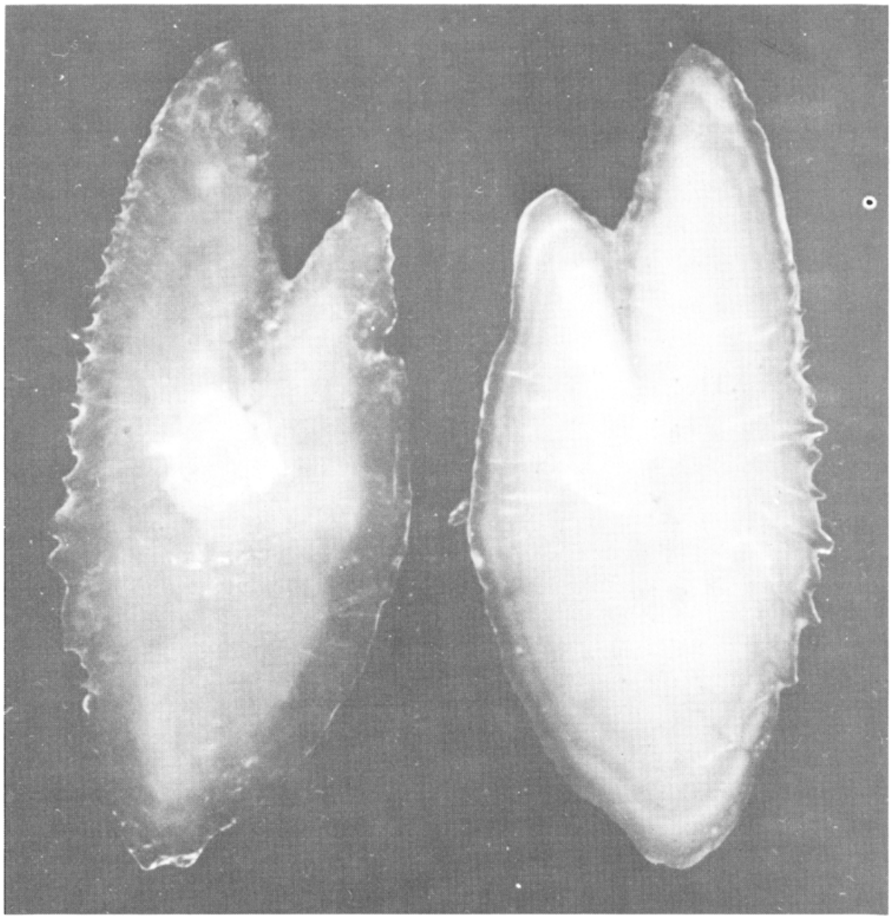

FIGURE 18. **An example of a deformed otolith. The other member of the pair is readable.** ***Photograph by Jack Schott.***

FIGURE 18. ***An example of a deformed otolith. The other member of the pair is readable.*** *Photograph by Jack Schott.*

3.3.4. Reading Program

After the basic technique was developed, a number of otoliths were read for experience and the actual reading of samples was begun. At this point, a second reader was trained. As the study progressed the readings became more consistent and the frequency of agreement became greater, stabilizing at about 70% during the latter part. This is considerally better than the 50% agreement between scale readers reported by Miller (1955). Each pair of otoliths was read independently by the two authors, and each was assigned a ring count. Differences in the ring count interpretation occurred most often because of difficulty in recognizing the type of zone on the margin of the otolith. The narrow opaque zones in the outer portions of the otoliths of older fish, mentioned above, were also a source of difficulty. Ring counts for each pair of otoliths were compared, and those which were different were re-examined and the reasons behind the differences discussed. A ring count was then agreed upon. These discussion sessions served to resolve differences in interpretation of otolith structures and to help establish uniform reading criteria. We feel that while this method served quite well for this study it should not be employed in a routine age determination program. Disagreement between experienced readers should be compensatory and relatively small, allowing some other method of checking readings, such as the Chisquare analysis of difference originally used with sardine age composition studies (Felin and Phillips, 1948).

The scales from our samples were submitted to the co-operative reading program of the Department and the U.S. Bureau of Commercial Fisheries. Each fish was aged by two of five readers, and those in which a disagreement on age resulted were examined by all during an "agreement session", and the differences resolved. Except for the number of readers involved the scale reading process and technique are the same as described by Miller (1955).

3.3.5. Year-Class Assignment

Since the date a fish hatches is not usually known, it is necessary arbitrarily to assign a birthdate for all anchovies in order to establish the year-class to which they belong. This date is usually the one on which a majority of fish show newly completed rings. The year-class assignment is based on this birthdate, for it is then that a given fish is assumed to be 1 year older, and a new year-class is "born." Miller (1955), accepting the above criteria, established April 1st as the birthdate for anchovies aged by scales. Since the majority of otoliths from our samples show newly completed rings by June 1st, we have used this date as the birthdate for anchovies aged by otoliths. We believe the difference in birthdates is due to the difficulty of detecting newly formed rings on otoliths.

The type of zone on the edge of the otolith, and the date of capture in relation to the birthdate are used when establishing the year-class to which a fish belongs. All fish are considered to have completed a winter growth zone and started a summer zone on their otoliths by the June 1 birthdate. Further, all fish are assumed to have completed a summer zone and started a winter zone by December 1. Since the opaque zones are considered summer growth, and the hyaline zones winter growth (Fitch, 1951; Jensen, 1965; Appendix A), year-class assignment can be made as follows: Remembering that a completed annual ring is defined as the interface between an inner hyaline zone and an outer white opaque zone, a fish with either an opaque or hyaline margin, caught during the period June 1 (its birthday) through November 30, is considered to have recently formed a ring. If a fish with a hyaline zone on the margin is caught during the period December 1 through May 31, it is considered to be about to form the annual ring; but a fish with an opaque margin caught during this same period is considered to have already formed the annual ring. Therefore, during the period December 1 through May 31 a fish with an opaque margin will be aged one year younger than one with a hyaline margin, and the same number of completed rings. For example: A fish, whose otoliths have two completed rings and an opaque edge, caught in March of 1969, would be assigned to the 1967 year-class; if taken in December of 1969 it would be placed in the 1968 year-class.

A two ring fish with a hyaline edge, caught in December 1969, would be assigned to the 1967 year-class.

Since year-class assignment is determined by time of ring formation, and because of a difference in time of apparent ring formation in otoliths and scales we decided to compare them by assigning both an artificial birthdate of January 1, thus avoiding confusion resulting from different birthdates. All otoliths were examined to determine if a ring had just been formed or was about to be formed. A year-class assignment was then made accordingly.

3.4. RESULTS

The age and year-class of each fish as determined from both scales and otoliths were recorded and the data for the two years, 1966 and 1967, analyzed separately. Direct comparison of the ages assigned to each fish by the two methods yielded agreements of 79% for the 1966 samples and 72% for the 1967 samples. Mosher (1954) reported 68% agreement for sardine scale and otolith readings.

Age compositions were constructed for each method, using all samples for which both a scale age and an otolith age were available (Table 11). A chi-square test for independence was then applied to the two sets of age composition data with the hypothesis that: The age composition obtained from the samples is independent of the method of age determination. We accepted the hypothesis for both years, at a significance level of 0.05.

The age-length frequencies obtained by the two methods were compared (Figures 19 and 20), and found to be remarkably similar, except for the 4- and 5-year-old fish.

Acceptance of this hypothesis says essentially that the two methods are comparable, and can be used with equal confidence. It does not rule out the possibility of their being quite different. The analysis of the two years of data and the age-length frequencies gives confidence that they are indeed comparable. The data reveal no consistent differences upon which to judge which method is most accurate.

TABLE 11

Anchovy Age Composition Derived From Scales and Otoliths for Two Years of Live Bait Sampling in Southern California

	Age						Total
	0	I	II	III	IV	V+	
1966							
Scales: Number	53	127	138	82	25	5	430
Percent	12.3	29.5	32.0	19.06	5.8	1.1	99.9
Otoliths: Number	67	157	114	63	20	9	430
Percent	15.6	36.5	26.5	14.6	4.6	2.1	99.9
1967							
Scales: Number	82	122	258	198	68	16	744
Percent	11.0	16.4	34.7	26.6	9.1	2.1	99.9
Otoliths: Number	102	157	224	162	66	33	744
Percent	13.7	21.1	30.1	21.7	8.8	4.4	99.9

TABLE 11

Anchovy Age Composition Derived From Scales and Otoliths for Two Years of Live Bait Sampling in Southern California

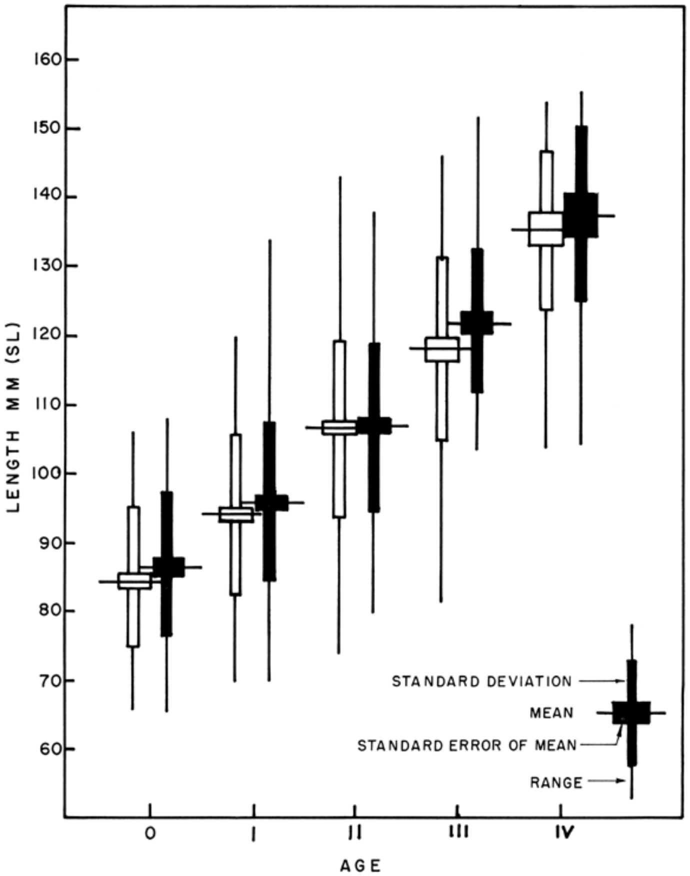

FIGURE 19. Range in length at age data derived from scale and otolith samples of the 1966 southern California live-bait fishery. Open figures scales, closed figures otoliths.

FIGURE 19. ***Range in length at age data derived from scale and otolith samples of the 1966 southern California live-bait fishery. Open figures scales, closed figures otoliths.***

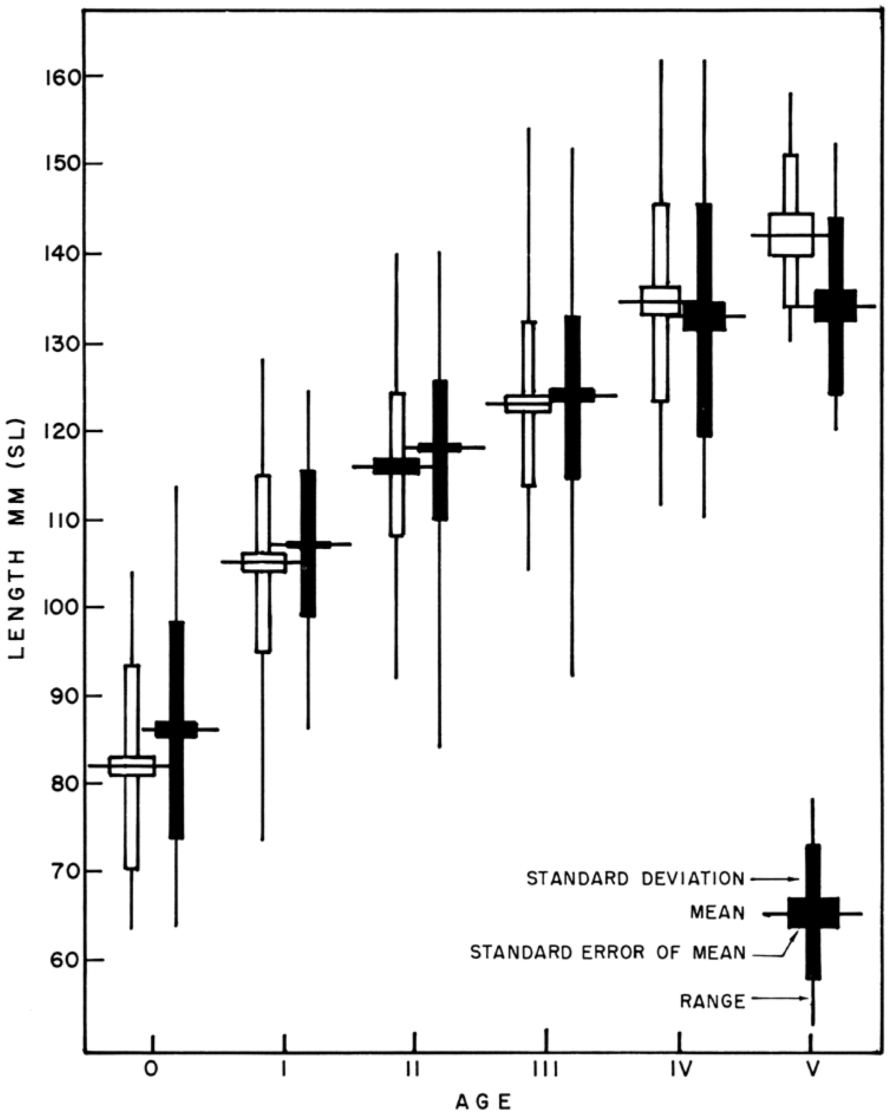

FIGURE 20. Range in length at age data derived from scale and otolith samples of the 1967 southern California live-bait fishery. Open figures scales, closed figures otoliths.

FIGURE 20. ***Range in length at age data derived from scale and otolith samples of the 1967 southern California live-bait fishery. Open figures scales, closed figures otoliths.***

3.5. DISCUSSION AND CONCLUSIONS

Up to 40% of the fish in samples taken from the reduction fishery are without scales that can be used for age determination while at least one readable otolith can be obtained from each fish. These facts weigh heavily in the choice between the two methods. The increase in sampling necessary to offset the lack of age data when scales are used is quite costly in terms of sampling and processing time and manpower.

Scales require considerable preparation before they are ready for reading, otoliths do not.

A comparison of age composition data derived from scale and otolith readings revealed that although the age compositions did not agree completely, differences were not sufficient to reject our hypothesis that: The age composition obtained from the samples is independent of the method used.

For these reasons we recommend that otoliths be used in age composition studies of the anchovy reduction fishery.

3.6. REFERENCES

Chugunova, N. I. 1959. Age and growth studies in fish. Translated from the Russian by D. Yasski, 1963. Washington, D.C., Natl. Sci. Found. 132 p. (Israel Program for Scientific Translations, Jerusalem).

Clark, Frances N., and Julius B. Phillips. 1952. The northern anchovy (Engraulis mordax mordax) in the California fishery. Calif. Fish and Game, 38(2) :189–207.

Felin, Frances E., and Julius B. Phillips. 1948. Age and length composition of the sardine catch off the Pacific coast of the United States and Canada, 1941–42 through 1946–47. Calif. Dept. Fish and Game, Fish Bull., (69) :1–112.

Fitch, John E. 1951. Age composition of the southern California catch of Pacific mackerel 1939–40 through 1950–51. Calif. Dept. of Fish and Game, Fish Bull., (83) :1–73.

Jensen, Albert C. 1965. A standard terminology and notation for otolith readers. Inter. Comm. Northwest Atlant. Fish., Res. Bull., (2) :5–7.

Miller, Daniel J. 1955. Studies relating to the validity of the scale method for age determination of the northern anchovy (Engraulis mordax) . *In* Age determination of the northern anchovy, Engraulis mordax. Calif. Dept. Fish and Game, Fish Bull., (101) :7–34.

Mosher, Kenneth H. 1954. Determining the age of adult Pacific sardines. *In* Age determinations of Pacific sardines from otoliths. U.S. Dept. of Interior, Fish and Wildlife Ser. Spec. Sci. Rept., (37) :1–6.

Schott, Jack W. 1965. A visual aid for age determination of immersed otoliths. Calif. Fish and Game, 51(1) :56.

Walford, Lionel A., and Kenneth H. Mosher. 1943. Determination of the age of juveniles by scales and otoliths. *In* Studies on the Pacific pilchard or sardine (Sardinops caerulea) . U.S. Fish and Wild. Ser., Spec. Sci. Rept., (37) :31–95.

Wood, Richard and Alec R. Strachan. 1970. A description of the northern anchovy live bait fishery, and the age and length composition of the catch during the seasons 1957–58 through 1964–65. Calif. Fish and Game, 56(1) : 49–59.

3.7. APPENDIX A
A Standard Terminology and Notation for Otolith Readers
(from Jensen 1965)

APPENDIX A

A Standard Terminology and Notation for Otolith Readers

(from Jensen 1965)

Table 1. Terminology to describe otolith marks.

Term	Synonyms	Definition
Zones	Annuli, rings, year marks, bands, winter rings, summer rings, growth zones	Bands of concentric hyaline or opaque material seen in otolith and counted for age determination.
Check	Check marks, check rings, false ring, secondary ring, secondary zone, split	Hyaline matter not counted in age determination. Checks are sometimes indistinct, discontinuous, or, in the judgment of the reader, do not meet the criteria established for identification as a year mark.
Nucleus	Focus, center, origin, kernel	The central area of the otolith bounded by the first check or zone. (In most laboratories the center of the otolith is not fully understood, thus many biologists have not yet developed a firm definition for this term.)
Opaque edge	Summer edge, fast-growth edge, dense edge	The otolith periphery composed primarily of white material that blocks light.
Hyaline edge	Winter edge, slow-growth edge, transluscent edge	The otolith periphery composed primarily of translucent material that passes light.
Spawning zones	Spawning marks, spawning rings	Hyaline and opaque zones formed in the otolith from the onset of sexual maturity. The hyaline spawning zones are clear and usually free of opaque material; in many species (e.g., cod) they are frequently broader than the subsequent opaque zones.

Table 1. Terminology to describe otolith marks.

Table 2. Notation to describe the character of otolith zones.

Notation and term	Definition
0—Good	The zones are plainly visible with generally good definition between hyaline and opaque zones. Any check readily identifiable as such. The reader has a good degree of confidence in resulting age determination.
1—Fair	The zones are visible but not well defined. There are many checks present. The reader has fair degree of confidence in resulting age determination. In many otoliths the zones may form distinct patterns that make reliable age determinations feasible.
2—Poor	The zones are vaguely marked. Otoliths with zones so poorly defined as to be undecipherable, or where the age is merely estimated, are placed in this category.

Table 2. Notation to describe the character of otolith zones.

Table 3. Notation to describe type of edge growth.

Notation	Abbreviation	Definition
1	Hn	Narrow hyaline zone at edge
2	Hw	Wide hyaline zone at edge
3	On	Narrow opaque zone at edge
4	Ow	Wide opaque zone at edge

Table 3. Notation to describe type of edge growth.

4. SIZE AND AGE COMPOSITION OF NORTHERN ANCHOVIES (ENGRAULIS MORDAX) IN THE CALIFORNIA ANCHOVY REDUCTION FISHERY FOR THE 1965–66, 1966–67, AND 1967–68 SEASONS

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4.1. INTRODUCTION

The data presented here are the results of sampling anchovy reduction landings during the 1965–66, 1966–67 and 1967–68 reduction seasons (November 12, 1965 through April 30, 1966, October 1, 1966 through April 30, 1967 and September 15, 1967 through May 15, 1968 respectively). Fishery sampling is one of the phases of fishery monitoring and biological studies conducted by the anchovy project (Messersmith, 1969). The primary objective of fishery sampling is to estimate the contribution of year-classes in the catch in terms of pounds and numbers. This report is the first in a projected series on this subject.

Two fishery areas are represented: central California, or Northern Permit Area, with landings at Monterey and Moss Landing; and southern California, or Southern Permit Area, with landings at Port Hueneme and San Pedro (Messersmith, 1969). Southern California landings accounted for 99% and 79% respectively of the total landings during the first two seasons. The third fishing season failed to develop in southern California and 87% of the total landings were made in central California. Essentially all of the remaining 13% were landed at Port Hueneme (Table 12).

TABLE 12

Anchovy Reduction Landings by Area and Season

	Season		
	1965–66	1966–67	1967–68
Southern California			
Tons	16,467.2	29,594.4	852.0
Percent	98.8	78.6	13.0
Central California			
Tons	375.3	8,020.5	5,654.7
Percent	2.2	21.4	87.0
Total			
Tons	16,842.5	37,614.9	6,506.7
Percent	100.0	100.0	100.0

TABLE 12

Anchovy Reduction Landings by Area and Season

4.2. ACKNOWLEDGMENTS

Appreciation is gratefully extended to those people whose assistance in the data collection and analysis was invaluable. Marvin Ogg collected samples at San Pedro, while Julius Phillips, Richard Parrish and Cress Lundstrom sampled central California landings. John Gingerich sampled at Port Hueneme. The scale readers, John MacGregor and Makoto Kimura of the U.S. Bureau of Commercial Fisheries, La Jolla, and C. E. Blunt, Jr., Patrick O'Brien, James Hardwick, Alexander Petrovich and Richard Wood of the Department carried out a large portion of the age determination work. James D. Messersmith offered advice and encouragement on the manuscript that Kathleen O'Rear and Micaela Wolfe typed for publication.

4.3. SAMPLING

4.3.1. 1965–66 Season (October 15, 1965 through April 30, 1966)

During this first season samples consisted of 50 fish selected at random from vessels fishing together in one area. If more than one area was fished on a given day a 50 fish sample was selected from each area of fishing. The standard lengths of all 50 fish were taken; from 10 of these, also selected at random, we obtained otoliths and scales for age determination, individual weights, sex, and female state of maturity.

4.3.2. 1966–67 Season (October 1, 1966 through April 30, 1967)

4.3.2.1. Southern California

During the second season we followed new sampling plans designed by Patrick K. Tomlinson (unpublished ms.). These were developed and based on data and experience gained during the first season. At San Pedro we used a stratified, two-stage sampling plan. Landings to be sampled were divided into strata of 5,000 short tons. Each 5,000 ton stratum was divided into unequal first-stage units consisting of boat loads. Twenty first-stage units were selected with replacement so that a boat load's probability of selection was proportional to its size. Each first-stage unit consisted of two clusters of 500+ g (1.1 pounds) each drawn from a random one-sixth of each load. In practice, 20 random numbers between 1 and 5,000 were picked with replacement to determine the tonnage to be sampled.

A cumulative total of tons landed was kept for each stratum. The fishing boats hailed their tonnage to shore by radio before arriving at the unloading dock. The sampler was then able to record the boats' tonnages as they were hailed, in order of arrival time, and select the boat or boats containing the ton(s) to be sampled.

Each cluster was processed by placing every other fish on a balance until 500 g was most closely approached. The 500 g cluster was then divided into secondary samples of 250 g (0.55 pounds) ± one fish, where each fish was chosen with equal probability and without replacement. The discarded 250 g portion was weighed and counted as a control, and the standard length of each fish was recorded. Each fish in the retained 250 g portion was measured, weighed, sexed, the state of maturity of both males and females recorded, and otoliths and scales taken for age determination.

At Port Hueneme samples were taken on an irregular basis. Landings at both Port Hueneme and San Pedro were generally caught at or near the same location. Early in the season, however, landings were made at Port Hueneme only. Landings here were approximately 10% of the coastwide total the first two seasons, and 13% the third. These data are included, although they are insufficient for year-class composition analysis.

The data from each stratum were treated independently in the analysis, and the results combined into season totals.

4.3.2.2. Central California

In central California we did not know the expected arrival time of the boats or the tonnages they had caught. Since the fleet is small in number (Messersmith, 1969), and the vessels operate in the vicinity of each other, we attempted to obtain one sample from a purse seiner and one from a lampara boat on each day of landing. We used a two-stage sampling plan with primary units (boat loads) of unequal size chose with equal probability and replacement. Secondary units of equal weight, 1,000 g (2.2 pounds) ± one fish, were chosen with equal probability and without replacement. Each stratum consisted of one month's catch. Processing of the sample was as in southern California except that a single 1,000 g cluster was taken rather than two 500 g clusters; 800 g (1.76 pounds) were measured only, and the remaining 200 g (0.44 pounds) were processed completely, as in southern California. The data were stratified by month, and the strata combined into a season report.

4.3.3. 1967–68 Season (September 15, 1967 through May 15, 1968)

Southern California landings were not sampled during this third season because landings did not reach the minimum required by the sampling plan. Central California sampling followed the same plan used during the previous season.

4.4. SIZE AND AGE COMPOSITION OF THE CATCH

4.4.1. Size Composition

The anchovies sampled ranged from 78 mm SL (3.1 inches) to 166 mm SL (6.5 inches) in southern California and from 90 mm SL (3.5 inches) to 172 mm SL (6.8 inches) in central California (Tables 13–19). In both areas the overlap in lengths of adjacent age groups was considerable. A fish of a given length could fall within one standard deviation of the mean length of as many as four age-groups (Figures [21] and [22]). Because of this overlap some 150,000 measurements, collected during the two seasons and without supplemental data, were not included in our analysis, and the procedure of taking lengths without supplemental information was omitted from our sampling plan.

Comparison of length-at-age data for the southern and central California fishery shows that central California samples were as much

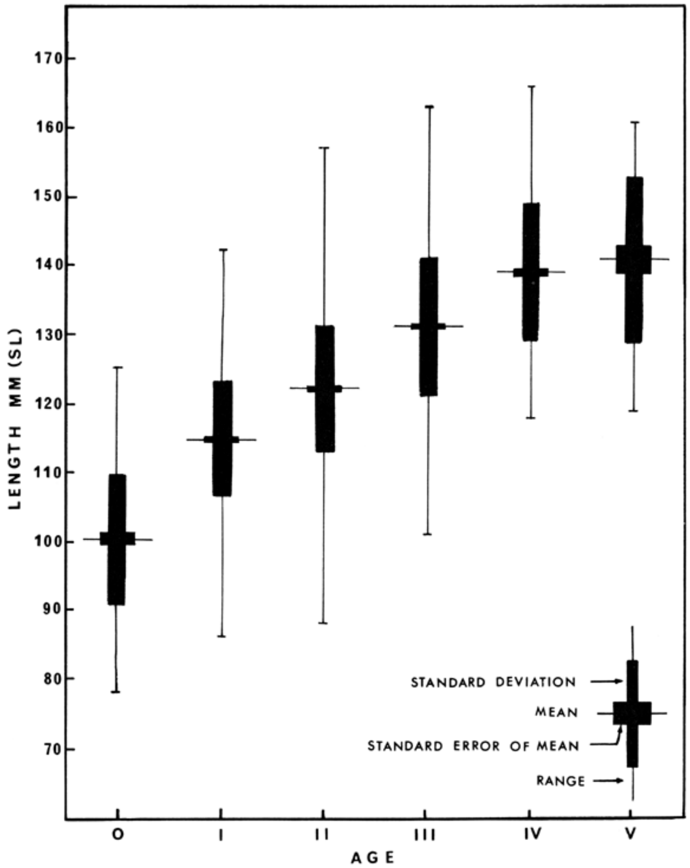

FIGURE 21. Range in length at age data for the 1966–67 southern California anchovy samples.

FIGURE 21. ***Range in length at age data for the 1966–67 southern California anchovy samples.***

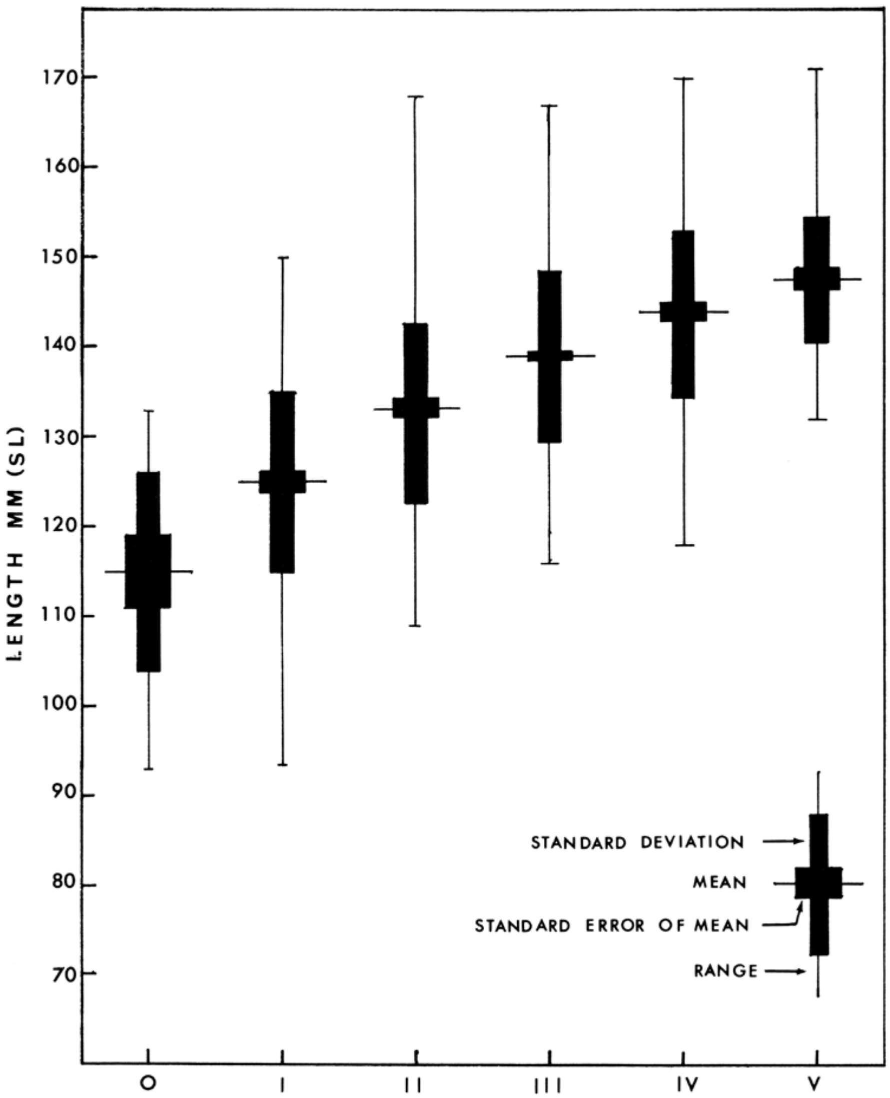

FIGURE 22. Range in length at age data for the 1966–67 central California anchovy samples.

FIGURE 22. ***Range in length at age data for the 1966–67 central California anchovy samples.***

as 5 to 10 mm larger at a given age (Figures 21 and 22; Tables 13 14 15 16 17 18 19). Reasons behind this difference are not readily apparent.

4.4.2. Age Composition

Both scales and otoliths were taken for age determination from samples obtained during the three seasons. Scales were normally used for age determination during the first two seasons; however, otoliths were used when scales were not available since both are valid means of determining the ages of anchovies (Collins and Spratt, 1969). During the third season otoliths were used exclusively for age determination

The scales were read by the co-operative reading program of the Department of Fish and Game and the U.S. Bureau of Commercial Fisheries at La Jolla, using criteria developed by Miller (1955). The otoliths were read only by the author and Jerome D. Spratt of the California Department of Fish and Game.

4.4.2.1. 1965–66 Season

In southern California, estimates of numbers and pounds landed by year-class were computed from the sample data using the double sampling method of Mackett (1963). Two-year-olds dominated the catch both in number (49%) and pounds (40%) (Tables 20 and 21).

Year-class catch estimates were not computed from central California data because the weights of individual fish were not obtained. However, the raw data are included (Table 17).

4.4.2.2. 1966–67 and 1967–68 Seasons

During the 1966–67 season, year-class estimates of the southern California catch were based on a stratified two-stage sampling plan, with units selected with probability proportional to size. The estimator is discussed by Sukhatme (1954–8.9 and 8.10). Two-year-old fish again dominated the southern California landings accounting for 38% of the catch by number and 37% by weight (Tables 20 and 21).

Central California landing estimates for both seasons were calculated from the samples by using the method described by Cochran (1963 section 11.6) with the assumption that all $S_{2i}^2 = 0$. In this area landings were dominated by three-year-old fish, with four-year-olds a relatively close second. The two year-classes accounted for 68% of the catch by number, and 69% by weight during the 1966–67 season. During the 1967–68 season, three-year-olds continued their domination; however, two-year-olds were of second importance. Together they accounted for 57% of the number landed and 56% of the weight (Tables 22 and 23).

Fish less than 5-inches TL (108 mm SL) are restricted in the catch by a legal minimum size limit.

4.5. SEX RATIOS, NUMBERS AND POUNDS

Data collected on sex and weight of sampled anchovies from both southern and central California provided an excellent opportunity to add a third estimate of the sex ratio to those of Clark and Phillips (1952) and MacGregor (1968). Clark and Phillips estimated a female: male ratio of 1.4:1 in the central California fishery during 1946–51 and 1.2:1 in the southern California live-bait fishery during 1947–51. MacGregor used Miller's (1955) data to conclude that the ratio was 1.3:1 statewide during the 1952–53 and 1953–54 seasons. Data from the 1966–67 season were used to estimate the numbers and pounds landed by sex for the southern California fishery, while data from both the 1966–67 and 1967–68 seasons were used for the central California fishery (Table 24). The data for southern California, taken during the period of peak spawning activity (November through April), yield a numerical ratio of 1.6 females for every male. The weight ratio (pounds of females:pounds of males) was 1.8:1. The two years of data from the central California fishery yielded different ratios. The 1966–67 data had a numerical ratio of 1.4:1 and a weight ratio of 1.5:1. The 1967–68 data had a numerical ratio of 1.3:1 and a weight ratio of 1.4:1. The discrepancy between numerical and weight ratios was due to a high proportion of females at the older ages as well as a tendency for females to be slightly larger than males at any given age (Figure 23) . Clark and Phillips (1952) reported a similar size discrepancy between the sexes.

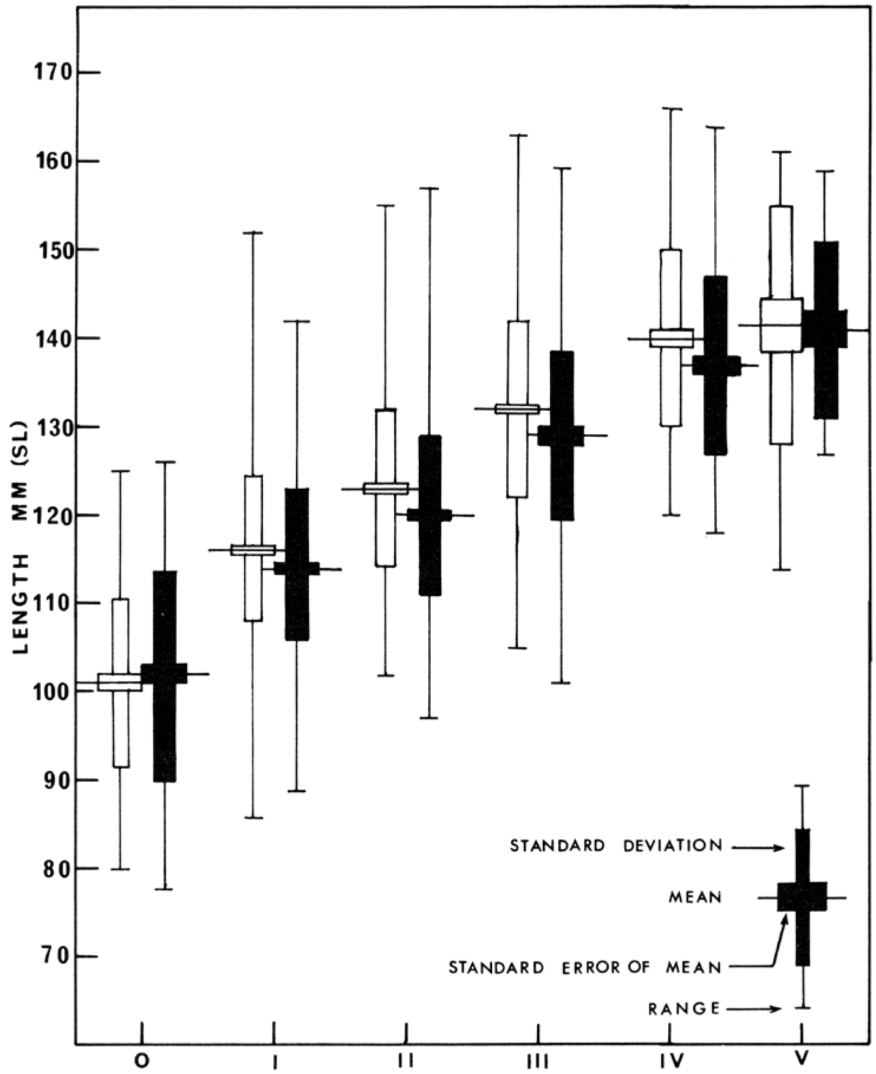

FIGURE 23. Range in length at age data for females (open figures) and males (closed figures) in 1966–67 southern California anchovy samples.

FIGURE 23. ***Range in length at age data for females (open figures) and males (closed figures) in 1966–67 southern California anchovy samples.***

4.6. WEIGHT-LENGTH RELATIONSHIP

Weight-length curves for southern and central California were calculated from individual fish length (mm SL) and weights (g) for the 1966–67 fishery; the only one for which extensive data for both areas were available. Separate calculations were made for males and females (Table 25). In southern California length and weight curves were based on 1,513 females and 926 males.

They are: Female $W = .000010933L^{2.98408}$ Male $W = .000008056L^{3.04859}$ Although the constants differ, plots of the two curves are very similar.

Central California data yielded weight curves of: Female $W = .00003582L^{2.74285}$ Male $W = .00002657L^{2.80529}$ for 407 females and 270 males.

The plots of these formulas are close to the one given by Clark and Phillips (1952). Central California fish are slightly less robust than those in southern California; but, since the samples were taken during a period of high spawning activity, the differences may be due to the weight of the sex products if the peak spawning period in central California were slightly later than in southern California.

The southern California curves were based on individuals from 97 mm to 161 mm SL, while the central California curves included individuals from 80 mm to 171 mm SL.

4.7. REFERENCES

Clark, Frances N., and Julius B. Phillips. 1952 . The northern anchovy (Engraulis mordax mordax) in the California fishery. Calif. Fish and Game, 38(2) :189–207.

Cochran, W. G. 1963. Sampling techniques. 2nd Ed., John Wiley and Sons, New York. 413 p.

Collins, Robson A., and Jerome D. Spratt. 1969. Age determination of the northern anchovy from otoliths. *In* The northern anchovy (Engraulis mordax) and its fishery, 1965–1968. Calif. Dept. Fish and Game, Fish Bull., (147) : 39–55.

MacGregor, John S. 1968. Fecundity of the northern anchovy, Engraulis mordax Girard. Calif. Fish and Game, 54(4) :281–288.

Mackett, D. J. 1963. A method of sampling the Pacific albacore (Thunnus germo) catch for relative age composition. Proc. World Sci. Meet. Biol. Tunas and Rel. Sp., FAO. Fish Rpt., 3(6) :1355–1366.

Messersmith, James D. 1969. A review of the California anchovy fishery and results of the 1965–66 and 1966–67 reduction seasons. *In* The northern anchovy (Engraulis mordax) and its fishery, 1965–1968. Calif. Dept. Fish and Game, Fish Bull., (147) : 6–32.

Miller, Daniel J. 1955. Studies relating to the validity of the scale method for age determination of the northern anchovy. *In* Age determination of the northern anchovy, Engraulis mordax. Calif. Dept. Fish and Game, Fish Bull., (101) :6–36.

Sukhatme, Pandurang. 1954. Sampling theory of surveys with applications. Iowa State College Press, Ames, Iowa. 491 p.

TABLE 13

Length Composition of Year Classes of San Pedro Landings in the Southern California Reduction Fishery, 1965–66 Season

Standard length (mm)	Year Class (Age)							
	1965 (0)	1964 (I)	1963 (II)	1962 (III)	1961 (IV)	1960 (V)	1959 (VI)	Total Aged
80	1	--	--	--	--	--	--	1
82	--	--	--	--	--	--	--	--
84	1	--	--	--	--	--	--	1
86	1	--	--	--	--	--	--	1
88	2	1	--	--	--	--	--	3
90	--	--	--	--	--	--	--	--
92	--	--	--	--	--	--	--	--
94	1	--	--	--	--	--	--	1
96	2	1	1	--	--	--	--	4
98	2	2	--	--	--	--	--	4
100	--	2	2	--	--	--	--	4
102	2	1	2	--	--	--	--	5
104	1	4	3	1	--	--	--	9
106	1	4	4	--	--	--	--	9
108	1	3	3	2	--	--	--	9
110	--	6	15	3	1	--	--	25
112	--	4	10	2	--	--	--	16
114	--	9	28	2	1	--	--	40
116	--	14	39	8	--	--	--	61
118	1	10	26	5	--	--	--	42
120	2	8	38	13	1	1	--	63
122	--	4	32	14	2	--	--	52
124	1	2	24	13	2	--	--	42
126	--	4	21	11	2	--	--	38
128	--	2	13	9	2	--	--	26
130	--	--	14	14	3	--	--	31
132	--	1	4	9	4	1	--	19
134	--	3	13	8	2	1	--	27
136	--	1	7	7	3	1	--	19
138	--	2	2	11	3	1	--	19
140	--	--	2	7	5	1	--	15
142	--	--	1	5	7	--	--	13
144	--	--	--	5	8	1	--	14
146	--	--	--	2	4	2	1	9
148	--	--	1	3	2	--	--	6
150	--	--	--	2	1	--	--	3
152	--	--	--	1	1	--	--	2
154	--	--	--	1	1	1	--	3
Totals	19	88	305	158	55	10	1	636
Mean Length	101	116	118	129	137	139	146	--

TABLE 13

Length Composition of Year Classes of San Pedro Landings in the Southern California Reduction Fishery, 1965–66 Season

TABLE 14

Length Composition of Year Classes of San Pedro Landings in the Southern California Reduction Fishery, 1966–1967 Season

Standard Length (mm)	Year Class (Age)							
	1966 (0)	1965 (I)	1964 (II)	1963 (III)	1962 (IV)	1961 (V)	1960 (VI)	Total Aged
78	1	--	--	--	--	--	--	1
80	1	--	--	--	--	--	--	1
82	1	--	--	--	--	--	--	1
84	2	--	--	--	--	--	--	2
86	4	1	--	--	--	--	--	5
88	10	1	1	--	--	--	--	12
90	7	1	--	--	--	--	--	8
92	12	2	--	--	--	--	--	14
94	8	3	--	--	--	--	--	11
96	16	5	--	--	--	--	--	21
98	16	3	1	--	--	--	--	20
100	13	8	1	--	--	--	--	22
102	12	9	4	1	--	--	--	26
104	12	19	7	--	--	--	--	38
106	7	20	20	2	--	--	--	49
108	11	36	23	2	--	--	--	72
110	3	41	35	4	--	--	--	83
112	7	59	58	6	--	--	--	130
114	6	42	48	7	--	1	--	104
116	5	65	76	16	--	1	--	163
118	2	61	66	12	1	--	--	142
120	2	52	80	26	1	--	--	161
122	3	45	92	48	5	1	--	194
124	2	20	65	41	4	--	--	132
126	1	20	98	58	2	1	--	180
128	--	17	77	61	18	2	--	175
130	--	11	76	69	16	1	--	173
132	--	9	45	59	12	2	--	127
134	--	5	27	35	9	--	--	77
136	--	3	29	33	15	2	--	82
138	--	1	14	37	10	1	--	63
140	--	2	15	25	10	5	--	57
142	--	1	13	36	19	1	--	70
144	--	--	4	9	18	--	1	32
146	--	--	4	18	7	3	--	32
148	--	--	3	8	13	4	--	28
150	--	--	4	6	9	3	--	22
152	--	1	1	6	15	2	--	25
154	--	--	2	5	8	1	1	17
156	--	--	1	6	2	1	--	10
158	--	--	1	3	5	1	2	12
160	--	--	--	4	2	2	--	8
162	--	--	--	2	1	1	--	4
164	--	--	--	1	1	--	--	2
166	--	--	--	--	1	--	--	1
Totals	164	563	991	646	204	37	4	2,609
Mean Length	100	115	122	131	140	141	153	--

TABLE 14

Length Composition of Year Classes of San Pedro Landings in the Southern California Reduction Fishery, 1966–1967 Season

TABLE 15

Length Composition of Year Classes of Port Hueneme Landings in the Southern California Reduction Fishery, 1965–66 Season

Standard length (mm)	Year Class (Age)							
	1965 (0)	1964 (I)	1963 (II)	1962 (III)	1961 (IV)	1960 (V)	1959 (VI)	Total Aged
114	--	--	--	--	--	--	--	--
116	--	--	2	--	--	--	--	2
118	--	--	--	1	--	--	--	1
120	--	1	3	1	--	--	--	5
122	--	1	1	--	--	--	--	2
124	--	--	4	3	--	--	--	7
126	--	1	2	--	--	--	--	3
128	--	--	5	1	1	--	--	7
130	--	--	3	4	1	--	--	8
132	--	--	2	6	--	--	--	8
134	--	--	3	4	1	--	--	8
136	--	--	5	3	--	--	--	8
138	--	--	1	2	1	--	--	4
140	--	--	2	4	--	--	--	6
142	--	--	1	4	1	--	1	7
144	--	--	--	5	3	1	--	9
146	--	--	1	3	1	--	--	5
148	--	--	--	3	1	--	--	4
150	--	--	1	1	1	--	--	3
152	--	--	--	--	--	1	--	1
154	--	--	--	--	3	--	--	3
156	--	--	1	1	2	--	--	4
158	--	--	1	1	1	--	--	3
160	--	--	--	1	1	--	--	2
Totals	0	3	38	48	18	2	1	110
Mean Length	0	123	132	138	147	148	142	

TABLE 15

Length Composition of Year Classes of Port Hueneme Landings in the Southern California Reduction Fishery, 1965–66 Season

TABLE 16

Length Composition of Year Classes of Port Hueneme Landings in the Southern California Reduction Fishery, 1966–67 Season

Standard length (mm)	Year Class (Age)							
	1966 (0)	1965 (I)	1964 (II)	1963 (III)	1962 (IV)	1961 (V)	1960 (VI)	Total Aged
102	--	1	--	--	--	--	--	1
106	--	1	--	--	--	--	--	1
108	--	2	--	--	--	--	--	2
110	--	2	2	--	--	--	--	4
112	--	4	3	1	--	--	--	8
114	--	2	4	2	--	--	--	8
116	--	5	3	1	--	--	--	9
118	--	2	8	2	--	--	--	12
120	--	2	8	--	--	--	--	10
122	--	1	6	9	1	--	--	17
124	--	2	8	8	2	--	--	20
126	--	2	7	9	2	--	--	20
128	--	1	11	13	1	--	--	26
130	--	2	8	11	1	--	--	22
132	--	--	10	9	--	--	--	19
134	--	--	4	13	--	--	--	17
136	--	1	9	9	--	--	--	19
138	--	1	4	5	1	--	1	12
140	--	1	5	2	1	--	--	9
142	--	1	5	2	2	--	--	10
144	--	1	3	3	--	--	--	7
146	--	--	2	7	1	--	--	10
148	--	--	3	2	1	--	--	6
150	--	--	1	3	2	--	--	6
152	--	--	--	--	--	--	--	0
154	--	--	--	2	1	--	--	3
156	--	--	--	--	1	--	--	1
158	--	--	1	4	--	--	--	5
160	--	--	--	--	1	--	--	1
164	--	--	--	--	1	--	--	1
170	--	--	--	1	--	--	--	1
Totals	0	34	115	118	19	0	1	287
Mean Length	0	120	129	133	140	0	138	

TABLE 16

Length Composition of Year Classes of Port Hueneme Landings in the Southern California Reduction Fishery, 1966–67 Season

TABLE 17

Length Composition of Year Classes in the Central California Reduction Fishery, 1965–66 Season

Standard Length (mm)	Year Class (Age)							
	1965 (0)	1964 (I)	1963 (II)	1962 (III)	1961 (IV)	1960 (V)	1959 (VI)	Total Aged
110	--	1	--	--	--	--	--	1
112	--	--	--	--	--	--	--	--
114	--	--	--	--	--	--	--	--
116	--	--	1	--	--	--	--	1
118	--	--	2	--	--	--	--	2
120	--	--	1	--	--	--	--	1
122	--	2	--	--	--	--	--	2
124	--	2	2	1	--	--	--	5
126	--	1	2	--	--	--	--	3
128	--	2	1	1	--	--	--	4
130	--	--	2	--	2	--	--	4
132	--	1	1	1	1	--	--	4
134	--	1	2	2	2	--	--	7
136	--	--	1	1	--	--	--	2
138	--	--	3	3	--	--	--	6
140	--	1	1	3	3	--	--	8
142	--	--	--	3	1	--	--	4
144	--	--	1	1	3	3	--	8
146	--	1	--	3	1	2	1	8
148	--	--	--	--	2	2	--	4
150	--	--	--	3	2	1	--	6
152	--	--	1	2	6	--	1	10
154	--	--	--	4	2	--	--	6
156	--	--	1	3	1	1	--	6
158	--	--	--	--	--	--	--	--
160	--	--	--	2	--	--	--	2
162	--	--	--	1	--	--	--	1
164	--	--	--	--	1	--	--	1
166	--	--	--	--	--	--	--	--
Totals	0	12	22	34	27	9	2	106
Mean Length	0	128	132	145	146	147	149	

TABLE 17

Length Composition of Year Classes in the Central California Reduction Fishery, 1965–66 Season

TABLE 18

Length Composition of Year Classes in Anchovy Samples in the Central California Reduction Fishery, 1966–67 Season

Standard Length (mm)	Year Class (Age)							
	1966 (0)	1965 (I)	1964 (II)	1963 (III)	1962 (IV)	1961 (V)	1960 (VI)	Total Aged
94	1	--	--	--	--	--	--	1
96	--	--	--	--	--	--	--	--
98	--	1	--	--	--	--	--	1
100	--	--	--	--	--	--	--	--
102	--	--	--	--	--	--	--	--
104	--	--	--	--	--	--	--	--
106	--	1	--	--	--	--	--	1
108	--	2	--	--	--	--	--	2
110	--	--	--	--	--	--	--	--
112	--	3	1	--	--	--	--	4
114	2	2	3	--	--	--	--	7
116	3	2	1	1	--	--	--	7
118	--	7	3	2	1	--	--	13
120	--	4	3	2	1	--	--	10
122	1	1	7	1	--	--	--	10
124	--	9	8	3	--	--	--	20
126	--	10	16	5	1	--	--	32
128	--	1	8	12	1	--	--	22
130	--	5	13	16	5	--	--	39
132	1	5	18	34	5	1	--	64
134	--	4	14	25	12	1	--	56
136	--	1	9	35	6	--	--	51
138	--	3	11	18	6	3	--	41
140	--	--	12	29	12	3	--	56
142	--	--	5	30	21	1	--	57
144	--	2	5	20	13	7	2	49
146	--	1	7	18	21	5	1	53
148	--	1	5	9	12	7	--	34
150	--	1	2	9	20	6	--	38
152	--	--	5	14	10	6	--	35
154	--	--	1	8	10	1	--	20
156	--	--	--	7	4	6	--	17
158	--	--	--	3	3	3	--	9
160	--	--	1	3	4	1	--	9
162	--	--	--	1	1	--	--	2
164	--	--	--	1	--	--	--	1
166	--	--	--	3	1	--	--	4
168	--	--	--	2	--	--	--	2
170	--	--	--	--	1	--	--	1
172	--	--	--	--	--	1	--	1
Totals	8	66	158	311	171	52	3	769
Mean Length	115	125	133	138	144	148	144	

TABLE 18

Length Composition of Year Classes in Anchovy Samples in the Central California Reduction Fishery, 1966–67 Season

TABLE 19

Length Composition of Year Classes in the Central California Reduction Fishery, 1967–68 Season

Standard length (mm)	Year Class (Age)							
	1967 (0)	1966 (I)	1965 (II)	1964 (III)	1963 (IV)	1962 (V)	1961 (VI)	Total
90	--	1	--	--	--	--	--	1
92	--	1	--	--	--	--	--	1
94	--	--	--	--	--	--	--	--
96	--	--	--	--	--	--	--	--
98	--	--	--	--	--	--	--	--
100	1	4	--	--	--	--	--	5
102	1	2	--	--	--	--	--	3
104	--	1	--	--	--	--	--	1
106	--	1	--	--	--	--	--	1
108	2	2	--	--	--	--	--	4
110	4	2	--	--	--	--	--	6
112	3	1	--	--	--	--	--	4
114	1	4	--	--	--	--	--	5
116	--	5	1	--	--	--	--	6
118	1	4	1	--	--	--	--	6
120	--	4	4	1	--	--	--	9
122	1	7	10	--	--	--	--	18
124	2	6	3	3	--	--	--	14
126	2	11	9	3	--	--	--	25
128	--	8	5	5	1	--	--	19
130	--	7	12	7	--	--	--	26
132	--	4	9	4	3	--	--	20
134	--	2	14	18	2	--	--	36
136	--	3	6	16	10	--	--	35
138	--	1	9	20	8	--	--	38
140	--	--	11	21	11	2	--	45
142	--	--	8	20	9	3	--	40
144	--	--	2	9	17	1	--	29
146	--	--	--	10	9	7	--	26
148	--	--	2	4	18	5	1	30
150	--	--	1	4	9	8	1	23
152	--	--	--	7	10	11	--	28
154	--	--	--	--	5	1	1	7
156	--	--	--	1	3	3	1	8
158	--	--	--	1	1	6	--	8
160	--	--	--	--	1	4	1	6
162	--	--	--	--	3	3	--	6
164	--	--	--	--	3	--	--	3
166	--	--	--	--	2	1	--	3
Totals	18	81	107	154	125	55	5	545
Mean Length	114	121	133	140	146	152	154	

TABLE 19

Length Composition of Year Classes in the Central California Reduction Fishery, 1967–68 Season

TABLE 20

Estimated Numbers of Anchovies Landed for Reduction by Age and Year Class, Southern California 1965–66 and 1966–67 Seasons

	Age							Total
	0	I	II	III	IV	V	VI	
1965–66 Season								
Year class	1965	1964	1963	1962	1961	1960	1959	
Number	35,431,000	116,287,000	383,249,000	184,638,000	58,903,000	10,455,000	931,000	789,894,000
Standard deviation	13,390,248	19,016,914	19,756,673	14,475,995	7,925,695	3,403,077	939,119	----
Percent of landings	4.48	14.72	48.51	23.37	7.46	1.32	0.12	99.98
1966–67 Season								
Year class	1966	1965	1964	1963	1962	1961	1960	
Number	73,636,000	245,610,000	408,471,000	246,425,000	80,517,000	14,814,000	1,704,000	1,071,177,000
Standard deviation	21,109,863	19,307,776	17,639,448	10,559,725	7,466,082	2,588,923	822,157	----
Percent of landings	6.87	22.92	38.13	23.00	7.51	1.38	0.15	99.96

TABLE 20

Estimated Numbers of Anchovies Landed for Reduction by Age and Year Class, Southern California 1965–66 and 1966–67 Seasons

TABLE 21

Estimated Weight of Year Classes Landed for Reduction, Southern California 1965–66 and 1966–67 Seasons

	Age							Total
	0	I	II	III	IV	V	VI	
1965–66 Season								
Year class	1965	1964	1963	1962	1961	1960	1959	
Weight in pounds	754,000	5,188,000	12,338,000	8,363,000	3,078,000	636,000	44,000	30,401,000
Percent of landings	2.48	17.06	40.58	27.50	10.12	2.09	0.14	99.97
1966–67 Season								
Year class	1966	1965	1964	1963	1962	1961	1960	
Weight in pounds	1,656,000	8,650,000	17,174,000	12,698,000	5,124,000	993,000	140,000	46,435,000
Standard deviation	390,325	631,855	627,023	642,198	508,333	188,511	69,356	----
Percent of landings	3.56	18.62	36.98	27.34	11.03	2.13	0.13	99.96

TABLE 21

Estimated Weight of Year Classes Landed for Reduction, Southern California 1965–66 and 1966–67 Seasons

TABLE 22

Estimated Numbers of Anchovies Landed by Age and Year Class, Central California 1966–67 and 1967–68 Seasons

	Age							Total
	0	I	II	III	IV	V	VI	
1966–67 Season								
Year class	1966	1965	1964	1963	1962	1961	1960	
Number	1,065,000	19,376,000	56,104,000	134,443,000	88,608,000	29,243,000	934,000	329,773,000
Standard deviation	827,502	4,530,368	6,074,987	8,602,329	9,058,458	4,642,994	672,877	----
Percent of landings	0.32	5.87	17.01	40.76	26.86	8.86	0.28	99.96
1967–68 Season								
Year class	1967	1966	1965	1964	1963	1962	1961	
Number	3,359,000	30,348,000	62,885,000	73,334,000	46,012,000	21,735,000	1,334,000	239,007,000
Standard deviation	1,657,311	16,644,840	16,797,374	16,932,501	9,180,978	8,768,214	685,204	----
Percent of landings	1.40	12.69	26.31	30.68	19.25	9.09	6.55	99.97

TABLE 22

Estimated Numbers of Anchovies Landed by Age and Year Class, Central California 1966–67 and 1967–68 Seasons

TABLE 23

Estimated Weight of Year Classes Landed, Central California 1966–67 and 1967–68 Seasons

	Age							Total
	0	I	II	III	IV	V	VI	
1966–67 Season								
Year class	1966	1965	1964	1963	1962	1961	1960	
Pounds	38,000	889,000	3,010,000	8,011,000	5,890,000	2,120,000	58,000	20,018,000
Standard deviation	28,536	218,290	322,267	493,146	606,338	341,005	43,140	----
Percent of landings	0.18	4.44	15.03	40.01	29.42	10.59	0.29	99.96
1967–68 Season								
Year class	1967	1966	1965	1964	1963	1962	1961	
Pounds	112,000	1,226,000	3,320,000	4,388,000	3,053,000	1,573,000	111,000	13,783,000
Standard deviation	52,054	640,267	754,943	930,531	539,142	531,778	57,443	----
Percent of landings	0.81	8.89	24.08	31.83	22.15	11.40	0.80	99.96

TABLE 23

Estimated Weight of Year Classes Landed, Central California 1966–67 and 1967–68 Seasons

TABLE 24

Sex and Biomass Ratio in Number and Pounds for the 1966–67 and 1967–68 Anchovy Reduction Seasons

Sex Ratio (Numbers)

	Southern California	Central California	
	1966–67	1966–67	1967–68
Males			
Number	413,079,288	137,365,338	103,194,993
Percent	38.5	41.6	43.41
Females			
Number	651,423,454	191,886,733	134,079,792
Percent	60.8	58.2	56.41
Unknown			
Number	6,674,450	520,921	410,656
Percent	0.6	0.2	0.17
Females: Males	1.58:1	1.39:1	1.30:1

Sex Ratio (Weight)

	Southern California 1966–67	Central California 1966–67	Central California 1967–68
Males			
Pounds	16,680,353	7,881,202	5,633,412
Percent	35.9	39.4	40.84
Females			
Pounds	29,540,328	12,104,473	8,149,697
Percent	63.6	60.4	59.09
Unknown			
Pounds	214,699	42,369	8,872
Percent	0.5	0.2	0.06
Females: Males	1.77:1	1.54:1	1.40:1

TABLE 24

Sex and Biomass Ratio in Number and Pounds for the 1966–67 and 1967–68 Anchovy Reduction Seasons

TABLE 25

Weight at Length for Anchovies Caught Off Central and Southern California During the 1966–67 Reduction Season

Standard length mm	Weight in grams			
	Central California[1]		Southern California[2]	
	Female	Male	Female	Male
50	1.637	1.551	1.284	1.218
55	2.127	2.026	1.707	1.628
60	2.700	2.586	2.213	2.123
65	3.363	3.237	2.809	2.710
70	4.121	3.985	3.505	3.397
75	4.979	4.836	4.306	4.192
80	5.943	5.796	5.221	5.103
85	7.018	6.870	6.256	6.139
90	8.210	8.065	7.419	7.308
95	9.522	9.386	8.718	8.618
100	10.960	10.839	10.160	10.076
105	12.530	12.428	11.752	11.692
110	14.235	14.161	13.503	13.474
115	16.081	16.042	15.418	15.429
120	18.072	18.076	17.506	17.567
125	20.213	20.269	19.774	19.895
130	22.509	22.626	22.229	22.422
135	24.964	25.153	24.879	25.156
140	27.582	27.855	27.730	28.105
145	30.369	30.737	30.792	31.278
150	33.329	33.803	34.070	34.684
155	36.465	37.060	37.572	38.330
160	39.783	40.512	41.306	42.226
165	43.286	44.165	45.278	46.379
170	46.980	48.023	49.497	50.798
175	50.868	52.091	53.969	55.491
180	54.954	56.375	58.702	60.467
185	59.243	60.879	63.703	65.735
Number Fish	407	270	1,513	926

[1] Range in length sampled: Females 97–171 mm SL, Males 106–157 mm SL.
[2] Range in length sampled: Females 80–161 mm SL, Males 84–159 mm SL.

TABLE 25

Weight at Length for Anchovies Caught off Central and Southern California During the 1966–67 Reduction Season

5. PROGRESS REPORT ON ANCHOVY TAGGING OFF CALIFORNIA AND BAJA CALIFORNIA, MARCH 1966 THROUGH MAY 1969

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5.1. INTRODUCTION

The dramatic increase in the northern anchovy (Engraulis mordax) population (Ahlstrom et al., 1967), and the authorization of a potentially large anchovy reduction fishery created a need for more information on the biology, population structure, and movements of anchovies. of immediate concern was the extent of anchovy movement. Specifically, might an intensive fishery decimate a local population or would it draw from a much larger population from other areas? Such knowledge is vital if the fishery is to be managed wisely. To help meet this need a tagging study was initiated in January 1966 as part of a larger project of fishery monitoring and biological studies (Messersmith, 1969).

Anchovies are used for live and dead bait, human consumption as canned or fresh fish, canned pet food, and reduction to meal and oil. Tags are recovered by means of magnets installed in the reduction plants. The rate of tag recovery is influenced by tagging and natural mortality, availability of tagged fish to the fishery, the amount of fish processed and its condition or degree of decomposition, changing conditions within the plants which cause fluctuating recovery rates, and the efficiency of the recovery system. Tagging mortality and the efficiency of the recovery system are the only parts of the complex that we can alter to improve tag recovery rates.

Reports have been published on the experimental development of tagging methods (Vrooman, et al., 1966) and on the field methods of catching, holding, and tagging anchovies and recovering the tags (Wood and Collins, 1969). This paper reports: (i) the results of the first 3 years of tagging, March 1966 through May 1969; and (ii) special studies to assess the cause and rate of tag loss occurring in the reduction plants.

5.2. ACKNOWLEDGMENTS

We wish to express our gratitude to the many people who have made a contribution to this paper: John L. Baxter (California Department of Fish and Game) for editorial guidance; Andrew M. Vrooman (U.S. Bureau of Commercial Fisheries) and Richard Wood (California Department of Fish and Game) for background information; Kathleen O'Rear and Micaela Wolfe who typed the manuscript; Ingrid L. K. Iverson who prepared Figure 25; and especially

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to the many fishermen, cannery personnel, and Department personnel who participated in the tagging and tag recovery operations.

5.3. RESULTS

During the 3-year period, March 1966 to May 1969, 380,815 anchovies were tagged and 1,080 tags were recovered. About 39% (422) of these recoveries demonstrated coastwise movements in a northerly or southerly direction. Fish from southern California (Port Hueneme to San Diego) and from San Francisco Bay were shown to contribute to the Monterey Bay fishery, anchovies from central California (San Francisco Bay to Morro Bay) to the southern California fishery, and southern California fish to the Ensenada fishery.

An indication of the rate of travel that an anchovy may attain was revealed when a tag from a fish released off San Diego was recovered at Monterey 129 days later. This fish had traveled at least 370 miles at a rate of nearly 3 miles per day.

Tagged fish were at liberty from 3 to 1,130 days. Tags from anchovies released in southern California were recovered at Monterey Bay during the fall and early winter (September to January), suggesting a northerly movement during late summer. The recovery in southern California during the late winter and spring (February to May) of tags from fish released in central California suggests a southerly movement during the winter.

The relatively low level of the reduction fishery during the period covered by this report has precluded the use of tagging data for estimating population size or mortality rates.

Low initial tag recovery rates stimulated efforts to improve recovery techniques. New and more efficient permanent magnets were purchased by the Department and installed in the plants increasing the recovery rate to between 36% and 100%. The average recovery rate at one plant was increased from 14% to 98%.

5.4. TAGGING

To test the hypothesis that anchovies move between major fishing areas, tagging was conducted at various localities along the coast from San Francisco Bay to Ensenada. Tagging localities and dates were to a large extent governed by the local availability of anchovies and by the activities of live bait fishermen and dealers, who supplied most of the fish to be tagged (Wood and Collins, 1969).

On March 14, 1966, the first anchovies were tagged with serially numbered, internal tags and released following methods described by Vrooman, et al. (1966) and Wood and Collins (1969). During the next 3 years, through May 1969, 380,815 anchovies were tagged and released in the folowing areas: 83,279 in San Francisco Bay; 5,390 in Monterey Bay; 55,838 off Morro Bay, 31,274 off Port Hueneme, 37,202 off San Pedro; 35,997 in Los Angeles-Long Beach Harbor; 17,821 off Santa Catalina Island; 15,554 off San Clemente Island; 83,186 off San Diego; and 15,274 off Ensenada (Figure 24 and Table 26).

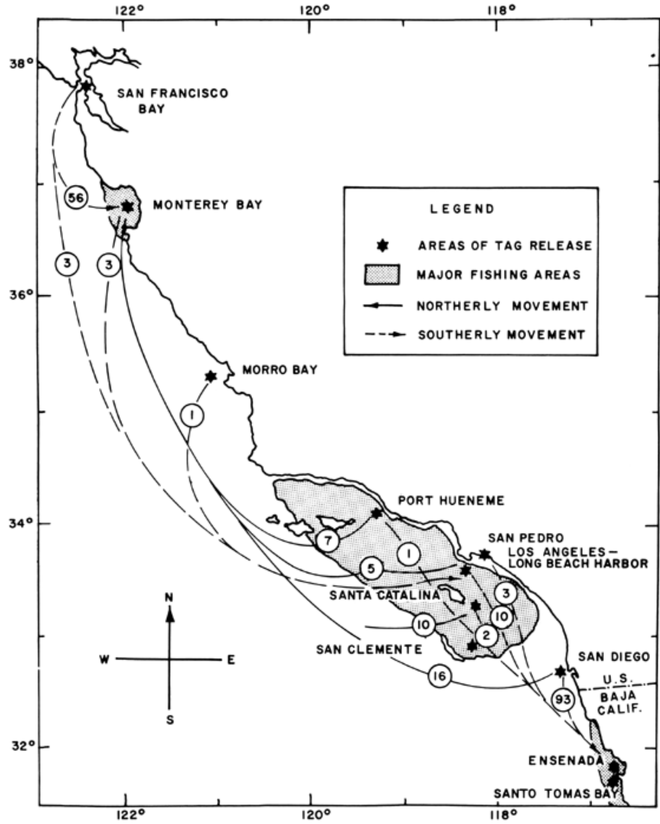

FIGURE 24. Major movements of anchovies tagged and recaptured March 14, 1966 through May 31, 1969.

FIGURE 24. ***Major movements of anchovies tagged and recaptured March 14, 1966 through May 31, 1969.***

TABLE 26

A Summary of Anchovy Tag Release and Recovery Data March 1966 Through May 1969

Release		Number Recovered by Area				
Area/Year	Number	Monterey Bay	Port Hueneme	Terminal Island	Ensenada	Total
San Francisco Bay						
July 1966	1,990	8	0	0	0	8
August 1967	3,500	5	0	0	0	5
November 1967	14,995	7	0	0	0	7
May 1968	26,208	8	0	1	0	9
June 1968	14,736	19	0	0	0	19
August 1968	5,464	3	0	0	0	3
September 1968	16,386	6	0	2	0	8
Total	83,279	56	0	3	0	59
Monterey Bay						
July 1966	5,390	9	0	3	0	12
Morro Bay						
August 1967	1,996	0	0	0	0	0
September 1967	9,989	0	0	1	0	1
January 1968	4,920	0	0	0	0	0
June 1968	12,222	0	0	0	0	0
September 1968	26,711	0	0	0	0	0
Total	55,838	0	0	1	0	1
Port Hueneme						
March 1966	3,186	2	6	9	0	17
April 1966	3,728	3	4	9	0	16
October 1966	24,360	2	18	55	1	76
Total	31,274	7	28	73	1	109
Santa Catalina Island						
April 1966	7,977	4	2	30	0	36
October 1966	9,844	6	6	42	2	56
Total	17,821	10	8	72	2	92
San Clemente Island						
May 1966	1,448	0	0	10	0	10
September 1966	8,655	0	0	0	0	0
October 1966	5,451	0	0	9	0	9
Total	15,554	0	0	19	0	19
Los Angeles-Long Beach Harbor						
November 1966	12,450	0	1	90	1	92
January 1968	11,734	0	0	9	2	11
April 1968	5,378	0	3	10	0	13
May 1968	6,435	0	5	14	0	19
Total	35,997	0	9	123	3	135
San Pedro						
March 1966	7,962	5	4	177	0	186
October 1967	24,824	0	1	7	9	17
January 1968	4,416	0	1	5	1	7
Total	37,202	5	6	189	10	210

TABLE 26
A Summary of Anchovy Tag Release and Recovery Data March 1966 Through May 1969

TABLE 26—Continued

A Summary of Anchovy Tag Release and Recovery Data March 1966 Through May 1969

Release		Number Recovered by Area				
Area/Year	Number	Monterey Bay	Port Hueneme	Terminal Island	Ensenada	Total
San Diego						
May 1966	3,914	0	0	8	0	8
June 1967	14,972	13	10	26	19	68
October 1967	3,000	0	0	4	4	8
November 1967	17,211	0	0	1	3	4
January 1968	12,497	1	2	8	16	27
February 1968	18,592	1	11	54	47	113
April 1968	13,000	1	10	78	4	93
Total	83,186	16	33	179	93	321
Ensenada						
May 1966	3,859	0	0	0	3	3
March 1969	1,450	0	0	0	22	22
April 1969	9,965	0	0	0	97	97
Total	15,274	0	0	0	122	122
Total all areas	380,815	103	84	662	231	1,080

TABLE 26

A Summary of Anchovy Tag Release and Recovery Data March 1966 Through May 1969

5.5. TAG RECOVERY

Anchovy tags were recovered on permanent magnets in seven California reduction plants, which processed over 80% of the anchovies caught off California, and three Ensenada, Baja California reduction plants that processed an unknown amount caught off nothern Baja California. The California plants are located as follows: two in the Monterey Bay area, one near Port Hueneme, and four at Terminal Island (Los Angeles Harbor).

Although all reduction plants handle fish in a similar manner each plant has its own peculiarities. In general, commercial fishermen deliver anchovies to the reduction plants where the fish are off-loaded with vacuum pumps, and are transported via a series of conveyors, flumes, and dewatering screens to a weighing tower and thence to fish pits where they are accumulated (Figure 25). When a sufficient quantity of fish has been accumulated it is conveyed to a steam-cooker, a press to remove oil and water, and finally dried and ground to meal.

In addition to tagging mortality, the success of a tagging program is determined, in large measure, by the success of the recovery system. In turn, the successful tag recovery system is one which extracts tags from the fish and/or the meal as well as recovering tags that have fallen from mutilated or partially decomposed anchovies but are still in the delivery or reduction system.

In each reduction plant, during the first two reduction seasons, 1965–66 and 1966–67, the only magnet available for tag recovery was the one near the final stage of the reduction process (M_4, Figure 25) between the drier and the mill used for fine grinding. The debris attracted to this magnet was removed by the plant operators at least once a day. During the reduction season the debris was collected daily by a

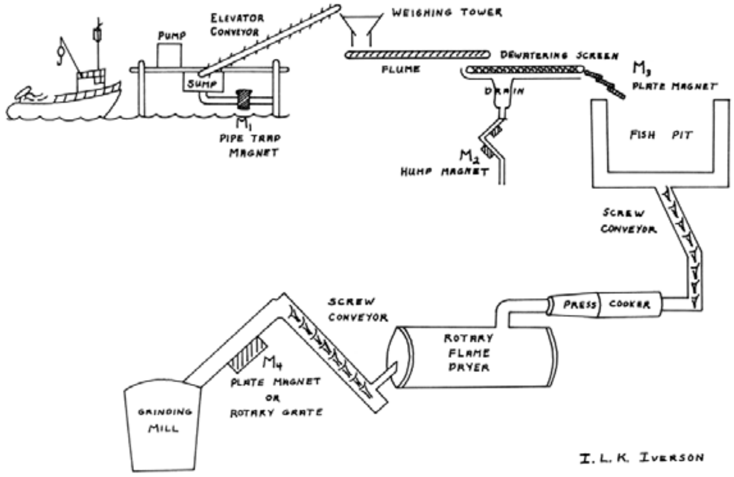

FIGURE 25. Flow diagram of the reduction system from the fishing vessel to the grinding mill, and locations of tag recovery magnets. Magnets are: M_1 pipe trap; M_2 hump; M_3 plate; M_4 plate or rotating grate. Plate magnet (M_4) was installed by the processor to remove metal scrap from the meal and was the only source of tag recoveries during the first two reduction seasons. The more efficient rotating grate magnets have since been installed at two plants.

FIGURE 25. ***Flow diagram of the reduction system from the fishing vessel to the grinding mill, and locations of tag recovery magnets. Magnets are: M_1 pipe trap; M_2 hump; M_3 plate; M_4 plate or rotating grate. Plate magnet (M_4) was installed by the processor to remove metal scrap from the meal and was the only source of tag recoveries during the first two reduction seasons. The more efficient rotating grate magnets have since been installed at two plants.***

Department of Fish and Game employee and weekly during the remainder of the year. The debris was sifted to remove fish meal and other extraneous matter. Then the remaining scrap was examined carefully for tags.

Tests conducted during these first two seasons, and discussed in a later section, revealed that between and within any one plant, recovery rates were very erratic ranging from 2% to 82%. Additional magnets were installed at the end of the 1966–67 reduction season in an attempt to increase the rate of recovery. Magnets were installed wherever we believed there was a practical chance to recover tags: from effluent water (M_1 and M_2 Figure 25); from individual fish as they were discharged onto de-watering screens or into fish pits (M_3); and from the meal prior to the final grinding process (M_4). In addition to increasing tag recovery rates we believed that magnets placed in the flume or at the end of the de-watering screens (M_3) would pull tags out of some of the tagged fish passing over them; thus the recovered tag could be related to the boat being unloaded and ultimately to the precise area and time of capture.

The 1967–68 fishery in southern California was a failure due mainly to economic problems and a low availability of fish, and no testing was conducted. During the 1968–69 season 38% of test-tag recoveries and 28% of California tag recoveries from ocean caught fish were obtained from these magnets. These tests also revealed that recoveries on magnet M_3, and from a given unloading, could occur over a 14-day period. The cause of this delay is not understood and requires further study before the condition may be corrected or predicted.

For these reasons only fish movement into a fishing area has been examined in detail. For example, if a tagged anchovy was released outside the southern California anchovy fishing grounds and recovered at a Terminal Island reduction plant, it would indicate that the tagged fish had moved north or south into the fishing grounds. On the other hand a tagged fish released and recaptured within the same fishing area is not considered to have moved. of course, it could have left the area temporarily and returned. Using these criteria only 422 of 1,080 tag recoveries show northerly or southerly movement; 210 moved considerable distances (Figure 24 and Appendix B) while the remainder (212) were released off San Diego and were recovered by the San Pedro or Port Hueneme fisheries.

5.6. ANCHOVY MOVEMENT

5.6.1. Northerly

Northerly movements of anchovies were demonstrated by 250 tag recoveries. Two hundred twelve of these represented a relatively minor movement from the San Diego area to the southern California fishing grounds (as boats landing fish at Port Hueneme and Terminal Island usually fish the same general areas, recoveries from reduction plants at both ports are combined for the purpose of this analysis). These recoveries occurred throughout the reduction season.

Major northerly movements were shown by the recovery of 38 tags at Monterey plants from releases at various points in southern California. These tags were recovered between September 3 and January 23.

5.6.2. Southerly

Southerly movements were demonstrated by 172 tag recoveries. Fifty-six of these were from fish released in San Francisco Bay and recovered at Monterey reduction plants. These recoveries took place throughout the year. Three tags from San Francisco Bay, three from Monterey Bay, and one from Morro Bay releases were recovered at southern California plants between February 23 and May 5. An additional 109 tags released in southern California were recovered at Ensenada. These recoveries took place throughout the year with the majority (63) occurring in April and May.

5.6.3.Offshore to Inshore

offshore to inshore movement was documented during a tag recovery experiment at Terminal Island reduction plants. During the experiment, 6 tons of anchovies caught in Los Angeles Harbor were sluiced over a magnet installed in an unloading flume. Five tags from fish released off San Clemente and Santa Catalina Islands were retained by the flume magnet. This is the only known landing for reduction of anchovies caught in the harbor, an area closed to reduction fishing.

5.6.4. Inshore to offshore

From the 35,997 tagged anchovies released within Los Angeles-Long Beach Harbor, 132 were caught on southern California fishing grounds and three were recovered off Baja California.

Actually, a great many of our tag recoveries from fish tagged off southern California have demonstrated offshore movement. Most of the anchovies tagged in this area have been released within 3 miles of shore, an area in which fishing for reduction is not permitted.

5.7. DISCUSSION

Our dependence on the reduction fishery for tag recoveries places some severe limitations on the program in determining the extent and timing of anchovy movements. We can expect no returns from tagged fish moving outside the range of fishing boats that deliver to the reduction plants. For example, we have no returns from north of Monterey Bay, although we know that at times anchovies are abundant off the coasts of Washington and Oregon.

A clear understanding of the timing of anchovy movements is hampered by the lack of a year-round reduction fishery in California. The season is closed from May 15 to August 1 in central California and from May 15 to September 15 in southern California. During the closed season, the few tags recovered are from canning activities in the Monterey area. In addition about 74% of the season's catch in central California has occurred during the period August through December, while about 78% of the landings in southern California have been from January through May.

In spite of these difficulties, tag returns have shown that anchovies move quite widely within the area covered by the program. Interchange of fish between the major fishing grounds of central California and southern California has been documented, though the portion of the anchovy population involved is not yet known. The data suggest that the major northerly component of this interchange occurs during the summer and the major southerly component during the winter.

We have also shown that anchovies from at least as far north as Port Hueneme contribute to the Ensenada fishery. As of May 31, 1969, no tags from fish released off Ensenada have been recovered at California plants. However, most of the Ensenada tagging was conducted within 2 months of the end of the 1968–69 California reduction season and we expect recoveries from these releases in the 1969–70 seasons.

of 55,838 tags released off Morro Bay, only one has been recovered. As yet, we are unable to explain this low recovery rate.

5.8. SPECIAL STUDIES OF TAG LOSS

Present anchovy tag recovery and analysis problems parallel those faced by Clark and Janssen (1945) when tagging Pacific sardines (Sardinops caeruleus) . Their introduction to the subject is as appropriate now as it was then.

“"For many years fisheries students throughout the world have been tagging fish to better understand migrations and more recently to measure the intensity of fishing. In most of these programs the recovery of tags has depended on the tag being observed on a recaptured fish and returned by the observer to the investigator. Under this method a certain number of tagged fish are recaptured but the tag is not returned to the proper authority, either because it was not seen or because the finder was not sufficiently interested. The proportion of tags thus lost is not known. To know its magnitude would aid materially in the analysis of results, but to measure its fluctuations between time intervals is of even greater importance. If the loss of recaptured tags is a fairly constant factor, calculations can be carried on under the assumption that this loss is operating equally at all times. If, on the other hand, the loss of recaptured tags varies from time to time this variation may be sufficient to affect seriously the conclusions drawn from tagging experiments."”

To measure this loss and to obtain data on which to base recommendations for improving recovery efficiency, we conducted a number of tag recovery experiments. For several reasons, including lack of funds, inconclusive results, and a low tonnage fishery, the experiments have not resulted in significant changes in the recovery system or in determining the recovery rate at each reduction plant. These tests have demonstrated that within-plant recovery rates are not constant and they have pointed out problems that must be solved if tagging is to be used for estimating anchovy population size and mortality rates for an expanded fishery.

5.8.1. Reduction Plant Losses

Tags in fish processed at reduction plants are subject to loss in a variety of ways. To identify and measure these losses we first had to determine if dead fish could be tagged (test tags) and used to simulate tag recovery rates of tagged anchovies caught in the ocean. To do this, live anchovies were tagged (live tags) and kept alive until the tag incision healed. When the test was conducted dead anchovies were tagged and both types were introduced dead into the reduction system at the offloading docks.

A Chi-square test revealed no significant difference in recovery rates between the two groups. About 39% (71 of 180) of the test tags and 36% (72 of 200) of the live tags were recovered. Therefore, we concluded that test tags could be used in experiments to determine tag losses in the plants. Since this conclusion is vital to the validity of subsequent tests replicate experiments should be conducted so that there is no question that our conclusion is correct.

5.8.1.1. Sites of Tag Loss in the Reduction System

In one experiment tags were introduced at various points in the reduction system in an attempt to pinpoint the site of tag loss. Anchovies containing test tags were introduced at the following points: (i) into the hold of an unloading fishing boat; (ii) into the conveyor that transports fish to the weighing tower; (iii) into the flume leading to the fish pit; (iv) and into the fish pit. Although there was no significant difference between recoveries from the various points (34 of 50 tags at the boat, 35 of 50 at the conveyor, 38 of 50 at the flume, and 41 of 50 at the fish pit), the tag recovery rate increased the closer the introductory points were to the recovery magnet (M_4, Figure 25).

This type of experiment should be repeated in each of the reduction plants and should consider the state of decomposition of the fish, whether the equipment is in continuous operation, and whether there is a constant flow of fish through the system.

5.8.1.2. Magnitude of Loss

Sixteen experiments were conducted with test tags at seven of eight California reduction plants to get some measure of tag loss within the plants. The resulting data indicated that tag recovery rates fluctuated drastically between 2% and 82%. To increase the tag recovery rate and, in special cases, aid in determining the exact area of capture, the Department purchased various models of permanent magnets and installed them in the reduction plants, as follows: (i) at location M_1 (Figure 25) in two plants; (ii) location M_2 in one plant; (iii) location M_3 in two plants; (iv) and location M_4 in two plants.

After the magnets were installed 20 additional test tag experiments were conducted. A comparison of the two series of experiments revealed that the majority of test tags (96% before and 98% after) were still recovered within 8 days of being introduced into the plants. of greater significance was the increase of recovery rates in all plants which now varied between 36% and 100%. The present reduction plants and equipment are 20 to 30 years old and in some cases are in a poor state of repair which may result in a depressed recovery rate.

The recovery rate at a reduction plant in the Monterey area increased from 14% (six tests) to 94% (three tests) when the plate magnet at M_4 was replaced with an Eriez rotating grate magnet. Nine tests conducted at a major Terminal Island reduction plant yielded recovery rates, from all magnets combined, that varied from 46% to 82%. We have no measure of tag recovery rates at Ensenada reduction plants.

Ninety-eight percent of all test tags recovered on magnet M_3 were recovered on the day of the test; the remaining 2% were recovered up to 14 days later. This suggests a 98% chance that tags recovered on magnet M_3 will be from fish unloaded that same day and therefore the area of capture is wherever the unloading vessels had been fishing. If the fleet had operated within a restricted area for the preceding 14 days the precise area of capture is even more certain.

5.8.1.3. Effects of Debris on Magnet Efficiency

One test was conductd to determine the effects of debris accumulation on the retention power of a magnet. Near the end of a "normal" day of reduction, and prior to cleaning the plate magnet (M_4), seven groups of 25 tags each, one group every 15 minutes, were scattered on a screw conveyor 2 feet before the tag-recovery magnet. At the end of the day the magnet was cleaned and 167 of the 175 tags were recovered. By the fourth day 172 tags had been recovered; three tags were never found. The three missing tags were from the last two groups of 25 tags.

The implication is that the debris accumulated during this "normal" day of operation had no significant effect on the tag-recovery rate. While it is interesting to speculate the significance of the three tags that were never recovered, it is equally important to determine why tags introduced so near the magnet took up to 4 days to move 2 feet up the conveyor. Replicate tests are needed to validate these results, and to identify and eliminate the cause of the delay and tag loss.

5.8.2. Losses During Canning

When fish are prepared for canning they are first decapitated and eviscerated. The trimmed body is canned and the offal is sluiced to a de-watering screen and passed into a fish pit. From there it is conveyed into the reduction plant along with whole fish also destined for reduction. The effects of the canning operation on tag recovery rates were tested only once. Ten fish containing test tags were introduced prior to the fishcutting machines. Two tags remained in the fish destined for the can, one was recovered 38 days later in the reduction plant, and seven tags were never recovered. This recovery rate was not typical of test tag experiments in the reduction plant where the recovery rate during this period was approximately 94% (Richard H. Parrish, pers. commun.).

The cause of this loss is difficult to identify but is important because by law, a portion of the landings taken for canning may be (and are) used for reduction as long as a specified number of cases of canned fish are produced for each ton landed. For this reason the weight of fish used for canning (and tag recoveries associated therewith) cannot be identified separately from that used for reduction. Thus, we do not know how much of the 4,339 tons taken for canning during the period of this report (March 13, 1966-May 31, 1969) was reduced as whole fish and may have contributed measurably to tag recoveries, and how much was actually canned and therefore contributed few tag returns.

5.8.3. Discussion

Studies of tag losses in reduction plants and canneries have led to a better understanding of the problems of tag recovery and some areas that need additional study; a fact of substantial value if the level of harvest is increased and tagging studies are conducted for purposes of estimating anchovy population size and mortality rates. To make such studies meaningful, it is essential that we be able to evaluate the magnitude and variability of tag losses.

5.9. REFERENCES

Ahlstrom, E. H., J. L. Baxter, J. D. Isaacs, and P. M. Roedel. 1967. Report of the CalCOFI Committee. Calif. Mar. Res. Comm., Calif. Coop. Oceanic Fish. Invest., Rept., 11:5–9.

Clark, Frances N., and John F. Janssen, Jr. 1945. Measurement of the losses in the recovery of sardine tags. *In* Results of tagging experiments in California waters on the sardine (Sardinops caerulea) . Calif. Div. Fish and Game, Fish Bull., (61):63–90.

Messersmith, James D. 1969. A review of the California anchovy fishery and results of the 1965–66 and 1966–67 reduction seasons. *In* The northern anchovy (Engraulis mordax) and its fishery, 1965–1968. Calif. Dept. Fish and Game, Fish Bull., (147): 6–32.

Vrooman, Andrew M., Pedro A. Paloma, and Rómulo Jordán. 1966. Experimental tagging of the northern anchovy. Calif. Fish and Game, 52(4):228–239.

Wood, Richard, and Robson A. Collins. 1969. First report of anchovy tagging in California. Calif. Fish and Game, 55(2):141–148.

5.10. APPENDIX B
Tagging and Recovery Data for 210 Anchovy Tag Recoveries Demonstrating Major Movement
March 14, 1966 to May 31, 1969

APPENDIX B

Tagging and Recovery Data for 210 Anchovy Tag Recoveries Demonstrating Major Movement

March 14, 1966 to May 31, 1969

Tagging Location	Tagging Date	Recovery Date	Number of Tags Recovered	Recovery Location*
San Francisco Bay	23 July 66	3 May 67	1	M
		24 Nov 67	1	M
		29 Nov 67	2	M
		2 Jan 68	1	M
		23 Jan 68	1	M
		1 April 68	1	M
		20 Sept 68	1	M
	24–26 Aug 67	22 Dec 67	1	M
		2 Jan 68	1	M
		25 Jan 68	2	M
		10 April 68	1	M
	21–23 Nov 67	29 Jan 68	2	M
		4 April 68	1	M
		22 Aug 68	1	M
		3 Sept 68	1	M
		23 Sept 68	1	M
		13 Oct 68	1	M
	14–16 May 68	23 Sept 68	1	M
		19 Nov 68	1	M
		9 Dec 68	2	M
		22 April 69	1	M
		29 April 69	1	S.C.
		2 May 69	3	M
	5–6 June 68	3 Sept 68	4	M
		16 Sept 68	1	M
		20 Sept 68	4	M
		23 Sept 68	1	M
		26 Sept 68	1	M
		19 Nov 68	4	M
		9 Dec 68	1	M
		22 April 69	2	M
		2 May 69	1	M
	16–17 Aug 68	19 Nov 68	1	M
		22 April 69	1	M
		2 May 69	1	M
	10–12 Sept 68	19 Nov 68	1	M
		22 Nov 68	1	M
		9 Dec 68	2	M
		27 Mar 69	1	S.C.
		22 April 69	1	M
		2 May 69	1	M
		8 May 69	1	S.C.
Santa Cruz	21–27 July 66	23 Feb 67	1	S.C.
		7 Mar 67	1	S.C.
		14 April 67	1	S.C.
Morro Bay	26–29 Sept 67	5 May 69	1	S.C.
Port Hueneme	22, 25 Mar 66	11 Oct 67	1	M
		30 Oct 67	1	M
	5–6 April 66	21 Oct 66	1	M
		26 Oct 66	1	M
		1 Nov 67	1	M
	18–28 Oct 66	26 Oct 67	1	M
		1 Nov 67	1	M
		24 April 68	1	E
San Pedro	14–17 Mar 66	26 Oct 66	1	M
		1 Nov 67	1	M
		22 Dec 67	1	M
		23 Jan 68	1	M
		3 Sept 68	1	M
	10–13 Oct 67	14 Mar 68	1	E
		22 April 68	2	E
		26 April 68	1	E
		30 April 68	1	E
		7 May 68	1	E

APPENDIX B—Cont'd.

APPENDIX B—Continued

Tagging and Recovery Data for 210 Anchovy Tag Recoveries Demonstrating Major Movement

March 14, 1966 to May 31, 1969

Tagging Location	Tagging Date	Recovery Date	Number of Tags Recovered	Recovery Location*
San Pedro—Continued				
		18 May 68	1	E
		25 May 68	1	E
		31 May 68	1	E
	9 Jan 68	25 May 68	1	E
Los Angeles-Long Beach	14–22 Nov 66	31 July 67	1	E
Harbor	10–12 Jan 68	27 Mar 68	1	E
		7 June 68	1	E
Catalina	26–30 April 66	4 Jan 67	1	M
		9 Oct 67	1	M
		26 Oct 67	1	M
		5 Dec 67	1	M
	2–3 Oct 66	14 Jan 67	1	E
		3 Feb 67	1	E
		5 Oct 67	1	M
		11 Oct 67	1	M
		26 Oct 67	1	M
		30 Oct 67	1	M
		13 Nov 67	1	M
		5 Dec 67	1	M
San Diego	5–7 June 67	16 Sept 67	1	E
		28 Sept 67	1	E
		12 Oct 67	1	M
		16 Oct 67	2	M
		26 Oct 67	1	M
		27 Oct 67	2	M
		30 Oct 67	1	M
		1 Nov 67	1	M
		7 Dec 67	1	M
		2 Jan 68	2	M
		9 Jan 68	1	M
		2 Feb 68	1	E
		7 Feb 68	1	E
		28 Mar 68	2	E
		10 April 68	1	E
		20 April 68	2	E
		24 April 68	1	E
		25 April 68	1	E
		27 April 68	1	E
		29 April 68	1	E
		3 May 68	1	E
		9 May 68	1	E
		20 May 68	1	E
		25 May 68	1	E
		21 July 68	1	E
		26 July 68	1	E
		20 Sept 68	1	M
	26 Oct 67	26 Mar 68	1	E
		26 April 68	1	E
		2 May 68	1	E
		12 July 68	1	E
	4 Nov 67	21 May 68	1	E
		22 May 68	1	E
		8 Aug 68	1	E
	18 Jan 68	31 Jan 68	1	E
		24 April 68	1	E
		26 April 68	1	E
		27 April 68	2	E
		2 May 68	1	E
		6 May 68	1	E
		30 May 68	2	E
		24 June 68	1	E
		4 July 68	2	E

APPENDIX B—Cont'd.

APPENDIX B—Continued

Tagging and Recovery Data for 210 Anchovy Tag Recoveries Demonstrating Major Movement

March 14, 1966 to May 31, 1969

Tagging Location	Tagging Date	Recovery Date	Number of Tags Recovered	Recovery Location*
San Diego—Continued				
		17 July 68	1	E
		2 Aug 68	1	E
		23 Sept 68	1	M
		16 Oct 68	1	E
		11 April 69	1	E
	16 Feb 68	26 Mar 68	1	E
		28 Mar 68	4	E
		1 April 68	1	E
		6 April 68	1	E
		10 April 68	2	E
		22 April 68	2	E
		24 April 68	1	E
		25 April 68	1	E
		26 April 68	3	E
		27 April 68	2	E
		29 April 68	2	E
		3 May 68	1	E
		7 May 68	1	E
		18 May 68	2	E
		20 May 68	1	E
		21 May 68	2	E
		22 May 68	1	E
		23 May 68	1	E
		25 May 68	2	E
		30 May 68	1	E
		7 June 68	1	E
		28 June 68	1	E
		4 July 68	2	E
		12 July 68	1	E
		22 July 68	1	E
		24 July 68	1	E
		25 July 68	1	E
		27 July 68	1	E
		2 Aug 68	1	E
		4 Aug 68	1	E
	16 Feb 68	16 Sept 68	1	M
		18 Nov 68	1	E
		10 Dec 68	1	E
		19 Mar 69	1	E
		23 May 69	1	E
	29 April 68	4 July 68	1	E
		5 July 68	1	E
		22 Nov 68	1	M
		19 Dec 68	1	E
		10 April 69	1	E

* Recovery Locations
M. — Monterey Bay.
S.C. — Southern California.
E. — Ensenada.

APPENDIX B—Cont'd.

6. RESULTS OF A LIVE BAIT SAMPLING STUDY

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6.1. INTRODUCTION

Live bait fishermen began submitting records of their catch to the Department of Fish and Game in 1939 (Aplin, 1942) and, except during World War II, have submitted them since. The records are voluntary and include the date and area of catch, number of hauls, and number of scoops of each species taken. The boats use lampara nets primarily; a comprehensive description of the fishery appears in Wood and Strachan (1970). Northern anchovies (Engraulis mordax) are the dominant species, accounting for approximately 98% of the live bait catch (op. cit.). A sampling program to determine the age composition of anchovies in the southern California live bait catch was initiated in 1955 (Miller and Wolf, 1958) and continued through May 1968.

6.2. ACKNOWLEDGMENTS

This study was made possible by the willing cooperation of the live bait dealers in southern California. I particularly wish to thank Richard Brock, William Duggan, Roy Everingham, Arthur Mello, and Lonnie Williams.

Several members of the Department provided assistance. Will Reid helped with sampling while James Hardwick and Russell Wickwire aided in processing samples. The assistance of Norman Abramson with statistical problems is greatly appreciated, as is the help of Robson Collins who read the otoliths used to age the anchovies and completed the preliminary mathematical work. Micaela Wolfe and Kathleen O'Rear typed the manuscript. James D. Messersmith gave guidance in conducting this study and his editorial assistance and that of John L. Baxter are also greatly appreciated.

6.3. LIVE BAIT SAMPLING STUDY

6.3.1. Justification

During the spring of 1968, a review of the live bait sampling program revealed several procedural flaws. Originally vessel skippers at several ports saved frozen fish samples for Department biologists. This procedure was later changed and the number of samples was limited to 10 per month, taken directly by the biologist assigned to the live bait study. The samples were divided among three ports, the number at each port depending on the volume of business done by the bait dealers within each port. Long Beach was sampled five times per month, San Diego three times, and Port Hueneme twice per month. During the summer of 1967 the sampling intensity was about 1 sample per 12 loads delivered at Long Beach, 1 sample per 40 deliveries at San Diego, and

1 sample per 15 deliveries at Port Hueneme. The program was not random in the selection of the day or vessel to be sampled. Instead, sampling was somewhat systematic, frequently opportunistic, and consequently the fishery was sometimes undersampled.

There were also problems associated with the sampling method. Sampling from receivers was biased because the fishermen, in order to maintain full receivers, usually combined catches from more than one day. Variations in the amount removed and replaced made it impossible to use anchovies from receivers in order to determine the age structure of a day's catch. This bias was further compounded because anchovies tend to stratify by size while in the tanks aboard bait boats. Consequently, when the fish were unloaded, and more than one receiver was needed, the fish at the top, usually the smaller ones, were crowded into one receiver while those at the bottom often went into another. Thus a receiver could contain the results of several days catch and/or two different size groups of fish which are not necessarily representative of all the different size groups caught in a set.

In addition, no provisions were made in the sampling program for properly integrating sample results and the log record of catch. Sampling was done on a numerical basis, a sample consisting of 50 fish. The total weight of anchovies was recorded and then the fish were measured and age and sex determined for every fifth fish. Unfortunately individual fish were not weighed. Logs were submitted reporting the catch in scoops weighing 12.5 pounds each. An estimate of the age composition of the catch was determined on a numerical basis but not by weight since individual weight-age data were not collected. Since the catch was reported by weight, it would have been better to weigh and age individuals so that age composition data could also be reported by weight.

Because the plan wasn't providing reliable quantitative data, an intensive, short-term study of live bait sampling was undertaken in southern California during June, July and August 1968.

6.3.2. Objectives

The purpose of this sampling study was to determine the level of sampling necessary to obtain reliable data from the southern California live bait fishery. Additionally, the study would also make possible a more rational appraisal of past sampling. Parameters to be estimated included:

1) Species composition of the catch by weight and number.
2) Year-class (age) composition of anchovies in the catch by weight and number.
3) Variances for all estimates.

6.3.3. Sampling Plan

6.3.3.1. Selecting the Vessel

Sampling was conducted at sea on vessels operated by five live bait dealers in southern California. Two dealers were located at San Diego, one at Newport Beach, and two at Long Beach Harbor. Their catch in 1967 represented over 85% of the statewide take and 92% of the southern California catch. The catch of one vessel from each dealer was sampled three times each month. Intuitively, this level of sampling seemed to be sufficient to give the desired results and the 15 samples per month was the maximum number the sampler could collect and process.

Selecting the actual day and dealer to sample was accomplished by first randomly selecting the day without replacement, then a dealer, from a table of random numbers. Another day and dealer were then selected and the procedure repeated until 15 sample days were chosen. A 16th sample day was chosen should a sample be missed before that day. Each month was treated as a separate stratum.

6.3.3.2. Selecting the Sample

The study called for:

1) Samples to be taken while at sea.
2) A sample cluster of approximately 2 kg (4.4 pounds) of fish to be taken from each set just after the fish were first brailed to insure a homogenous sample.
3) The species composition of each sample to be determined by weight and numbers.
4) Determining the mean length of 50 anchovies from each set and weighting that length according to the number of scoops in the set.
5) A 250 g (0.55 pound) sample to be taken from the cluster which had a mean length most near that of the weighted mean for all sets.
6) The sample to be processed for age, individual weight, length, sex, and female state of maturity according to the method described by Collins (1969).

Conditions 4 and 5 above violate Assumption I of Appendix C. At the time the plan was conceived, it was difficult to decide which set should be sampled. Intuitively it seemed the set determined by the above method would be the most representative of the actual catch.

6.4. RESULTS

Estimates of the number of anchovies taken revealed that Age I fish (1967 year-class) occurred most frequently and accounted for 60% of the catch by weight. Age groups 0 and II were also important, contributing 14% and 18% of the catch by weight, respectively. By numbers, 0 age fish were more important than II's. Fish older than II years made up over 4% of the catch and those not aged accounted for the rest of the landings (Tables 27 and 28; Appendices C and D).

Sample data relating to the dominant 1967 year-class were used to determine the number of samples necessary to achieve 0.90 and 0.95 confidence intervals of lengths equal to 30% of the catch. The figures were set by determining the confidence intervals whose half-lengths were equal to 15% of the catch. The summer catch amounted to 1,502,899 kg. Fifteen percent represented 225,435 kg and the 95% confidence interval allowed for a standard error of 115,018 kg. The 90% confidence interval provided for a standard error of 137,460 kg. Squaring the standard error provided the V needed for the equation in Appendix E. To achieve 90% (± 15%) confidence, 21 samples are needed for a 30 day month and 22 samples for a 31 day month. At the 95% (± 15%) confidence interval, each day in the month must be sampled.

Data on the species composition of the catch showed an extremely large variance between sets. The sample catch data for August 22, 1968 (Table 31) revealed that the average catch of anchovies for each set was 25.9 scoops with a standard deviation of the mean of 24.0. Anchovies were the most consistently captured species, thus they would have the lowest variance between sets (Table 29). Because their standard deviation (variance) is great, it is logical to believe that the other species, captured with much less consistency, would have a greater variance than anchovies. Because of the anticipated high variance the species composition of the catch was not determined.

The estimated summer catch of the selected dealers based on sampling was 2,777 short tons (2,524 metric tons). The dealers reported 2,513 short tons on their log books. The difference, 264 short tons, is 10.5% of the reported landings. Oversampling of one vessel at the expense of another at one port is probably partially responsible for the difference. Samples were to have been taken three times a month from each boat but five were taken from one boat and one from the other. The vessel sampled 5 times caught 180 short tons more during the study period. By substituting the reported catch of the under-sampled vessel, it is possible to calculate an adjusted estimate of 2,612 short tons. This adjusted estimate is 4.0% larger than the reported catch and 5.9% less than the original estimate.

6.5. RECOMMENDATIONS

Sampling the anchovy catch in the live bait fishery should be based on techniques that can be evaluated statistically. In southern California a sampling plan like that used in 1968, should center around the five dealers who caught approximately 90% (in 1968) of the live bait. Each day in the month should be sampled to insure 95% (± 15%) confidence in the estimate of the dominant year-class. Four alternate sample days per month should be selected to insure against missed samples. They could be discarded if not needed.

The manpower requirements for sampling 30 days per month is high. During this study 270 hours per month were required to collect 15 samples. Because of this, it would be advisable to have at least three persons collecting and processing samples.

Before the sampling plan used in the summer of 1968 can be simplified, more data are needed as follows:

1) Variance of anchovy ages between samples drawn from the same set.
2) Variance of anchovy ages between sets on the same boat.
3) Variance of anchovy ages between boats on the same day.
4) Variance of scoop weights.

If 1, 2, and 3 above are low, fewer boats can be sampled without lowering the confidence limits. Present data indicate that the log record of catch can be used to determine total catch.

At present there is little justification for sampling the live bait catch. However, should a large commercial fishery develop, live bait sampling could be used to detect changes in year-class strength. This would enable the Department to make appropriate recommendations should the commercial fishery become large enough to have an effect on the live bait fishery. It would also assist in managing the resource because it would enable predictions of recruitment to the commercial fishery since the live bait fishery is based on 0, I, and II-year-old fish while the commercial catch consists of I, II, and III-year-olds.

6.6. REFERENCES

Aplin, J. Alfred. 1942. Bait records. *In* The commercial fish catch of California for the year 1940. Calif. Dept. Fish and Game, Fish Bull., (58) :20–23.

Collins, Robson A. 1969. Size and age composition of northern anchovies (Engraulis mordax) in the California anchovy reduction fishery for the 1965–66, 1966–67, and 1967–68 seasons. *In* The northern anchovy (Engraulis mordax) and its fishery 1965–1968. Calif. Dept. Fish and Game, Fish Bull., (147) : 56–74.

Miller, Daniel J., and Robert S. Wolf. 1958. Age and length composition of the northern anchovy catch off the coast of California in 1954–55, 1955–56, and 1956–57. *In* Age and length composition Pacific coast catches sardines and Pacific mackerel, 1955–56 and 1956–57 seasons and the northern anchovy, 1954–55 through 1956–57 seasons. Calif. Dept. Fish and Game, Fish Bull., (106) :27–72.

Wood, Richard, and Alec R. Strachan. 1970. A description of the northern anchovy live-bait fishery, and the age and length composition of the catch during the seasons 1957–58 through 1964–65. Calif. Fish and Game, 56(1) : 49–59.

TABLE 27

Estimated Weight (Kg) of Anchovies Caught by Age and Year-Class With Standard Deviations

Age	0	I	II	III	IV	V	Unknown	Total
Year class	1968	1967	1966	1965	1964	1963	--	--
June								
Weight	100,645	472,192	82,585	19,471	15,300	9,193	47,126	746,512
Standard Deviation	29,286	88,392	29,420	10,368	[1]	[1]	17,915	--
Percent Deviation	29.09	18.71	35.62	53.24	[1]	[1]	38.01	--
July								
Weight	80,243	529,275	200,293	14,913	16,856	--	25,035	866,615
Standard Deviation	24,592	112,392	44,989	7,010	11,898	--	12,475	--
Percent Deviation	30.64	21.23	22.46	47.00	70.58	--	49.83	--
August								
Weight	182,754	501,432	162,344	21,426	8,506	8,525	25,438	910,425
Standard Deviation	47,741	90,930	41,734	9,283	6,381	[1]	16,048	--
Percent Deviation	26.12	18.13	25.70	43.32	75.01	[1]	63.08	--
Summer								
Weight	363,642	1,502,899	445,222	55,810	40,662	17,718	97,599	2,523,552
Standard Deviation	61,168	169,450	68,053	15,582	--	--	27,094	--
Percent Deviation	16.82	11.27	15.28	27.91	--	--	27.26	--

[1] No standard deviations were calculated because only one sample contained the designated age group.

TABLE 27

Estimated Weight (Kg) of Anchovies Caught by Age and Year-Class With Standard Deviations

TABLE 28

Estimated Number of Anchovies Caught by Age and Year-Class With Standard Deviations

Age	0	I	II	III	IV	V	Unknown	Total
Year class	1968	1967	1966	1965	1964	1963	--	--
June								
Number	11,170,250	46,987,750	8,626,500	990,000	840,000	390,000	4,027,500	73,032,000
Standard Deviation	2,847,878	8,172,620	2,733,929	569,019	[1]	[1]	1,356,689	--
Percent Deviation	25.49	17.39	31.69	57.47	[1]	[1]	33.68	--
July								
Number	6,872,589	45,517,411	15,322,857	1,187,411	780,536	--	1,976,250	71,657,054
Standard Deviation	2,240,778	9,993,250	3,527,152	566,916	569,301	--	1,013,664	--
Percent Deviation	32.60	21.95	23.01	47.74	72.93	--	51.29	--
August								
Number	20,720,917	43,213,483	11,296,400	1,311,817	549,733	341,000	1,960,233	79,393,583
Standard Deviation	6,179,338	8,061,154	2,705,072	561,993	441,106	[1]	1,068,243	--
Percent Deviation	29.82	18.65	23.94	42.84	80.24	[1]	54.49	--
Summer								
Number	38,763,644	135,718,644	35,489,228	3,489,228	2,170,269	731,000	7,963,983	224,082,637
Standard Deviation	7,163,498	15,219,689	5,218,485	980,312	--	--	2,002,314	--
Percent Deviation	18.47	11.21	14.70	28.09	--	--	25.14	--

[1] No standard deviations were calculated because only one sample contained the designated age group.

TABLE 28

Estimated Number of Anchovies Caught by Age and Year-Class With Standard Deviations

TABLE 29

Catch Data of Sets Sampled in Los Angeles Harbor on August 22, 1968

Species	Grams of Fish in the Sample							
	Set I	Set II	Set III*	Set IV	Set V	Set VI	Set VII	Set VIII*
Anchovy (*Engraulis mordax*)	825	225	--	3,205	4,119	703	2,612	--
Midshipman (*Porichthys myriaster*)	--	--	--	--	--	--	122	--
Pompano (*Palometa simillima*)	--	22	--	17	25	--	--	--
Queenfish (*Seriphus politus*)	741	8	--	217	638	1,533	3,819	--
Perch, Shiner (*Cymatogaster aggregata*)	30	--	--	--	42	27	--	--
Perch, Unidt.	30	--	--	59	98	214	--	--
White Croaker (*Genyonemus lineatus*)	--	--	--	--	--	--	347	--
Smelt, Unidt. (*Atherinops* sp.)	--	--	--	--	63	--	--	--
Total	1,656	234	--	3,498	5,015	2,477	6,900	--
Scoops Landed	80	30	--	80	40	60	40	--
Scoops of Anchovies In Set	40	29	--	73	33	17	15	--

* Sets dumped and not sampled because they contained no anchovies.

TABLE 29
Catch Data of Sets Sampled in Los Angeles Harbor on August 22, 1968

6.8. APPENDIX C

6.8.1. Formulas

The number or weight of anchovies for a given age on a specific day was determined from the equation:

$$\hat{X}_{gh} = \frac{N_{gh}}{n_{gh}} \sum_{i=1}^{n_{gh}} \frac{L_{ghi}}{l_{ghi}} W \sum_{j=1} x_{ghij}$$

where

$\hat{X}_{gh}$ = Estimate of a given age (X) fish on the h^{th} day for the g^{th} stratum.

N_{gh} = Number of vessels fishing on the h^{th} day of the g^{th} month.

n_{gh} = Number of vessels sampled on the h^{th} day of the g^{th} month.

L_{ghi} = Number of scoops taken on the i^{th} trip.

l_{ghi} = Number of scoops sampled from the i^{th} trip.

W = Weight factor equal to 12.5 lbs per scoop/250g =25. Note: 250g = 0.5 lb.

x_{ghij} = Number or weight of a given age fish taken on the i^{th} trip of the h^{th} day of the g^{th} month.

EQUATION

The estimate for the month is computed by summing the weight or number estimates for the days of sampling and multiplying by the fraction of days in the month sampled.

The standard error was calculated using the equation:

$$SE(\hat{X}_g) = \sqrt{\frac{Q_g^2 \sum_{h=1}^{q_g} \left(\hat{X}_{gh} - \frac{1}{Q_g}\hat{X}_g\right)^2}{q_g(q_g - 1)}}$$

where

$SE(\hat{X}_g)$ = Monthly standard error of a given age (X) fish for the g^{th} month.

Q_g = Numbers of days in the g^{th} month.

$\hat{X}_{gh}$ = Estimate of the number of X age fish on the h^{th} day of the g^{th} month.

$\hat{X}_g$ = Estimated number of X age fish in the g^{th} month.

q_g = Number of days sampled from the g^{th} month.

EQUATION

Monthly standard errors were figured for each year class. Summer standard errors were also calculated.

6.8.2. Assumptions

The above equations are valid, only if the following assumptions are true:

1) An unbiased estimation at each stage is a sufficient condition for the estimators to be unbiased.
2) The variance formula is correct if and only if the first stage units (days) are independently selected and assumption 1 holds also.

6.9. APPENDIX D Trip, Catch, and Age Distribution of Anchovies

APPENDIX D

Trip, Catch, and Age Distribution of Anchovies

Sample Date	Number Vessel Fishing	Catch of Vessel Sampled (scoops)	Age Distribution (Number and grams)															
			0		I		II		III		IV		V		Unknown		Total	
			No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
June 1	6	325	5	47	15	147	--	--	1	20	--	--	--	--	2	19	23	233
8		No anchovies caught																
10	6	875	--	--	12	120	7	88	2	28	--	--	--	--	1	14	22	250
12	6	950	2	20	17	172	3	31	--	--	--	--	--	--	3	29	25	252
13	6	950	3	30	20	209	1	12	--	--	--	--	--	--	--	--	24	251
14		Hauled from San Pedro[1]																
15	6	1,400	5	54	14	145	2	20	--	--	2	34	--	--	2	22	25	275
16	7	625	7	81	17	200	--	--	--	--	--	--	--	--	--	--	24	281
17	6	900	3	20	18	159	1	9	1	26	--	--	--	--	2	18	25	232
19	6	325	7	66	16	163	--	--	1	19	--	--	--	--	--	--	24	248
21	7	970	6	--	15	--	6	--	--	--	--	--	--	--	--	--	27	--
22	6	30	3	31	16	177	3	31	--	--	--	--	--	--	5	57	27	296
24		Caught jack mackerel only																
25	6	1,000	1	11	13	156	4	50	--	--	--	--	--	--	3	52	21	269
26	7	300	2	24	19	226	1	15	--	--	--	--	--	--	--	--	22	265
27	6	1,300	4	43	12	130	3	36	--	--	--	--	1	22	1	8	21	239
July 1	6	750	3	41	5	70	5	108	1	14	1	25	--	--	1	15	16	273
3		No anchovies caught																
5	6	1,600	4	42	15	160	2	25	--	--	1	20	--	--	--	--	22	247
8	6	750	2	22	13	155	3	40	1	11	--	--	--	--	1	13	20	241
9		Missed the boat																
10	7	800	2	23	16	172	4	41	--	--	--	--	--	--	--	--	22	236
11	6	1,250	--	--	13	163	5	64	--	--	--	--	--	--	2	24	20	251
12	6	200	8	93	9	88	5	60	--	--	--	--	--	--	--	--	22	241
13		Hauled from San Pedro[1]																
14	6	975	3	38	11	137	5	65	--	--	--	--	--	--	2	25	21	265
17		No anchovies caught																
21		No anchovies caught																

APPENDIX D—Cont'd.

22	6	625	2	29	9	127	6	79	1	14	--	--	--	--	--	--	18	249
25	7	950	--	--	13	145	9	107	--	--	--	--	--	--	--	--	22	252
28	6	1,450	2	22	14	169	4	49	1	12	--	--	--	--	--	--	21	252
30	6	775	--	--	20	217	2	25	--	--	--	--	--	--	--	--	22	242
August 2	6	1,365	4	41	14	156	4	57	--	--	--	--	--	--	--	--	22	254
4	6	315	5	60	10	112	3	36	2	49	--	--	--	--	--	--	20	257
6	6	380	4	38	15	147	5	52	2	23	--	--	--	--	--	--	26	260
10		Caught sardines only																
11	7	160	5	62	6	64	6	98	--	--	2	42	--	--	--	--	19	266
12	6	1,400	2	27	12	125	4	73	1	14	--	--	--	--	1	9	20	248
13		No anchovies caught																
14	6	1,100	1	12	9	129	5	80	1	19	--	--	1	25	--	--	17	265
15	7	1,400	11	44	13	147	4	49	--	--	1	14	--	--	--	--	29	254
17	7	1,100	10	83	13	142	1	13	--	--	--	--	--	--	--	--	24	238
19	6	1,600	5	47	10	120	3	39	--	--	--	--	--	--	2	32	20	238
21	6	600	--	--	20	220	2	25	--	--	--	--	--	--	--	--	22	245
22	5	410	4	42	11	158	5	59	1	13	--	--	--	--	2	23	23	295
25	6	1,040	13	130	9	107	--	--	--	--	--	--	--	--	1	10	23	247
27	5	1,000	5	72	12	160	2	31	--	--	--	--	--	--	--	--	19	263

[1] I was unable to sample these boats because of the long trip (2-3 days) involved.
[2] No weights were taken because of the deteriorated condition of the anchovies.

APPENDIX D—Cont'd.

6.10. APPENDIX E

The number of days to sample per month for a given confidence interval was determined using the equation:

$$C = \frac{\sum_{g=1}^{P} Q_g S_g^2}{V}$$

where

C = The fraction of days in a month which should be sampled.
Q_g = Number of days in the month sampled.
S_g^2 = Simple variance for the month sampled.
V = Variance needed to obtain desired confidence intervals.

APPENDIX E—Cont'd.

7.