Title
Fish Bulletin No. 115. The Migration, Age, And Growth of Pacific Albacore (Thunnus germo), 1951–1958

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The Migration, Age, And Growth of Pacific Albacore (Thunnus germo), 1951–1958

By
HAROLD B. CLEMENS

1961

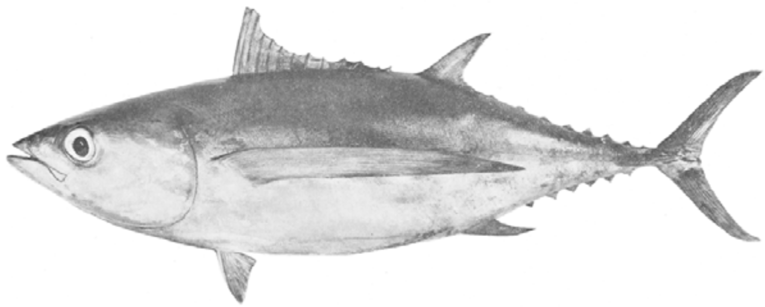

FIGURE 1. Pacific albacore, *Thunnus germo* (Lacepede).

FIGURE 1. Pacific albacore, Thunnus germo (Lacepede)

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1. ABSTRACT

During January 1952, California Department of Fish and Game marine biologists developed history's first successful tuna tag. It resembles a piece of spaghetti and has been employed as a research tool for studying the populations of important tuna species. Using these tags Department scientists discovered: that albacore migrate northward up the west American coast averaging at least six nautical miles per day; that they perform a transpacific migration between the American mainland and the Hawaiian Islands and Japan; that their growth rate is relatively rapid, averaging seven pounds per year for the catch-dominating 13-pound fish; that the natural size groups in the fishery are successive year classes; that individuals and perhaps the same schools return to the American fishing grounds during several seasons; and that there is but one population in the North Pacific.

In addition Department scientists have determined the ages of albacore by studying rings on the scales; have obtained valuable data on the time and place of albacore spawning; and have determined their size at maturity.

Data obtained from research cruises and specially designed fishermen's logbooks disclosed that albacore abundance is greatest where sea-surface temperatures are 60–68 degrees F. This information led to our discovery of the albacore coastward migration routes and the successful prediction of vast migration route changes in 1958, 1959, and 1960.

2. FOREWORD

This paper summarizes some of the investigations conducted by California Department of Fish and Game marine biologists between 1951 and 1958 to determine migrations, populations, ages, growth rates, and other previously undiscovered facets of the life history and behavior of North Pacific albacore. Much of the data were obtained by using the first successful tuna tag after it had been developed by the Department's marine scientists at the research laboratory on Terminal Island, California. This achievement represented one of the most significant breakthroughs in tuna biology studies in the last half century. The remainder of the data came primarily from sea cruises aboard our research vessels, *N. B. Scofield* and *Alaska*, and from numerous logs kept by the skippers of America's tremendous albacore fishing fleet.

Investigations of this scope, encompassing the North Pacific, require the whole-hearted efforts of numerous individuals. The entire tuna research staff has assisted in this project; many of these people have contributed countless hours of their own time: at sea; at various fishing ports; and in their own homes during evenings and week-ends.

Clark E. Blunt, William L. Craig, Tom Jow, Leslie E. Lahr Jr., Kenneth F. Mais, Leo Pinkas, Robert C. Wilson, and Joe A. Yontz conducted a majority of the sea cruises.

Over 1,000 American fishing-boat captains consistently have contributed details of their fishing activities and were prepared to furnish information about any tagged albacore they may have captured.

Arthur C. Engeness, Captain of the *Deluxe*, and Joseph C. Giannini, Captain of the *Arctic*, voluntarily took Department personnel aboard and assisted them in tagging and releasing part of their albacore catches. In addition, Captain Giannini, Homer H. Moore, Captain of the *GM*; and Michael J. Salisbury, Captain of the *Willa*, occasionally tagged albacore during their regular fishing activities.

In the Western Pacific, the Captains and crews of seven Japanese fishing vessels: Chosho-Maru; Genkichi-Maru; Konpira-Maru; Shinya-Maru; Sin-O-Maru; Sho-Ei-Maru; and Nankai-Maru captured our tagged albacore—the Sho-Ei-Maru captured two marked albacore. These fishermen and personnel at the Kanagawa, Nankai, and Tohoku Fisheries Research Laboratories provided us with the tags and desired data concerning the recaptured albacore.

Finally, John E. Fitch has provided considerable assistance by carefully editing the manuscript, and Patricia P. Powell has assisted by checking all references. To these people and to my wife, who has given me constant encouragement and help during evenings and week-ends at home where this paper was written, I extend my sincere thanks and appreciation.—HAROLD B. CLEMENS, June 1961.

3. INTRODUCTION

The Pacific albacore is a migratory species; they are cosmopolitan in distribution and prefer a deep, oxygen-rich, oceanic realm. This salty aristocrat abounds in temperate wind-swept waters throughout much of the south and north Pacific Oceans; primarily well-seaward from cold, dirty, coastal areas. A few have been found in the central Pacific near the equator, swimming in the cool depths many fathoms beneath the warmer surface waters.

In the eastern North Pacific individuals have been recorded off Mexico's mainland at Clarion Island, of the Revilla Gigedo Island group, and northward along coastal Baja California, California, Oregon, Washington, British Columbia, and in the Gulf of Alaska. The most productive fishing grounds, however, lie between central Baja California and the Columbia River.

The California albacore fishery was the first tuna fishery on the Pacific coast of North America and thus has the most extended history. For decades our fishermen eagerly have sought albacore, and tremendous sport and commercial industries, employing thousands of individuals, have been established for utilizing this species (Figure 1). Among fisheries resources of the United States, the California albacore fishery consistently has ranked near the top in value. Typically it begins in June; develops very rapidly in July; peaks in August; gradually declines during September, October, and November and ends during December or January; in exceptional years some albacore are caught almost every month (Clemens, 1955).

Commercial fishermen cruising from southern Baja California to Vancouver Island, British Columbia, during the 10-year period 1950–1959, have docked 191,000 tons of albacore in California and received about 70 million dollars for their efforts. During this same period, the southern California party boat industry, operating between northern Baja California and Point Conception, has taken multitudes of recreation-seeking men and women to sea sportfishing for albacore. These enthusiasts have boated 640,000 longfins weighing an estimated 4,000 tons and valued at close to 1.5 million dollars (Figure 2). We do not know the quantity taken by sportfishing from private skiffs, but it is undoubtedly somewhat less than that recorded for party boats.

Paradoxically almost nothing was known about the life history, biology, or environment of this species until fairly recently; as a result, unexpected, sudden, and violent catch fluctuations historically have plagued sport fishermen and industry alike, and Pacific albacore have gained a world-wide reputation as erratic and exotic mystery fish.

In 1951 the California Department of Fish and Game assigned a marine biologist to conduct albacore research and thus launched a continuing scientific program designed to improve our knowledge of the species. Since that time a considerable amount of data has been gathered and analyzed, and today the albacore is no longer a fish of mystery.

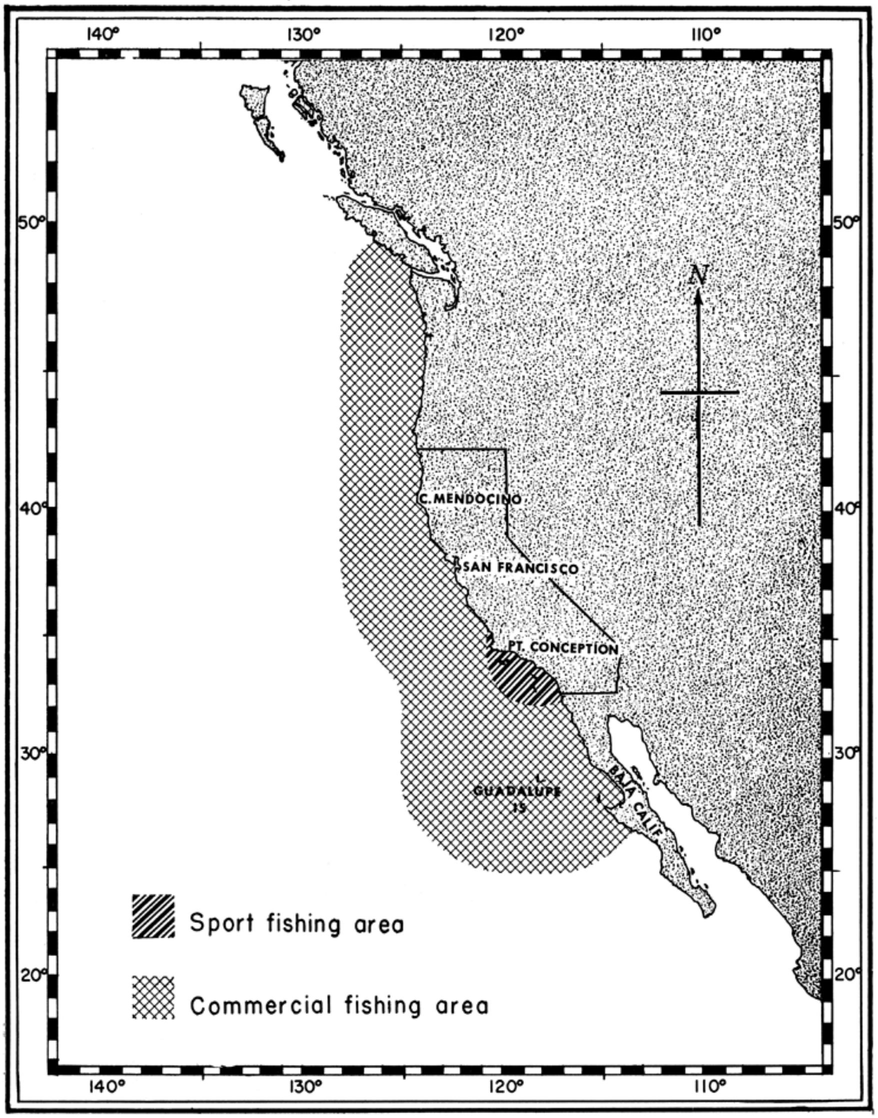

FIGURE 2. American albacore fishing grounds utilized by sport and commercial fishermen.

FIGURE 2. American albacore fishing grounds utilized by sport and commercial fishermen

In 1952 Department marine scientists at the State Fisheries Laboratory developed and used the first successful tuna tag. With it they discovered that albacore in the California fishery seasonally migrate northward up the west American coast, and then span the Pacific to enter the fisheries of the Hawaiian Islands and Japan, indicating that there is one population in the North Pacific. In addition they established albacore growth rates, demonstrated that the natural size groups in the fishery are successive age groups, and discovered that albacore return to the American fishing grounds during several seasons. Also they

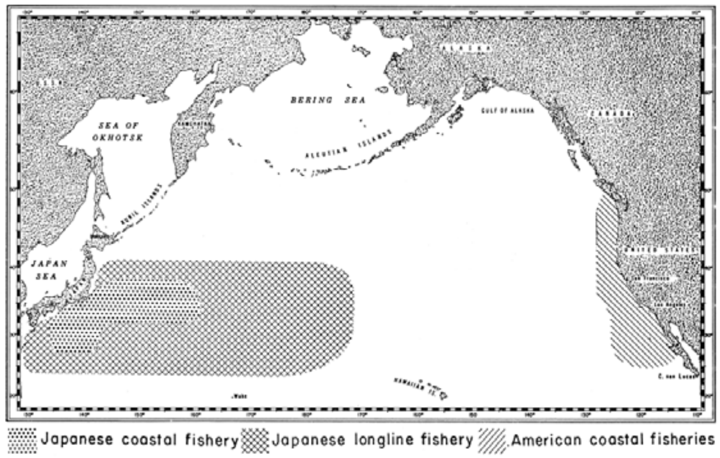

FIGURE 3. Principal albacore fishing grounds in the North Pacific.

FIGURE 3. Principal albacore fishing grounds in the North Pacific

determined the ages of albacore by studying rings on the scales, obtained valuable data related to the albacore spawning period and location, and determined their size at maturity. Finally, by conducting research cruises and analyzing quantities of logs provided by the fishing fleets, Department scientists established a definite albacore-sea temperature relationship. They used this information to discover and chart the previously unknown albacore coastward migration route, and to predict successfully large shifts in the migration routes in 1958, 1959, and 1960 seasons.

The purpose of this paper is to summarize progress made from 1951 to 1958, by California Department of Fish and Game marine biologists,

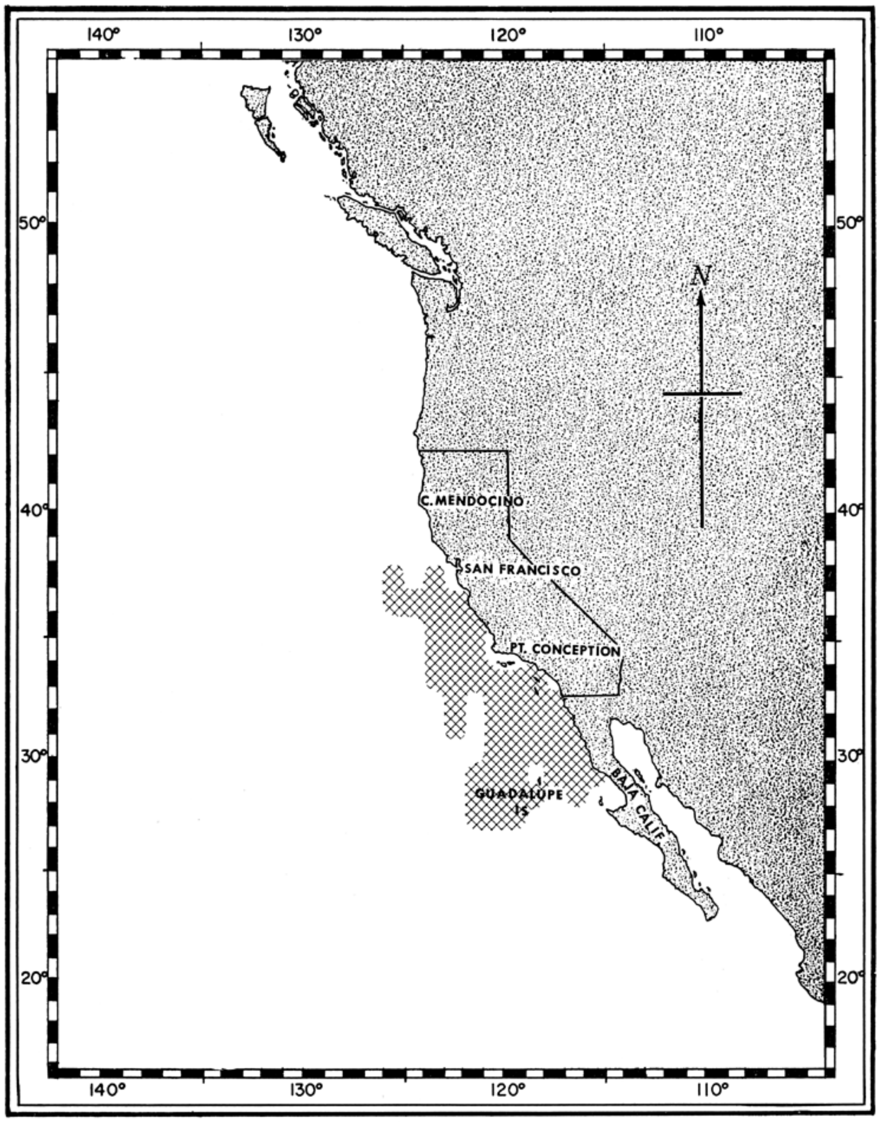

FIGURE 4. General release area for 4,585 albacore tagged during the six seasons, 1952 through 1957.

FIGURE 4. General release area for 4,585 albacore tagged during the six seasons, 1952 through 1957

in the study of North Pacific albacore stocks. Emphasis has been to determine migrations, populations, ages, growth rates, and environmental requirements; studies that will improve the fishery.

I am assuming that the North Pacific albacore stocks are separate from those in the south Pacific.

4. PROCEDURE

4.1. Scope of Operations

Our approach toward obtaining the knowledge we needed has included numerous methods and activities. Primarily we have investigated albacore interchange between principal North Pacific fishing grounds (Figure 3) and changes in fish size. We have done this by tagging and subsequently recovering marked individuals from which we could interpret migration patterns and growth rates.

A limited budget has precluded assigning more than one biologist to do albacore research, and tagging operations have not received priority over other tuna work. Tagging has been confined to a small portion of each fishing season and to the eastern Pacific Ocean between central Baja California and San Francisco, within 300 miles of the coast (Figure 4).

4.2. Tag Development and Testing

Developing and testing tags suitable for marking albacore was an important part of the work program initiated on tunas in January 1952, by E. C. Greenhood and the author. The experimental albacore phase of this program was concluded in July 1954.

Shoreside facilities were not available for testing various newly designed tags on live fish, so we went to sea for a few weeks each season aboard the *N. B. Scofield* (Figure 5) and experimentally marked a number of albacore (Wilson, 1953; Clemens, 1953). During the field

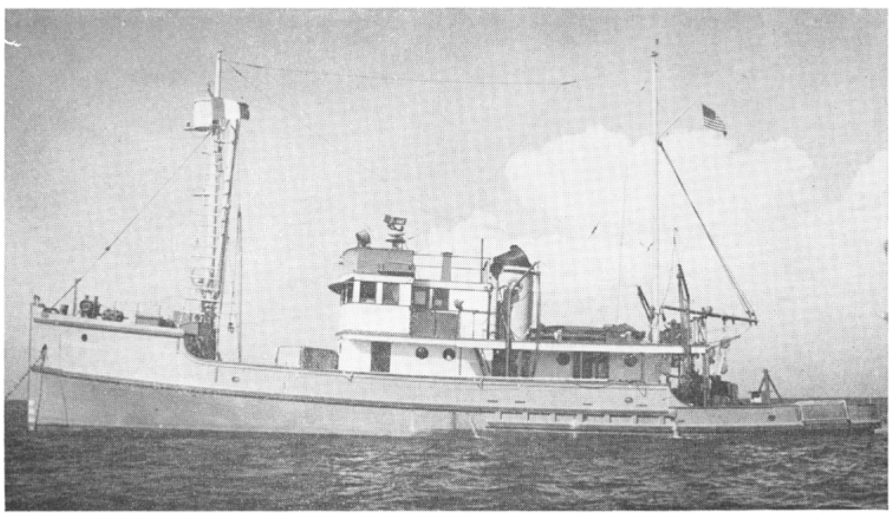

FIGURE 5. The California Department of Fish and Game research vessel *N. B. Scofield.*

FIGURE 5. The California Department of Fish and Game research vessel N. B. Scofield

trials three tag types were selected which we felt would fulfill our major requirements:

1. For maximum recovery efficiency the tag must be seen readily from either side of a fish lying on deck or the butchering table.
2. It must not injure the fish, or impair its movements so that its behavior differed from an untagged fish.
3. The tag should be retained for a long period—preferably for life.
4. It should be easy and rapid to apply.

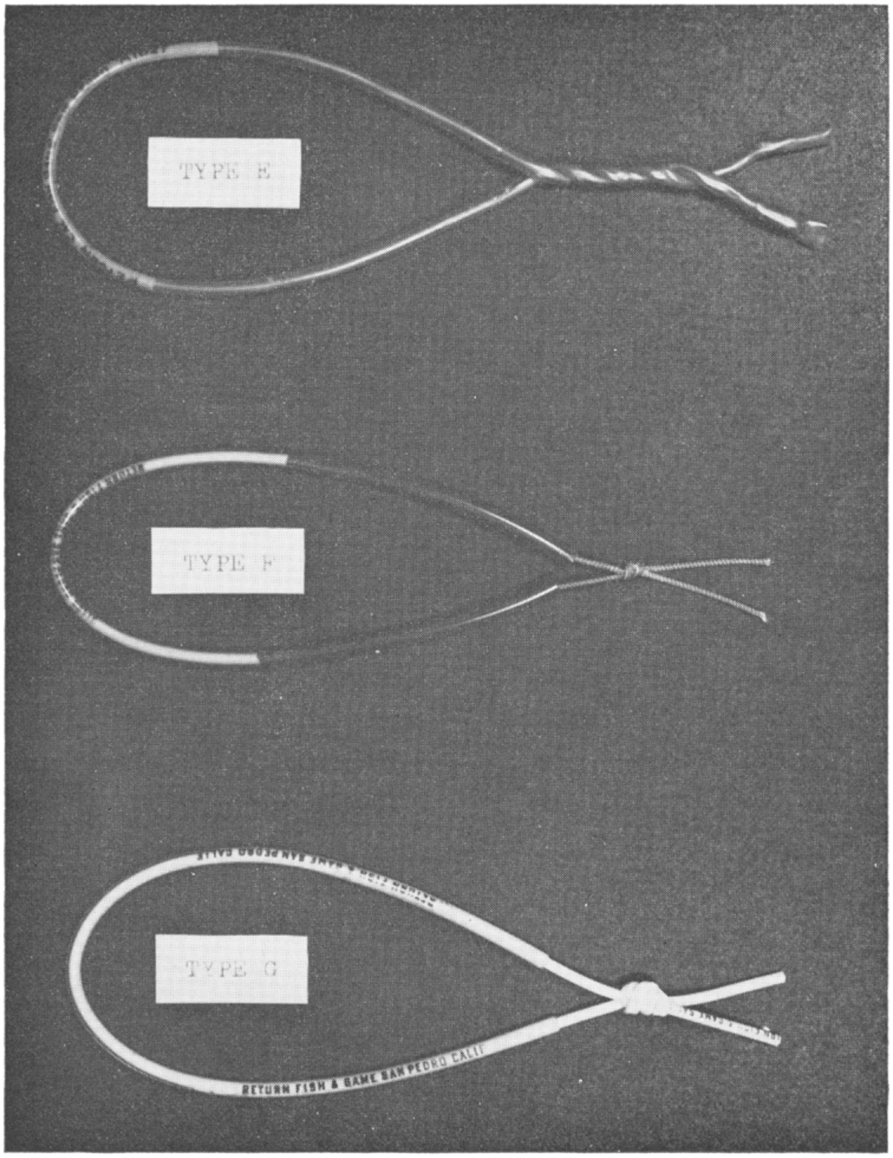

FIGURE 6. California spaghetti tags developed for tuna and tested in 1952 aboard the *N. B. Scofield*. *Photograph by Robert A. Iselin.*

FIGURE 6. California spaghetti tags developed for tuna and tested in 1952 aboard the N. B. Scofield. Photograph by Robert A. Iselin

5. It must be made from a material sufficiently nontoxic and chemically inert that it would not affect the fish.

These tags (Figure 6) were made from polyvinylchloride plastic tubing (XTE-30 Fibron) that resembles spaghetti. They were designated Types E, F, and G and have been described by Wilson (1953) and Blunt and Messersmith (1960).

The field trials led us to conclude: that Type E tags should be discontinued because they were heavy and might cause abnormal fish behavior, and they were difficult to bend into a streamlined shape while twisting the ends together—particularly if the fish began to struggle; that Type F tags should be eliminated because the braided nylon line used to tie the ends was difficult to knot with slimy fingers, and the line frayed after the tag had been in place for a few months on an albacore; and that Type G tags were promising because they were easy to apply, showed no deterioration after remaining secure for 192 days on an albacore, and had provided the largest percentage of returns (Table 1). In addition the tag wound healed satisfactorily with no apparent harm to the fish.

Based on the above evidence several thousand Type G tags, now called California spaghetti tags, were manufactured and have been used regularly since 1953. The tag was modified during August 1955 by eliminating the transparent jacket of No. 14 tubing (Figure 7). This jacket was designed to protect the legend and number printed on the smaller No. 20 tubing, but it was no longer needed because a suitable resistant vinylite ink (No. 104N5A4) had been developed.

Two spaghetti darts were designed in 1956 and field tested during the 1957 fishing season by double-tagging 85 albacore with California spaghetti tags and darts (Mais, 1957). During June 1959, and May and June 1960, we field tested darts manufactured by the Floy Tag Manufacturing Company of Seattle, Washington (Craig, 1959 and 1960). The number tagged was small and there were few recoveries, making it difficult to evaluate the darts; however, we plan to continue experimenting with them because they can be applied rapidly.

White tags were used from 1952 through 1954, because white spaghetti was available in quantity. During 1955 we dyed some white tags a brilliant blue and others pink, to determine in a field test if one color would yield more recoveries than another. However, the dye faded rapidly in sea water. In April 1956, blue and red material became available in quantity, so tags were made and a color test completed.

TABLE 1

Results of Field Testing Three Types of Albacore Tags

Tagging Season	Tag Type	Number Tagged	Number Recovered	Percent Recovered	Days Out (Range)
1952	E	80	0	--	--
1952+1953	F	565	4	0.7	30–324
1952+1953	G	687	13	1.9	23–192
Totals		1,332	17	1.3	

TABLE 1

Results of Field Testing Three Types of Albacore Tags

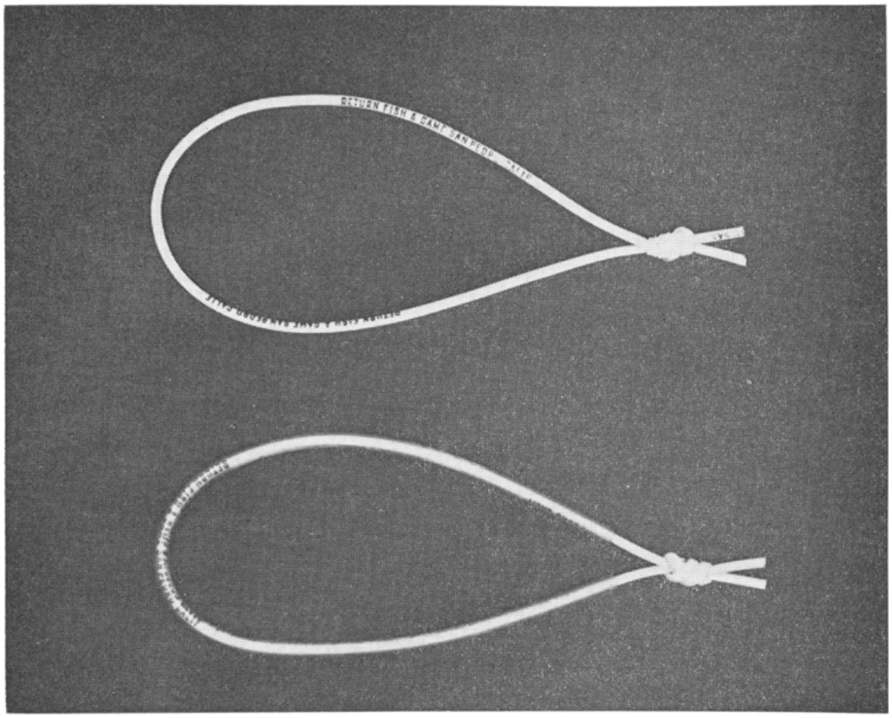

FIGURE 7. Type G spaghetti tag designed in 1952 (bottom) and modified in 1955 (top), by eliminating the transparent legend-protecting jacket. *Photograph by Robert A. Iselin.*

FIGURE 7. Type G spaghetti tag designed in 1952 (bottom) and modified in 1955 (top), by eliminating the transparent legend-protecting jacket. Photograph by Robert A. Iselin

During the test 774 albacore were tagged and released; 254 with blue tags, 261 with white, and 259 red (Mais, 1956; Clemens, 1956). Subsequently five blue, seven white, and eleven red tags were recovered (Table 2). Statistical tests indicated that no one color was significantly better than any other.

Color experiments conducted by Department personnel, in cooperation with the California Optometric Association and the National Rifle Association of America, revealed that yellow is easily visible to the human eye and also readily visible to people with color-deficient vision (Lahr *et al.*, 1959). On this basis, yellow spaghetti tags currently are being used.

TABLE 2

Results of Field Testing Three Colors of California Spaghetti Tags (1956)

Tag Color	Number Tagged	Number Recovered	Days Out (Range)
Blue	254	5	10–654
White	261	7	20–319
Red	259	11	6–401
Totals	774	23	

TABLE 2

Results of Field Testing Three Colors of California Spaghetti Tags (1956)

Originally we constructed tags of polyvinylchloride plastic purchased from the C. D. La Moree Co., Los Angeles, California, and utilized vinylite-black ink developed by the California Ink Co., Los Angeles for printing the tag legend and number. At present we are using yellow Resinite plastic tubing (EP-2AWG-18 and No. X270-1) manufactured by the Borden Company, Santa Barbara, California. The tag legend is machine printed with cellophane-backed carbon under heat and pressure by the Floy Manufacturing Co. and the Teletronic Laboratories, Gardena, California.

One identification number is printed on the tag portion which rides embedded in the fish 's flesh and a duplicate on the part that remains outside. Frequently the number in the flesh has been easiest to read upon recovery several months later.

We have had good success tagging tuna with California spaghetti tags manufactured from the above-mentioned plastics. All can be tied securely with a figure-eight or simple overhand knot, and they have remained pliable for years on various species of fish. We recently tested the strength of some original, white Type G tags that had remained secured to albacore for one and two years; the one-year tag withstood a stretching test of nine pounds before snapping, while the two-year tag broke at nine and one-half pounds. Tags made from polyvinylchloride plastics have remained pliable and knotted securely on kelp bass, Paralabrax clathratus, for 1,053 days (Young, ms.); California yellowtail, Seriola dorsalis, 1,440 days (John L. Baxter, personal communication); Pacific yellowfin tuna, Neothunnus macropterus, 842 days (Blunt and Messersmith, 1960); California halibut, Paralichthys californicus, 1,662 days (Parke H. Young, personal communication); and Pacific albacore, Thunnus germo, for 761 days. The Resinite plastics have proven equally reliable.

Many other fish species have been marked with spaghetti tags both in California and throughout the nation. A few of these are: steelhead, Salmo gairdnerii gairdnerii; silver hake, Merluccius albidus; whiting, Merluccius bilinearis; haddock, Melanogrammus aeglefinus; striped bass, Roccus saxatilis; California barracuda, Sphyraena argentea; skipjack, Katsuwonus pelamis; California bluefin tuna, Thunnus saliens; bigeye tuna, Parathunnus sibi; yellowfin croaker, Umbrina roncador; spotfin croaker, Roncador stearnsi; California corbina, Menticirrhus undulatus; barred surfperch, Amphistichus argenteus; rainbow trout, Salmo gairdnerii; and large-mouth bass, Micropterus salmoides.

When used on large-mouth bass they proved highly visible to fishermen, did not interfere with fish growth, had no obvious effect on bass recapture in mark-and-recovery experiments using nets, and the tags were not attacked by other fish (Tebo, 1956).

Many plastics are available on the market and one should use caution in selecting materials for tag construction. Some workers have not been careful, and the tag knots came untied and the tubing became brittle after about six months.

4.3. Tagging Practices and Equipment

We have tagged albacore at every opportunity and fish have been released from nine vessels: five commercial, three research, and one sport (Table 3).

TABLE 3

Summary of Cruises During Which Albacore Were Tagged

Year	Month/Day	Vessel (Cruise Number)	Number Tagged	Number Recovered	Percent Recovered	DaysOut (Range)	Tag Types
1952	7/27– 8/ 8	WILLA	5	0		--	E
	8/ 4– 9/17	OCEAN BOY (52C2)	215	3		31–324	E, F, G
		1952 Total	**220**	**3**	**1.4**		
1953	8/ 5– 8/26	SCOFIELD (53S4)	750	14		23–192	F, G
	10/ 5–10/23	SCOFIELD (53S6)	362	0		--	F, G
		1953 Total	**1,112**	**14**	**1.3**		
1954	8/ 2–10/ 1	SCOFIELD (54S4)	1,455	3		57–342	G
	9/14–10/19	PAOLINA T (5409P)	1	0		--	G
		1954 Total	**1,456**	**3**	**0.2**		
1955	7/21– 7/28	DELUXE (55C3)	40	6		18–761	G
	7/29– 8/ 5	GOODWILL	1	0		--	G
	8/ 4–10/17	ARCTIC (55C6)	216	6		317–672	G
	8/ 3– 8/26	PAOLINA T (55C7)	93	1		137	G
		1955 Total	**350**	**13**	**3.7**		
1956	7/ 2– 7/23	SCOFIELD (56S3)	415	17		10–443	G
	8/ 4– 9/ 6	NAUTILUS (56N2)	359	6		6–654	G
		1956 Total	**774**	**23**	**3.0**		
1957	6/ 3– 7/15	SCOFIELD (57S2)	630	17		16–585	G & G +Darts
	8/ 5–10/12	GM	38	0		--	G
	8/14– 9/20	ARCTIC	5	0		--	G
		1957 Total	**673**	**17**	**2.5**		
		Grand Total	**4,585**	**73**	**1.6**		

TABLE 3

Summary of Cruises During Which Albacore Were Tagged

Three methods have been used to capture fish for tagging: live bait, trolling, and rod-and-reel (Blunt, 1952). Aboard commercial vessels albacore are caught on trolled jigs, on baited hooks attached to handlines, and on artificial squids attached to conventional striker-pole lines (Clemens, 1955). On our research vessels, albacore schools were located by trolling lures through the water; when a fish struck, the vessel was stopped and live fish (chum) tossed overboard to attract the school and hold it nearby. With the trolling lines secured, albacore were caught on live-baited hooks attached to handlines, or on counterfeit squid secured to conventional tuna striker-pole lines. When the latter method succeeded, quantities of fish were caught quickly. Frequently, however, the schools could not be attracted vessel-ward by live-bait chumming and we had to rely on trolling gear. When trolling failed we turned to sportfishing, but as a last resort because rod-and-reel fishing never produced the albacore numbers desired for tagging.

Regardless of the capture method each fish was brought carefully aboard, placed in a specially designed sponge-rubber cradle, and its eyes and head covered with a wet cloth (Figure 8). Tagging was accomplished by deftly thrusting a hollow, tag-loaded, stainless-steel needle (one-eighth inch in diameter) through the flesh immediately behind

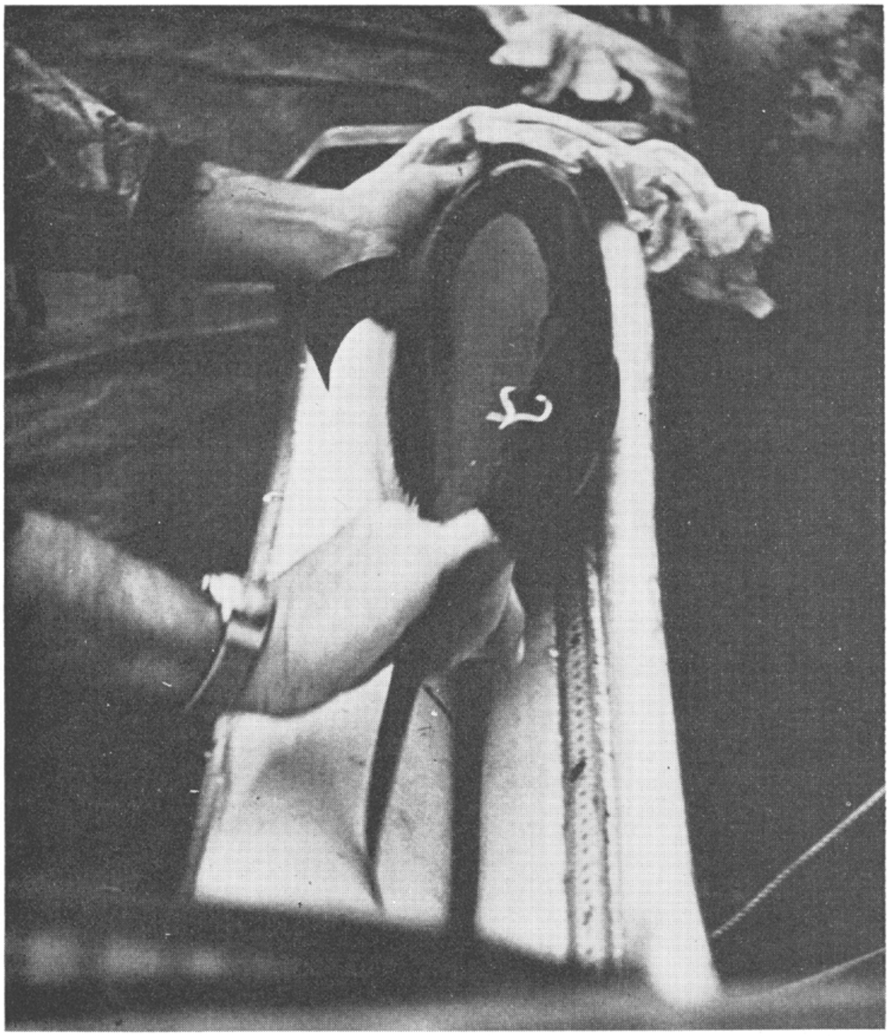

FIGURE 8. A tagged albacore an instant before being released alive into the sea. Note tag in place behind the second dorsal fin. *Photograph by Donald C. Greenland.*

FIGURE 8. A tagged albacore an instant before being released alive into the sea. Note tag in place behind the second dorsal fin. Photograph by Donald C. Greenland

and one-half inch below the posterior base of the second dorsal fin. When the needle is pressed through the fish, one end of the tag riding inside also is carried through; the needle is then dropped in the cradle bottom, and tag ends are tied with a simple overhand knot (Figure 9).

After tagging, each fish was measured by placing the tip of its upper jaw against the cradle headboard and reading its fork length from a meter stick screwed to the cradle bottom or side. The entire operation from the time an albacore is placed in the cradle until it is released takes an experienced person less than 10 seconds. After being tagged, an albacore may start to flurry before it can be measured. When this happens it is instantly tossed overboard and the length estimated. If the albacore's eyes and head are not covered with a wet cloth during

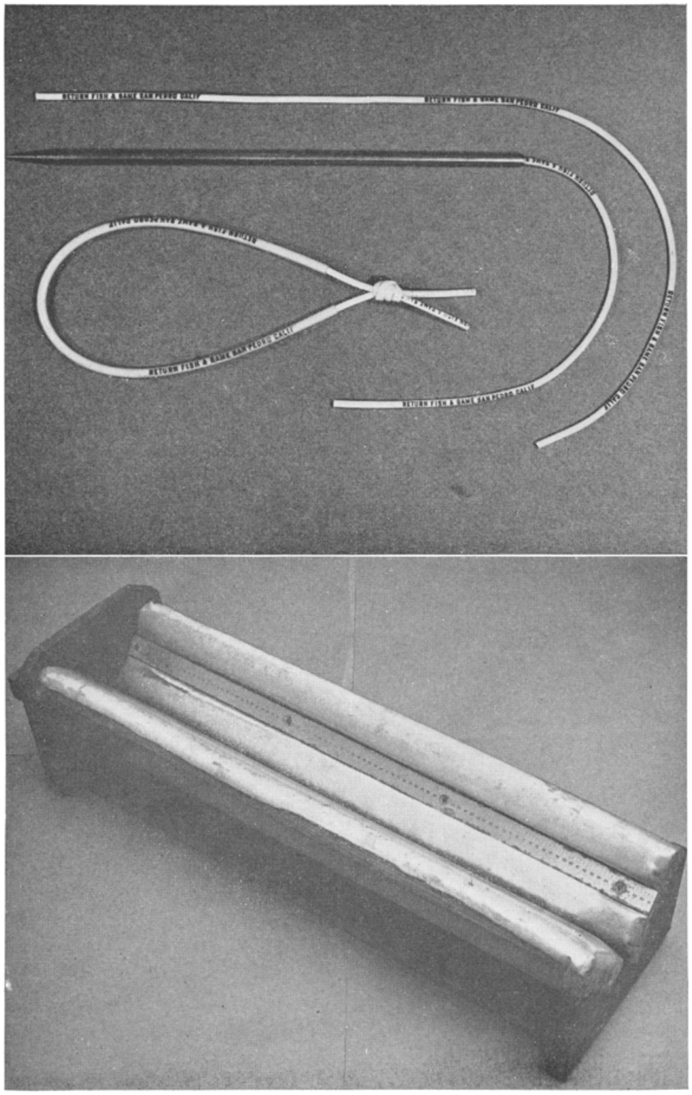

FIGURE 9. Tagging equipment: top—spaghetti tag, tag-loaded needle and tag with ends secured; bottom—sponge-rubber-lined tagging cradle with meter stick screwed to the side for measuring albacore. *Photograph by Robert A. Iselin.*

FIGURE 9. Tagging equipment: top—spaghetti tag, tag-loaded needle and tag with ends secured; bottom—sponge-rubber-lined tagging cradle with meter stick screwed to the side for measuring albacore. Photograph by Robert A. Iselin

the tagging ordeal, it usually will begin to flurry before tagging is completed and death results.

4.4. Tag Recovery Methods

A tagging program of this magnitude will fail unless considerable effort is expended to recover tags and obtain the necessary information about each fish recaptured. Trying to recover a few thousand marked albacore scattered in the millions of miles of north Pacific Ocean is like looking for the proverbial needle in a haystack. Our methods for recovering tags and the required data are elaborate and have produced good results:

1. Inscribed on each tag is a message informing the fisherman where to send it.

2. Field personnel regularly contact fishermen and cannery employees to explain our tagging program, show them what a tag looks like and where it is attached on the fish, and to ask for their cooperation in returning promptly all tags along with desired catch data.

3. Large posters illustrating the tags and providing instructions for their return have been printed in Spanish, Japanese, and English (Figure 10). These have been placed at various landing ports in Mexico, Japan, the Hawaiian Islands, and along the United States west coast (Outdoor California, 1955).

4. Each person returning a tag receives a one dollar incentive reward, an informative letter about the fish, and an official wallet-size commendation card (Figure 11).

5. Fisheries biologists working in various north Pacific landing ports have been well-informed of our program. These people always cooperate in seeing that tags and catch data are returned promptly.

When an albacore is tagged and released the date, location, tag number, and fish fork length are recorded. When it is recaptured similar information is desired. We have had excellent success in obtaining the tag, capture date, and capture location, but it has been more difficult to get fork-length information. Some fishermen removed the tags and sent them to us, but did not measure fork length; in these instances we had to be content with their weight estimates, which we converted to average lengths from our weight-length table.

5. RELEASES OF TAGGED ALBACORE

During six seasons (1952 to 1957), we marked and released 4,585 albacore on 15 cruises in the area offshore between central Baja California and San Francisco. These tag releases have been summarized on a chart, by one-degree squares of latitude and longitude, and show that roughly one-half were marked off Baja California and the remainder between San Diego and San Francisco (Figure 12). Monthly summaries of tag releases by one-degree squares for each year are recorded in Appendix A.

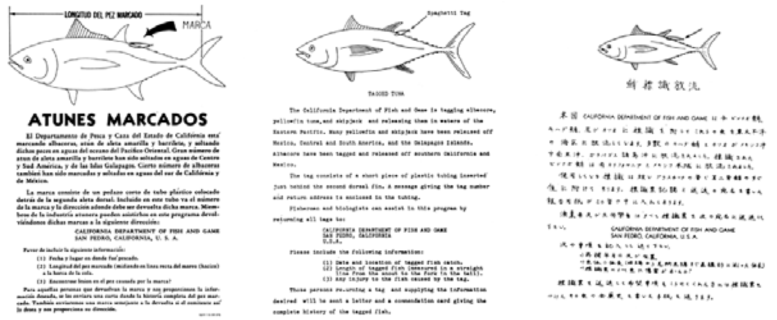

FIGURE 10. Spanish, English and Japanese posters used to provide fishermen with instructions for handling recaptured tagged tunas.

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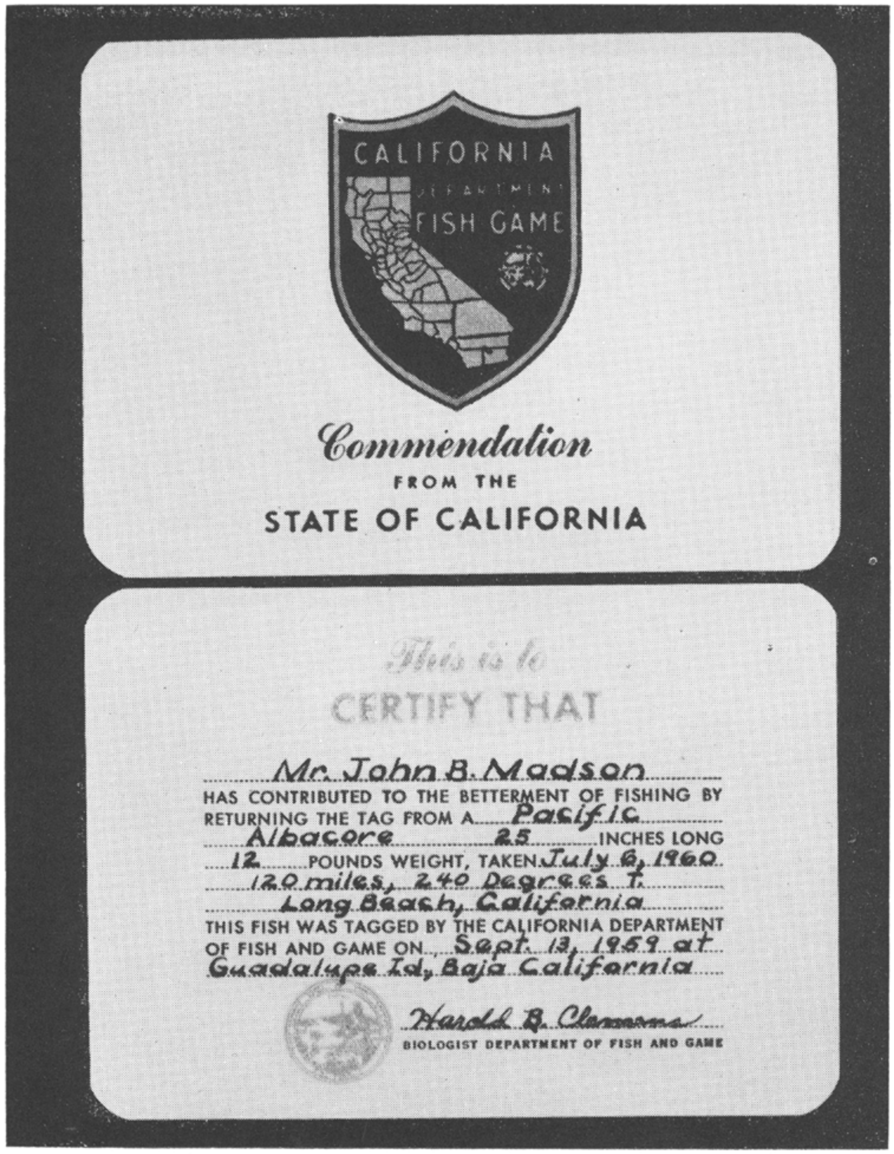

FIGURE 11. Both sides of the California official commendation card given to fishermen returning tagged tuna. *Photograph by Robert A. Iselin.*

FIGURE 11. Both sides of the California official commendation card given to fishermen returning tagged tuna. Photograph by Robert A. Iselin

The tag-development field trials were performed on four cruises beginning in July 1952 and ending in October 1953 (Table 1). During these, 1,332 albacore were marked experimentally with Type E, F, and G spaghetti tags and released in the major fishing areas south of San Francisco. By mid-October 1957, during 11 subsequent cruises, an additional 3,253 albacore were marked with Type G spaghetti tags and released (Table 3).

We measured the fork length of 99 percent (4,538) of the tagged albacore before they were returned to the sea. The marked fish ranged in length from 50 to 99 centimeters and fell into five broad size categories

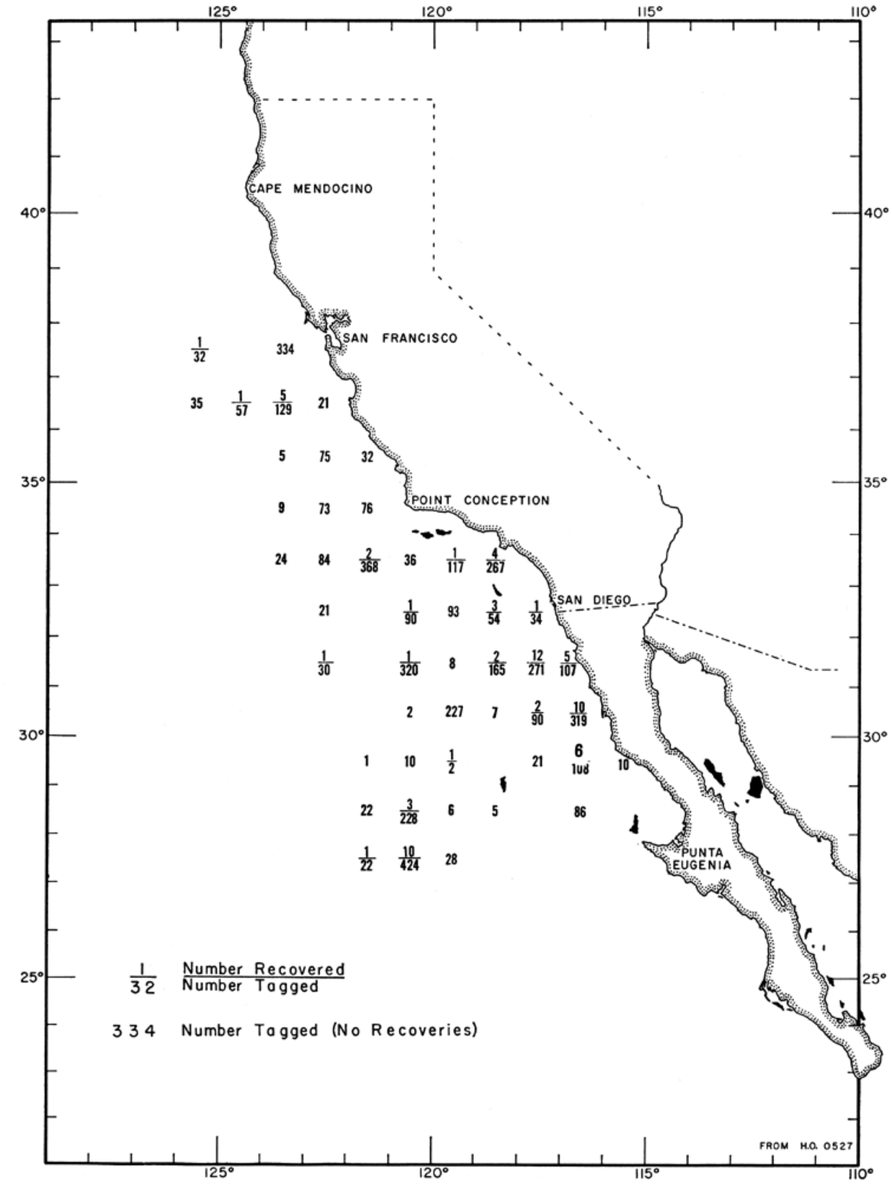

FIGURE 12. Tags released in one-degree squares of latitude and longitude from 1952 through 1957. The top number represents tags returned (regardless of locality) from the total releases within that specific one-degree area.

FIGURE 12. Tags released in one-degree squares of latitude and longitude from 1952 through 1957. The top number represents tags returned (regardless of locality) from the total releases within that specific one-degree area

(Table 4). These categories correspond fairly well to the size groups caught by the commercial fishermen during the tagging period, although marked fish averaged somewhat larger (Figure 13a). Monthly fork-length summaries of albacore tagged each year are recorded in Appendix B.

TABLE 4

Size Categories of Tagged Albacore

Range in Length (cm)	Number Tagged and Measured	Number Recovered	Percent Recovered
<59	423	3	0.7
59-72	2,099	31	1.5
73-83	1,485	32	2.2
84-90	462	6	1.3
>90	69	1	1.4
Totals	4,538	73	1.6

TABLE 4
Size Categories of Tagged Albacore

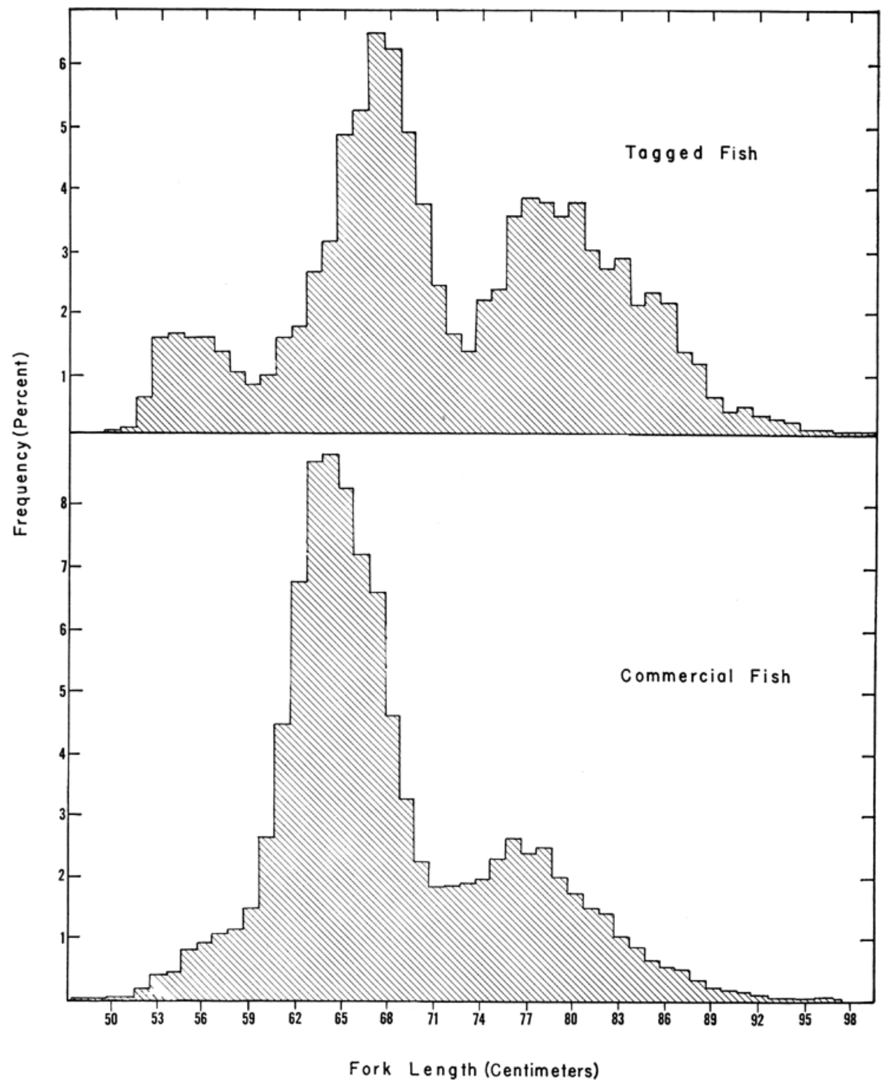

FIGURE 13a. Lengths of tagged albacore (top) compared with lengths of albacore caught by the commercial fishery during the six seasons, 1952 through 1957.

FIGURE 13a. Lengths of tagged albacore (top) compared with lengths of albacore caught by the commercial fishery during the six seasons, 1952 through 1957

TABLE 5
Statistics of Tagged and Recovered Albacore

Tag Recovery Data					Tag Release Data							
		Location				Location						
Tag Recovery No.	Date	N. Latitude	W. Longitude	Fork Length (mm)	Date	N. Latitude	W. Longitude	Fork Length (mm)	Days at Liberty	Change in Length (mm)	Nautical Mi. Traveled (St. Line)	Nautical Miles Per Day
1	9/19/52	35° 07′	121° 50′	813	8/ 7/52	33° 30′	118° 10′	785	44	28	206	4.7
2	9/20/52	35° 17′	121° 40′	673	8/21/52	33° 15′	118° 15′	645	31	28	209	6.7
3	6/23/53	31° 30′	149° 40′ E.	815	8/ 4/52	33° 25′	118° 15′	760	323	55	4,485	13.9
4	9/ 2/53	30° 00′	121° 57′	838	8/11/53	27° 56′	120° 23′	805	23	33	148	6.4
5	9/ 6/53	35° 45′	123° 30′	838	8/11/53	27° 56′	120° 23′	855	27	−17	490	18.1
6	9/ 3/53	30° 19′	121° 54′	819	8/11/53	27° 56′	120° 23′	775	24	44	162	6.8
7	9/12/53	36° 53′	124° 44′	762	8/11/53	27° 56′	120° 23′	800	33	−38	568	17.2
8	9/15/53	36° 54′	125° 07′	847	8/11/53	27° 56′	120° 23′	855	36	−8	584	16.2
9	9/17/53	36° 28′	123° 29′	815	8/13/53	28° 58′	120° 45′	820	36	−5	486	13.5
10	9/24/53	38° 33′	124° 16′	813	8/11/53	27° 56′	120° 23′	780	45	33	679	15.1
11	9/18/53	36° 39′	125° 25′	795	8/11/53	27° 56′	120° 23′	770	39	25	573	14.7
12	9/13/53	36° 29′	124° 12′	825	8/11/53	27° 56′	120° 23′	810	34	15	545	16.0
13	9/16/53	36° 09′	123° 36′	732	8/11/53	27° 56′	120° 23′	785	37	−53	511	13.8
14	9/11/53	36° 27′	124° 21′	817	8/13/53	28° 50′	120° 40′	860	30	−43	493	16.4
15	9/14/53	35° 41′	123° 31′	885	8/16/53	28° 10′	120° 45′	875	30	10	476	15.9
16	2/ 2/54	36° 40′	178° 12′ E.	882	8/11/53	27° 56′	120° 23′	845	175	37	3,114	17.8
17	2/23/54	30° 10′	178° 54′	932	8/16/53	27° 32′	121° 06′	910	192	22	3,000	15.6
18	10/19/54	35° 04′	121° 46′	690	8/24/54	31° 32′	120° 32′	695	57	−5	221	3.9
19	4/10/55	31° 55′	143° 15′ E.	760	9/26/54	33° 42′	121° 15′	755	196	5	4,608	23.5
20	8/11/55	32° 50′	117° 52′	625	7/25/55	31° 46′	117° 29′	620	18	5	75	4.2

TABLE 5
Statistics of Tagged and Recovered Albacore

21	9/ 2/55	31° 39′	118° 28′	815	9/26/54	33° 42′	121° 15′	700	342	115	--	--
22	11/ 9/55	28° 42′	117° 51′	625	7/26/55	31° 46′	117° 29′	623	107	2	184	1.7
23	12/24/55	29° 29′	118° 47′	660	8/10/55	31° 30′	122° 01′	600	137	60	210	1.5
24	6/26/56	29° 24′	115° 56′	663	8/15/55	33° 24′	116° 34′	560	317	103	--	--
25	8/ 1/56	33° 28′	118° 50′	750	7/23/56	33° 02′	118° 15′	750	10	0	39	3.9
26	7/31/56	30° 36′	116° 41′	683	8/16/55	33° 15′	116° 47′	545	351	138	--	--
27	7/28/56	33° 17′	118° 13′	745	7/25/55	31° 46′	117° 29′	633	370	112	--	--
28	8/11/56	33° 10′	118° 24′	761	7/13/56	31° 12′	117° 02′	760	30	1	139	4.6
29	8/13/56	32° 06′	117° 23′	684	8/10/55	32° 28′	117° 42′	560	370	124	--	--
30	8/17/56	32° 24′	118° 30′	744	7/15/56	31° 04′	116° 59′	745	34	−1	111	3.3
31	8/11/56	31° 04′	116° 55′	732	7/11/56	29° 18′	116° 06′	800	32	−68	113	3.5
32	8/20/56	31° 56′	117° 23′	756	7/15/56	31° 04′	116° 59′	770	37	−14	56	1.5
33	8/20/56	31° 56′	117° 23′	758	7/18/56	30° 40′	117° 10′	670	34	88	77	2.3
34	8/12/56	31° 25′	118° 36′	775	7/11/56	29° 18′	116° 06′	770	33	5	179	5.4
35	8/17/56	31° 43′	117° 17′	813	7/10/56	29° 10′	116° 00′	795	39	18	166	4.3
36	8/25/56	32° 40′	118° 20′	784	7/18/56	31° 14′	117° 23′	790	39	−6	98	2.5
37	8/13/56	29° 23′	120° 29′	726	7/15/56	31° 04′	116° 59′	755	30	−29	212	7.1
38	8/25/56	33° 35′	119° 40′	631	7/ 4/56	31° 39′	117° 29′	640	53	−9	166	3.1
39	7/30/56	31° 04′	116° 59′	736	7/11/56	29° 18′	116° 06′	740	20	−4	113	5.7
40	8/30/56	33° 24′	118° 58′	763	8/25/56	33° 33′	119° 27′	770	6	−7	25	4.2
41	8/20/56	31° 57′	117° 12′	755	7/11/56	29° 18′	116° 06′	750	41	5	167	4.1
42	8/ 8/56	31° 52′	117° 08′	696	8/13/55	32° 48′	118° 12′	600	362	96	--	--
43	7/31/56	30° 46′	116° 44′	--	7/10/56	29° 10′	116° 00′	740	22	--	102	4.6
44	10/23/56	32° 04′	117° 21′	732	7/26/55	31° 59′	117° 33′	657	456	75	--	--
45	11/ 9/56	32° 25′	118° 07′	745	10/ 5/55	37° 25′	125° 54′	605	402	140	--	--
46	6/ 1/57	35° 50′	142° 50′ E.	688	9/ 3/56	36° 39′	123° 16′	610	271	78	4,365	16.1
47	7/ 3/57	31° 22′	117° 10′	833	7/25/55	31° 57′	117° 33′	636	710	197	--	--
48	7/ 5/57	31° 45′	118° 08′	750	9/ 3/56	36° 39′	123° 16′	670	306	80	--	--
49	7/20/57	30° 10′	119° 04′	755	9/ 5/56	36° 40′	123° 07′	660	319	95	--	--
50	8/ 4/57	32° 33′	118° 10′	787	6/29/57	30° 28′	116° 40′	790	37	−3	145	3.9
51	7/26/57	32° 33′	118° 31′	789	7/11/57	31° 45′	118° 34′	780	16	9	48	3.0
52	8/24/57	31° 34′	118° 58′	637	7/ 4/57	30° 32′	116° 50′	640	52	−3	126	2.4
53	8/19/57	30° 01′	118° 16′	813	7/15/56	31° 04′	116° 59′	715	401	98	--	--
54	8/25/57	31° 30′	119° 15′	887	7/27/55	31° 57′	117° 33′	638	761	249	--	--
55	8/20/57	31° 30′	119° 06′	768	7/18/56	31° 20′	117° 49′	640	399	128	--	--

TABLE 5—Cont'd.

TABLE 5—Continued
Statistics of Tagged and Recovered Albacore

Tag Recovery Data					Tag Release Data							
		Location				Location						
Tag Recovery No.	Date	N. Latitude	W. Longitude	Fork Length (mm)	Date	N. Latitude	W. Longitude	Fork Length (mm)	Days at Liberty	Change in Length (mm)	Nautical Mi. Traveled (St. Line)	Nautical Miles Per Day
56	9/ 8/57	32° 28′	118° 32′	--	7/ 4/57	30° 32′	116° 50′	760	67	--	147	2.2
57	9/17/57	34° 37′	121° 38′	648	7/11/57	31° 45′	118° 34′	640	69	8	232	3.4
58	9/ 9/57	34° 39′	122° 18′	783	7/ 4/57	30° 32′	116° 50′	780	68	3	372	5.5
59	9/17/57	33° 55′	121° 30′	760	9/ 3/56	36° 39′	123° 16′	675	380	85	--	--
60	9/17/57	33° 35′	121° 30′	772	7/12/57	32° 04′	118° 31′	780	68	−8	177	2.6
61*	9/17/57	34° 49′	121° 26′	--	8/ 1/57	34° 49′	121° 57′	665	48	--	25	0.5
62	9/23/57	35° 19′	122° 04′	749	7/ 2/57	31° 15′	117° 05′	715	84	34	355	4.2
63	9/30/57	35° 40′	121° 28′	857	7/15/56	31° 04′	116° 59′	740	443	117	--	--
64	9/26/57	35° 20′	121° 52′	689	6/29/57	30° 52′	117° 05′	693	90	−1	360	4.0
65	8/12/57	32° 20′	117° 41′	838	10/10/55	36° 07′	124° 10′	630	673	208	--	--
66	10/ 2/57	40° 59′	124° 59′	622	7/12/57	32° 04′	118° 31′	670	83	−48	627	7.6
67*	10/ 7/57	36° 24′	123° 07′	670	7/22/57	35° 43′	122° 58′	655	78	15	41	0.5
68	11/ 1/57	34° 51′	120° 57′	850	7/ 9/57	30° 45′	116° 42′	860	116	−10	328	2.8
69	6/ 4/58	32° 53′	143° 26′ E.	882	7/ 5/57	30° 32′	116° 42′	770	334	112	4,878	14.6
70	6/19/58	35° 35′	148° 50′ E.	840	9/ 3/56	36° 39′	123° 16′	675	654	165	--	--
71	9/10/58	35° 31′	122° 31′	805	6/13/57	29° 17′	119° 46′	670	455	135	--	--
72	9/ 4/58	34° 35′	123° 30′	870	7/ 5/57	30° 32′	116° 42′	670	427	200	--	--
73	9/ 9/58	35° 50′	122° 40′	758	7/14/57	32° 33′	120° 10′	660	423	98	--	--
74	8/12/58	33° 41′	121° 30′	800	7/ 2/57	31° 15′	117° 05′	640	407	160	--	--
75	2/13/59	28° 22′	150° 18′ E.	880	7/ 8/57	30° 45′	116° 42′	780	585	100	--	--

* Nepas Survey—Two albacore that were returned from among 110 tagged and released by Department scientists, while cooperating in a north-eastern Pacific albacore survey (NEPAS) with fisheries research agencies from Oregon, Washington, and the USFWS in the Hawaiian Islands, under the liaison of the Pacific Marine Fisheries Commission (Pacific Marine Fisheries Commission, 1957).

TABLE 5—Cont'd.

6. RECOVERIES OF TAGGED ALBACORE

Tags from 73 albacore have been returned, representing 1.6 percent of the total released during all cruises (Table 5). These fish were recaptured throughout the Baja California and California coastal (troll and live-bait) fisheries, in the central Pacific (longline) fishery near Midway Island, and in the Japanese coastal (live-bait) fishery (Figure 3).

In the California fishery 44 tagged albacore were recaptured by commercial trolling, 16 were taken on live-bait gear, and 5 by sport-fishing. Five tagged fish were taken in the Japanese coastal live-bait fishery and three in their longline fishery, which extends offshore from the coastal waters at least to the vicinity of Midway Island.

Seventeen (1.3 percent) tags have been returned that were released during the early field trials and 56 (1.7 percent) that were released during the regular tagging program. About 90 percent of the recaptured fish came from those marked off Baja California and southern California (Figure 12).

A histogram of the measurements made on recovered albacore shows that they ranged in length from 55 to 91 cm at time of tagging, compared with the 50–99 cm range for all tagged fish (Figure 13b).

7. FACTORS AFFECTING TAG RECOVERIES

Many factors influence the recovery of albacore tags. Some of these can and some cannot be controlled. Because the number of recoveries

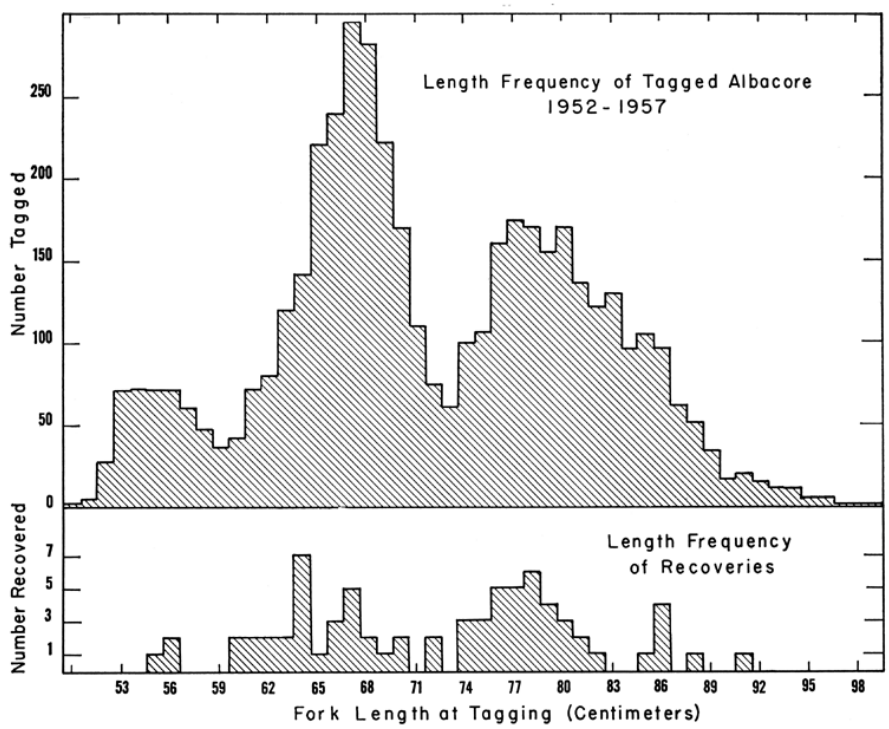

FIGURE 13b. Lengths of all tagged albacore (top) compared with lengths (at time of tagging) of recaptured albacore 1952 through 1957.

FIGURE 13b. Lengths of all tagged albacore (top) compared with lengths (at time of tagging) of recaptured albacore 1952 through 1957

may bear directly on certain inferences drawn from the data, it is important to identify these factors and measure them quantitatively whenever possible so they can be taken into account when interpreting results.

7.1. Tagging Mortality (Capturing and Handling)

Albacore, as well as other tunas and skipjack, are remarkably well adapted to their environment and as a group they are among the most difficult of fishes to tag and release alive. Frequently they flurry with such violence after being withdrawn from the water, that in a few seconds their gills hemorrhage and rip loose; they tear themselves apart at the isthmus, throw the food out of their stomachs, and fling quantities of blood, partially digested food items, and slime over dozens of square feet. Our objective was to catch, tag, measure, and release these fish before the death struggle began. Although they are powerful antagonists, they also are delicate and a light tap on its snout will kill one.

During albacore fishing activities aboard our research vessels, live-bait fishing was generally either slow or fast. When fishing was "hot", albacore could be landed faster than our personnel could tag, measure, and release them. If fishing was slowed, however, the schools frequently left the boat and disappeared. For maximum tagging efficiency a fairly fast fishing rate was maintained, and only those coming aboard in excellent condition were selected for tagging.

Albacore captured on trolling gear, similarly were selected carefully for tagging. Individuals that had been hooked deeply in either jaw, near the eye, or were bleeding at the gills or eyes were rejected. In addition, those that kept their jaws open while being pulled in on the trolling lines were not tagged for fear that the increased water pressure exerted in the stomach and on other internal organs had injured the fish enough to cause it to behave abnormally.

Bait fishing and trolling can both provide fair numbers of quality albacore for tagging, if one exercises care in handling. Additional rejections, however, sometimes had to be made during actual tagging operations—depending upon individual fish behavior. Some came aboard quietly, remained rigid in the tagging cradle, and were marked and released without a struggle. Others began to flurry nervously when taken from the water and did not stop until they had injured themselves fatally.

Although all gradations in behavior were noted within a school or closely-knit school group, there was a tendency for individual schools to consist predominately of fish that reacted either violently or nonviolently to capture and handling. When large numbers of albacore reacted violently to capture, the person doing the tagging soon found that the length of his temper was inversely proportional to the number of jittery albacore landed.

Immediately after each fish had been marked and released, its chances of having survived the tagging ordeal were estimated. These estimates were designated "good", "fair", and "poor"; based on the time each fish was out of water, the amount of struggling and physical damage that occurred during tagging, and its behavior upon return to the sea (Table 6). There was little difference in recovery rates between fish designated "good" or "fair" at release time; albacore could survive moderate handling (Table 7). Although statistically too few fish were labeled "poor" to expect recoveries, experience tells us that all these died from the tagging skirmish. Therefore, we feel that none of the 85 "poor" albacore (1.9 percent of the tags) survived.

After having tagged several tons of albacore, yellowfin tuna, and skipjack, and a few bluefin and bigeye tuna, I believe that albacore are the hardiest of the five followed by bluefin, bigeye, yellowfin, and skipjack. Several commercially caught albacore have been noted with well-healed scars on their jaws and body, illustrating their hardy nature. These scar-bearing albacore lead us to believe they have a lower handling mortality rate than the other tunas or skipjack that rarely are found bearing old scars.

TABLE 6

Release Condition of Tagged Albacore

Month	Condition	1952	1953	1954	1955	1956	1957	Totals
June	Good	0	0	0	0	0	91	91
	Fair	0	0	0	0	0	6	6
	Poor	0	0	0	0	0	2	2
July	Good	2	0	0	35	396	489	922
	Fair	0	0	0	5	9	34	48
	Poor	1	0	0	1	10	8	20
Aug.	Good	186	699	479	123	158	2	1,647
	Fair	14	44	109	17	4	0	188
	Poor	15	7	9	3	4	0	38
Sept.	Good	2	0	688	67	184	36	977
	Fair	0	0	156	9	5	2	172
	Poor	0	0	14	2	4	1	21
Oct.	Good	0	338	1	76	0	2	417
	Fair	0	22	0	10	0	0	32
	Poor	0	2	0	2	0	0	4
Totals	Good	190	1,037	1,168	301	738	620	4,054
	Fair	14	66	265	41	18	42	446
	Poor	16	9	23	8	18	11	85

TABLE 6

Release Condition of Tagged Albacore

TABLE 7

Recoveries of Albacore Designated Good, Fair, and Poor When Released

Year	Good		Fair		Poor		Total
	Tagged	Recovered	Tagged	Recovered	Tagged	Recovered	
1952	190	2	14	1	16	0	220
1953	1,037	14	66	0	9	0	1,112
1954	1,168	2	265	1	23	0	1,456
1955	301	11	41	2	8	0	350
1956	738	22	18	1	18	0	774
1957	620	16	42	1	11	0	673
Totals	4,054	67	446	6	85	0	4,585

TABLE 7

Recoveries of Albacore Designated Good, Fair, and Poor When Released

We realized during the first field trials, that the length of time an albacore is kept out of water is a critical factor contributing to tagging mortality. Further, we felt that this factor could be reduced by one-third if we did not spend time measuring their lengths. However, by measuring each fish when tagged and again when recaptured the interim growth may be determined and the species growth curve established. This is one of the best means available for determining tuna growth rates—a prime objective of our tagging program.

We decided, therefore, to accept the possibility of a greater handling mortality and a lower tag recovery rate to gain the invaluable growth data, which is fundamental to any serious study of fish populations.

7.2. Tag Shedding

When a marked albacore was recaptured, the tag and wound were examined thoroughly for evidence that tag shedding eventually would occur. We found no such evidence. There were a few cases in which 10-to 20-pound fish had been tagged shallowly, but even in these instances one could lift and shake the fish by the tag without tearing it out. This is possible because a tough strip of skin, in which the dorsal finlets are imbedded, lies directly above the tag insertion area—one reason for choosing this position to affix the tag. The tags are held even more securely, however, in living fish flesh; the wound heals rapidly (frequently in less than 30 days) and soon the tag is imbedded firmly in healthy new growth.

Many tags used in the 1952 and 1953 experimental field trials were longer than necessary. The tagging wound in some recaptured albacore, although well healed, appeared needlessly enlarged due to drag exerted on the tag by these fast-traveling fish moving through the water. The enlarged area was always confined to the outer, posterior rim of the wound where the tag had rubbed against flesh. This minor defect was remedied by shortening the tag early in 1954 and removing the jacket in 1955.

7.3. Defective Materials and Tag Types

Tuna tagging cruises lasted from 2 to 16 weeks and involved many hours of tedious work each day; sometimes in treacherous weather and seas. We never have taken a chance on wasting our efforts by using defective materials and tags. We always have physically pre-tested the materials used for fabricating spaghetti tags. In addition, each tag recovered was examined for imperfections that could cause it to break and eventually drop off the fish. If defects were found or suspected, the tag type was discontinued immediately.

Experimental Type E tags were made from stainless steel (Type 302) wire and Fibron tubing (No. 14 and 20 XTE-30). After marking 80 albacore during two 1952 cruises, we deemed them unsatisfactory. None was considered to have been effective, and none has been recovered.

The 45-pound test braided-nylon fishing line that tied the ends of experimental Type F tags became frayed after six months on an albacore. One, however, stayed on an albacore for 324 days. Although this type was eliminated early, the 73 applied during 1952 and 492 in 1953 probably were not retained more than one year. Four Type F tags have been recovered—one from Japan represented the first recorded transpacific albacore migration (Ganssle and Clemens, 1953).

None of the plastics used in albacore tags was found defective, and none deteriorated or gave any indication that the tags eventually would fall off the fish. Evidence obtained to date, by examining recovered tuna and tags, indicates that a properly applied all-plastic spaghetti tag remains on a fish throughout its life—one of our major objectives.

7.4. Tag Visibility

Albacore tag-recovery efficiency depends upon the fishermen seeing the tags and returning them. During the early days, we maximized visibility by using fairly long tags made of brightly colored spaghetti. Subsequent events, however, demonstrated that a moderate length was satisfactory.

Any color that contrasts with the steel-blue albacore back would be adequate, because the fishermen have opportunities to see a tag when:

(1) the fish first comes aboard the vessel and is landed on deck;

(2) transferring it from the deck to the cooling compartment or well;

(3) it is picked up and individually packed in ice;

(4) it is being unloaded at the dock.

There is ample opportunity for finding each tag and apparently none has gone unnoticed.

7.5. Miscellaneous

During tag recovery experiments on yellowfin tuna and skipjack, Blunt and Messersmith (1960) found that a fair percentage of the tags was overlooked by fishermen but found in the canneries—some never were recovered. By comparison, albacore are not subjected to the mass handling techniques required in the yellowfin and skipjack fisheries, and tagged albacore never have been found in a cannery.

When a tagged fish is captured the word spreads quickly through the fishing fleet; our port-contact man, who keeps abreast of all fishing activities and serves as a Department representative to the fishermen, frequently is informed of a recovery several days before the fish and tag arrive in port (Figure 14).

Sometimes the harsh methods used to catch fish for tagging may result in their eventual death. However, albacore jigged while trolling at six knots and then tagged and released have been recaptured at a rate comparable to that for live-bait caught fish. This indicates that we have eliminated the possibility of differential recovery rates, that may have been caused by gear, by carefully selecting each fish we tag. These data also show that lightly hooked, small albacore (under the legal seven-pound limit) will probably live to bite again if they are carefully handled and quickly returned to the sea. To hold the leader in one hand and smash these small fish against the boat side to knock them off the hook is always fatal.

On a tagging cruise as many fish as possible are marked and released, regardless of when and where they are captured. During slow fishing only an occasional fish or two are caught at a time, and eventually a few tags are scattered over a wide area. This is "low density" tagging, compared to "high density" tagging that occurs when fishing is hot and large numbers of tags are concentrated in a single school or school

FIGURE 14. Port-contact man John C. Nowell keeps abreast of fishing activities, issues logbooks and explains the progress of our research program to fishermen. *Photograph by Robert A. Iselin.*

FIGURE 14. Port-contact man John C. Nowell keeps abreast of fishing activities, issues logbooks and explains the progress of our research program to fishermen. Photograph by Robert A. Iselin.

group. There were no important differences in recovery rates for fish tagged and released under either of these conditions.

The effect of various above-mentioned factors on seasonal tag recovery rates during both the experimental and regular tagging cruises has been estimated. These data, assuming no natural mortality, indicate that there were 130 tagged albacore in the ocean at the beginning of the 1953 fishing season, 1,151 at the start of the 1954 season, etc. Losses from 1952 to 1957 totaled 85 from handling and 72 from defective experimental tags. Finally, from 1952 to 1954 defective experimental materials caused an eventual loss of 552 tags—albacore tagged and released in 1959 are not included in this study (Table 8).

8. ALBACORE MIGRATION

Previous to 1952 little information was available concerning albacore migrations, or most other facets of their life history. All that was known about their migrations was that they suddenly appeared along the West Coast in the early summer and disappeared in the winter—except for sporadic catches in exceptional years.

Gross estimates of albacore migration patterns into, within, and from the West Coast fishing grounds have been obtained by conducting exploratory fishing aboard our research vessels, by studying the activities of sport and commercial fishing fleets, and by plotting catch localities for individual albacore size groups. Simultaneously more precise measures of migration have been made by using tag-and-recapture data.

8.1. Exploratory Fishing Aboard Research Vessels

The Department for years has conducted exploratory fishing and oceanographic surveys in the eastern North Pacific, to obtain information that would lead to a better understanding of albacore populations, biology, and environment. These research cruises, extending from southern Baja California to the Columbia River and offshore to the Hawaiian Islands, have provided considerable information bearing directly on albacore migrations (Phillips, 1933a, 1933b, 1933c, and 1933d; Godsil, 1934; Weseth, 1937; Godsil, 1941, 1948a, 1948b, 1948c, and 1948d; Godsil and Greenhood, 1952; Wilson, 1954; Pinkas, 1954).

Exploratory fishing cruises utilizing gill nets, trolling gear, live bait, and longlines during various seasons since 1933, showed that albacore are present from May to December. However, from January through April there are no sizeable concentrations available to the California fishing fleet, either in the coastal fishing grounds or as far seaward as approximately 1,000 miles (California Department of Fish and Game, 1954). We conclude from these data that a majority of the albacore schools have migrated out of the eastern Pacific by December's end.

Six pre-season surveys aboard the *N. B. Scofield*, during May or June or both, located the migrating albacore schools enroute from the central North Pacific to the West Coast (Pinkas, 1955; Mais, 1957; California Department of Fish and Game, 1958; Craig, 1958, 1959, and 1960; Craig and Graham, 1961). These schools have been intercepted about 1,000 miles offshore, but have not been followed coastward into the California fishing grounds except from 500 miles seaward (Craig, 1960). By mid-August most albacore destined for the Baja California-Southern California fishing grounds have arrived.

Data from our exploratory fishing cruises and fishermen logbooks indicate that the route used by albacore entering the West Coast fishing grounds each season was transient in nature. From 1951 through 1955 the main body of albacore swarmed into the coastal grounds well south of Guadalupe Island; in 1956 the migrants swept through the Island area; in 1957 the route lay north of the Island; in 1958 they entered the fishery near San Juan Seamount off southern California; and in

TABLE 8

Factors Causing Tag Losses

Season (June 1-May 31)	Number Tagged	Total Tagged (Cumulative)	Losses From: Handling	Defective Experimental Tags	Defective Experimental Materials	Fishing	Potential Effective Tags at Start of Season (Cumulative)
1952	220	220	16	72	0	2	----------
1953	1,112	1,242	9	0	67	15	130
1954	1,456	2,607	23	0	485	2	1,151
1955	350	2,447	8	0	0	4	2,097
1956	774	3,209	18	0	0	22	2,435
1957	673	3,842	11	0	0	21	3,169
1958	0	3,810	0	0	0	7	3,810
Totals	4,585	----------	85	72	552	73	----------

TABLE 8
Factors Causing Tag Losses

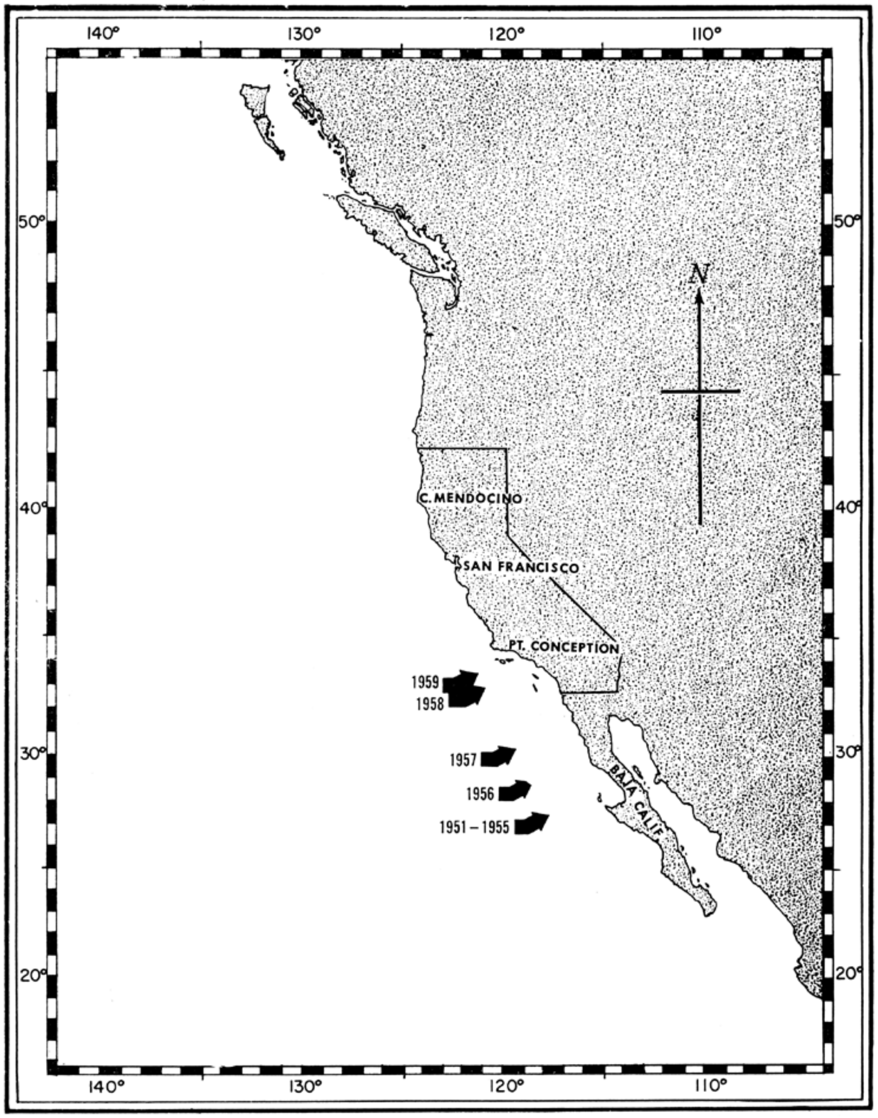

FIGURE 15. Areas where the main body of incoming albacore migrants entered the southern fishing grounds during the nine seasons, 1951 through 1959.

FIGURE 15. Areas where the main body of incoming albacore migrants entered the southern fishing grounds during the nine seasons, 1951 through 1959

1959 they traveled into the fishing grounds slightly farther north (Figure 15).

We have not measured all of the factors that might influence albacore movements and distribution but sea-surface temperature, location and abundance of desirable food items, and albacore size and state of sexual maturity are among the most important. Beginning in 1954, fishing fleet captains were asked to provide us with information concerning the surface temperatures in which they fished each day and their ensuing catch (Clemens, 1954). These and other data we had gathered demonstrated conclusively for the first time, that there is a definite albacore catch-temperature relationship in the eastern North

TABLE 9

Number of Albacore by Surface Temperature

Surface Temperature (Degrees F.)	Albacore Seasons										5-Year Total	
	1954-55		1955-56		1956-57		1957-58		1958-59			
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
<60	1,802	3.15	4,114	1.89	9,834	2.24	581	.16	306	.14	16,637	1.28
60-65	51,807	90.56	132,895	60.87	337,145	76.78	214,751	58.67	185,496	84.49	922,094	70.92
66-71	3,580	6.26	76,762	35.16	92,136	20.98	149,439	40.83	33,736	15.37	355,653	27.35
>71	20	.03	4,541	2.08	000	00.00	1,237	.34	000	00.00	5,798	.45
Totals	57,209		218,312		439,115		366,008		219,538		1,300,182	

TABLE 9
Number of Albacore by Surface Temperature

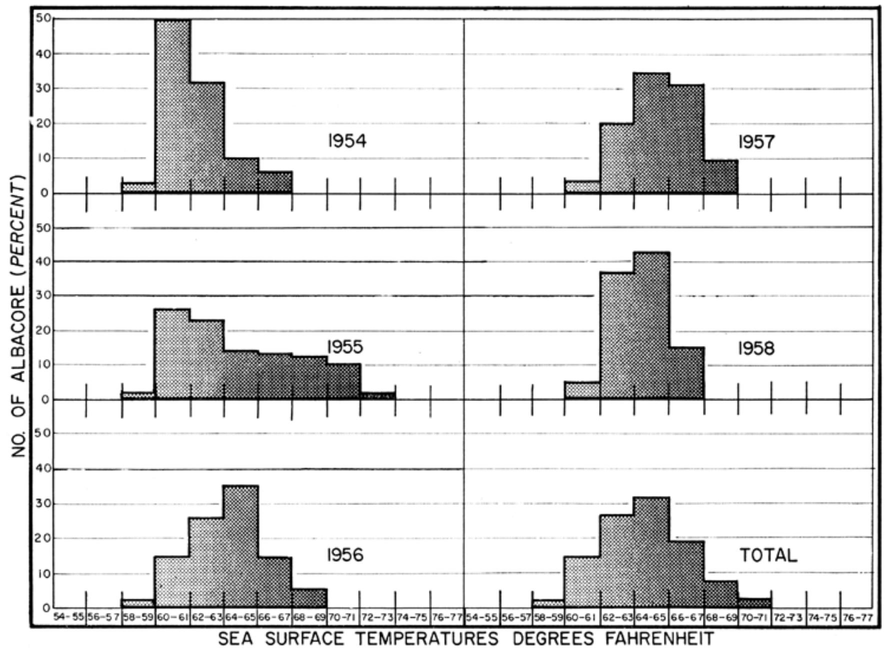

FIGURE 16a. Sea-surface temperatures in which 1.3 million albacore were caught during the five seasons, 1954 through 1958.

FIGURE 16a. Sea-surface temperatures in which 1.3 million albacore were caught during the five seasons, 1954 through 1958

TABLE 10

Relative Abundance of Albacore by Surface Temperatures

Sea Surface Temperature (Degrees F.)	1957-58 Average Catch Per Day		1958-59 Average Catch Per Day	
	Number	Pounds	Number	Pounds
54			5.0	88.0
55			----	----
56			6.0	64.0
57	11.3	171.7	1.0	13.0
58	24.5	335.4	5.1	85.2
59	13.5	218.1	20.2	278.4
60	46.1	682.7	36.8	529.6
61	65.8	1020.2	64.8	918.6
62	84.2	1234.8	75.9	1054.4
63	90.6	1344.3	76.7	1073.4
64	93.1	1425.7	89.4	1315.0
65	94.2	1590.1	94.2	1622.6
66	71.7	1292.8	85.8	1833.1
67	65.6	1226.7	76.0	1722.1
68	61.9	1193.6	35.7	561.0
69	52.8	1047.2	26.2	375.8
70	27.7	556.6	20.1	334.5
71	13.1	259.5		
72	24.3	499.7		
73	9.0	183.7		
74	2.0	490.8		
75	53.0	979.5		
76	1.0	21.0		

TABLE 10
Relative Abundance of Albacore by Surface Temperatures

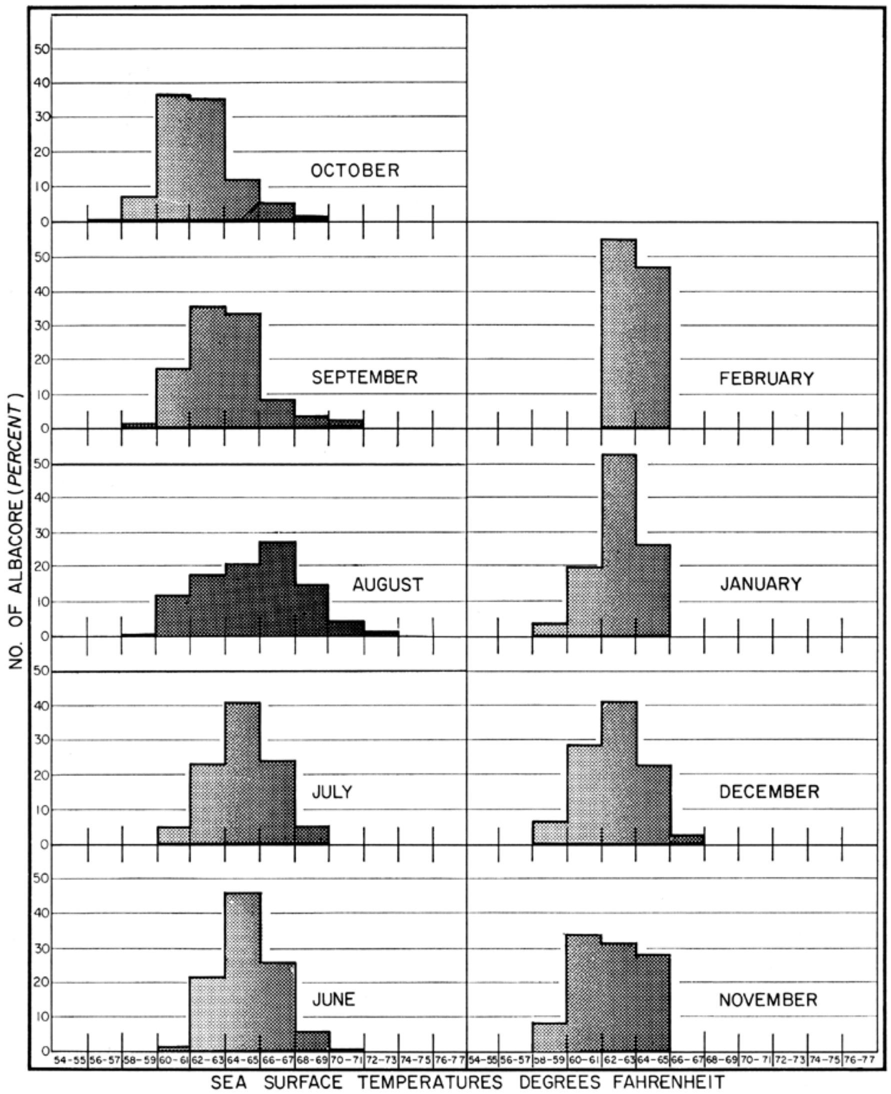

FIGURE 16b. Sea-surface temperatures in which 1.3 million albacore were caught by month during the five seasons, 1954 through 1958. March has been omitted, for only 16 albacore were reported—all from 62 degree F. water.

FIGURE 16b. Sea-surface temperatures in which 1.3 million albacore were caught by month during the five seasons, 1954 through 1958. March has been omitted, for only 16 albacore were reported—all from 62 degree F. water

Pacific (California Deparment of Fish and Game, 1958; Clemens, 1959). A majority of the fish, over the past several years, has been caught while traveling within the narrow temperature range of 60–67 degrees F., although some have been captured where surface temperatures were as low as 54 and as high as 77 degrees F. (Clemens, 1957 and 1958; Craig, 1959). The fact that albacore prefer an environment that is characterized, among other things, by certain water temperatures is not surprising, for it is well known that the metabolic rate and therefore the rates of growth and reproduction of fish species are temperature regulated.

FIGURE 17. Albacore commercial fishing vessels (live-bait and jig boats). *Photograph by Harold B. Clemens.*

FIGURE 17. Albacore commercial fishing vessels (live-bait and jig boats). Photograph by Harold B. Clemens

Temperature information was obtained involving more than 1.3 million albacore (approximately 19 million pounds) captured offshore between central Baja California and the Columbia River, from 1954 through 1958. These data revealed that almost 90 percent of the catch was made where sea-surface temperatures were 60 to 67 degrees F. (Figure 16a, b and Appendix C). During all five seasons best fishing was in 60 to 65 degree F. water; however, during some seasons (notably 1957–58) the catch was much better in 66 to 71 degree F. water than in other seasons (Table 9). Catch-effort estimates based on 1957–58 and 1958–59 data, indicate that albacore schools were relatively more abundant where sea-surface temperatures were 60 to 68 degrees F. (Table 10).

Bait boats, which have comprised an estimated 10 percent of the California fishing fleet (Clemens, 1958, 1961), usually account for most of the catches in water 66 degrees F. and warmer (Craig, 1959). A majority of the larger albacore (20 pounds and above) historically have been harvested by these vessels, which experience best bait fishing where sea-surface temperatures are warmer (Figure 17). These data confirm information obtained on our exploratory fishing cruises and demonstrate that for albacore there is a definite size-temperature relationship in the eastern North Pacific. In our coastal fishery, therefore, we find albacore migrating within a fairly narrow temperature range and they are distributed by size within this range; *i.e.* small fish in the cooler surface water to the north and large ones in warmer water.

Almost 80 percent of the Japanese "summer" albacore catch, which consists primarily of large fish (20 pounds and heavier), is made where surface temperatures range from 66 to 70 degrees F. (Sasaki, 1939). The Japanese "summer" fishery is a live-bait fishery and thus on both sides of the North Pacific the coastal live-bait fisheries harvest albacore primarily weighing 20 pounds and heavier, where sea-surface temperatures are 66 degrees F. and warmer. The Japanese do not have a coastal troll fishery similar to ours, that harvests large quantities of albacore lighter than 20 pounds in waters cooler than 66 degrees F.

We used our knowledge of the albacore catch-temperature relationship and accurately predicted the tremendous shifts in the albacore coastward migration route from 1957 through 1960. These predictions were mailed pre-season to more than 500 commercial fishing captains and boat owners in an experiment designed to put fishermen on albacore schools more quickly and thus improve fishing efficiency (Clemens, 1958; Craig, 1959 and 1960; California Department of Fish and Game, 1958 and 1961).

8.2. Fishing Fleet Activities

Although the size of the commercial fleet has declined since 1950, well over 1,000 vessels fished for albacore during the 1950 to 1959 seasons inclusive (Clemens, 1958 and 1961). A fleet this large consisting of many vessels well-equipped with radio communication and electronic navigation gear and capable of operating hundreds of miles offshore, succeeds in finding the albacore schools and staying with them once they have entered the fishing grounds (Figure 18). Thus, by examining the fleet catch records, it is possible to estimate gross albacore movements.

Fishermen record their daily fishing activities for us on special chart-type logbooks (California Department of Fish and Game, 1956; Clemens, 1957). From these logs we can plot the location of the fleet catches each month on a chart and obtain an approximation of the average seasonal albacore movements within the West Coast fishery. These data show that each year as the season advances, albacore schools travel northward upcoast (Clemens, 1957).

The route taken by the fish during this northward migration is transient and has been illustrated diagramatically in Figures 19a through i. For example, for the grounds south of Point Conception, California, the fleet catch records show that, during the five-year period 1951 through 1955, the albacore schools swept into the fishing grounds south of Guadalupe Island and then traveled northward. In 1951, they swam upcoast fairly close to shore from June through about mid-August; by September, however, the inshore run had dwindled and many schools were traveling farther offshore (Figure 19a). In 1952, the northward migration again commenced near shore; during August and September it shifted offshore in the south, moved northward

FIGURE 18. Albacore fishing fleet tied up at Fish Harbor, Terminal Island, California, July 1960. *Photograph by Harold B. Clemens.*

FIGURE 18. Albacore fishing fleet tied up at Fish Harbor, Terminal Island, California, July 1960. Photograph by Harold B. Clemens.

through the Guadalupe Island area, and then turned abruptly toward the coast (Figure 19b). By comparison, the 1953 migration began even farther offshore during June and July; during August and September, however, the inshore portion of the run diminished and albacore moved northward well-outside of Guadalupe Island (Figure 19c). In 1954 the seasonal migration started outside of Guadalupe Island and then swept nearshore during June and July; by August, however, the inshore part of the run had tapered off and most of the albacore traveled north well-offshore from August to October inclusive (Figure 19d). The 1955 season began nearshore in the south, and traveled upcoast during the four months June through September and part of October. The migrations of October and November were a little farther seaward, and there was a decline of the inshore fishery (Figure 19e).

In 1956, again considering the grounds south of Point Conception, the main body of albacore moved into the coastal fishing grounds a little farther to the north (by comparison with seasons 1951 through 1955), sweeping through the Guadalupe Island area before turning upcoast. In June and July, the run occurred near shore and then moved

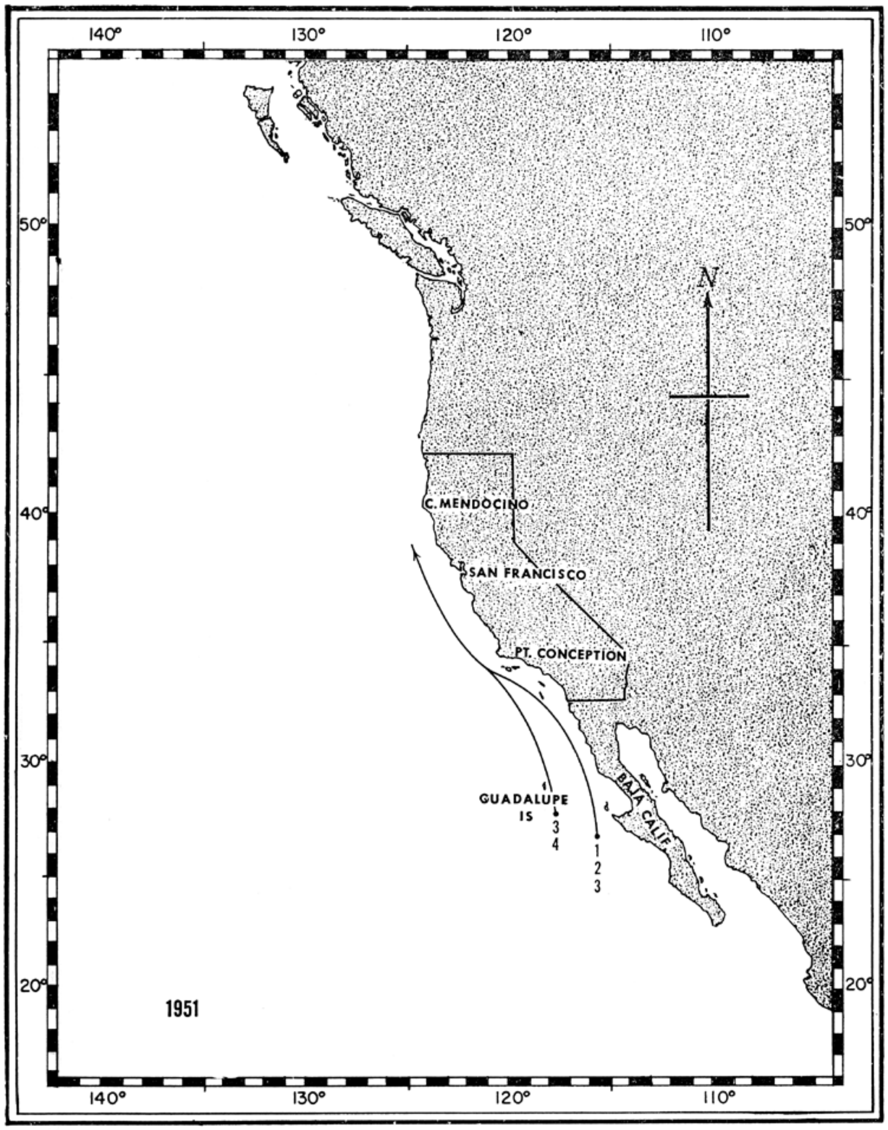

FIGURE 19a. Diagram of the 1951 coastal albacore migration determined from catch data. Numbers represent months: 1=June, 2=July, 3=August, etc.

FIGURE 19a. Diagram of the 1951 coastal albacore migration determined from catch data. Numbers represent months: 1=June, 2=July, 3=August, etc

farther off during the four months August through November (Figure 19f). In 1957 the main migration entered the fishing grounds to the north of Guadalupe Island. In June it moved upcoast relatively near shore, but during July through October the inshore segment had diminished and albacore were traveling north farther seaward (Figure 19g).

During the seven years 1951 through 1957, the main characteristic of that part of the northward albacore migration through the southern area (southern Baja California to Point Conception) was its substantial within-season variability in position. It began relatively near shore only to move seaward later within each season, depending upon

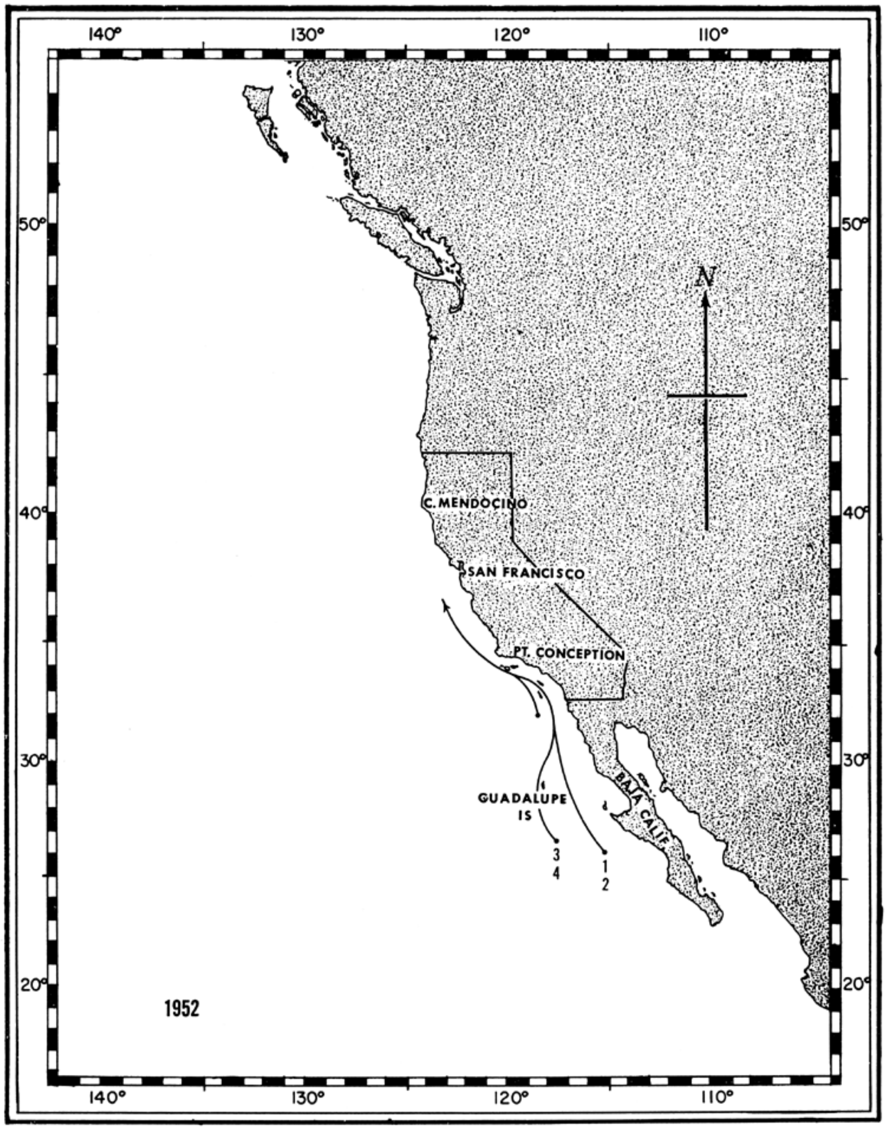

FIGURE 19b. Diagram of the 1952 coastal albacore migration determined from catch data. Numbers represent months: 1=June, 2=July, 3=August, etc.

FIGURE 19b. Diagram of the 1952 coastal albacore migration determined from catch data. Numbers represent months: 1=June, 2=July, 3=August, etc

the timing, rate, and manner of advance of warm southern water moving counter to the California current or to seasonal warming that usually advances more rapidly along the coast (within about 100 miles) than it does farther offshore. In addition, the major portion of these migrating fish did not round Point Conception until August; during the 1957 season, the migration began farther to the north and a fair number of fast-traveling fish consequently rounded the Point in July.

North of Point Conception the major part of the albacore run also varied within and between seasons with respect to distance from shore,

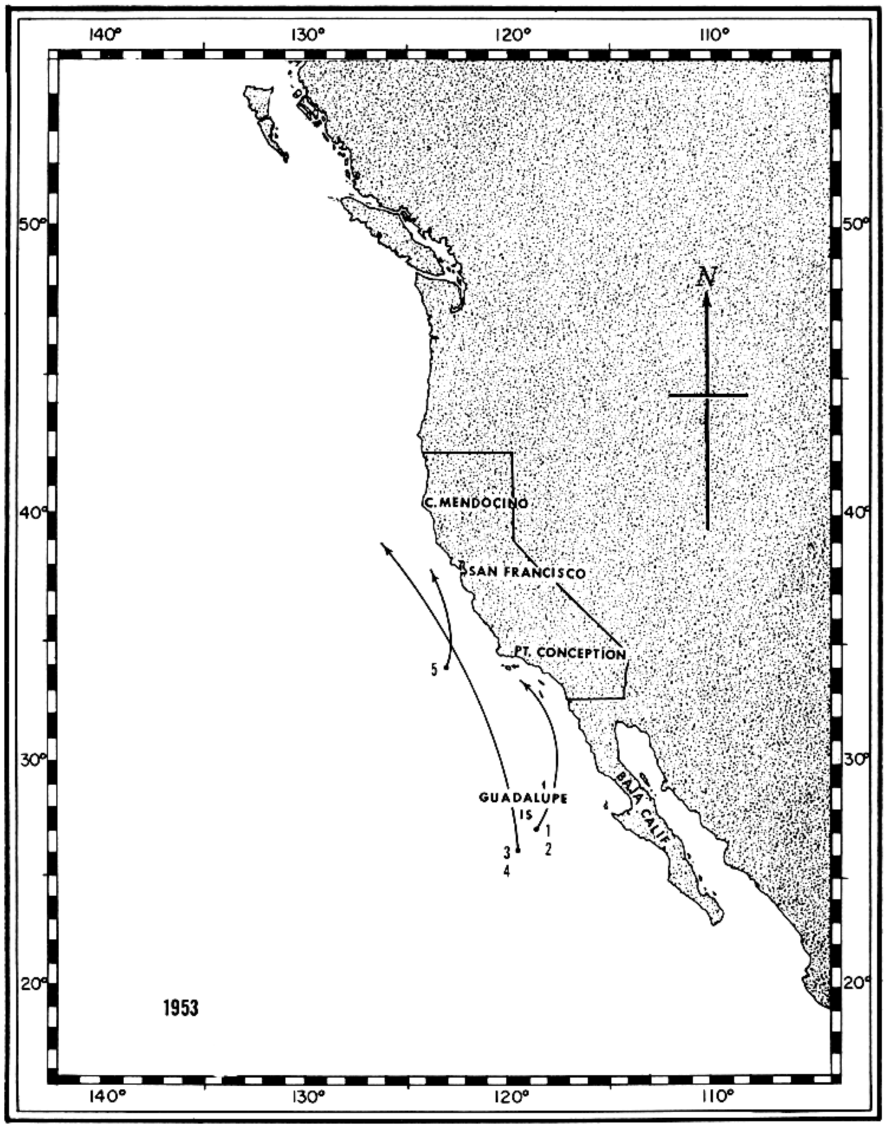

FIGURE 19c. Diagram of the 1953 coastal albacore migration determined from catch data. Numbers represent months: 1=June, 2=July, 3=August, etc.

FIGURE 19c. Diagram of the 1953 coastal albacore migration determined from catch data. Numbers represent months: 1=June, 2=July, 3=August, etc

although the schools were more scattered and the catches more erratic once they rounded the Point. This portion of the migration moved north outside of the cold upwelled coastal waters and there was considerable variation in the locality of the offshore (westward) migration. Fleet catch records indicated that, during 1951 to 1955, albacore schools began traveling northwestward (offshore) and out of fishing-boat range in the general area of Eureka, California. By comparison, in 1956 and 1957 many of the school groups began traveling offshore considerably farther to the north.

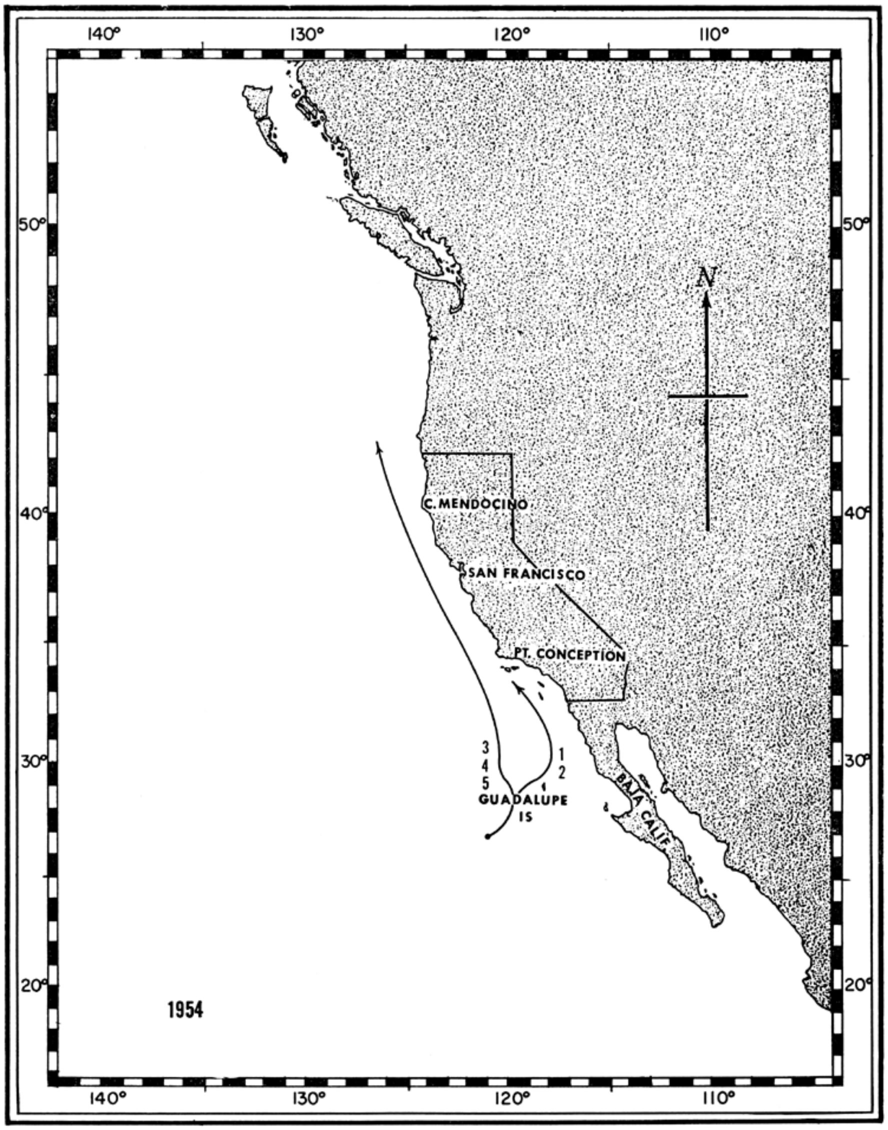

FIGURE 19d. Diagram of the 1954 coastal albacore migration determined from catch data. Numbers represent months: 1=June, 2=July, 3=August, etc.

FIGURE 19d. Diagram of the 1954 coastal albacore migration determined from catch data. Numbers represent months: 1=June, 2=July, 3=August, etc

During the 1958 and 1959 warm-water seasons, the main albacore migration swept into the fishing grounds in the vicinity of San Juan Seamount and moved rapidly up the coast (Figures 19h, i). In July 1958 the migration rate of some school groups was so fast that the fishing fleet had to run northward almost every night to keep up with the fish and be in position to catch them the next day. During these two years, the region of major westward exodus may have been as far north as Washington.

A few albacore were taken during the winter of the four seasons 1954 to 1958. This small "winter" fishery progressed in a north-south

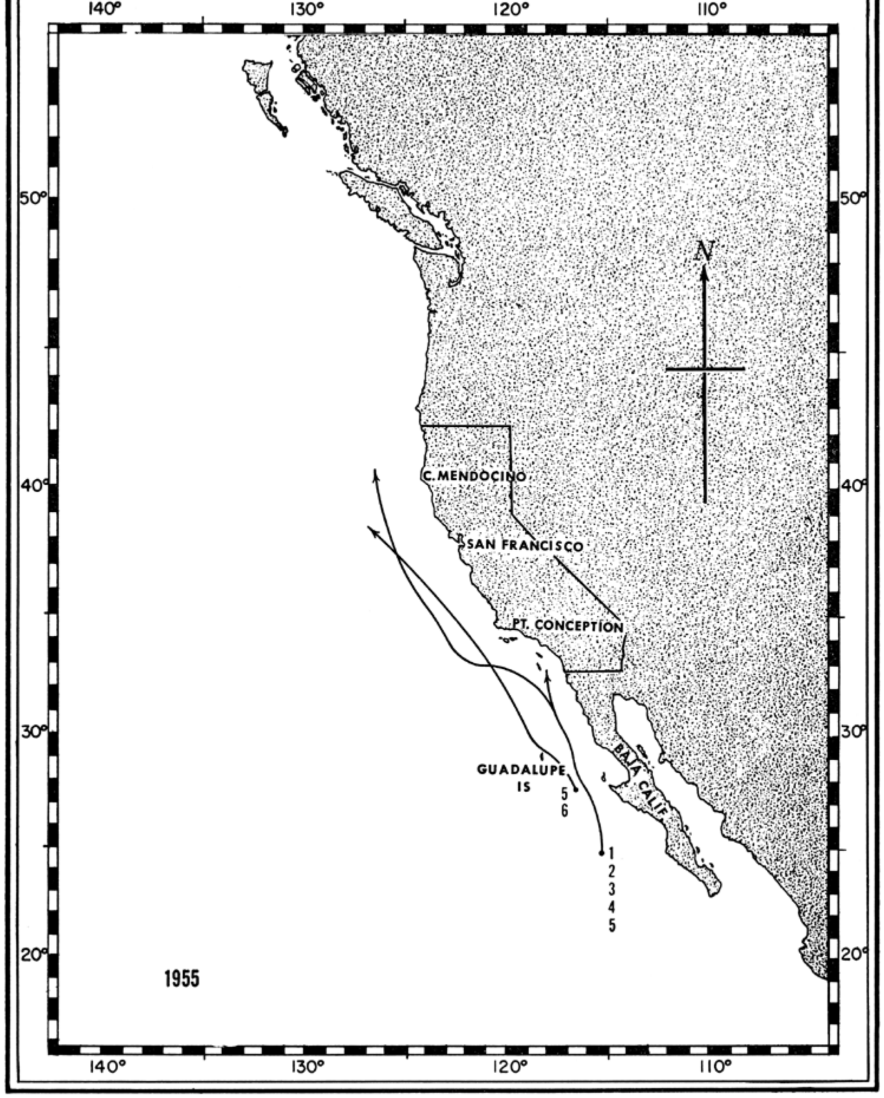

FIGURE 19e. Diagram of the 1955 coastal albacore migration determined from catch data. Numbers represent months: 1=June, 2=July, 3=August, etc.

FIGURE 19e. Diagram of the 1955 coastal albacore migration determined from catch data. Numbers represent months: 1=June, 2=July, 3=August, etc

direction, from Point Conception to the Guadalupe Island area. It indicated that frequently a few albacore do not complete a northward coastal migration; instead, in response to changing environmental conditions to the north, they head south in the fall to overwinter in the vicinity of Guadalupe Island or southward. Tagging tended to substantiate this information for three tags, or four percent of the recoveries, were from fish taken more than 180 miles south of the release area. These fish were tagged in more northerly areas earlier in the season and recovered in August, November, and December as far south as the Guadalupe Island area.

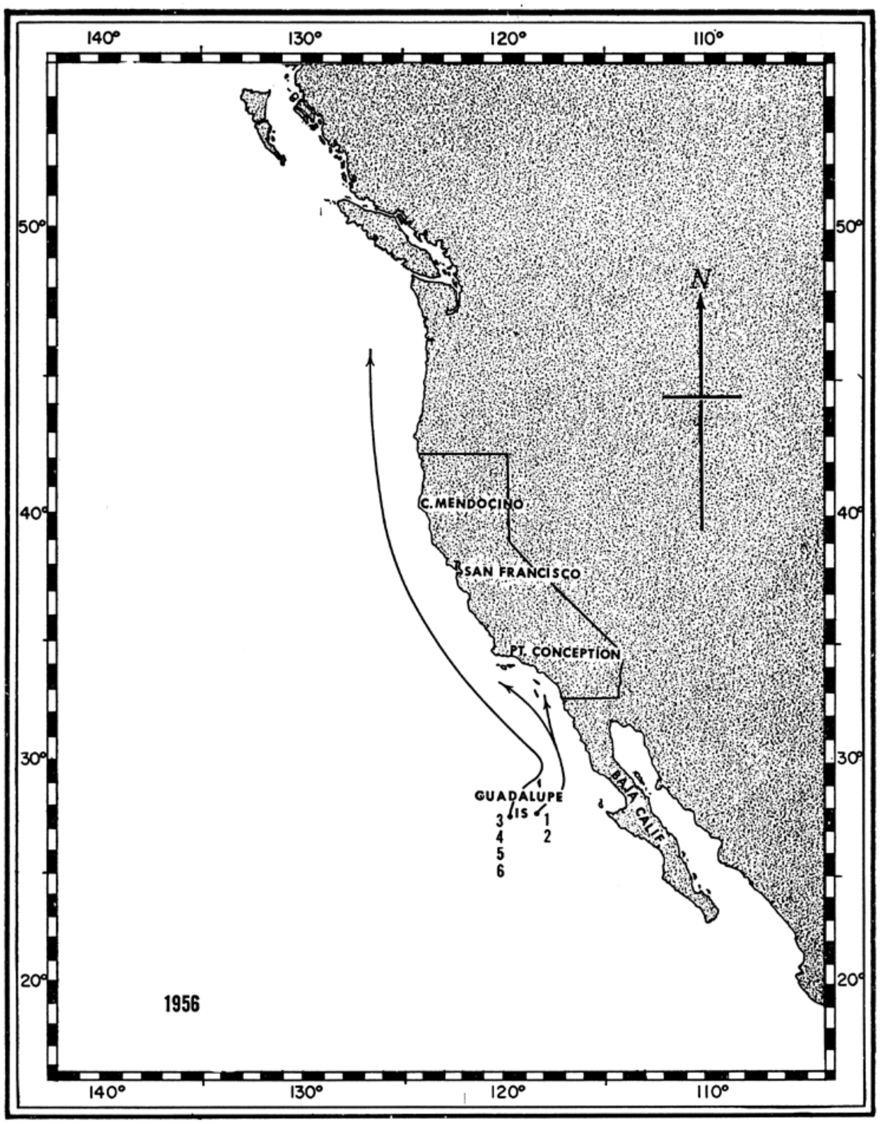

FIGURE 19f. Diagram of the 1956 coastal albacore migration determined from catch data. Numbers represent months: 1=June, 2=July, 3=August, etc.

FIGURE 19f. Diagram of the 1956 coastal albacore migration determined from catch data. Numbers represent months: 1=June, 2=July, 3=August, etc

The above data demonstrate that, as far as the main migration is concerned, there are route shifts of considerable magnitude in the northward within-season migration and in the locality of the annual offshore (departure) migration, in addition to the tremendous between-season changes in the path of their coastward (approach) migration.

The Pacific albacore is a major sport species in southern California and lends support to one of the nation's largest sport fisheries. When these "dragonfly" tuna move into the sport-angling grounds a veritable bedlam results; anything that will float is eagerly put to sea in a sometimes reckless attempt to hook a few of these prized tuna. There

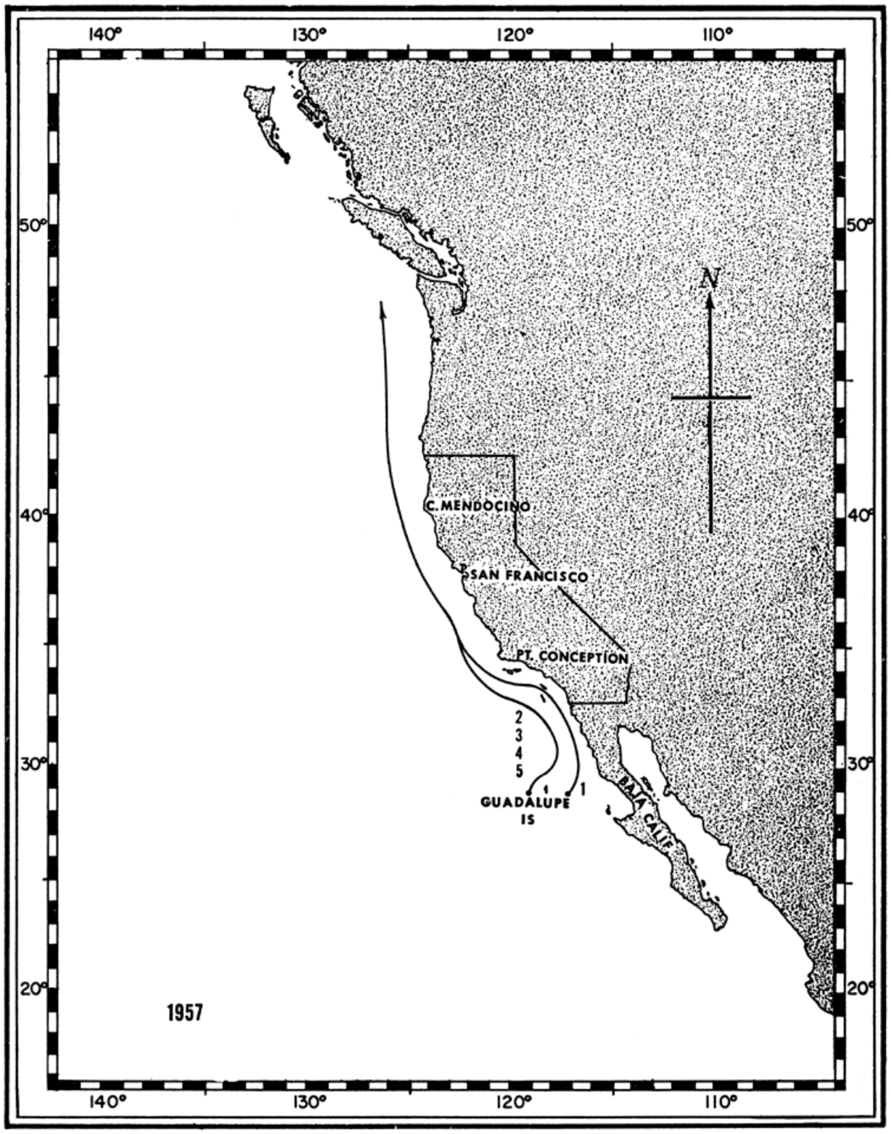

FIGURE 19g. Diagram of the 1957 coastal albacore migration determined from catch data. Numbers represent months: 1=June, 2=July, 3=August, etc.

FIGURE 19g. Diagram of the 1957 coastal albacore migration determined from catch data. Numbers represent months: 1=June, 2=July, 3=August, etc

are several reasons why the albacore is rated as a sportfish king: it is an excellent fighter, large in size (averaging 13–14 pounds during the past 10 years), delicious to eat either fresh or canned, and its erratic seasonal appearance provides an exotic aura of mystery. The California party-boat industry (the albacore fishing portion of which centers in southern California) is especially vulnerable to shifting migration patterns. The sportfishing fleets generally are equipped for one-day cruises and operate within a few miles of port; as a result, anglers experience poor albacore fishing when a migration occurs well offshore (Clemens, 1957).

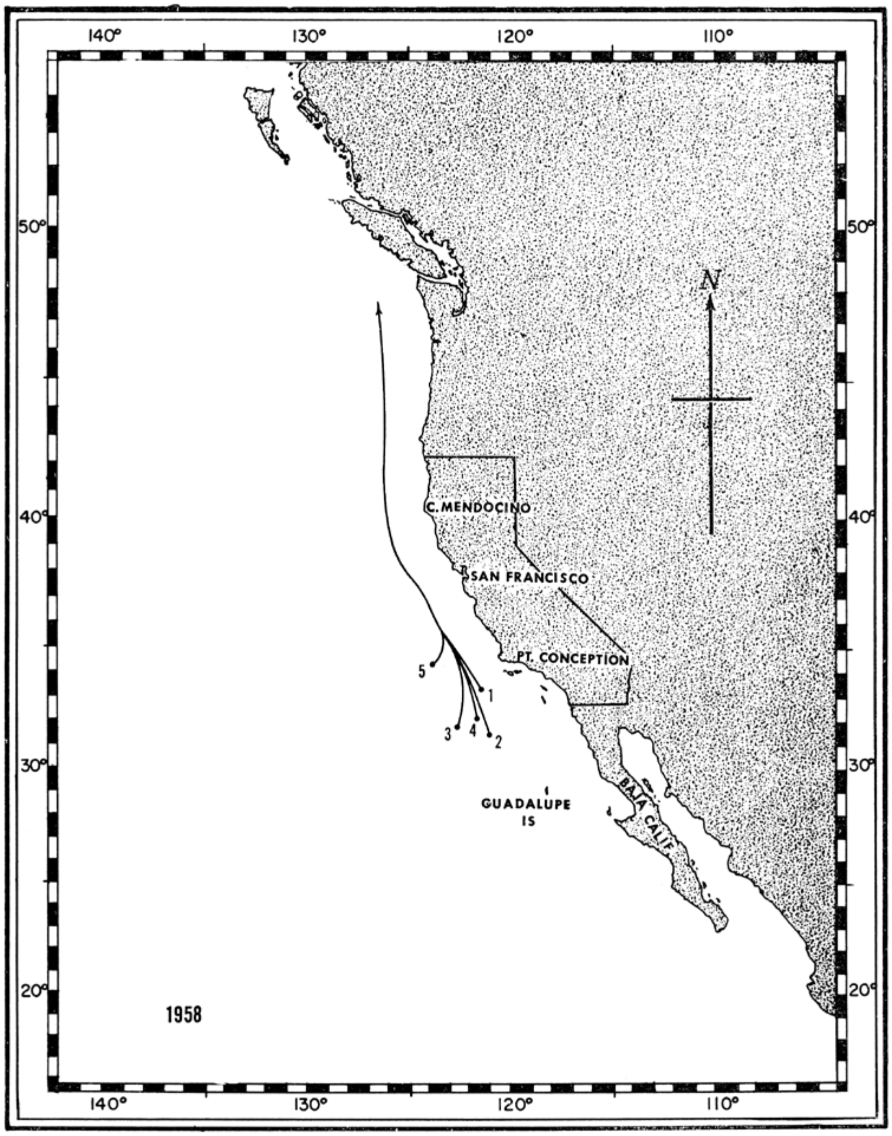

FIGURE 19h. Diagram of the 1958 coastal albacore migration determined from catch data. Numbers represent months: 1=June, 2=July, 3=August, etc.

FIGURE 19h. Diagram of the 1958 coastal albacore migration determined from catch data. Numbers represent months: 1=June, 2=July, 3=August, etc

During the 1950 through 1952, 1955 and 1956 fishing seasons, a large portion of the albacore run was within reach of the sport fleet (Figure 20). Well over 65,000 fish were reeled in during each of these years by enthusiastic anglers; in 1952, an all-time record of 187,267 sport-caught albacore was established. During the 1953, 1954, and 1957 through 1959 seasons, however, most of the albacore were either offshore or to the north and the sport catch declined. In 1953, 23,363 albacore were hooked; in 1954, there were 20,098 landed; while in 1957, 41,540 were taken by seagoing sportsmen. In 1958 and 1959, however, the onshore albacore migration began well outside of the major southern

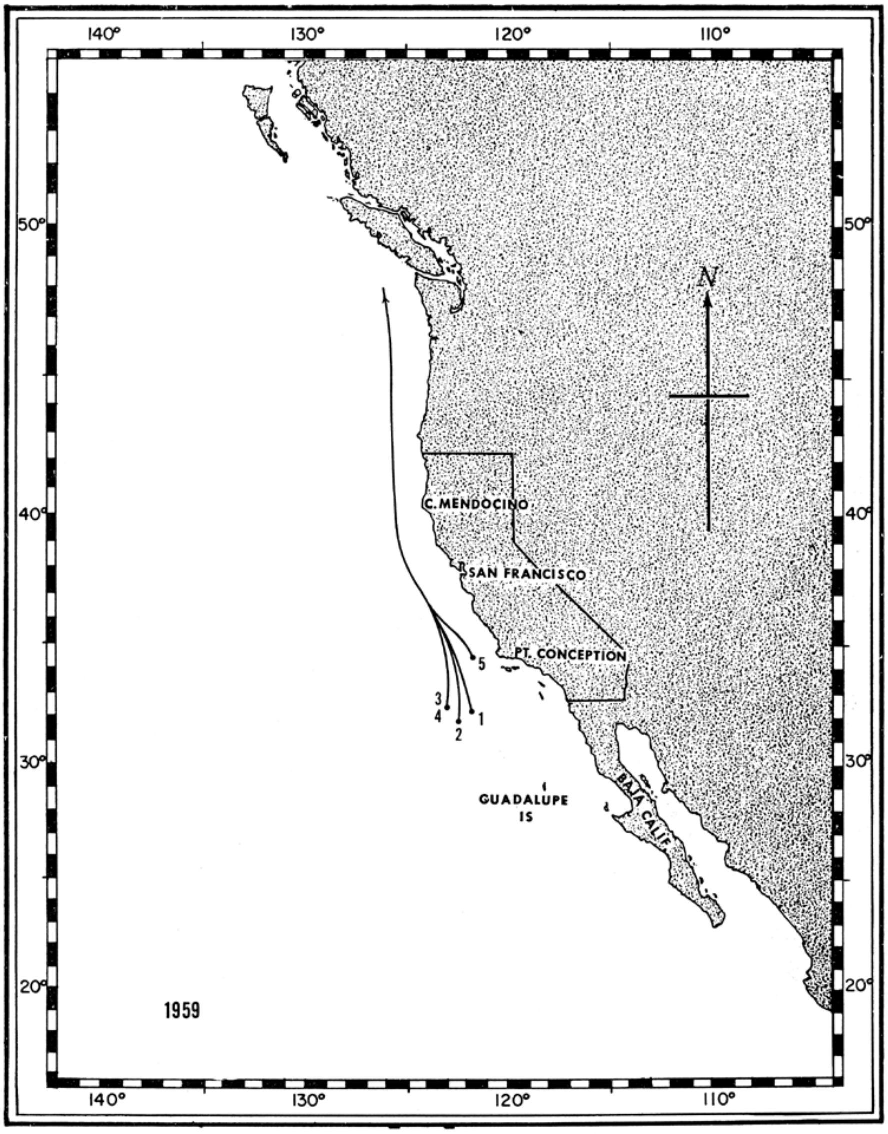

FIGURE 19i. Diagram of the 1959 coastal albacore migration determined from catch data. Numbers represent months: 1=June, 2=July, 3=August, etc.

FIGURE 19i. Diagram of the 1959 coastal albacore migration determined from catch data. Numbers represent months: 1=June, 2=July, 3=August, etc

California sportfishing grounds and then spread northward (Figures 15 and 19h, i). Consequently the sport fishery failed—6,482 albacore were landed in 1958 and only 39 felt the gaff in 1959 (Clemens, 1961).

The commercial fishery was a failure during the seven years 1928 through 1934, when an annual average of only 0.2 million pounds was landed—far below the 12.6 million average of the preceding seven years. This failure undoubtedly was caused by major shifts in albacore migration patterns similar to those described above, which resulted in runs well-offshore during some seasons and considerably farther north than expected during others. Fishermen located only a few of the albacore schools, mostly along the inshore fringe of the main coastal migration, because they were not equipped to search far enough from port (Clemens, 1961). During the period 1900 to 1935, most commercial albacore fishing in the eastern North Pacific was restricted to the southern California coastal area, although a few fish occasionally were taken as far north as southern Alaska (Scofield, 1956). In 1925 and 1926 small catches were made off central California. Commercial fishing prior to and during the so-called failure period, was confined almost exclusively to the area of today's sportfishing activities (Figure 2). If the fishermen had not constructed more, larger, and better-equipped vessels and extended the lengths of their trips plus their area of operations, the commercial albacore fishery would have been a failure for the past 10 or more years also. Commercial fishing within this small restricted area (which was fished during the 1928 to 1934 failure) produced an annual average of only 2.9 million pounds of albacore from 1951 to 1957. The 35.8 million-pound average that actually was landed came from the area between central Baja California and British Columbia. The peak catch in the restricted area would have been 4.1

FIGURE 20. Albacore sport-fishing enthusiasts at the end of a successful cruise. *Photograph courtesy of Pierpoint Landing.*

FIGURE 20. Albacore sport-fishing enthusiasts at the end of a successful cruise. Photograph courtesy of Pierpoint Landing.

million pounds (in 1952). Actually 49.8 million pounds were landed in 1952. During the warm 1958 and 1959 years, when the albacore migration shifted to the north, real disaster would have hit a fishery limited to southern California for an average of less than 19 thousand pounds would have been landed, compared to the 27.2 and 32.7 million pounds that were delivered.

Fishermen operating off southern California must have experienced some tremendous inshore migrations during the 12-year pre-failure period 1916 to 1927, for the annual catch was below 12.5 million pounds only three times (1918, 1926 and 1927). The peak year of 1917 produced history's largest inshore albacore run, for the records show that 30.6 million pounds (an estimated minimum of 1.5 million albacore) were taken from the area now covered by our sportfishing fleet.

By contrast, today's commercial albacore fishermen range some 300–400 miles offshore and from southern Baja California to British Columbia. There is little likelihood that past failures will be repeated for other than economic reasons.

8.3. Size Group Observations

Small albacore (four to eight pounds) appeared in our coastal fishery in unusually large numbers during 1954. Details from 12 commercial fishing trips showed that over 50 percent of the albacore caught within certain areas between San Diego and Cape Mendocino, California, had to be discarded because they fell below the nine-pound legal minimum size limit then in effect. Small fish were so abundant, at times, that many fishermen had to pull in their jig lines and leave the area. We believe this influx of small fish resulted from a super-abundant year-class. We were able to observe its impact as it moved through the fishery during a four-year period. It also played an important role in the enactment (in 1955) of State legislation lowering the legal minimum size from nine to seven pounds (California Department of Fish and Game, 1957).

By plotting where and when fishermen encountered large concentrations of these small fish during 33 separate cruises, we obtained additional evidence of a seasonal migration northward along the coast over a three-month period (Figure 21). The migration locale indicated that small albacore travel nearly the same route as do larger ones. By contrast, in the southern areas (off Baja California) we have discovered that fish weighing in excess of 20 pounds, frequently are on the inshore and southern edge of an albacore run, while somewhat smaller fish are on the offshore and northern edge. A notable exception occurred in August 1953 when Department scientists aboard the *N. B. Scofield* discovered numbers of large albacore (weighing in excess of 40 pounds) traveling northward through an area centered approximately 125 miles west-southwest of Guadalupe Island, Baja California (Wilson, 1953). Since albacore undoubtedly respond, to environmental fluctuations, variations in the location of the several size groups (within a run) can be expected.

8.4. Tagging

The above methods of estimating albacore movements have provided us with valuable information of a general nature. More precise measures,

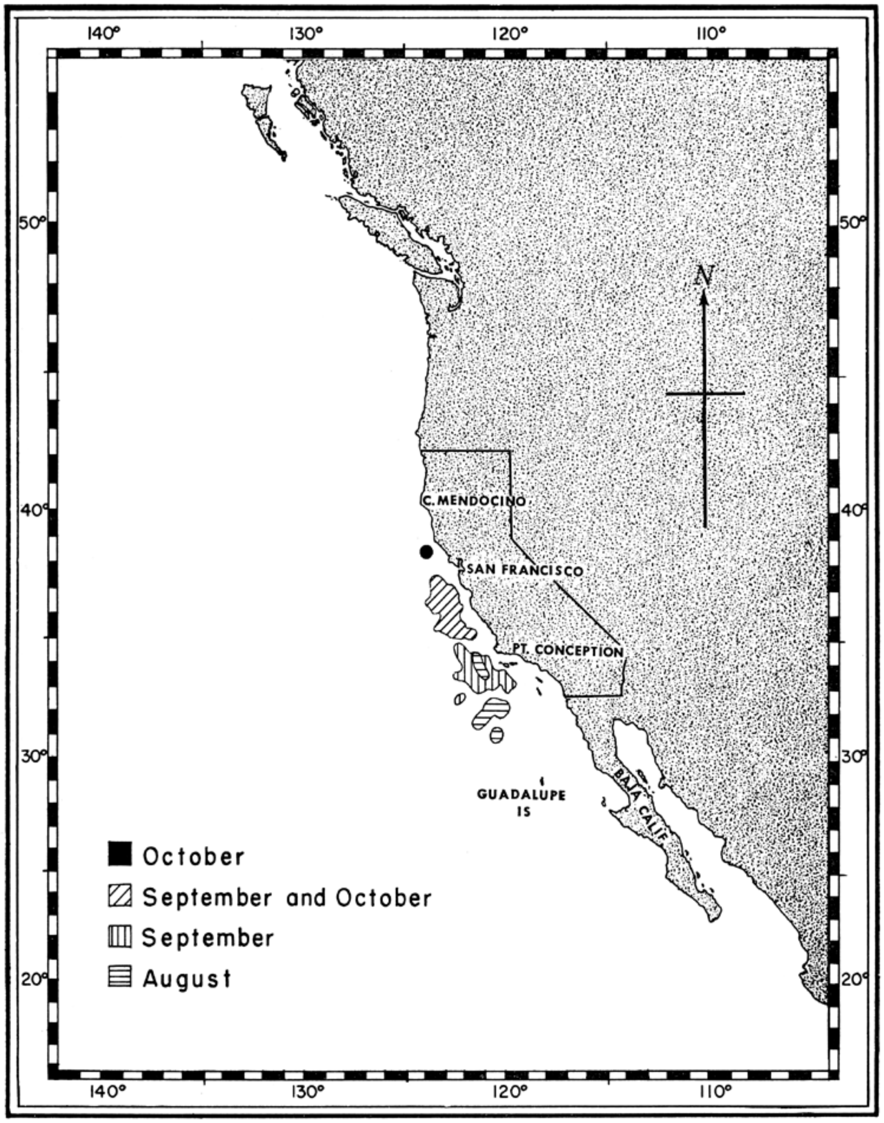

FIGURE 21. Coastal migration of small albacore in 1954. These fish were under the nine-pound legal size limit then in effect.

FIGURE 21. Coastal migration of small albacore in 1954. These fish were under the nine-pound legal size limit then in effect

however, have been obtained by tagging and subsequently recovering marked individuals (Clemens, 1957). Limitations on research vessel use and a lack of manpower made it impossible to tag and release the number of fish desired.

We have relied on the tremendous sport and commercial fishing fleets, operating on both sides of the Pacific and in the Hawaiian Islands area, to recapture tagged albacore and provide us with the required recovery data. Therefore, the results, to a certain extent, reflect the peculiarities of these fisheries.

From 1952 through 1957, 4,585 albacore were tagged and released from central Baja California to San Francisco. Subsequently, 73 (1.6

percent) were recovered—80 percent within the first calendar year (Table 11). If all tags recovered in the West Coast fishery during the season of release are omitted, 7 percent of the remainder were recaptured in the central Pacific, 21 percent off Japan, 62 percent in our coastal fishery the second season, and 10 percent in our fishery the third season (Pacific Marine Fisheries Commission, 1959; Clemens, 1959).

8.4.1. Migrations Within the West Coast Fishery

To describe the average monthly albacore movements within our West Coast fishery, data for each recapture during the season of tagging were combined. The location where each recapture had been tagged was plotted on a chart by tagging month. These data were subdivided to form tag lots by natural geographical areas and a monthly release location was calculated for each lot. Straight lines were then connected between all individual tag-recovery points and their calculated release location (Table 12; Figure 22a, b, c). These trend lines represent 60 percent of the recoveries and illustrate the direction and minimum distance that individual albacore traveled away from the tagging area. About 88 percent of the tags were from

TABLE 11

Recoveries of Tagged Albacore

Days at Liberty	Number Recovered	Percent Recovered	Cumulative Percent
1- 30	13	17.81	17.81
31- 60	21	28.77	46.58
61- 90	7	9.59	56.17
91-120	2	2.74	58.91
121-150	1	1.37	60.28
151-180	1	1.37	61.65
181-210	2	2.74	64.39
211-240	0	----	----
241-270	0	----	----
271-300	1	1.37	65.76
301-330	4	5.48	71.24
331-360	3	4.11	75.35
361-390	4	5.48	80.83
391-420	4	5.48	86.31
421-450	3	4.11	90.42
451-480	2	2.74	93.16
481-510	0	----	----
511-540	0	----	----
541-570	0	----	----
571-660	1	1.37	94.53
601-630	0	----	----
631-660	1	1.37	95.90
661-690	1	1.37	97.27
691-720	1	1.37	98.64
721-750	0	----	----
751-780	1	1.37	----
Total	73		

TABLE 11
Recoveries of Tagged Albacore

fish that were recovered within five months and had traveled less than 700 miles (Table 13).

The results substantiated the gross migration estimates we obtained by using other methods and confirmed a northward coastal migration as the season progresses (Clemens, 1954, 1955, 1957, 1958, and 1959). In fact, 69 (95 percent) tagged albacore recaptured during their first season at liberty had moved northward from the release point.

These data also show that the average minimum northward migration rate was six nautical miles per day (24 hours). When the data are summarized by distance from shore, however, the albacore traveling comparatively close to shore (within 90–100 miles) averaged about

TABLE 12

Local Within-Season Tag Recoveries for Albacore by Tagging Month and Tagging Lots

Tag Lot	Month	Number of Fish	Calculated Release Location		True Recovery Location	
			N. Latitude	W. Longitude	N. Latitude	W. Longitude
1	June	2	30° 40′	116° 53′	32° 33′	118° 10′
					35° 20′	121° 52′
1	July	6	29° 15′	116° 04′	31° 43′	117° 17′
					31° 04′	116° 55′
					31° 25′	118° 36′
					31° 04′	116° 59′
					31° 57′	117° 12′
					30° 46′	116° 44′
2	July	14	31° 02′	117° 05′	32° 28′	118° 32′
					31° 34′	118° 58′
					34° 39′	122° 18′
					31° 56′	117° 23′
					34° 51′	120° 57′
					29° 23′	120° 29′
					31° 56′	117° 23′
					32° 24′	118° 30′
					33° 10′	118° 24′
					32° 40′	118° 20′
					35° 19′	122° 04′
					33° 35′	119° 40′
					28° 42′	117° 51′
					32° 59′	117° 52′
3	July	4	31° 55′	118° 33′	32° 33′	118° 31′
					34° 37′	121° 38′
					40° 59′	124° 59′
					33° 35′	121° 30′
4	July	1	33° 02′	118° 15′	33° 28′	118° 50′
1	August	12	28° 10′	120° 28′	36° 27′	124° 21′
					36° 28′	123° 29′
					35° 41′	123° 31′
					36° 29′	124° 12′
					30° 00′	121° 57′
					35° 45′	123° 30′
					30° 19′	121° 54′
					36° 53′	124° 44′
					36° 54′	125° 07′
					38° 33′	124° 16′
					36° 39′	125° 25′
					36° 09′	123° 36′
2	August	2	31° 31′	121° 16′	29° 29′	118° 47′
					35° 04′	121° 46′
3	August	3	33° 26′	118° 35′	35° 07′	121° 50′
					35° 17′	121° 40′
					33° 24′	118° 58′

TABLE 12

Local Within-Season Tag Recoveries for Albacore by Tagging Month and Tagging Lots

TABLE 13

Distance Traveled by Migrating Albacore

Days at Liberty	Minimum Distance Traveled (Nautical Miles) — Eastern Pacific														Mid and Western Pacific							Total	Percent	Accumulative Percent
	1 to 50	51 to 100	101 to 150	151 to 200	201 to 250	251 to 300	301 to 350	351 to 400	401 to 450	451 to 500	501 to 550	551 to 600	601 to 650	651 to 700	3000 to 3300	3301 to 3600	3601 to 3900	3901 to 4200	4201 to 4500	4501 to 4800	4801 to 5100			
1-30	3	1	4	1	1	..	..	..	..	3	..	..	..	..	..	..	..	..	..	..	..	13	26	26
31-60	..	3	4	4	3	..	..	..	..	1	2	3	..	1	..	..	..	..	..	..	..	21	42	68
61-90	..	..	1	1	1	..	..	3	..	..	..	..	1	..	..	..	..	..	..	..	..	7	14	82
91-120	..	..	..	1	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2	4	86
121-150	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	2	88
151-180	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	1	2	90
181-210	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	1	..	2	4	94
211-240	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
241-270	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
271-300	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	1	2	96
301-330	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	1	2	98
331-360	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	1	2	100
Totals	3	4	9	7	6	0	1	3	0	4	2	3	1	1	2	0	0	0	2	1	1	50	100	
Percent	6	8	18	14	12	..	2	6	..	8	4	6	2	2	4	..	..	..	4	2	2			
Accumulative Percent	6	14	32	46	58	..	60	66	..	74	78	84	86	88	92	..	..	..	96	98	100			

TABLE 13
Distance Traveled by Migrating Albacore

four nautical miles daily, while offshore migrants swam at a 15 mile-per-day rate. There was no apparent difference in swimming speed due to fish size.

These calculations assume that a tagged albacore will travel normally and in a straight line. It also is assumed that these fish had not reached the recapture location several days before they were caught. Knowledge of albacore swimming speeds is useful for comparative purposes, drawing

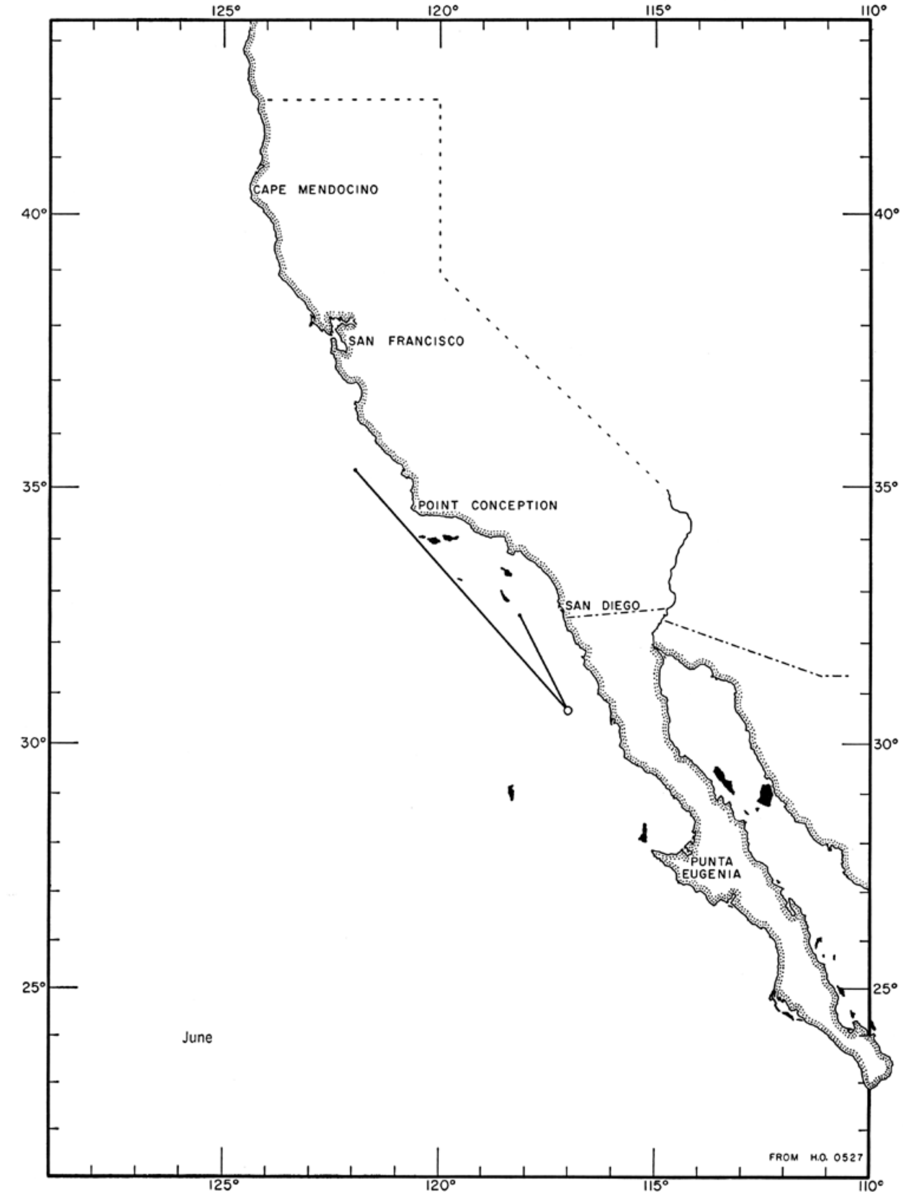

FIGURE 22a. June albacore migrations from a calculated tag-release location (open circle); solid circles are recovery points for individual albacore,

FIGURE 22a. June albacore migrations from a calculated tag-release location (open circle); solid circles are recovery points for individual albacore inferences concerning albacore behavior, and estimating minimum migration rates (Clemens, 1957). For example, in our coastal fishery albacore well-offshore traveled northward at an average rate nearly four times faster than those close to shore.

Although an albacore tagged off Baja California in July 1957 was recaptured within 60 miles of Oregon in October 1957, none marked off Baja California or California has been recaptured in the Oregon and Washington fisheries (Clemens, 1958). This is not surprising, however,

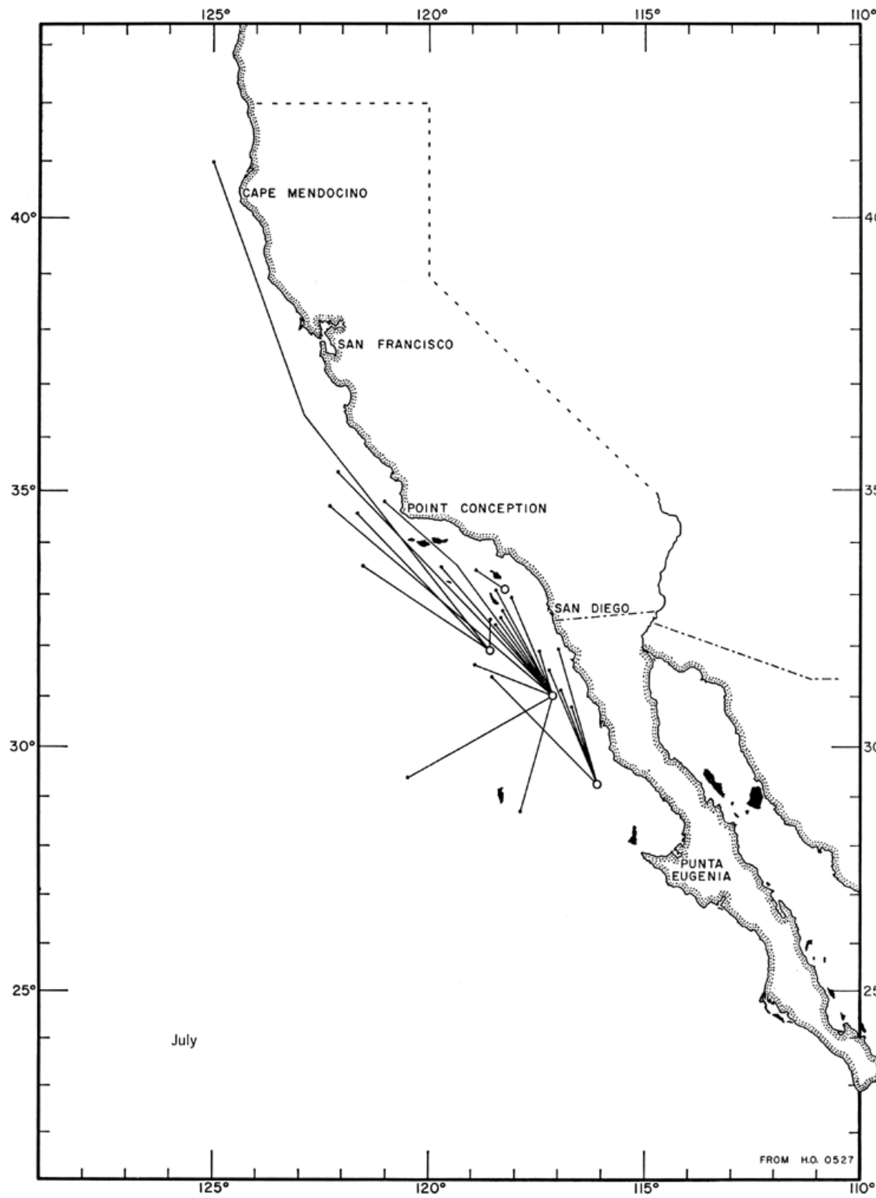

FIGURE 22b. July albacore migrations from calculated tag-release locations (open circles) ; solid circles are recovery points for individual albacore.

FIGURE 22b. July albacore migrations from calculated tag-release locations (open circles); solid circles are recovery points for individual albacore

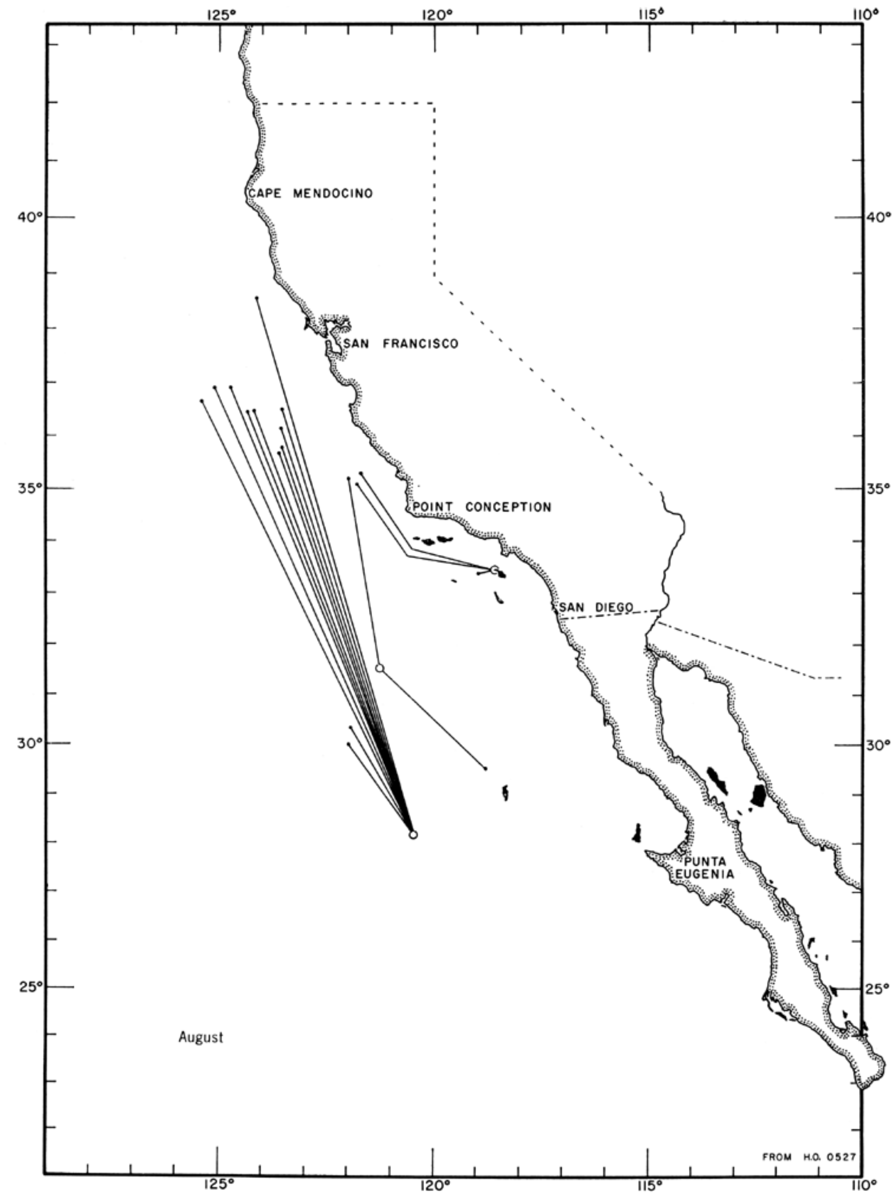

FIGURE 22c. August albacore migrations from calculated tag-release locations (open circles) ; solid circles are recovery points for individual albacore.

FIGURE 22c. August albacore migrations from calculated tag-release locations (open circles); solid circles are recovery points for individual albacore

because during the period 1952 to 1957 comparatively few albacore were harvested in the coastal fisheries north of California. In 1958 and 1959, catches off Oregon and Washington increased markedly, but lack of manpower prevented us from releasing tagged albacore to the south.

Judging by our catch records over a 10-year period, the main body of northward traveling migrants gradually headed seaward, in a northwesterly direction, somewhere offshore from Eureka during the 1950 through 1955 seasons. Thus most schools were outside the fishing fleet range by the time they had traveled as far north as Oregon and Washington, and no tag recoveries were anticipated. Catch records also revealed that during 1956 many albacore schools began traveling a little farther north before heading offshore, for a small Oregon and Washington fishery developed (Pacific Marine Fisheries Commission, 1956). This trend continued, and these states had excellent 1958 and 1959 fisheries (Pacific Marine Fisheries Commission, 1960; Clemens, 1961). Migration pattern shifts plus frequent violent-weather help explain why the northern fisheries have had such tremendous catch fluctuations by comparison with recent California fisheries. During the 1959 season at least eight vessels were reported sunk and 17 men lost their lives because of rough seas (Craig, 1959).

An examination of logbooks from fishing vessels operating off Oregon and Washington and landing their catches in California, and a preliminary study of albacore sizes in these catches, indicate that many schools, first fished off Baja California and California, migrate northward and periodically play a major role in the northern fisheries (Pacific Marine Fisheries Commission, 1958).

The coastward albacore migration is a large fish group; its main body quickly moves eastward from the central North Pacific into the coastal fishing grounds of southern California or Baja California and then swings upcoast as the season progresses, following desirable food and temperature conditions. The extent to which the mass of albacore moving north through the fishing grounds is augmented by late arrivals moving in from offshore and farther north is unknown, but when this does happen it most likely occurs during August and September and north of Point Conception.

8.4.2. Transpacific Migrations

Although considerable work remains before we can describe the North Pacific albacore population structure, we have taken a tremendous stride in this direction. Our tagging operations have demonstrated clearly, that the albacore stocks in the major fishing areas of the eastern, central, and western North Pacific are closely related and perhaps are a single population.

A tagged albacore released August 4, 1952, between Santa Catalina Island and Long Beach, California and recaptured 323 days later by Japanese fishermen operating southeast of Tokyo, Japan represented history's first authentic transpacific migration (Ganssle and Clemens, 1953). Subsequently, two California Department of Fish and Game tags recovered near Midway Island in the central Pacific, represented the first record of albacore migration into this island area (Blunt, 1954; Clemens, 1954).

To date, six of our tagged albacore have been recaptured off the coast of Japan, and two near Midway Island in the central Pacific representing 8.2 and 2.7 percent respectively of the total tag recoveries (Figure 23). These migrations have completely outdistanced those of the famous Atlantic eels, and thus the Pacific albacore has become the marine world's migrant king.

Albacore enroute from our coastal fishery to the Midway Island area averaged 17 nautical miles per day (fastest 18) and those swimming to

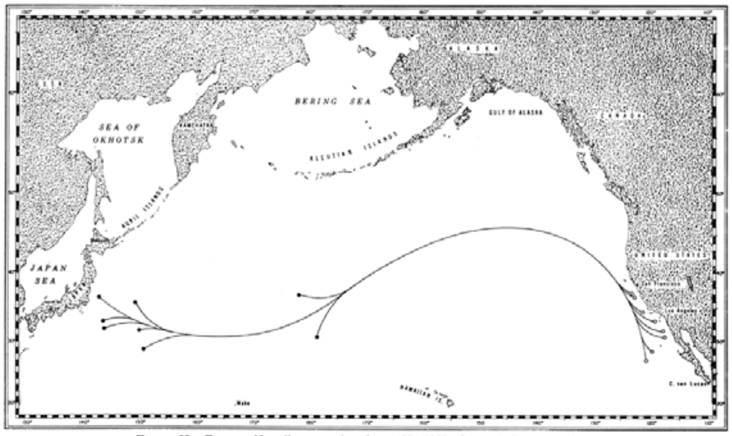

FIGURE 23. Transpacific albacore migrations 1951-1957. Open circles are release locations of tagged albacore; solid circles are points of recapture.

FIGURE 23. Transpacific albacore migrations 1951–1957. Open circles are release locations of tagged albacore; solid circles are points of recapture

Japan 16 (fastest 23) miles daily. These rates compare favorably with those estimated for offshore migrants in the California coastal fishery, which had traveled at an average minimum rate of 15 miles per day. Apparently albacore are capable of swimming over 500 miles per month with ease and do so while traveling well-offshore.

8.4.3. Re-entry Into the West Coast Fishery

Many albacore visit California's coastal areas more than once during their lifetime (Clemens, 1957, 1958). In fact 18 albacore (25 percent of the total recoveries) were captured in our fishery the season following tagging and over four percent during a third season (Table 14).

TABLE 14
Recoveries of Tagged Albacore

Tagging Date	Number Tagged	Recovered off West Coast			Recovered in Central Pacific	Recovered off Japan	Number Recovered	Percent
		Tagging Season	Second Season	Third Season				
1952								
July	3						0	
August	215	2				1	3	
September	2						0	
Total	220						3	1.36
1953								
August	750	12			2		14	
October	362						0	
Total	1,112						14	1.26
1954								
August	597	1					1	
September	858		1			1	2	
October	1						0	
Total	1,456						3	0.21
1955								
July	41	2	2	2			6	
August	143	1	4				5	
September	78						0	
October	88		1	1			2	
Total	350						13	3.71
1956								
July	415	14	3				17	
August	166	1					1	
September	193		3			2	5	
Total	774						23	2.97
1957								
June	99	2	1				3	
July	531	9	3			2	14	
August	2						0	
September	39						0	
October	2						0	
Totals	673						17	2.53
Grand Total	4,585	44	18	3	2	6	73	
Percent		60.27	24.66	4.11	2.74	8.22		

TABLE 14
Recoveries of Tagged Albacore

Some fish could have migrated across the Pacific and back; others may have overwintered off Baja California.

Albacore tagged during one season and recaptured the next, within a month of the comparable release date, were found close to the tagging location. One was recaptured only 21 miles from its release point a year previously and another within 40 miles of where it had been tagged two years previously. Albacore recaptured the season after tagging, but a month or more earlier than the comparable tagging date, generally were south of their release point; those captured the season after tagging, but later than the comparable tagging date were north. This tendency also was apparent for those captured a third season after tagging and indicates that during the period 1952 through 1956, albacore migrations occurred with remarkable precision.

8.4.4. Migrations of Albacore Schools

The beginning of a West Coast albacore run consists of average 13-pound fish and is characterized by a relatively few, small, scattered, loosely knit, fast-traveling, schools. These move inshore near the sea surface and then upcoast in pulses or widely separated school groups (Clemens, 1957). A school group is a discrete cluster of albacore schools that, although sometimes widely scattered, appear loosely related by having a tendency to act in unison. During the peak of a run, small fish (6- to 8-pounders) and larger ones (36 pounds or more) are more abundant and individual schools, although still somewhat loosely knit, are larger. In addition the groups appear more compact, each containing a greater number of schools. When these large school groups are close together, as frequently happens during the fishing season peak, fair numbers of fish can be jigged by trolling through them hour after hour in the same direction.

Albacore larger than 20 pounds usually are not widely scattered near the surface; they seem to be more compactly schooled than smaller fish, and to spend more time in deeper water. Also, when school groups of these larger fish are feeding near the surface, they are in warmer water.

The end of a season's run, like the beginning, is characterized by small, widely scattered schools, although they are spread over a larger geographical area by comparison.

Albacore have been taken by purse seiners and large high-seas tuna clippers, but sizeable, tightly knit, slow-moving schools are not sufficiently available for many of these vessels to make a profit fishing for albacore—recent advances in purse-seine and associated gear, however, may enable seiners (Figure 24) to make a successful entry into the albacore fishery (California Department of Fish and Game, 1961).

Some schools as well as entire school groups, at times will not react readily to live-bait and albacore can be taken only on trolling gear—these are "jig fish." Others react vigorously to chum and can be harvested efficiently on handlines or conventional tuna striker poles—"bait fish." There is a tendency for school groups of jig fish to react like bait fish for a short period and vice versa, but this behavior is subject to large local changes.

Although we have found considerable year-to-year variation, there is an inclination for the slower-moving schools traveling near shore to react more readily to live-bait. The scattered, faster-moving ones, usually

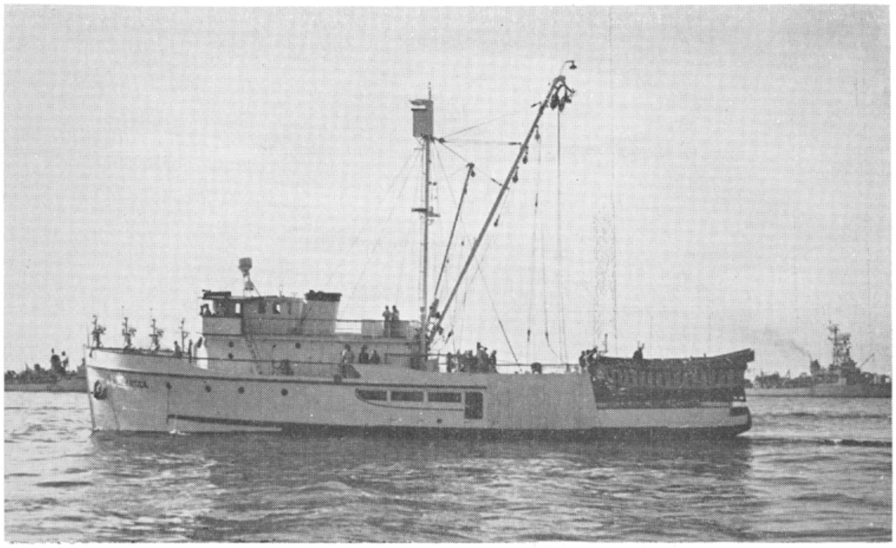

FIGURE 24. Large high-seas tuna clipper recently converted from a live-bait boat to a purse seiner. Converted clippers landed 70 tons of albacore during the 1960 season. *Photograph by John J. Seapin.*

FIGURE 24. Large high-seas tuna clipper recently converted from a live-bait boat to a purse seiner. Converted clippers landed 70 tons of albacore during the 1960 season. Photograph by John J. Seapin.

located in the northern part of a run and frequently farther offshore, are most efficiently harvested by surface trolling. As a rule, the small 7- to 20-pounders are caught on trolling gear, used by roughly 90 percent of the albacore fleet, while larger ones are caught primarily by the live-bait boats.

Charting individual albacore journeys by tagging has provided excellent general information. It has revealed short-term travels during West Coast runs, demonstrated an east-to-west transpacific migration, etc. These data are too limited, however, for drawing detailed inferences about migratory habits.

Charting albacore school movements has enabled us to follow a fish group for a substantial period and to develop hypotheses concerning many details of seasonal migrations. Also, one can examine the question of a west-to-east transpacific migration and perhaps obtain additional insight into albacore behavior.

We have used live-bait and trolling methods to capture albacore for tagging and attempted to gain some idea of individual school activities by logging which tags were released in single schools and then noting where and when these marked fish were recovered. We are not certain that we always succeeded in marking a school because while chumming with livebait, fish from undetected passing schools could have been caught and tagged. This is also true for those caught while trolling. If this happened, the tagged albacore may have joined the school we were marking. There is a possibility too, that a few tagged fish released in one school could have left it and joined other passing groups.

The following discussion of albacore school travels is based on the fact that the fish aggregate by size, and on the assumption that the schools retain their identity while in the West Coast fishery. Albacore tagged and released at one location in less than a day's time were assumed to belong to a single school (Table 15). Thus:

TABLE 15

Statistics of Albacore School Movements

Release Data			Recovery Data								
					Eastern Pacific		Central Pacific	Japan		Distance Covered	
					First Season	Second Season					
Date	N. Lat., W. Long.	Number Tagged	Date	No. Rec.	N. Lat., W. Long.	N. Lat., W. Long.	N. Lat., E. Long.	N. Lat., E. Long.	Days at Liberty	Total Miles	Miles Per Day
8/11/53	27° 56′ 120° 23′	285	9/ 2/53	10	30° 00′ 121° 57′				23	148	6.4
			9/ 3/53		30° 19′ 121° 54′				1	19	19.0
			9/ 6/53		35° 45′ 123° 30′				3	337	112.3
			9/12/53		36° 53′ 124° 44′				6	89	14.8
			9/13/53		36° 29′ 124° 12′				1	34	34.0
			9/15/53		36° 54′ 125° 07′				2	52	26.0
			9/16/53		36° 09′ 123° 36′				1	85	85.0
			9/18/53		36° 39′ 125° 25′				2	93	46.5
			9/24/53		38° 33′ 124° 16′				6	127	21.2
			2/ 2/54				36° 40′ 178° 12′		131	2,712	20.7
9/26/54	33° 42′ 121° 15′	96	4/10/55	2				31° 55′ 143° 15′	196	4,608	23.5
			9/ 2/55			31° 39′ 118° 28′					
7/25/55	31° 46′ 117° 29′	13	8/11/55	2	32° 59′ 117° 52′				18	75	4.2
			7/28/56			33° 17′ 118° 13′					
7/10/56	29° 10′ 116° 00′	47	7/31/56	2	30° 46′ 116° 44′				22	102	4.6
			8/17/56		31° 43′ 117° 17′				17	62	3.7
7/11/56	29° 18′ 116° 06′	29	7/30/56	4	31° 04′ 116° 59′				20	113	5.7
			8/11/56		31° 04′ 116° 55′				12	5	0.4
			8/12/56		31° 25′ 118° 36′				1	89	89.0
			8/20/56		31° 57′ 117° 12′				8	78	9.8

TABLE 15
Statistics of Albacore School Movements

7/15/56	31° 04′ 116° 59′	95	8/13/56	5	29° 23′ 120° 29′				30	212	7.1
			8/17/56		32° 24′ 118° 30′				4	207	51.8
			8/20/56		31° 56′ 117° 23′				3	65	21.7
			8/19/57			30° 01′ 118° 16′					
			9/30/57			35° 40′ 121° 28′			42	378	9.0
9/ 3/56	36° 39′ 123° 16′	76	6/ 1/57	4				35° 50′ 142° 50′	271	4,365	16.1
			7/ 5/57			31° 45′ 118° 08′					
			9/17/57			33° 55′ 121° 30′			74	214	2.9
			6/19/58					35° 35′ 148° 50′	275	4,272	15.5
7/ 2/57	31° 15′ 117° 05′	46	9/23/57	2	35° 19′ 122° 04′				84	355	4.2
			8/12/58			33° 41′ 121° 30′					
7/ 4/57	30° 32′ 116° 50′	56	8/24/57	3	31° 34′ 118° 58′				52	126	2.4
			9/ 8/57		32° 28′ 118° 32′				15	59	3.9
			9/ 9/57		34° 39′ 122° 18′				1	231	231.0
7/ 5/57	30° 32′ 116° 42′	40	6/ 4/58	2				32° 53′ 143° 26′	334	4,878	14.6
			9/ 4/58			34° 35′ 123° 30′					
7/11/57	31° 45′ 118° 34′	92	7/26/57	2	32° 33′ 118° 31′				16	48	3.0
			9/17/57		34° 37′ 121° 38′				53	202	3.8
7/12/57	32° 04′ 118° 31′	14	9/17/57	2	33° 35′ 121° 30′				68	177	2.6
			10/ 2/57		40° 59′ 124° 59′				15	475	31.7

TABLE 15—Cont'd.

(1) On August 11, 1953, 285 albacore were marked and released in a school some 120 miles west-southwest of Guadalupe Island, Baja California (Lat. 27° 56' N., Long. 120° 23' W.). of these, 10 subsequently were recovered, enabling us to follow the school's movements in fair detail for the several months it remained in the California fishery and enroute to the central Pacific area (Figure 25). On September 2, 23 days after tagging, the first marked albacore was recaptured

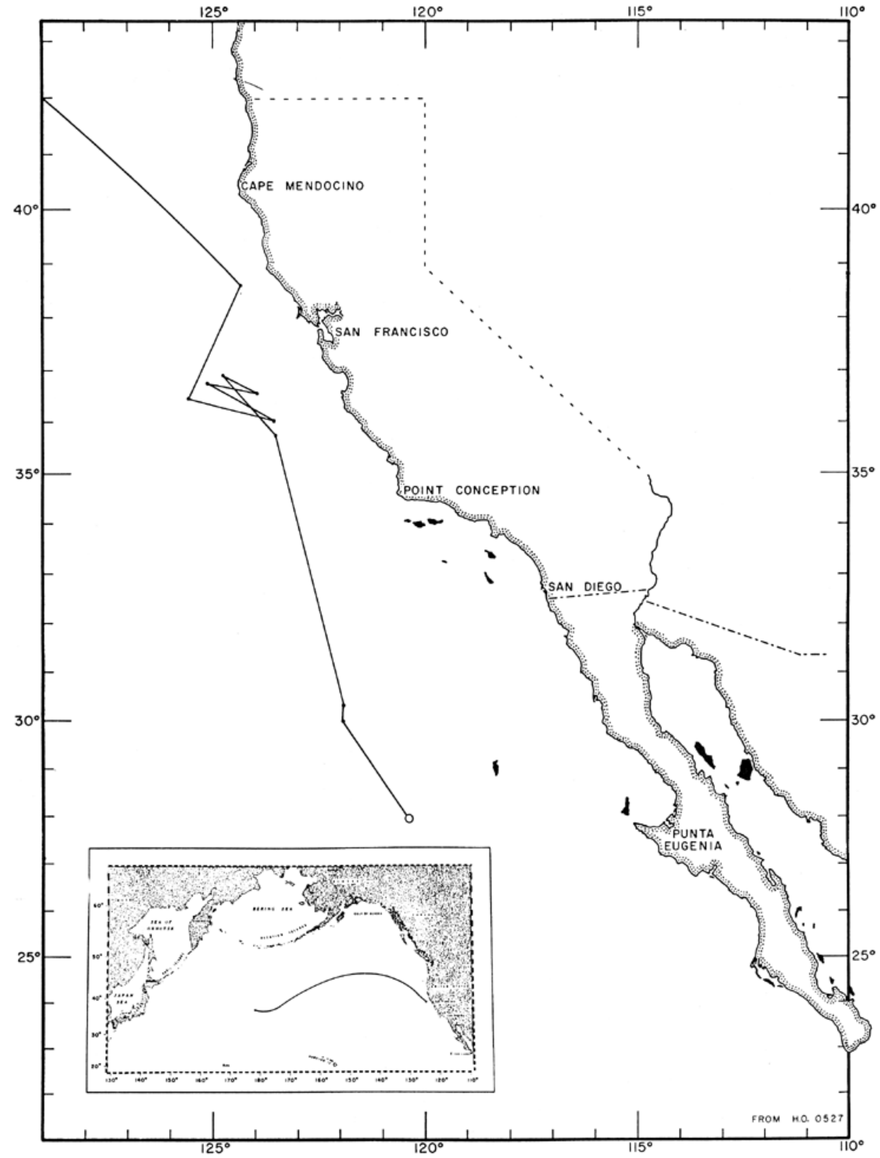

FIGURE 25. Migration of an albacore school marked with 285 tags during August 1953. It traveled northward through the American coastal fishery and across the Pacific to the Midway Island area. The open circle is the release location, and solid circles are recapture points.

FIGURE 25. Migration of an albacore school marked with 285 tags during August 1953. It traveled northward through the American coastal fishery and across the Pacific to the Midway Island area. The open circle is the release location, and solid circles are recapture points

at Lat. 30° 00' N., Long. 121° 57' W. indicating that the school had traveled approximately 148 miles northward; on September 3, a second recovery revealed that it had moved another 19 miles upcoast. From August 11 to September 3, the school had migrated northward at an average minimum rate of seven nautical miles per day. On September 6, the school again was located through a tag recovery, this time about 130 miles west of Morro Bay, California at Lat. 35° 45' N., Long. 123° 30' W. It had traveled an additional 337 miles northward, while averaging a spectacular 112 miles per day—about 4.5 miles per hour and 16 times faster than the previous average rate. During the period September 12 to 18, the school apparently milled in a relatively small area centered about 130 miles offshore from Monterey. On September 24, it was 127 miles upcoast near Point Arena, California at Lat. 38° 33' N., Long. 124° 16' W. after having averaged 21 miles per day for 6 days. From this point, the school gradually swam offshore in a northwesterly direction and out of fishing-fleet range. It then headed across the Pacific Ocean to the Midway Island area where the final marked albacore was recaptured by a Japanese fisherman operating in the winter longline fishery. This fish was taken February 2, 1954, about 555 miles north-northwest of Midway Island (Lat. 36° 40' N., Long. 178° 12' E.) and had traveled 2,712 miles offshore in 131 days; averaging at least 21 miles per day.

(2) On September 26, 1954, 96 tagged albacore were used to mark a school approximately 70 miles southwest of Point Conception, California at Lat. 33° 42' N., Long. 121° 15' W. On April 10, 1955, 196 days later, the first of two tagged fish recovered from this school was recaptured by fishermen operating in the Japanese coastal live-bait fishery; approximately 290 miles southeast by south of Tokyo at Lat. 31° 55' N., Long. 143° 15' E. It had averaged 24 miles per day, or one mile per hour during its dramatic, 4,608-mile ocean-spanning migration. When we next learned of the school, on September 2, 1955, another 146 days had passed and part of it (at least) had returned from the western Pacific and re-entered our coastal fishery. One of the marked albacore had been recaptured 90 miles southwest of San Diego, California at Lat. 31° 39' N., Long. 118° 28' W.

We have very little information about schooling habits or the movements of albacore once they enter the Japanese fisheries, but it seems likely that many of the eastern Pacific schools would intermingle with those in the western Pacific and thus lose their identity. If this is true the albacore school tagged on September 26, 1954 could have traveled northward through the American fisheries (Figure 19d), migrated across the ocean, and entered the Japanese winter longline fishery where it intermingled with numerous other schools and lost its identity. At this point, one part of it continued on into the Japanese coastal live-bait fishery while another part returned to the American fishery (Figure 19e). If, however, this albacore school had retained its identity it would have had to return to our fishery after migrating over 4,800 miles from the Japanese coastal fishing grounds in 146 days—a rate of at least 33 miles per day (Figure 26). This would indicate that albacore traveling toward the West Coast move considerably faster than those leaving here and moving to Japan (our exploratory fishing data lend some support to this rapid-ingress idea). Few albacore could be

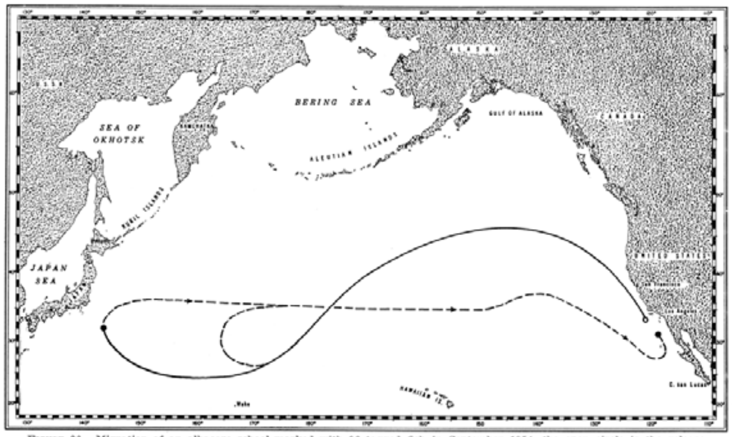

FIGURE 26. Migration of an albacore school marked with 96 tagged fish in September 1954. the open circle is the release area, and the solid circles are recapture points for tagged albacore. The broken lines represent possible eastward migration routes.

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expected to journey from the Japanese summer fishery directly into the American fishing grounds, because their fishery produces primarily 70 to 90 cm fish; sizes that make only a small contribution to ours.

(3) On July 25, 1955, an albacore school located 60 miles south of San Diego at Lat. 31° 46' N., Long. 117° 29' W. was marked with 13 tagged fish. The first recovery occurred 18 days later when the school had traveled 75 miles northward, reaching a point approximately 60 miles south of Long Beach at Lat. 30° 59' N., Long. 117° 52' W. It

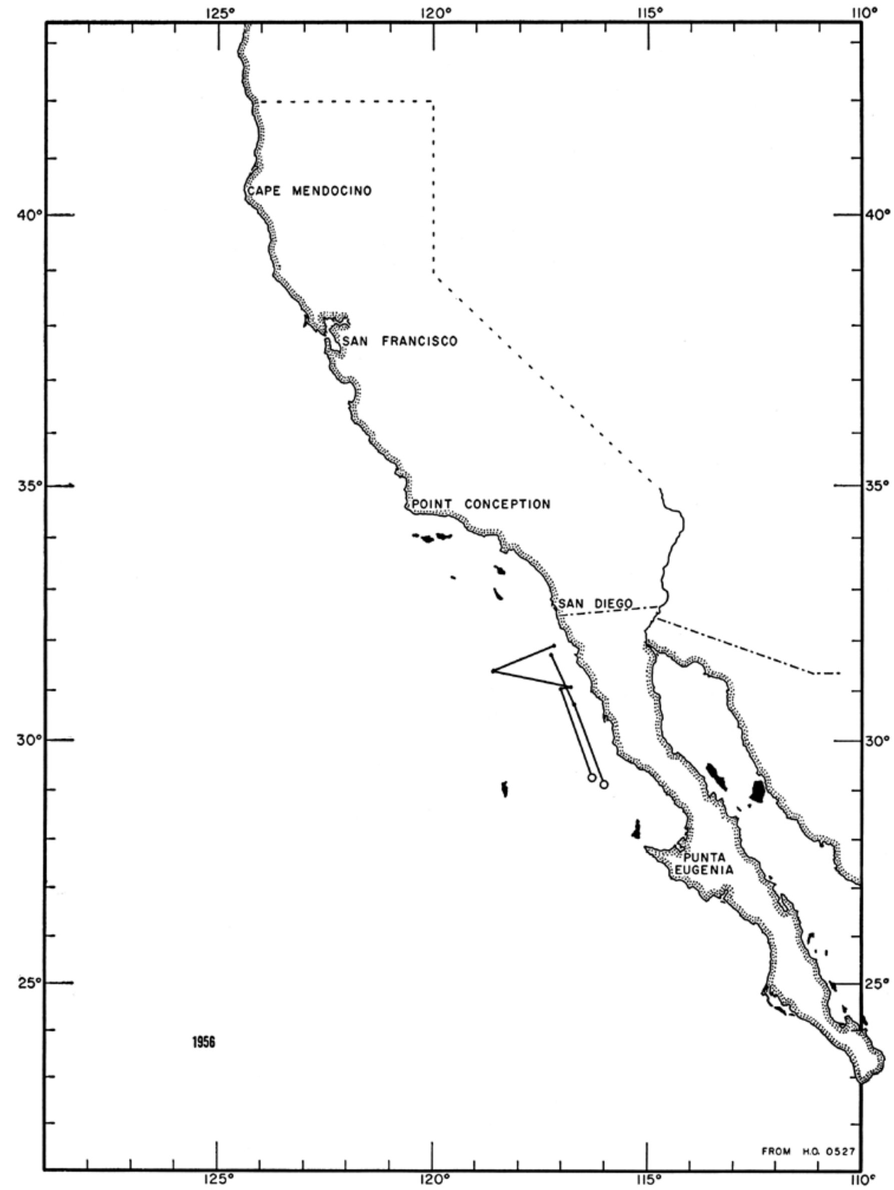

FIGURE 27. Migration of two albacore schools marked with 76 tags during July 1956. Open circles are release areas, and solid circles are recapture points for tagged albacore.

FIGURE 27. Migration of two albacore schools marked with 76 tags during July 1956. Open circles are release areas, and solid circles are recapture points for tagged albacore

had averaged a mere four miles per day. This school was not heard from again until the following season, when on July 28, 1956, the final (second) tagged albacore was caught near Santa Catalina Island at Lat. 33° 17' N., Long. 118° 13' W. It also could have migrated northward through the American fishery (Figure 19e), across the ocean and through the Japanese fisheries, and then all or part of it returned where the last tagged fish was recaptured while on another annual migration up our coast (Figure 19f).

(4) Two albacore schools located between Guadalupe Island and the Baja California mainland were marked with 76 tagged fish during July 10 and 11, 1956. Six tags recovered between July 30 and August 20, indicated that the schools meandered northward to Todos Santos, Baja California at an average rate of about six nautical miles daily (Figure 27).

(5) On July 15, 95 albacore were tagged and released, during the 1956 run (Figure 19f), in a school 30 miles off Cape Colnett, Baja California, at Lat. 31° 04' N., Long. 116° 59' W. The first recovery occurred 30 days later from an area outside Guadalupe Island at Lat. 29° 23' N., Long. 120° 29' W. indicating that the school had traveled 212 miles southwest by west, for an average of seven miles per day. The next tagged fish was taken four days later at Lat. 32° 24' N., Long. 118° 30' W. after the school apparently had turned around and traveled 207 miles northeastward, averaging 52 miles per day. Three days later a third recovery at Lat. 31° 56' N., Long. 117° 23' W. indicated that it had moved southeast at a rate of 22 miles daily, for an additional 65 miles. Nothing more was known about this school until the fourth and fifth tag recoveries were made during the next (1957) season (Figure 19g). The fourth recovery was August 19, 1957, one year after the third one, about 50 miles north of Guadalupe Island at Lat. 30° 01' N., Long. 118° 16' W.; and the final recovery was made September 30, 1957, about 35 miles northwest by west of Morro Bay, California, at Lat. 35° 40' N., Long. 121° 28' W.; about 378 additional miles northward in 42 days—or nine miles per day (Figure 28).

The last two albacore recovered from this school, like some of those previously mentioned, had sufficient time to span the Pacific and then move back again into our coastal fishery.

(6) On September 3, 1956, 76 albacore were tagged and released in a school 60 miles off Monterey, California, at Lat. 36° 39' N., Long. 123° 16' W. The first of four recoveries from this school was on June 1, 1957, by fishermen operating in the Japanese coastal live-bait fishery approximately 150 miles east of Tokyo (Lat. 35° 50' N., Long. 142° 50' E.). It had traveled at least 4,365 miles while crossing the Pacific Ocean in 271 days, at an average rate of 16 miles per day. On July 5, 1957, a little over one month later, a second fish was recovered; this time in our fishery about 80 miles off Todos Santos, Baja California (Lat. 31° 45' N., Long. 118° 08' W.). The third recapture from this school also was in our fishery. It was taken on September 17, 1957, indicating that the school had moved an additional 214 miles upcoast to southwest of Point Conception at Lat. 33° 55' N., Long. 121° 30' W. at a speed of three miles per day. On June 19, 1958, 275 days later a fisherman caught the last (fourth) tagged fish from this school while live-bait fishing approximately 435 miles east of Tokyo, Japan

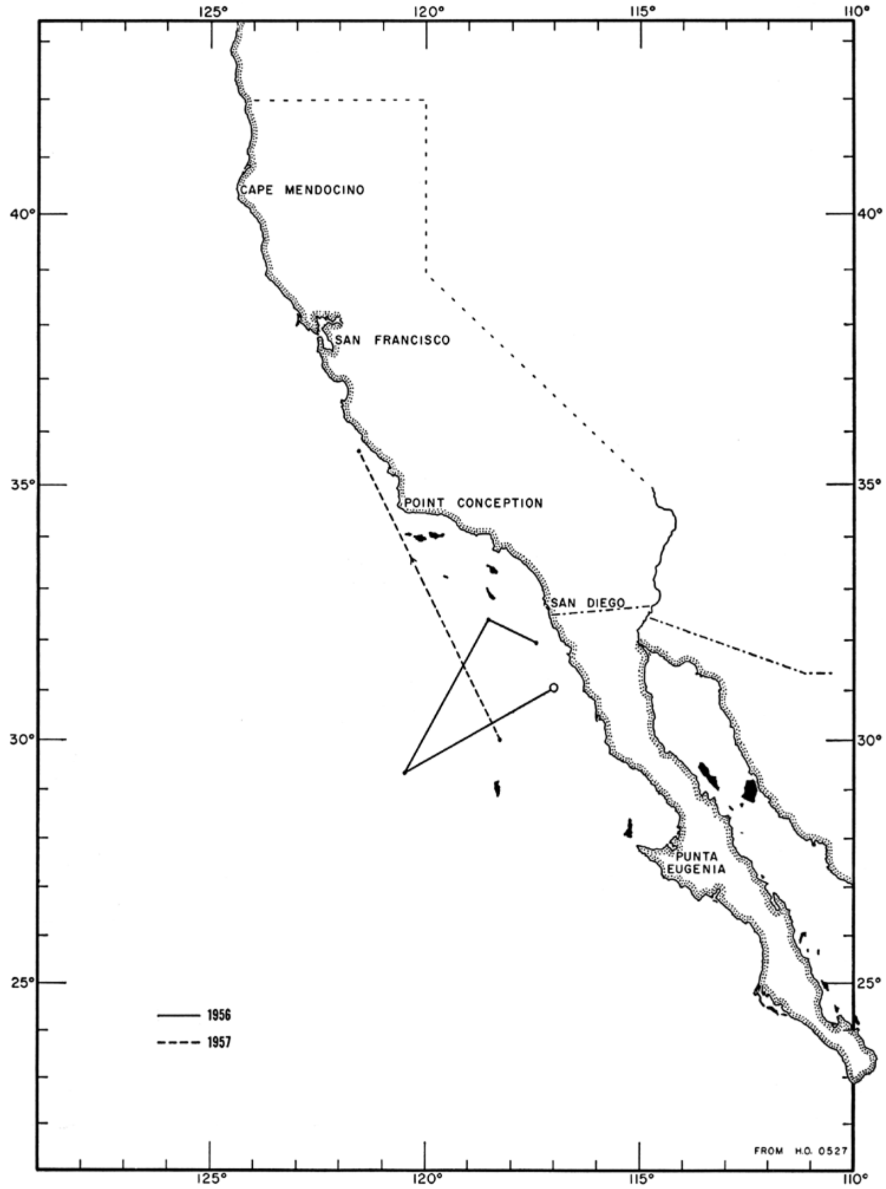

FIGURE 28. Migration of an albacore school marked with 95 tags in July 1956. The open circle is the tagging locality, and solid circles are recapture points. The solid line represents movements during season of release (1956) based upon three recoveries; and broken line represents travels during the next season (1957), based upon two recoveries.

FIGURE 28. Migration of an albacore school marked with 95 tags in July 1956. The open circle is the tagging locality, and solid circles are recapture points. The solid line represents movements during season of release (1956) based upon three recoveries; and broken line represents travels during the next season (1957), based upon two recoveries

(Lat. 35° 35' No., Long. 148° 50' E.). It had traveled the 4,272 miles at an average rate of 16 nautical miles daily.

Judging by the behavior of other albacore schools, it is unlikely that the one marked on September 3, 1956 could have re-entered our fishery from Japan in only 34 days. A more reasonable hypothesis would be that it migrated through the 1956 American West Coast

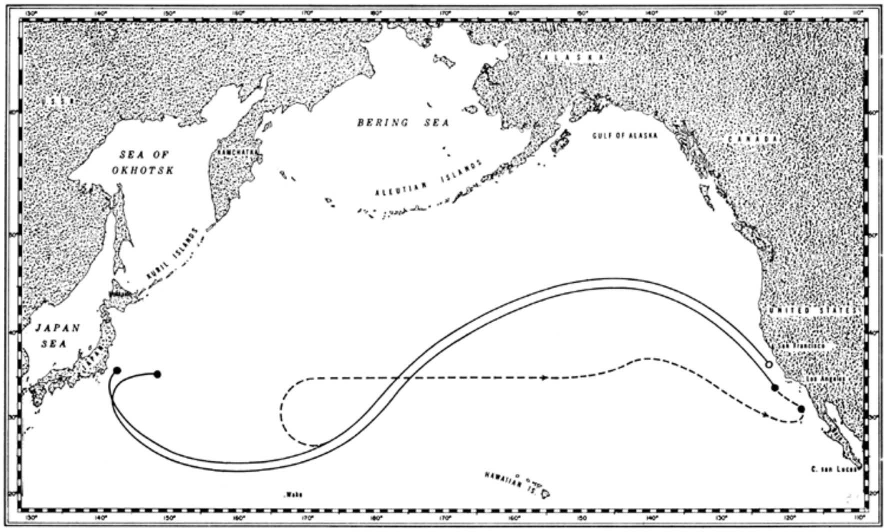

FIGURE 29. Migration of an albacore school marked in September 1956 with 76 tagged fish. The school traveled through the American fishery and across the Pacific into the Japanese winter longline fishery. Part of it continued into the Japanese coastal live-bait fishery, while another part re-entered our coastal fishery during the 1957 season. At season's end it again crossed the Pacific and entered the coastal fishery of Japan. The open circle is the tag-release area, and the solid circles are recapture points. The broken line represents the probable eastward migration route.

FIGURE 29. Migration of an albacore school marked in September 1956 with 76 tagged fish. The school traveled through the American fishery and across the Pacific into the Japanese winter longline fishery. Part of it continued into the Japanese coastal live-bait fishery, while another part re-entered our coastal fishery during the 1957 season. At season's end it again crossed the Pacific and entered the coastal fishery of Japan. The open circle is the tag-release area, and the solid circles are recapture points. The broken line represents the probable eastward migration route

fishery (Figure 19f) and then across the Pacific where it entered the Japanese winter longline fishery. At that point the school split up and part of it traveled into the Japanese coastal (summer) fishery, while the remainder headed back toward the 1957 American fishery. Once in our fishery it traveled northward upcoast during a second seasonal migration (Figure 19g), and then again spanned the Pacific to enter the 1958 Japanese coastal live-bait fishery (Figure 29).

(7) A total of 46 albacore was tagged and released on July 2, 1957, in a school about 40 miles offshore from Cape Colnett, Baja California (Lat. 31° 15' N., Long. 117° 05' W.). It was located 84 days later on September 23, after having traveled 355 miles upcoast to Morro Bay, California (Lat. 35° 19' N., Long. 122° 04' W.) at an average rate of four miles per day. A second (the last) tag was recovered in our fishery the next season on August 12, 1958 at Lat. 33° 41' N., Long. 121° 30' W.; again demonstrating the possibility that albacore schools migrate up our coast, span the Pacific, and return to re-enter the coastal fishery.

(8) On July 4, 1957, 56 tagged albacore marked a school 40 miles off San Quintin, Baja Cailfornia, at Lat. 30° 32' N., Long. 116° 50' W. This school was traced upcoast as far as Point Conception by tag recoveries on August 24, September 8, and September 9, while traveling 126, 59, and 231 miles respectively at a speed of six miles per day (Figure 30a).

9) On July 5, 1957, 40 albacore tagged in a school off Baja California (about eight miles east of the July 4 release location) produced two tag returns. The first moved through the coastal fishery (Figure 19g)

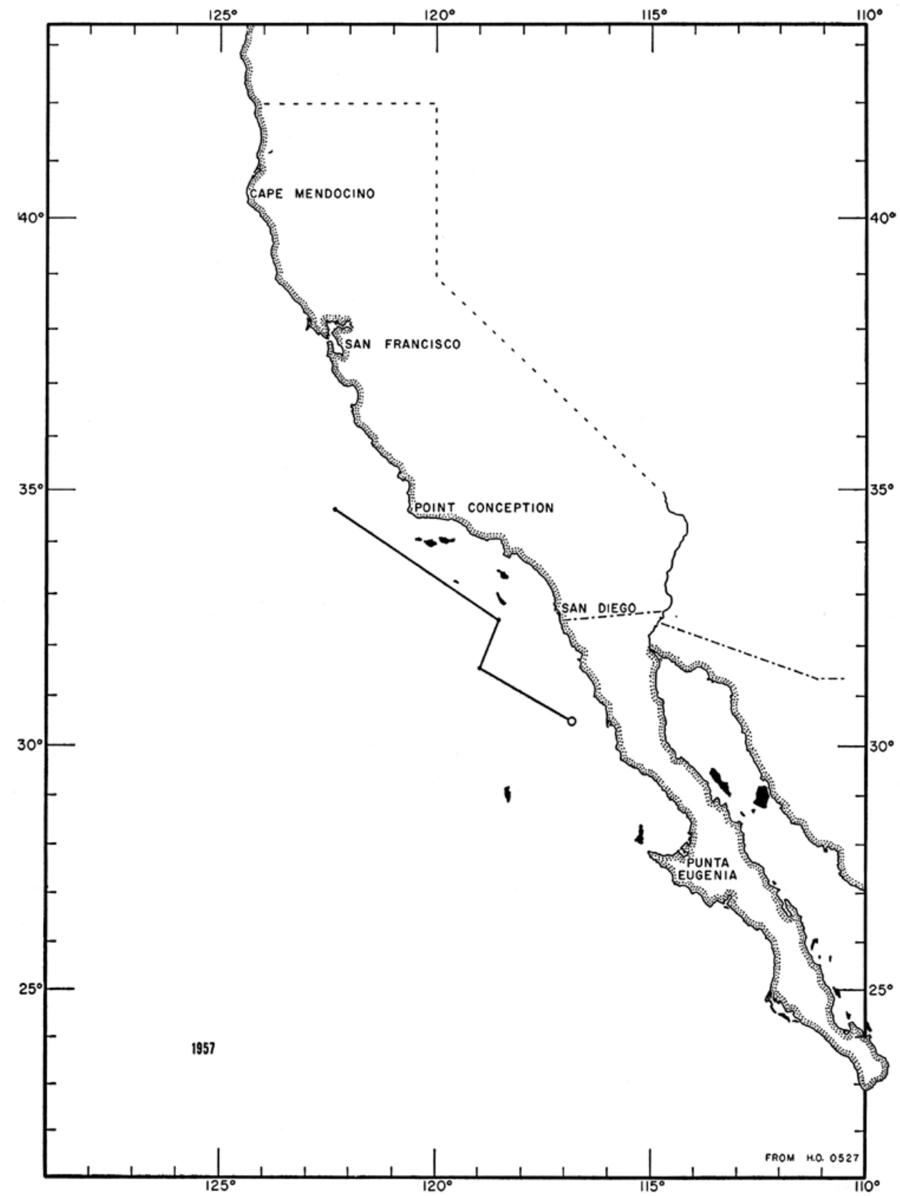

FIGURE 30a. Migration of an albacore school marked with 56 tags during July 1957. The open circle is the tag-release area, and the solid circles are recovery points.

FIGURE 30a. Migration of an albacore school marked with 56 tags during July 1957. The open circle is the tag-release area, and the solid circles are recovery points

and was recovered after 334 days on June 4, 1958, by Japanese live-bait fishermen about 250 miles southeast of Tokyo (Lat. 32° 53' N., Long. 143° 26' E.). The school had traveled over 4,878 miles while crossing the Pacific at an average rate of 15 miles per day. The second albacore was found in our coastal fishing grounds during the 1958 season (Figure 19h); it was caught 92 days after the Japanese recovery, 150 miles off Point Conception at Lat. 34° 35' N., Long. 123° 30' W., indicating the possibility that at least part of the school had returned from one of the two major areas fished by the Japanese—probably from the winter longline area, for the possibility of albacore moving from the Japanese coast across the Pacific in time to enter our coastal fishery seems remote. Schools 8 and 9 have been combined into a school group. The movements of fish in this group have been included here (Figure 30b) to avoid repetition in a later section.

10) A total of 106 tagged albacore marked two schools on July 11 and 12, 1957, in an area centered approximately 80 miles southwest of San Diego. Four tag recoveries: one on July 26, two September 17, and one October 2, enabled us to follow these schools upcoast over 650 miles to a point off Eureka at Lat. 40° 59' N., Long. 124° 59' W. (Figure 31).

We have only the indirect evidence from our tagging and exploratory fishing and oceanographic cruises to substantiate inferences that albacore migrate from the Japanese into the American fisheries. Final verification will require recapturing in the eastern Pacific fisheries albacore that have been tagged and released in the western Pacific.

Although we believe a goodly number of albacore re-enter our fisheries after having traveled to Japan's, some remain here during the winter. Evidence of overwintering has been obtained from landing records and fishing logbooks. During the winter of 1955–56 a few albacore were caught in December, January, and early February. During the winter of 1956–57 some were taken from December through April; and in 1957–58 albacore were caught in December, January, February, March, and May. The amount landed in these months, however, totaled less than one percent of a season's catch, although during the 1957–58 winter there were more large fish than usual, averaging close to 30 pounds each.

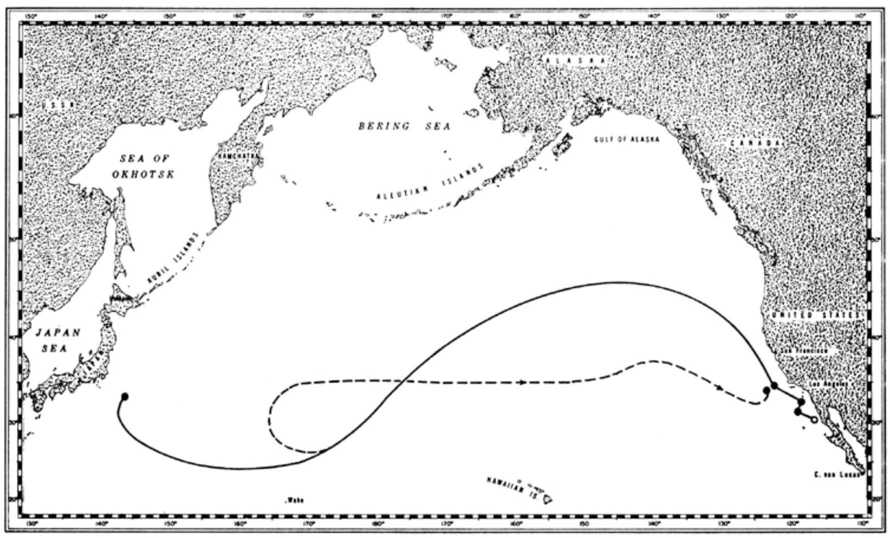

FIGURE 30b. Migration of two albacore schools marked in July 1957. The group traveled upcoast and across the Pacific into the Japanese winter longline fishery. Part of it moved into the Japanese coastal live-bait fishery, while another part re-entered our 1958 fishery. The open circle is the albacore release area, and the solid circles are recapture points for tagged albacore; the broken line represents the probable eastward migration route.

FIGURE 30b. Migration of two albacore schools marked in July 1957. The group traveled upcoast and across the Pacific into the Japanese winter longline fishery. Part of it moved into the Japanese coastal live-bait fishery, while another part re-entered our 1958 fishery. The open circle is the albacore release area, and the solid circles are recapture points for tagged albacore; the broken line represents the probable eastward migration route

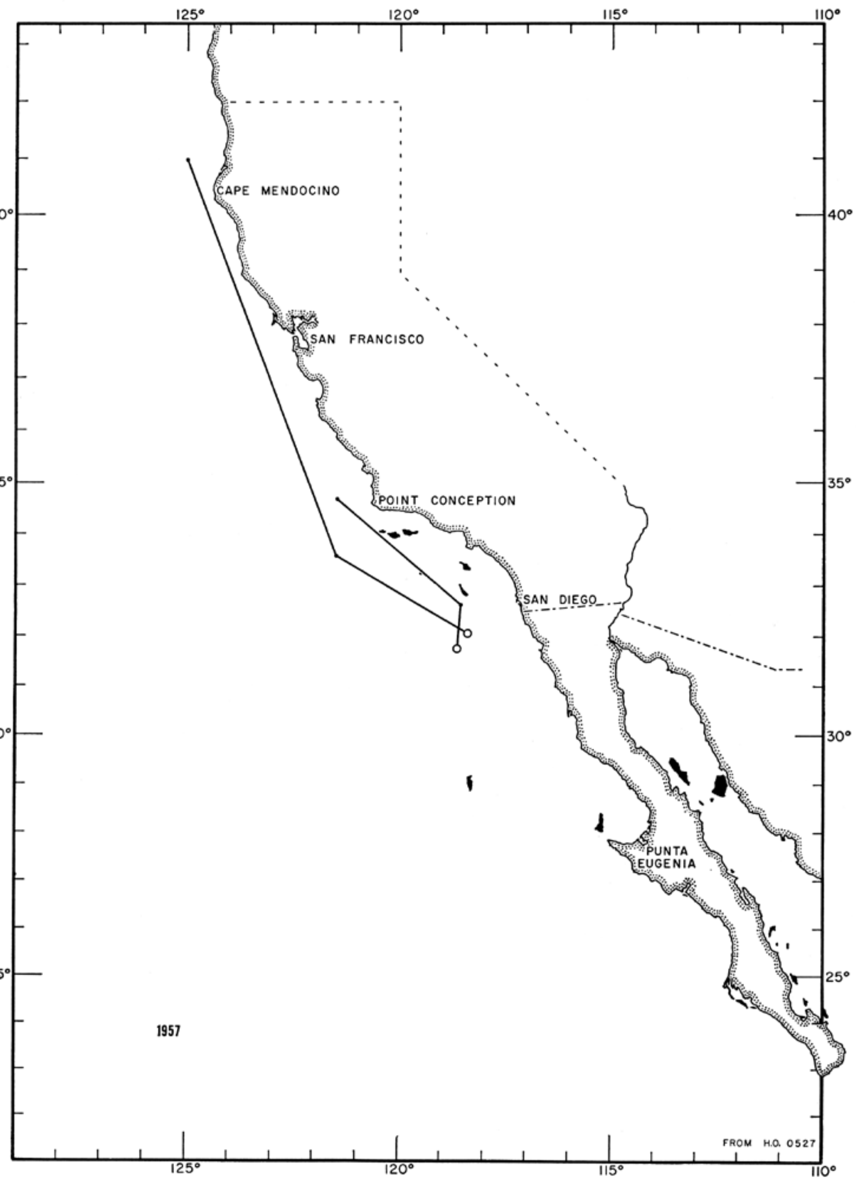

FIGURE 31. Migration of two albacore schools marked with 106 tags in July 1957. Open circles are tag-release locations, and solid circles are albacore recapture points.

FIGURE 31. Migration of two albacore schools marked with 106 tags in July 1957. Open circles are tag-release locations, and solid circles are albacore recapture points

These overwintering albacore were at the southern extremity of areas commercially fished during the peak of regular seasons (Figure 32). They frequently started traveling northward a few weeks prior to the June onrush of a seasonal migration, creating a "false" albacore run. Fishermen scouting for the season's first fish sometimes captured these holdovers and believed they had located the current season's migration. They have relayed this information to the albacore fleet and many members have left port to participate in the fishing.

From 1951 to 1957, the location and capture dates of overwintering fish would have coincided with those of albacore from the regular run and resulted in fair early fishing (Figure 15, 32). During the 1958 season, however, the incoming albacore were several hundred miles to the north of their usual route (Figure 15). Early-scouting fishermen, operating in traditional fishing areas off central and southern Baja California, caught a few large fish overwintering from the 1957 season and assumed they had located the incoming 1958 run (Figure 33). As a result, several vessels left port and headed south to participate in the expected fishery, only to discover that the true run was underway

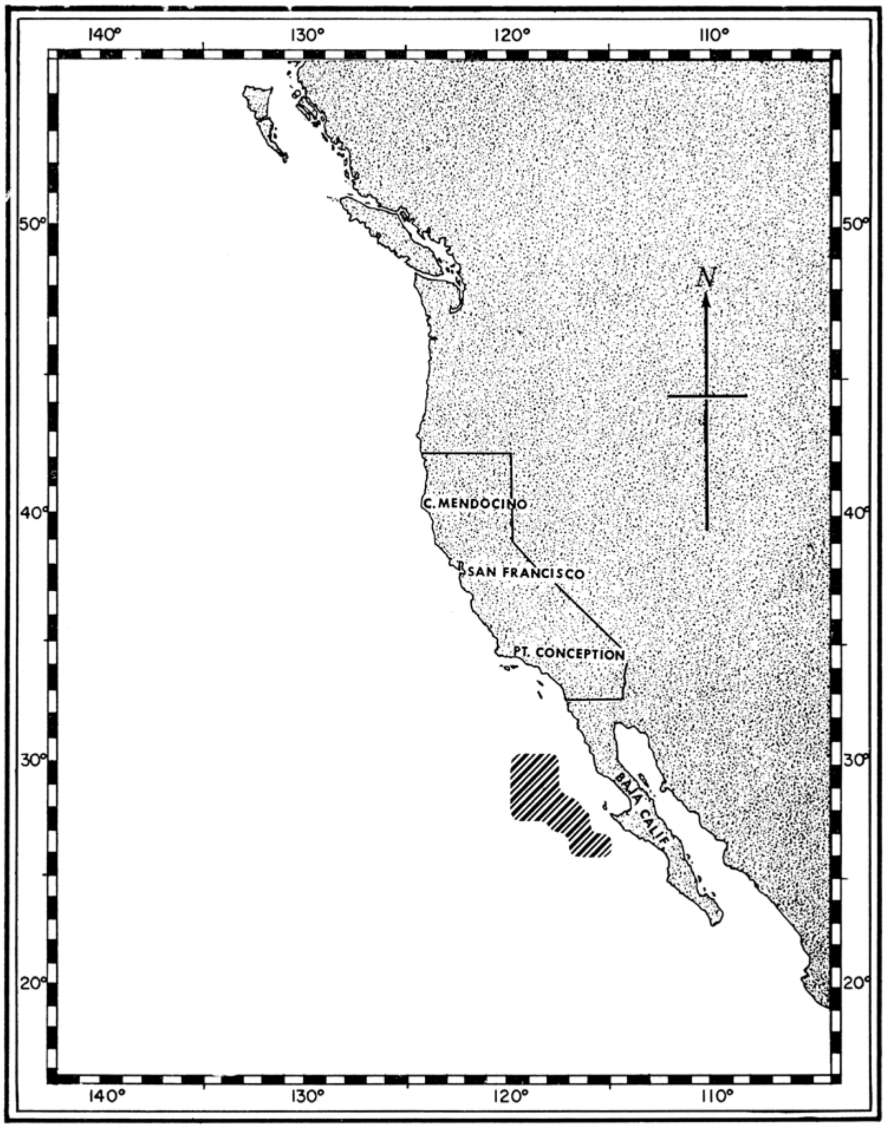

FIGURE 32. Catch localities of overwintering albacore during the three seasons, 1955-56, 1956-57 and 1957-58.

FIGURE 32. Catch localities of overwintering albacore during the three seasons, 1955–56, 1956–57 and 1957–58

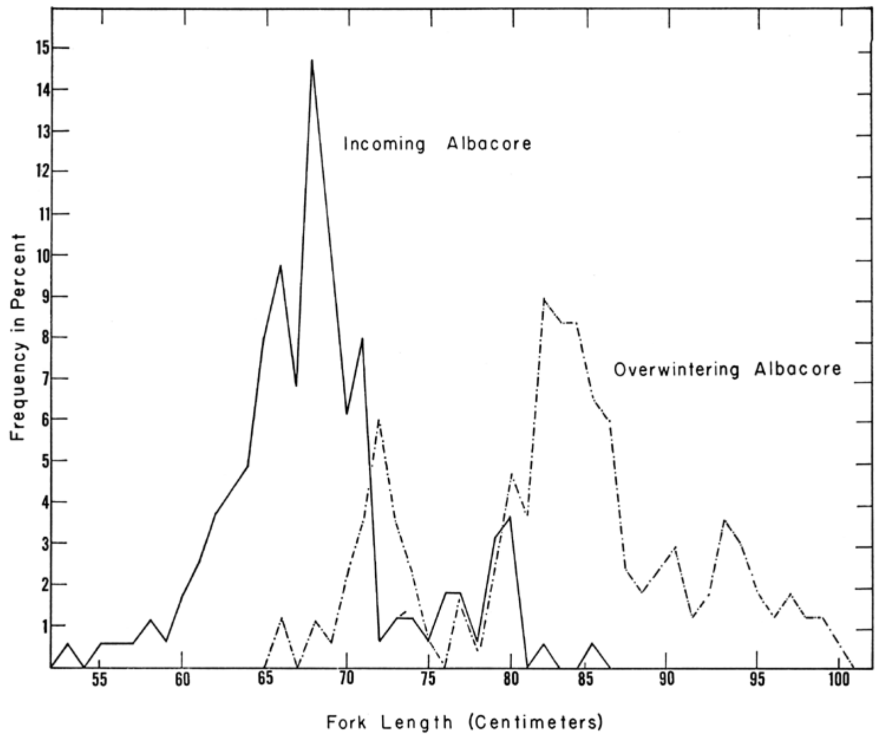

FIGURE 33. Length-frequency polygon of the June-early July 1958 incoming albacore "run" compared with that of large albacore overwintering from the 1957 season.

FIGURE 33. Length-frequency polygon of the June-early July 1958 incoming albacore "run" compared with that of large albacore overwintering from the 1957 season

beginning of the 1960 season, when a few fish were captured from a hundreds of miles to the north. A similar situation occurred at the "false" run near Guadalupe Island in late May and early June. The actual run occurred later and many miles to the north, where an excellent fishery subsequently developed—the Guadalupe Island area failed in 1960.

8.4.5. *Migrations of Albacore School Groups*

To gain additional insight into albacore behavior, we have tried to unravel the activities of school groups. School groups vary in size during any one fishing season with respect to both time and space. To minimize the possibility of involving several school groups in one analysis we established an arbitrary limit on school group size. All tagged fish released in any four-day period within a circle having a 20-mile radius were considered to have belonged to a single school group. Exceptions were made to the four-day rule when during analysis of our data it became obvious that on two occasions a school group had remained in the tagging area for longer periods. The following results were obtained by using this method to study albacore movements:

1) A small albacore school group that apparently lingered between Santa Catalina Island and the California mainland for three or four weeks was marked with 56 tagged albacore during August 4, 7, 14, and 21, 1952. This group was traced northward, by means of two tag

recoveries, to approximately 50 miles off Morro Bay, by September 20 and then across the Pacific Ocean to Japan where a final tag was recovered the following summer (June 23, 1953) by Japanese fishermen operating about 552 miles east-southeast of Tokyo (Lat. 31° 30' N., Long. 149° 40' E.) (Figure 34).

2) A large school group centered about 130 miles outside of Guadalupe Island was labeled with 513 tags during August 11, 13, and 16,

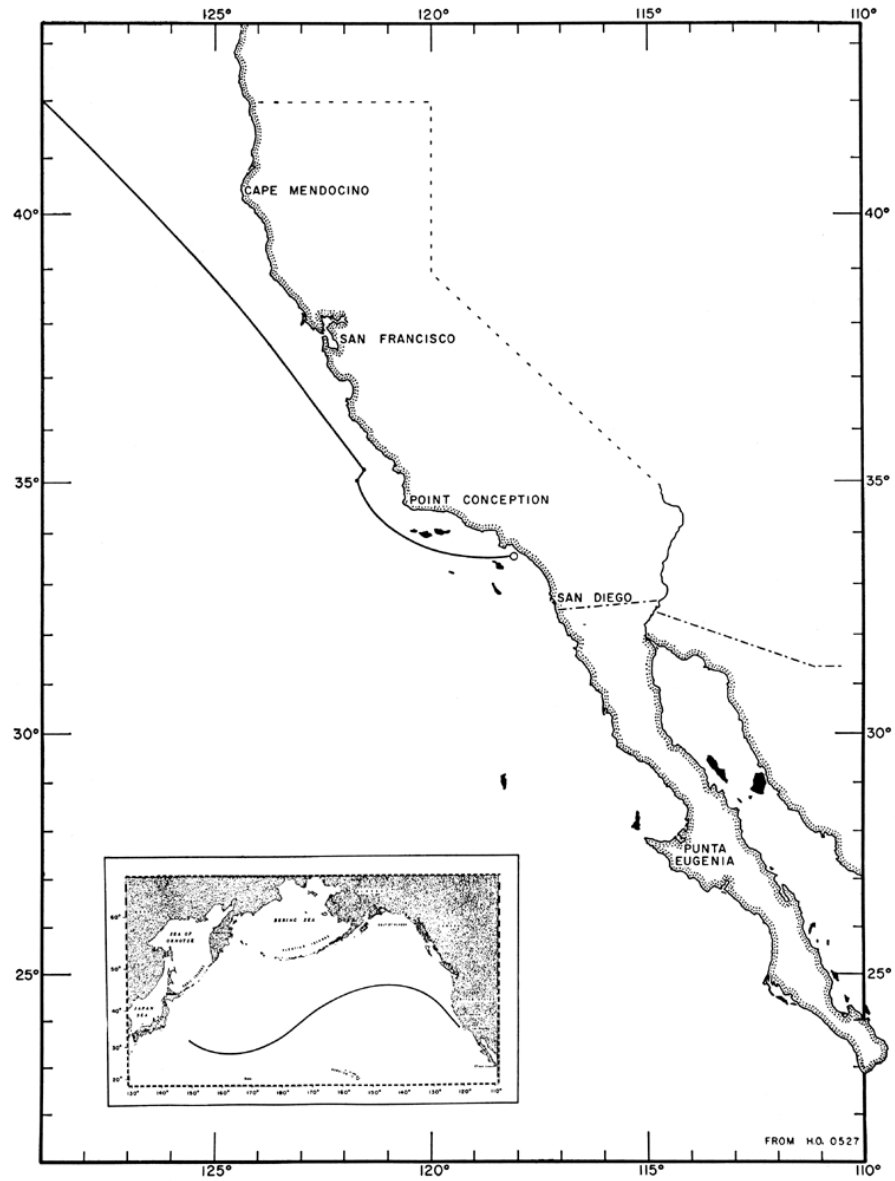

FIGURE 34. Migration of an albacore school group. It was marked in August 1952 and traveled from Santa Catalina Island northward through the coastal fishery, and then across the ocean to Japan. The open circle is the release area, and the solid circles are recapture points.

FIGURE 34. Migration of an albacore school group. It was marked in August 1952 and traveled from Santa Catalina Island northward through the coastal fishery, and then across the ocean to Japan. The open circle is the release area, and the solid circles are recapture points

1953 (Figure 19c). Subsequently, 14 tag recoveries enabled us to follow it northward to Point Arena, California. From there the group apparently traveled over half-way across the Pacific, for the final two tagged albacore were recaptured by Japanese fishermen operating in the winter longline fishery north of Midway Island (Figure 35).

3) During the three days July 25 to 27, 1955, a school group 40 miles off Todos Santos, Baja California, was marked with 26 tags. Six

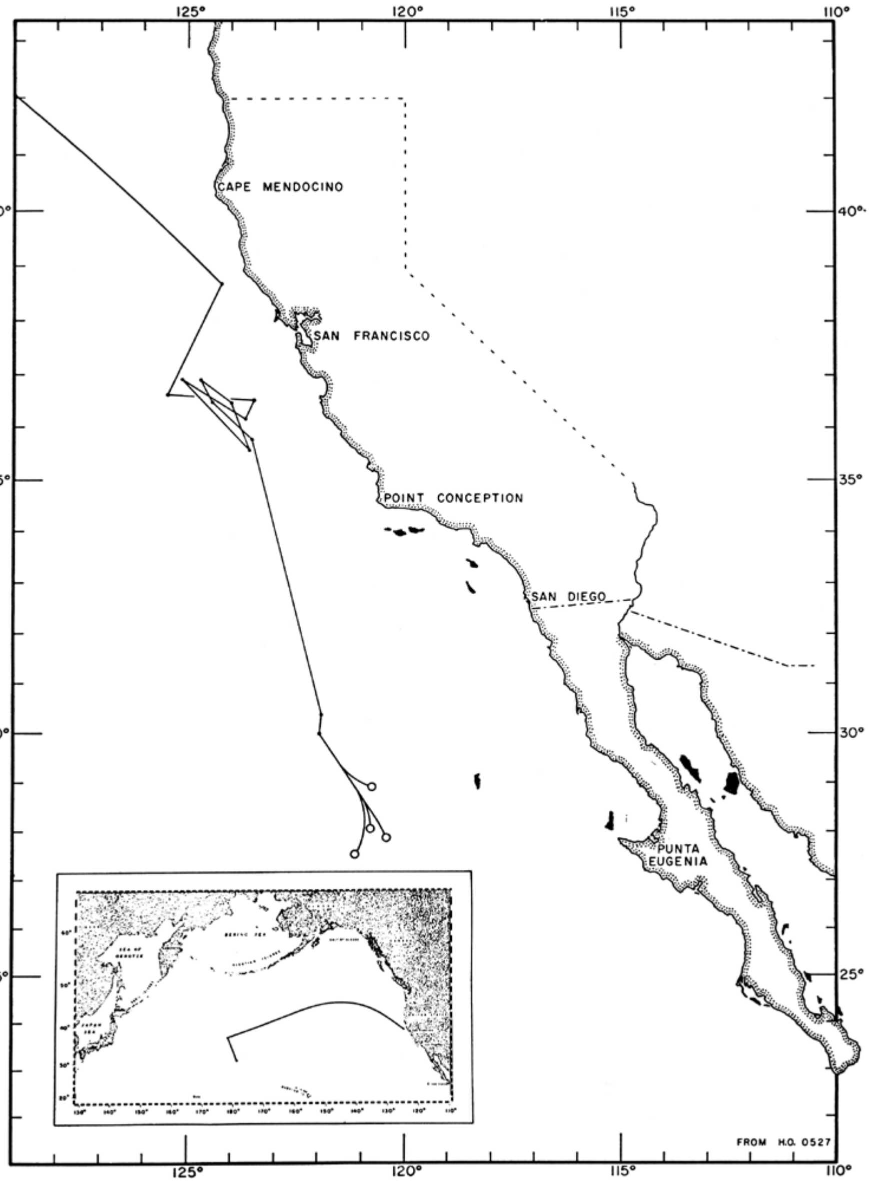

FIGURE 35. Migration of an albacore school group marked in August 1953. It traveled northward in the coastal fishery and then across the Pacific Ocean to the Midway Island area. Open circles are release locations, and solid circles are recapture points.

FIGURE 35. Migration of an albacore school group marked in August 1953. It traveled northward in the coastal fishery and then across the Pacific Ocean to the Midway Island area. Open circles are release locations, and solid circles are recapture points

eventually were recovered south of Santa Catalina Island: two during the tagging season (one November 9 near Guadalupe Island, indicating the start of possible overwintering), two the following season (1956), and two during a third season (1957)—revealing that members of this group might have visited our shores three seasons in a row.

4) Ten albacore were tagged and released in a school group approximately 40 miles off San Quintin, Baja California, on August 15 and

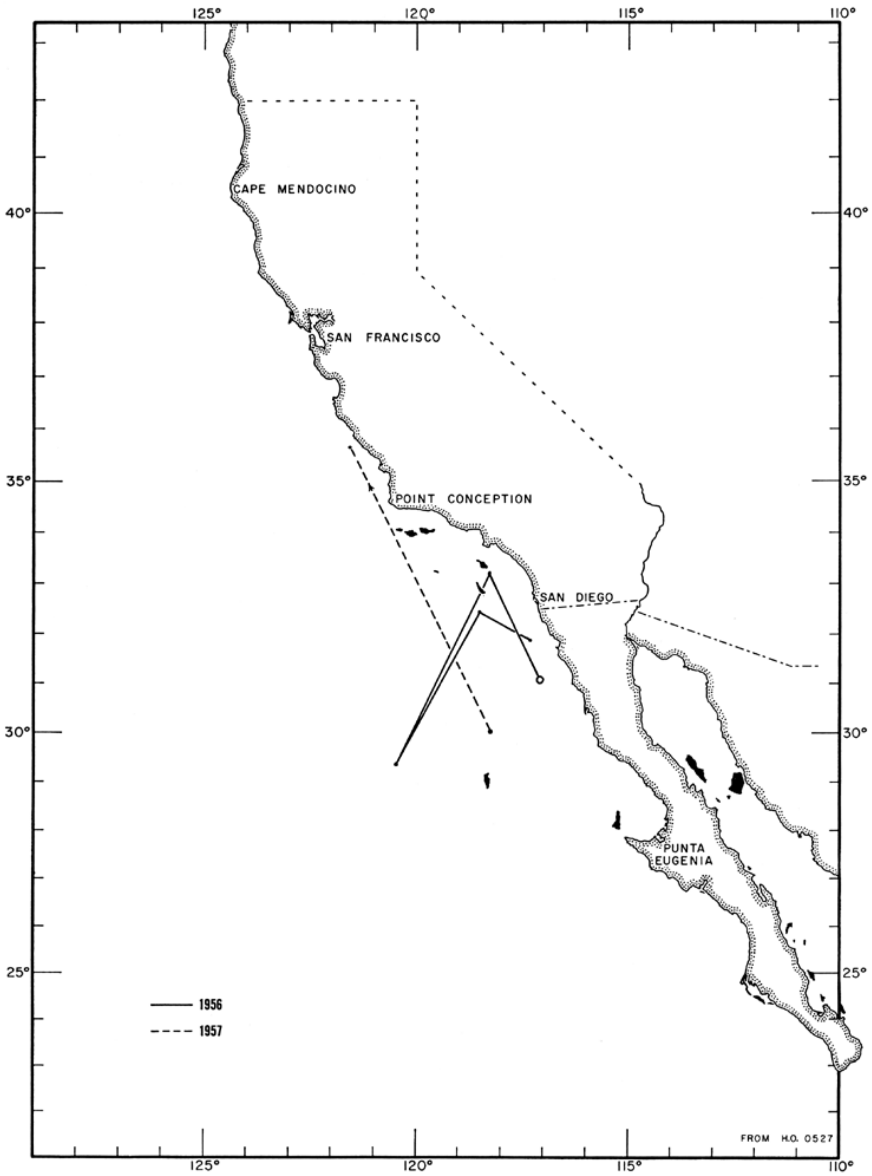

FIGURE 36. Migration of an albacore school group marked with 152 tags during July 1956. Open circle is tagging area; solid circles are recapture points. Solid line represents movements during season of release (1956) based upon four recoveries; and broken line represents travels during the next season (1957) based upon two recoveries.

FIGURE 36. Migration of an albacore school group marked with 152 tags during July 1956. Open circle is tagging area; solid circles are recapture points. Solid line represents movements during season of release (1956) based upon four recoveries; and broken line represents travels during the next season (1957) based upon two recoveries

16, 1955. Both of the fish recovered from this group were caught the following season (1956); the first on June 26, about 25 miles off Point San Carlos, Baja California and the other July 31, 35 miles off San Quintin, Baja California. Members of this group easily could have traveled to the Japanese fisheries and back again.

5) A school group was labeled with 152 tagged albacore on July 13 and 15, 1956, approximately 35 miles off Cape Colnett, Baja California.

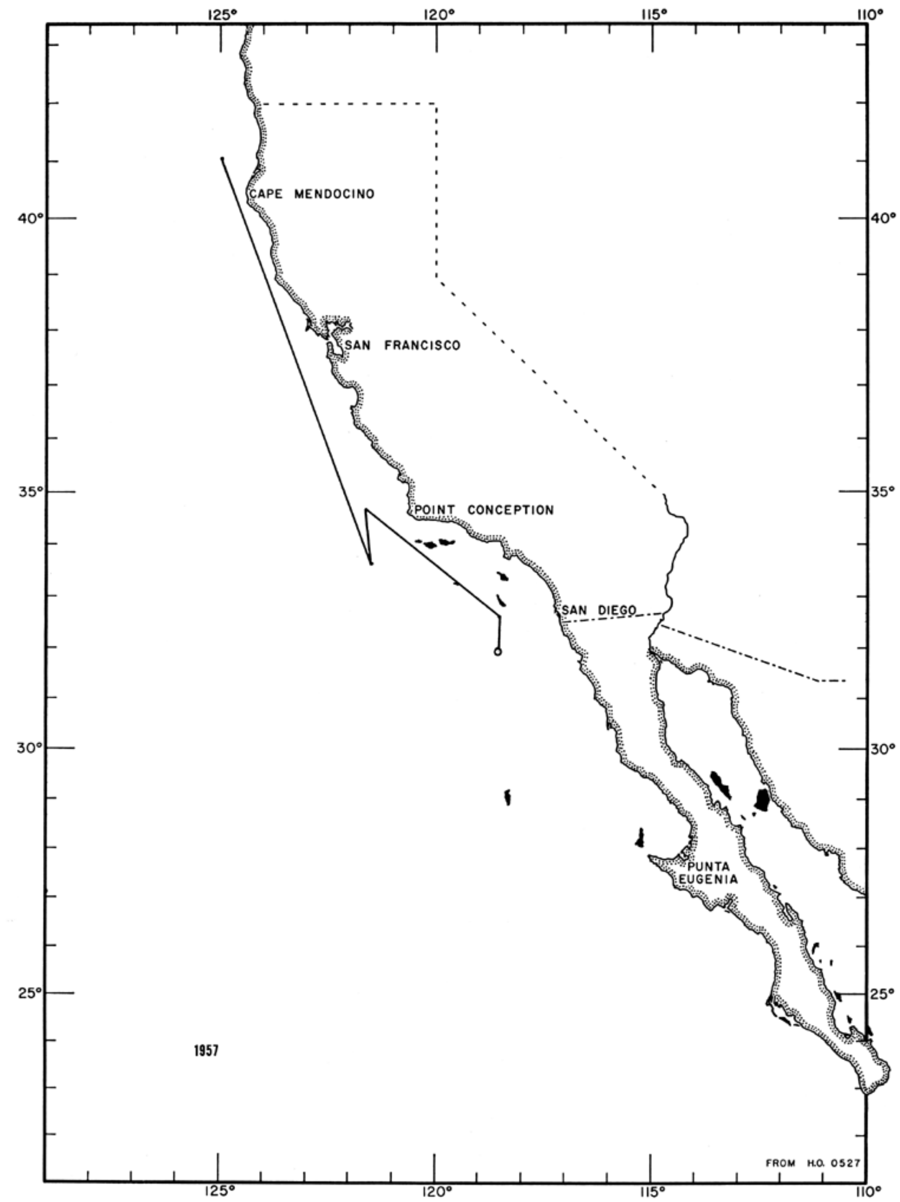

FIGURE 37. Migration of a group of albacore schools marked with 122 tags during July, 1957. The group traveled from Baja California to within 60 miles of the Oregon border.

FIGURE 37. Migration of a group of albacore schools marked with 122 tags during July, 1957. The group traveled from Baja California to within 60 miles of the Oregon border

Six tag recoveries (four in 1956 and two in 1957) indicated that the group traveled northward to an area between Santa Catalina and San Clemente Islands, southwest to outside of Guadalupe Island, northeast to south of San Clemente Island, and then southeast to Todos Santos, Baja California. The last two tags were recovered from this group during the 1957 season, after the fish had begun another coastal migration (Figure 36).

6) A school group 30 miles off Cape Colnett, Baja California, received 125 marked albacore on July 8 and 9, 1957. The first recovery was off Avila in November 1957, while the second (last) was caught in the winter longline fishery off Japan (Lat. 28° 22' N., Long. 150° 18' E.) two years later on February 13, 1959—585 days after release.

7) On July 11 and 12, 1957, a school group approximately 90 miles off Todos Santos, Baja California was marked with 122 tags. Four recoveries enabled us to follow it northward to the Eureka area (Figure 37).

9. GROWTH RATES AND AGE ESTIMATES

Age and growth knowledge is of paramount importance to any investigation designed to provide factual information, which can be used to improve a fishery and achieve a maximum harvest therefrom. For many fish species, growth rates have been estimated satisfactorily from age-length data; determined by interpreting and measuring the spacing of rings or annuli on body hard parts.

FIGURE 38. Robert R. Bell, at the California State Fisheries Laboratory, Terminal Island, interpreting markings on albacore scales to determine age. Note enlarged pictures of tuna scales in the background. *Photograph by Robert A. Iselin.*

FIGURE 38. Robert R. Bell, at the California State Fisheries Laboratory, Terminal Island, interpreting markings on albacore scales to determine age. Note enlarged pictures of tuna scales in the background. Photograph by Robert A. Iselin.

In the case of Pacific albacore, there is disagreement among various investigators concerning age determinations and the growth rates estimated from them (Aikawa and Kat#, 1938; Partlow, 1955; Otsu and Uchida, 1959). A major objective of our albacore tagging program was to obtain growth rates, to use as an aid in aging studies (Figure 38). We have estimated growth by plotting a series of length-frequency histograms, that have been obtained by measuring random samples of fish landed by the commercial fishery, and studying the monthly progression of the resulting modal groups. However, measuring individual fish length at time of tagging and again upon recovery, and calculating the interim length change has proven more satisfactory.

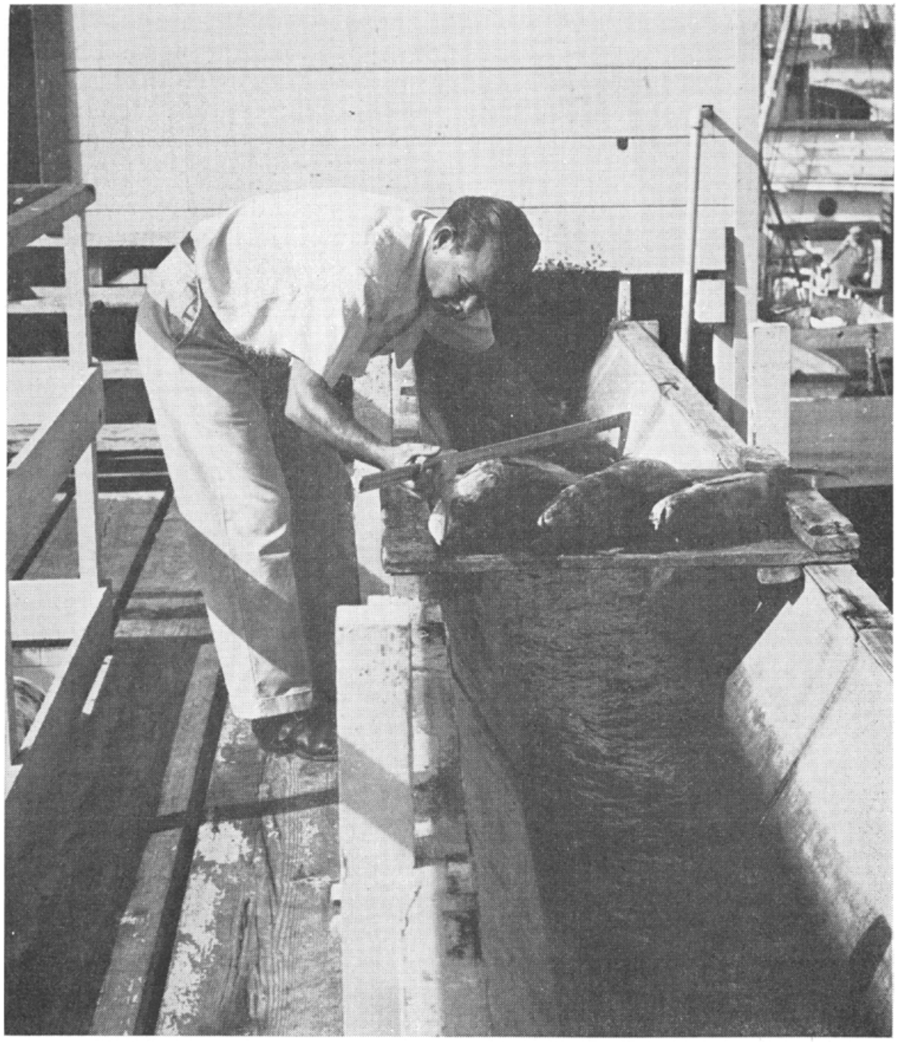

FIGURE 39. Field man John J. Seapin conducting length-frequency studies of tuna landed at Terminal Island, California. Note specially designed tuna calipers. *Photograph by Robert A. Iselin.*

FIGURE 39. Field man John J. Seapin conducting length-frequency studies of tuna landed at Terminal Island, California. Note specially designed tuna calipers. Photograph by Robert A. Iselin.

Albacore caught by the fishery during this study period, as determined from random market measurements (Figure 39), ranged from 48 to 97 cm fork length, while the tagged and recaptured fish ranged from 55 to 91 cm at the time of tagging and were at liberty for 6 to 761 days.

The length change (increment) for each tagged fish was plotted against days at liberty and the resulting scatter diagram indicated that the data trend probably was linear (Figure 40). A regression equation of best fit ($Y = -11.83 + 0.309\ X$) was calculated to show the average length change during various periods of liberty; the standard error of estimate is SE = 30.04 mm, and the 95 percent confidence limits on the regression placed the upper limit at 0.344 mm and the lower at 0.274 mm. The correlation coefficient is $r = 0.903$, and the 95 percent confidence limits are 0.939 for the upper and 0.848 for the lower limit. These data show the average length change (about 101 mm per year) of the tagged fish with respect to time and illustrate the variation encountered while using the tag-and-recapture method for determining growth. A majority of the variation can be attributed to four factors:

1) inherent difficulties involved with holding and quickly measuring a live, powerful, slippery fish without injuring it—frequently during rough weather;

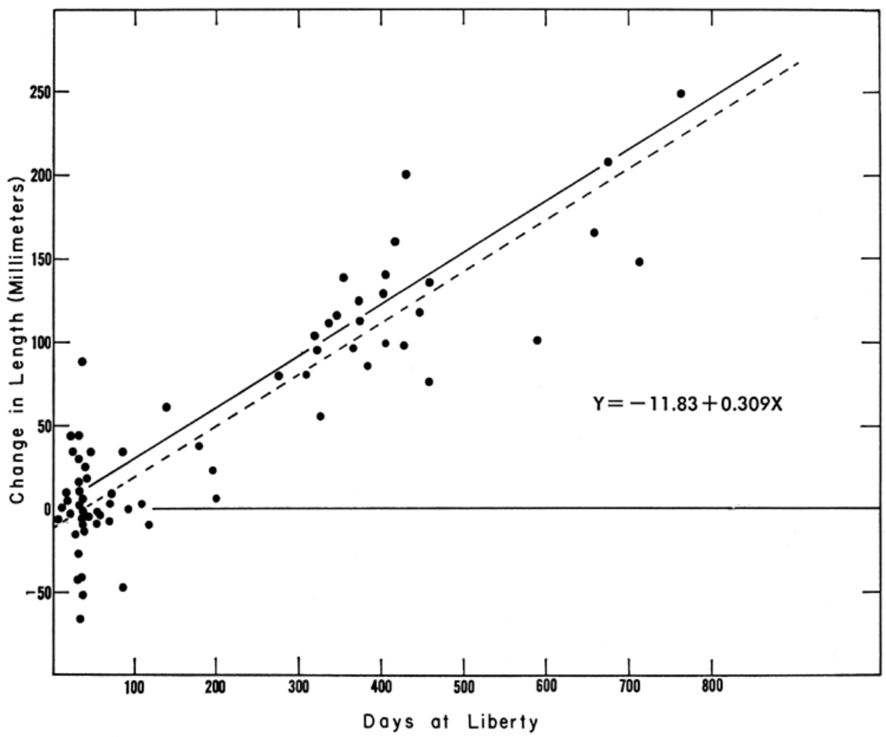

FIGURE 40. Scatter diagram of length changes of tagged albacore recovered during the eight seasons, 1952-1959.

FIGURE 40. Scatter diagram of length changes of tagged albacore recovered during the eight seasons, 1952–1959

2) differences in measurements made by various personnel at time of tagging and recovery;

3) shrinkage due to loss of body fluids, during freezing and thawing of the albacore aboard ship;

4) normal variation in albacore growth rates.

Data from each of the 21 tagged albacore that had been at liberty from 9 through 15 months, were used to calculate an annual growth curve. These calculations were based on the assumption that the nine-month growth rate would continue for three additional months (one year), the 10-month growth rate for two more months, etc. In addition we assumed that the 13-, 14-, and 15-month growth rates essentially were the same at 12 months (Table 16). The fish ranged from 545 to 770 mm fork length at time of tagging, and were released during the 1952 and 1954 through 1957 fishing seasons. This information, when plotted as a growth transformation, provides an estimated yearly growth for albacore above the inflection point (Figure 41). The line of best fit for these data is described by the equation $Y = 210.31 + 0.845\ X$, and the average maximum size attained by the species is calculated at 135.6 cm; 7.6 cm longer than the largest albacore on record.

From this equation, albacore averaging 52 cm fork length in June (the start of the California albacore season) grew to 65 cm in one year; a gain of 13 cm or just over 1 cm per month. Albacore 65 cm long grew to 76 cm, an increase of 11 cm per year. Those averaging 76 cm grew to 85 cm, a gain of 9 per year. Albacore averaging 85 cm

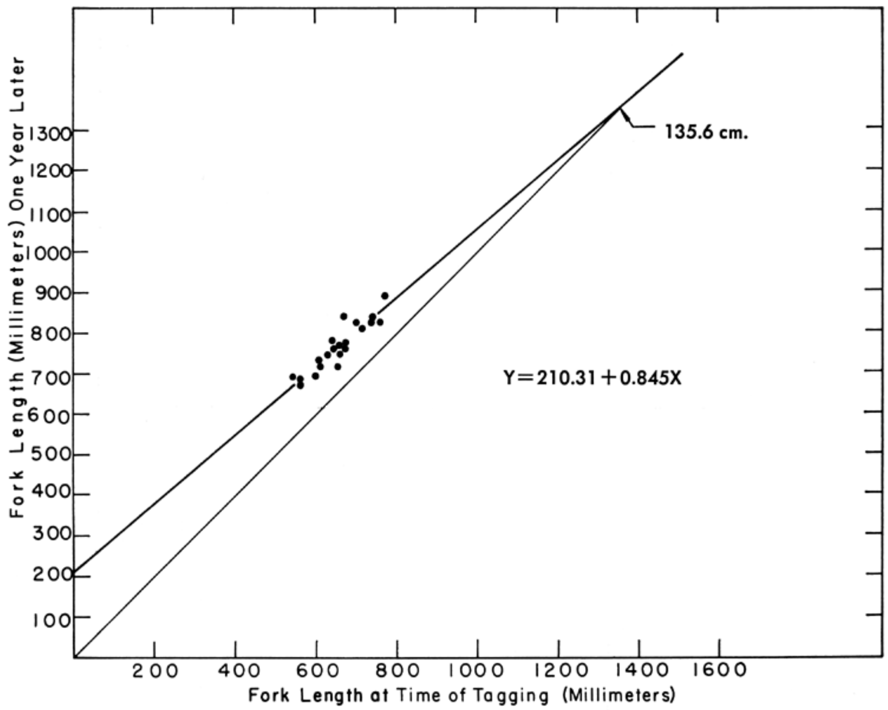

FIGURE 41. Albacore growth based on length increases of fish at liberty from 9 to 15 months.

FIGURE 41. Albacore growth based on length increases of fish at liberty from 9 to 15 months

TABLE 16

Statistics of 21 Tagged Albacore Used to Calculate an Annual Growth Curve

Tag Recovery Number	Tagging Date	Tagging Length (mm)	Recovery Date	Recovery Length (mm)	Days At Liberty	Gain In Length (mm)	Calculated Annual Gain (mm)	Calculated Length (1 Yr) (mm)
3	8/ 4/52	760	6/23/53	815	323	55	62	822
21	9/26/54	700	9/ 2/55	815	342	115	123	823
27	7/25/55	633	7/28/56	745	370	112	110	743
44	7/26/55	657	10/23/56	732	456	75	60	717
24	8/15/55	560	6/26/56	663	317	103	119	679
26	8/16/55	545	7/31/56	683	351	138	144	689
29	8/10/55	560	8/13/56	684	370	124	122	682
42	8/13/55	600	8/ 8/56	696	362	96	97	697
45	10/ 5/55	605	11/ 9/56	745	402	140	127	732
53	7/15/56	715	8/19/57	813	401	98	89	804
55	7/18/56	640	8/20/57	768	399	128	117	757
63	7/15/56	740	9/30/57	857	443	117	96	836
46	9/ 3/56	610	6/ 1/57	688	271	78	105	715
48	9/ 3/56	670	7/ 5/57	750	306	80	95	765
49	9/ 5/56	660	7/20/57	755	319	95	109	769
59	9/ 3/56	675	9/17/57	760	380	85	82	757
71	6/13/57	670	9/10/58	805	455	135	108	778
69	7/ 5/57	770	6/ 4/58	882	334	112	122	892
72	7/ 5/57	670	9/ 4/58	870	427	200	171	841
73	7/14/57	660	9/ 9/58	758	423	98	85	745
74	7/ 2/57	640	8/12/58	800	407	160	143	783

TABLE 16
Statistics of 21 Tagged Albacore Used to Calculate an Annual Growth Curve

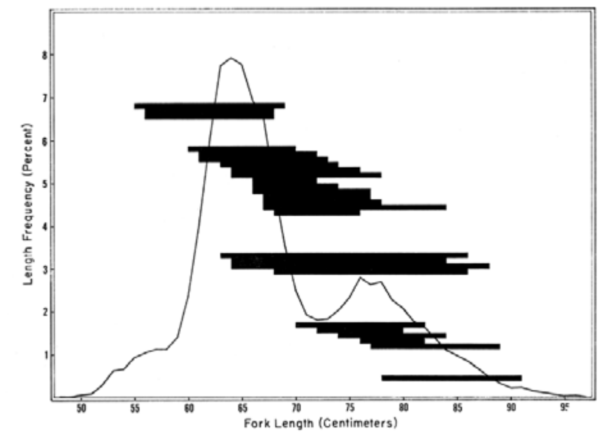

FIGURE 42. A comparison of the length-frequency of albacore landed in California during months of tagging and the growth of 26 tagged fish at liberty for one- and two-year periods. Length of an individual fish at time of tagging is left end of solid bar while length at recovery is right end of same bar.

FIGURE 42. A comparison of the length-frequency of albacore landed in California during months of tagging and the growth of 26 tagged fish at liberty for one- and two-year periods. Length of an individual fish at time of tagging is left end of solid bar while length at recovery is right end of same bar

would have grown to 93 for an increase of 8 per year, while the 93 cm fish would measure 100 cm a year later.

Except for the 52 cm size group, which appears at 55 to 57 cm in our frequency data because only its largest members migrate into the West Coast fishing grounds, all of the calculated means compare favorably with the modal lengths obtained by plotting length-frequencies of the commercial catch. Thus the natural albacore size groups that occur in the California fishery are year-classes (Clemens, 1957). Additional evidence obtained from our tagging data demonstrated, for the first time, that these size groups were consecutive year-classes—one year apart in age. Albacore in the first (52 cm) size group when tagged, grew into the second group in one year; those marked in the second group, grew into the third the next year; and the ones in the third grew into the fourth a year later. Also, four albacore tagged in the second size group, were in the fourth group two years (21–27 months) later when recovered; and finally an albacore in the third size group when tagged, was in the fifth group when recaptured two years later (Figure 42, Table 16, 17). These data also indicate that albacore have one major spawning period each season.

To determine the actual age of the fish, however, requires that we know when albacore spawn, and larval and juvenile growth rates—only fragmentary data related to their spawning habits are presently available. Observations made on thousands of fish landed in California during the periods 1921 to 1927, 1953 to 1956, and in 1960, indicated that the sex ratio is close to 1:1, although in many samples of fish 72 cm fork length and larger, males predominated.

Running-ripe albacore never have been recorded from the California landings which in some years, notably the warm-water years 1958 and 1959, have been caught from Baja California to Alaska. Maturity observations (Figure 43) made during various California fishing seasons since 1950 showed that ovaries in a large majority of the albacore were immature. Some ovaries were developing; however, very few were comparatively well-developed. Eggs from ovaries of fish in the 52 and 65 cm size groups measured less than 0.06 mm in diameter and were considered immature; those in the 76 and 85 cm groups measured 0.06 to 0.09 mm, and were designated as developing; while ova from larger fish were comparatively well-developed, measuring larger than 0.10 mm in diameter. Albacore in the 93 cm group and larger are relatively unavailable to the California surface fishery and rarely are caught in deeper waters, as evidenced by our exploratory longline fishing cruises (Wilson, 1954; Pinkas, 1954, 1955 and 1955a; and Mais, 1957). In addition to the maturity observations made on albacore in our coastal fishery, we measured 500 eggs from a 1,079 mm fork-length fish captured in the Japanese winter longline fishery and received at a Terminal Island cannery during April 1953. This albacore had eggs ranging from 0.08 to 0.67 mm in diameter, with the largest modal size at 0.6 mm and second largest at 0.3 mm (Clemens, unpublished data).

Judging from length-frequency data obtained by market sampling during the past 10 years, these large fish (93+ cm) contribute less than one percent, by numbers, to an average season's catch. However, observations at sea (Wilson, 1953) and on the waterfront (Clemens, 1953), of large albacore caught near Guadalupe Island during July

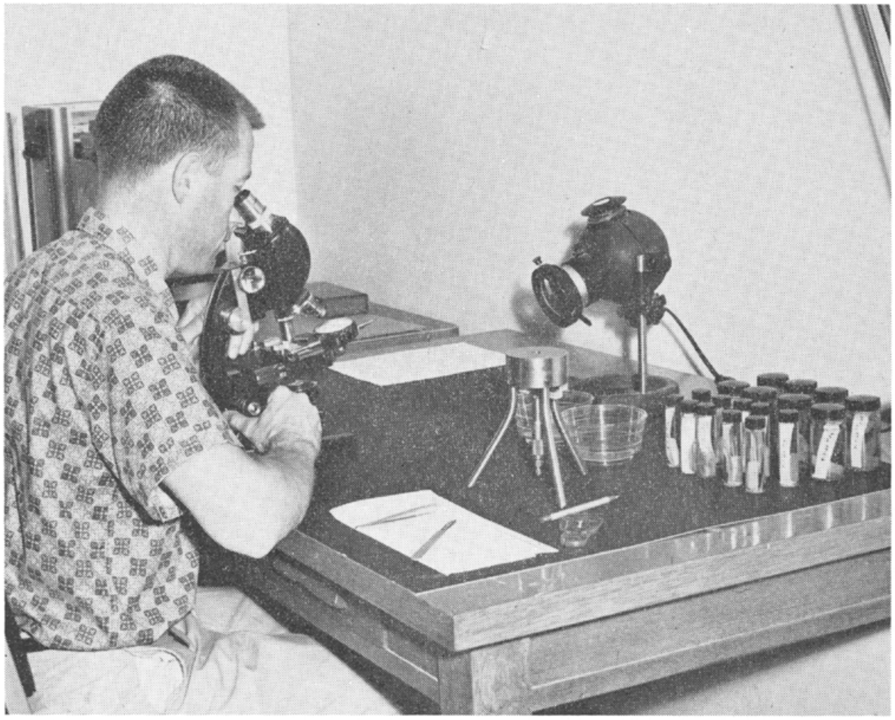

FIGURE 43. Robert A. Iselin, at the California State Fisheries Laboratory, Terminal Island, measuring albacore eggs as part of a maturity study. Note dial indicator attached to microscope, for measuring egg diameters. *Photograph by Robert R. Bell.*

FIGURE 43. Robert A. Iselin, at the California State Fisheries Laboratory, Terminal Island, measuring albacore eggs as part of a maturity study. Note dial indicator attached to microscope, for measuring egg diameters. Photograph by Robert R. Bell

and August 1953, revealed that those in the 93 and 100 cm size groups, 37- and 46-pounders, recently had spawned; possibly during the spring. Since albacore in the 93 cm size group are spawners, it seems likely that first maturity may be reached by some of the large fish in the next smaller (85 cm) group (Clemens, 1961). Apparently these large albacore had spawned prior to their coastward migration from the mid-Pacific, which is in progress between June and September for large fish and May to August for smaller ones. This means that albacore spawning may occur in the west-central Pacific during the period immediately preceding an annual coastward migration, for it seems unlikely they would spawn enroute.

If mature adults consist predominantly of fish in the 93 cm group and larger, very little spawning would be expected to take place in the eastern Pacific. The same may be true in the coastal western Pacific during the summer; for although the Japanese fishery there produces albacore ranging in fork length from 50 to 100 cm, the largest part of the catch consists of medium-sized fish between 70 and 90 cm long—only very small numbers of larger ones are caught (Suda, 1955). This so-called coastal fishery is frequently referred to as a summer or pole-and-line fishery, and the distance offshore varies from less than 100 to over 1,000 miles (Van Campen, 1960).

The winter longline fishery, which proceeds from September to April and harvests fish at considerable depths between the Hawaiian Islands

TABLE 17

Statistics of Five Albacore Used to Calculate Growth for Two Years

Tag Recovery Number	Tagging Date	Tagging Length (mm)	Recovery Date	Recovery Length (mm)	Days At Liberty	Gain In Length (mm)	Calculated Annual Gain (mm)	Calculated Length (1 Yr) (mm)	Calculated Length (2 Yr) (mm)
47	7/25/55	636	7/ 3/57	833	710	197	101	737	838
54	7/27/55	638	8/25/57	887	761	249	119	757	876
65	10/10/55	630	8/12/57	838	673	208	113	743	856
70	9/ 3/56	675	6/19/58	840	654	165	92	767	859
75	7/ 8/57	780	2/13/59	880	585	100	62	842	904

TABLE 17
Statistics of Five Albacore Used to Calculate Growth for Two Years

and Japan, yields albacore ranging from 50 to 120 cm long; the largest portion, however, consists of fish 70 to 120 cm long (Suda, 1956). This winter fishery extends from southern Japan to about 3,000 miles eastward, encompassing the summer fishing grounds and extending some 2,000 miles farther offshore. Japanese commercial fishing records, which have been edited by the Nankai Fisheries Research Laboratory staff (1954), indicate that these albacore perform a mass migration southward in a long, narrow, east-west band each year as the fishing season progresses from September through March, and the larger ones 90 to 100 cm possibly spawn south of the Subtropical Convergence—the boundary between the North Pacific Current and the North Equatorial Current. Apparently only large, mature albacore, that presumably will take part in the forthcoming season's spawning, penetrate the Subtropical Convergence (at least during March and April) while most of the immature ones shorter than 90 cm remain to the north. It seems likely that some spawning occurs during this period.

Small albacore 23 cm long were taken about 500 miles west of Midway Island from January to May, 1937 (Aikawa and Kat#, 1938), indicating recent spawning—perhaps winter or spring. In June 1951, 139 albacore from 30 to 37 cm long (average 34.6) were captured in the Japanese coastal fishery (Suda, 1955), suggesting that spawning may have taken place during the winter or spring. Yabe, *et al* (1958) identified young albacore 188 and 124 mm standard length from the stomachs of black marlin, Makaira indica. These were caught during May 1949 and June 1952; this evidence points to spring spawning.

Although considerable natural variation is to be expected, data now at hand indicate that a large part of the albacore spawning, in the north Pacific Ocean, occurs in the vicinity of the Subtropical Convergence and south, and over a wide area extending at least from the longitude of Japan to that of the Hawaiian Islands. These data also indicate that during past years, some albacore spawning may have occurred at any time between January and June inclusive (Clemens, 1961). Therefore, most of the albacore comprising the California fishery may originate between the longitudes of Japan and the Hawaiian Islands (probably nearer the Islands) and migrate into the West Coast fishing grounds during the first season they become strong enough to school and endure a long migration.

There is a possibility that, in some years, a few albacore spawned south of Guadalupe Island in the spring or summer. During March 1912, albacore were captured on trolling lines in deep water well-offshore from Magdalena Bay, Baja California. They were mature and ready to spawn, and contained eggs about the size of "codfish roe." During August they were off Cape San Lucas and all had spawned. They were still off Cape San Lucas in January, five months later (Scofield, 1914). This is considerably farther south than albacore usually are caught; however, a large fish reported to have been an albacore (915 mm standard length) in the 35–40 pound class was taken February 24, 1956, near Clarion Island; one of the Revilla Gigedo Islands off Mexico. This is some 440 miles southwest of Cape San Lucas.

Albacore sometimes will overwinter south of Guadalupe Island, and the largest of these overwintering fish (> 90 cm) may mature and spawn in this area (Figure 32). An albacore 38.1 cm fork length was

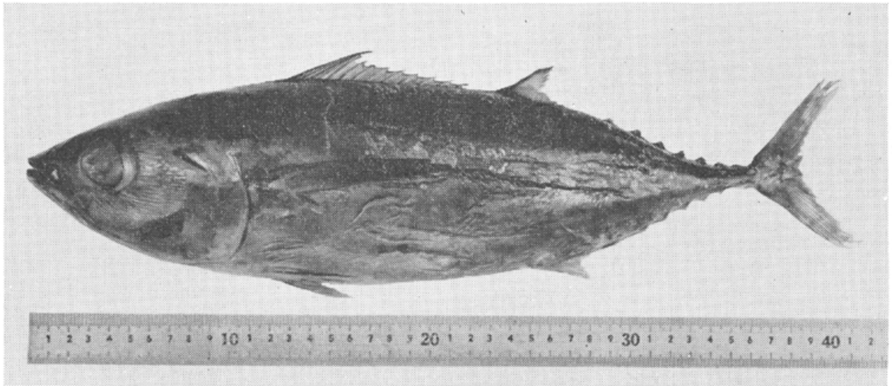

FIGURE 44. This two-pound albacore captured by the *Norma B.*, on December 7, 1957, is the smallest recorded from the California fishery. *Photograph by Robert A. Iselin.*

FIGURE 44. This two-pound albacore captured by the Norma B., on December 7, 1957, is the smallest recorded from the California fishery. Photograph by Robert A. Iselin

caught December 7, 1957, near Guadalupe Island and delivered to the California State Fisheries Laboratory. It could have been the young of large adults that remained off Baja California during the winter of 1956–57 and spawned the following spring or summer (Figure 44). This two-pound albacore, the smallest recorded in the commercial fishery, is about 12 cm or one-third shorter than the smallest usually migrating into the West Coast fishery. Fish this size and smaller, apparently do not have enough strength to complete rapidly an ocean-spanning migration. If they did, these youngsters would enter the fishing grounds in tremendous numbers, and many would be hooked on the prevailing fishing gear (trolling jigs and rod and reel). These two gear types easily capture quantities of small (30 cm) tuna-like frigate mackerel, Auxis thazard, when they enter the fishing grounds (Iselin, 1960); and unquestionably would capture quantities of small albacore.

If we assume that spawning (and hatching) peaks in April and the first winter ring is formed on the scales of the juveniles in February, the 52 cm size-class fish, which first appear in the California fishery in June, would be 14 months old. They would have one winter ring on their scales or body hard parts (Bell, ms.). Thus the 52 cm size group would consist of one-year-old fish, and their average growth rate from time of hatching would have been 4 cm per month (Figure 45). This is somewhat slower growth than was noted for young black skipjack, Euthynnus lineatus, reared in aquaria aboad the *N. B. Scofield*. These black skipjack, which are a closely related but more tropical species, averaged 2.7 cm standard length at time of capture and gained 4 cm in 10 days (Clemens, 1956).

If, however, the 52 cm size group of albacore consists of two-year-olds in their third year of life, two winter checks would be expected on their scales and their growth from the time of hatching would have averaged just under 2 cm per month. This seems slow when one considers that tagging revealed the 52 cm size group grew slightly in excess of 1 cm per month during the succeeding year.

Estimated ages and calculated lengths and weights are presented in Table 18. The weights were calculated from a weight-length equation, based upon 1,073 albacore landed at Terminal Island, California, in 1952, 1955, and 1960 (Figure 46). These fish ranged between 38 and 1,000 cm fork length and included 378 males and 358 females. A convenient regression of weight (pounds) on length (millimeters) for individual sexes was calculated by the least-squares method. The weight-length equation for the males was $W = 0.00000005035\ L^{2.99}$; and for females $W = 0.00000004979\ L^{2.99}$. Statistically there was no significant

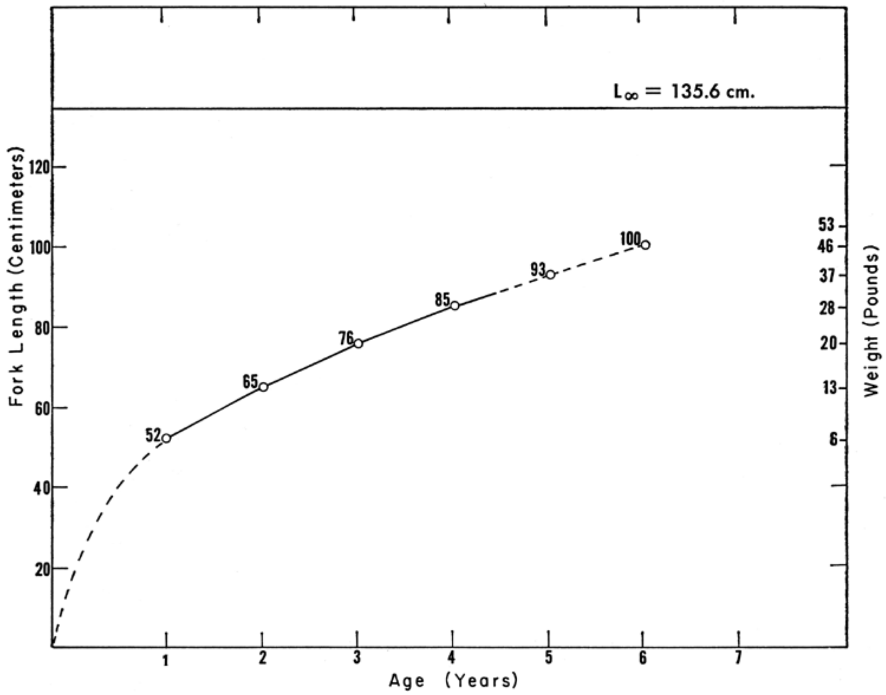

FIGURE 45. Albacore weight-length-age curve based upon 21 tag recoveries, 1952 through 1957.

FIGURE 45. Albacore weight-length-age curve based upon 21 tag recoveries, 1952 through 1957

TABLE 18

Calculated Average Lengths and Weights for Albacore Age Groups

Age Groups	Fork Length (cm)	Increment (cm)	Weight (lbs.)	Increment (lbs.)
I	52		6.4	
		13		6.2
II	65		12.6	
		11		7.4
III	76		20.0	
		9		8.0
IV	85		28.0	
		8		8.6
V	93		36.6	
		7		8.9
VI	100		45.5	
		5		7.2
VII	105		52.7	

TABLE 18

Calculated Average Lengths and Weights for Albacore Age Groups

FIGURE 46. Field man John A. Shaver conducting weight-length studies of tuna landed at Terminal Island, California. *Photograph by Robert A. Iselin.*

FIGURE 46. Field man John A. Shaver conducting weight-length studies of tuna landed at Terminal Island, California. Photograph by Robert A. Iselin

difference between the sexes, therefore these data were combined with those of the 337 unsexed albacore into a composite weight-length curve (Figure 47, Table 19). The final equation was $W = 0.00000004936\, L^{2.99}$, and the 95 percent confidence limits on the regression placed the upper limit at 3.0212 and the lower at 2.9553.

Our growth calculations were fitted to von Bertalanffy's growth equation (Beverton and Holt, 1957), and the length at each estimated age was given equal weight in fitting the data to it. The equation with the fitted constants becomes:

$$l_t = 1356\,[1 - e^{-0.17\,(t\,+\,1.87)}]$$

FORMULA

10. DISCUSSION

Variation is the keynote in any discussion of albacore habits. However, data now available are sufficient to develop some working hypotheses

TABLE 19

Relationship Between Albacore Fork Length and Weight

Fork Length (mm)	Weight (lbs.)	Fork Length (in.)	Fork Length (mm)	Weight (lbs.)	Fork Length (in.)	Fork Length (mm)	Weight (lbs.)	Fork Length (in.)
380	2.53	14.96	590	9.41	23.23	800	23.36	31.50
385	2.63	15.16	595	9.65	23.43	805	23.80	31.69
390	2.73	15.35	600	9.89	23.62	810	24.25	31.89
395	2.84	15.55	605	10.14	23.82	815	24.70	32.09
400	2.95	15.75	610	10.39	24.02	820	25.15	32.28
405	3.06	15.94	615	10.65	24.21	825	25.62	32.48
410	3.17	16.14	620	10.91	24.41	830	26.08	32.68
415	3.29	16.34	625	11.17	24.61	835	26.56	32.87
420	3.41	16.54	630	11.44	24.80	840	27.03	33.07
425	3.53	16.73	635	11.72	25.00	845	27.52	33.27
430	3.65	16.93	640	12.00	25.20	850	28.00	33.46
435	3.78	17.13	645	12.28	25.39	855	28.50	33.66
440	3.91	17.32	650	12.56	25.59	860	29.00	33.86
445	4.05	17.52	655	12.85	25.79	865	29.51	34.06
450	4.19	17.72	660	13.15	25.98	870	30.02	34.25
455	4.33	17.91	665	13.45	26.18	875	30.54	34.45
460	4.47	18.11	670	13.75	26.38	880	31.06	34.65
465	4.62	18.31	675	14.06	26.57	885	31.59	34.84
470	4.77	18.50	680	14.38	26.77	890	32.13	35.04
475	4.92	18.70	685	14.70	26.97	895	32.67	35.24
480	5.08	18.90	690	15.02	27.17	900	33.22	35.43
485	5.23	19.09	695	15.34	27.36	905	33.78	35.63
490	5.40	19.29	700	15.68	27.56	910	34.34	35.83
495	5.57	19.49	705	16.01	27.76	915	34.90	36.02
500	5.74	19.69	710	16.36	27.95	920	35.48	36.22
505	5.91	19.88	715	16.70	28.15	925	36.06	36.42
510	6.08	20.08	720	17.05	28.35	930	36.64	36.61
515	6.26	20.28	725	17.41	28.54	935	37.23	36.81
520	6.45	20.47	730	17.77	28.74	940	37.83	37.01
525	6.64	20.67	735	18.14	28.94	945	38.44	37.20
530	6.83	20.87	740	18.51	29.13	950	39.05	37.40
535	7.02	21.06	745	18.89	29.33	955	39.66	37.60
540	7.22	21.26	750	19.27	29.53	960	40.29	37.80
545	7.42	21.46	755	19.65	29.72	965	40.92	37.99
550	7.62	21.65	760	20.04	29.92	970	41.56	38.19
555	7.83	21.85	765	20.44	30.12	975	42.20	38.39
560	8.05	22.05	770	20.84	30.31	980	42.85	38.58
565	8.26	22.25	775	21.25	30.51	985	43.51	38.78
570	8.48	22.44	780	21.66	30.71	990	44.17	38.98
575	8.71	22.64	785	22.08	30.91	995	44.84	39.17
580	8.94	22.84	790	22.50	31.10	1000	45.52	39.37
585	9.17	23.03	795	22.93	31.30			

TABLE 19

Relationship Between Albacore Fork Length and Weight

concerning several facets of North Pacific albacore life history. These inferences will be modified and revised when additional information becomes available and are presented here to assist the fishermen, and as a guide for fisheries agencies in their research planning.

10.1. The Spawning Population

Although much remains to be done to determine if there is a link between north and south Pacific albacore stocks (especially the spawning adults), data now at hand strongly indicate there is but a single population in the North Pacific. There is evidence that some of the four-year-old (85 cm group) albacore spawn, but a majority of the spawning population comprises five-years-old and older adults averaging 93 cm fork length (37 pounds) and larger. These large adults include several year-classes which have migrated from the surface layers to a large region well beneath the sea surface. In the western North Pacific they inhabit the North Pacific Current area, the North Equatorial Current, and the Equatorial Countercurrent area between the longitudes of the Hawaiian Islands and Japan (Suda, 1956). Many have been taken on longline gear fishing as deep as 70 to 80 fathoms, although the depth of abundance undoubtedly varies by area and season with fluctuating environmental conditions. There are no large numbers of subsurface adults living in the eastern North Pacific water mass between the longitude of the Hawaiian Islands and that of the

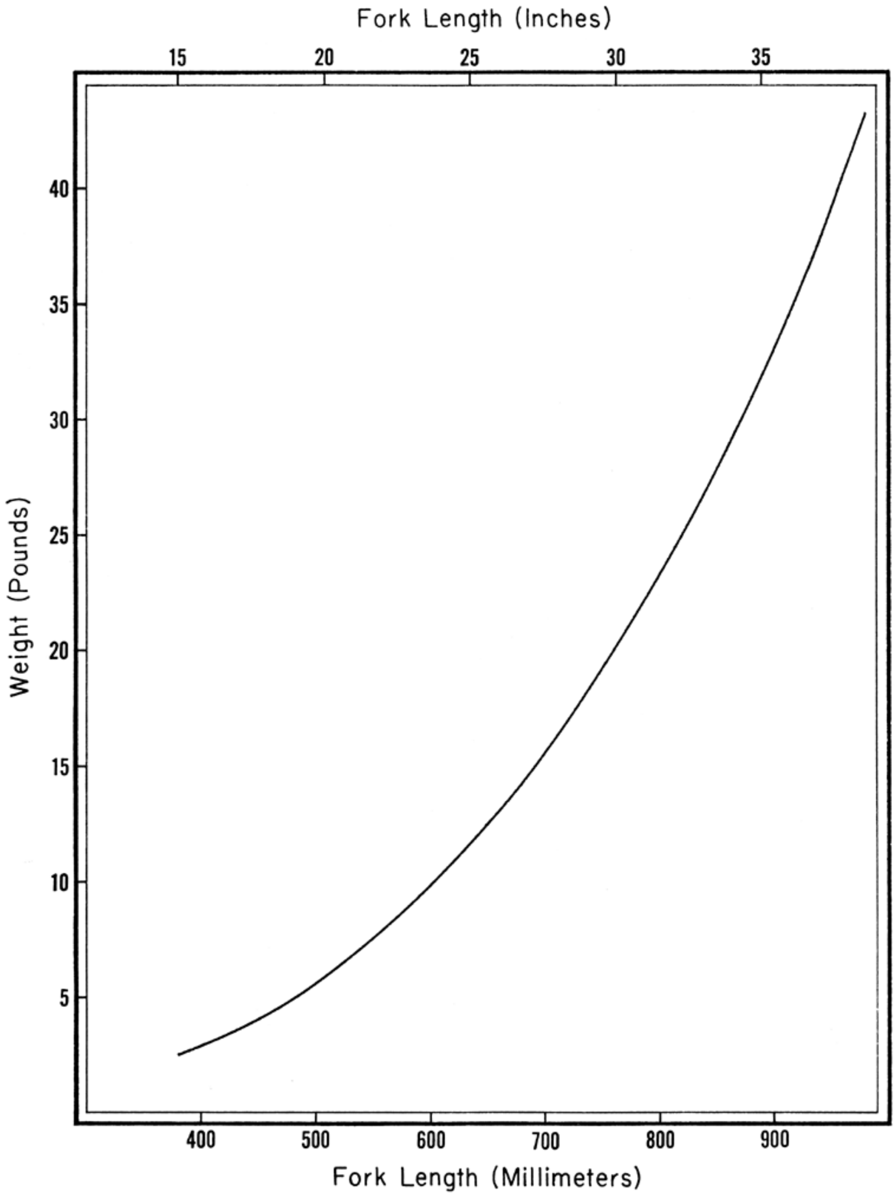

FIGURE 47. Albacore weight-length relationship based upon 1,073 fish.

FIGURE 47. Albacore weight-length relationship based upon 1,073 fish

American coast. This area has not been exhaustively explored, however, and future oceanographic changes could bring numbers of large adults into the area.

Although there seems to be a lot of year-to-year variation, most albacore spawning apparently takes place during the late winter and spring, and at considerable depths in the area of the western North Pacific water mass including the North Equatorial Current, and Equatorial Countercurrent environments (Figure 48). The temperatures in these spawning depths, however, are probably warmer than 57 degrees F.

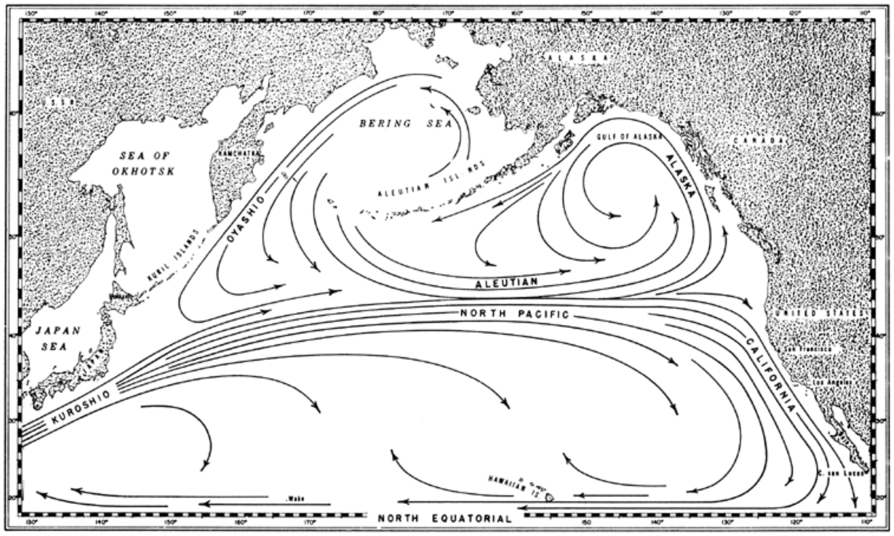

FIGURE 48. Major North Pacific current features.

FIGURE 48. Major North Pacific current features

10.2. Migrations (General)

After hatching, the youngsters apparently grow an average of four centimeters per month during their first year, and most of them gradually move up into the surface layers in an area northward of the Hawaiian Islands latitude (above the Subtropical Convergence) and south of the subarctic North Pacific water mass. Albacore never have been recorded from water colder than about 53 or 54 degrees F.; instead they prefer to live south of the cold Arctic "salmon water," which in the eastern Pacific often is characterized by relatively low salinities and temperatures of 54 degrees F. and colder.

Early in the spring following hatching, the largest and strongest individuals of this incoming albacore year-class have congregated in the north-central Pacific region and joined forces with members of several older age groups (the majority of which are immature), in preparation for an annual shoreward migration. A few of these youngsters travel toward Japan for they appear in their summer coastal fishery which peaks in June (two months earlier than ours); others travel somewhat farther, entering our West Coast fishery as one-year-olds averaging 54 to 57 cm fork length and weighing seven or eight pounds. The overwhelming majority, however, remains undiscovered in the central North Pacific region until the following season when, as two-year-olds (13-pounders), they migrate eastward and dominate our coastal fishery. Two-year-old albacore are not abundant in the Japanese summer fishery, but they annually contribute more than 60 percent to the West Coast catch. At the age of three they are quite important to the Japanese coastal (summer) live-bait and offshore (winter) longline fishery. These choice 20-pounders decline sharply in importance in the California fishery, however, contributing an average of less than 15 percent to the catch. Four-year-old albacore are caught in very small numbers in our fishery, while they rank among the most important contributors to the Japanese fisheries. Five-year-old and older albacore are in greatest abundance in the depths of the west-central North Pacific. If the two-year-old fish should fail to migrate into our fishery, it would decline suddenly and drastically without warning; also, since our fishery depends heavily upon a single year-class, poor survival of the young during one spawning season may result in a decline two years later (Clemens, 1957). An event such as this would be impossible to anticipate with information presently available. A few one-year-old albacore and a larger part of the two-, three-, and four-year-olds are harvested on both sides of the Pacific before they have had a chance to reproduce.

Catch records accumulated over a number of years by Japanese scientists show that most North Pacific albacore winter in the west-central portion of the ocean between latitudes 25 and 40 degrees north and from the Hawaiian Islands to Japan (Nankai Regional Fisheries Research Laboratory, 1954). In the spring and summer, hundreds of thousands of one- to six-year-old fish, ranging primarily from 50 to over 100 centimeters fork length, move into the American coastal fishing grounds. The migration route, of those destined for the West Coast, lies in the North Pacific Current area and varies seasonally with respect to changing sea-surface temperatures. Ocean salinity also may play an important part in albacore distribution as evidenced by a recent cruise of the *Scofield*, but at present we do not have adequate data to describe the effect of this environmental factor

The route is several hundred miles wide in May and June and apparently extends shoreward from 1,500 or more miles at sea. It has its greatest north-south extension along the American coast, becoming narrower to the west. It is delineated fairly sharply to the north where sea-surface temperatures are 57 to 58 degrees F., and less sharply on the south by the 67- or 68-degree isotherm. Within this broad, shifting band of "albacore water" the one-, two-, and three-year-old fish, which will comprise over 75 percent (by numbers) of a season's catch, are found traveling eastward well-scattered in the 57-through 65-degree F. surface layers (Figure 49). According to our exploratory fishing data, many albacore four years of age and older travel coastward about a month or so later, a little to the south of the younger ones, and presumably at somewhat greater average depths. Temperatures near the surface where these larger fish are found usually range from 66 to 68 degrees F.—seldom are they as high as 70 or 71 degrees. All albacore sizes are thought to stay in the mixed layer above the thermocline, or above the 57 degree F. water whichever happens to be shallowest.

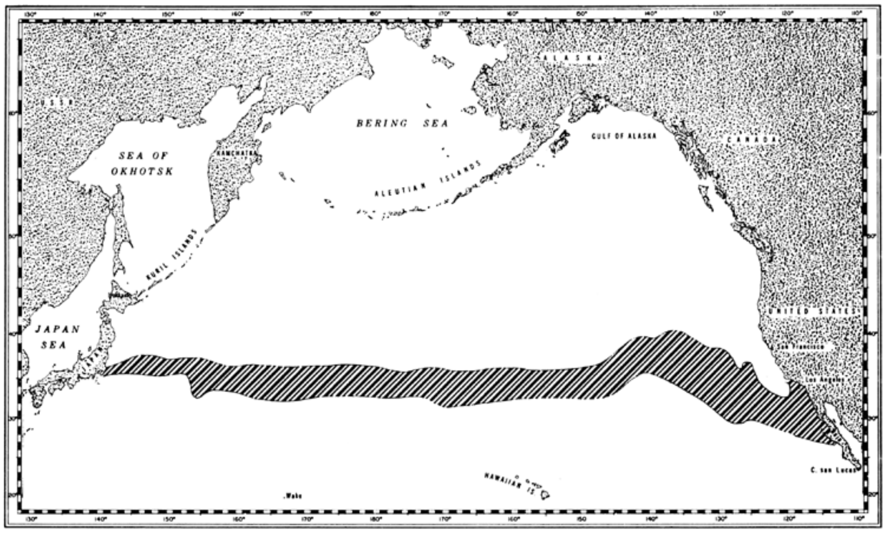

FIGURE 49. May-June band of 60 to 65 degree F. "albacore water" extending across the north Pacific Ocean (US. HO., 1948). The eastern portion of this constantly-shifting band is the route taken by coastward migrating albacore.

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By the end of July or early August their rapid migration into the West Coast fishery has diminished, and by mid-August most of the scattered incoming schools have arrived on the southern grounds. Once albacore have entered the coastal fishery area, their distribution changes and they become concentrated with respect to such environmental factors as local, highly variable, sea-temperature conditions both at the surface and in the depths, location and abundance of desirable food items, etc. In early August they begin a gradual, mass, northward advance following optimum environmental conditions.

While the coastward migration is underway, seasonal warming of the sea-surface layers causes a gradual shift of the migration path. Typically, the northern boundary not only shifts northward, but in June its eastern portion advances more rapidly, creating a bulge well offshore. Albacore, which have been migrating toward our coast along this temperature boundary, now can travel northeastward behind the advancing warm water, and Powell *et al* (1950) have demonstrated adequately that some do. If this warm water "intrusion" develops early in the season and moves on into the fishing grounds, an albacore fishery may start off Oregon or Washington in July (Figure 50). A major fishery, however, usually does not occur in this area until September when a large part of the main body of albacore traveling upcoast from Baja California and southern California has arrived. The number of fish migrating from mid-ocean directly into the Oregon and Washington fisheries would be influenced seasonally by the northward advance of warm sea-surface temperatures.

During some seasons, good September fishing is found between Baja California and the Columbia River area. Also, during late September, a gradual offshore migration begins in the northern part of the fishery. This exodus increases in magnitude during October, and by late November most of the fish have traveled upcoast and westward across

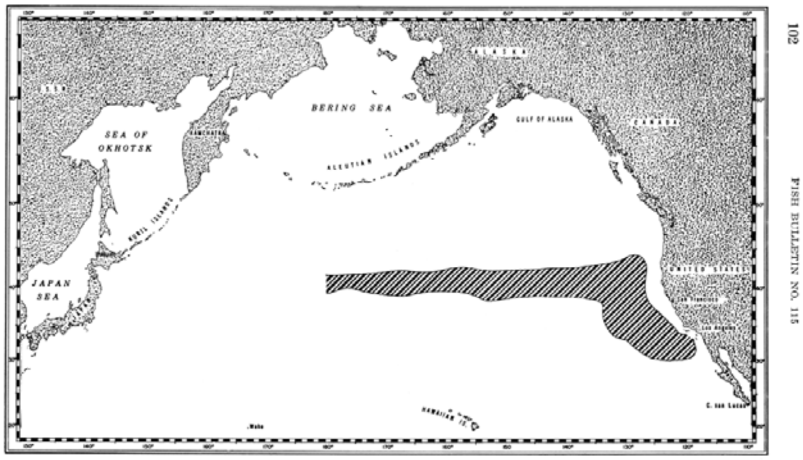

FIGURE 50. Warm-water intrusion (60-65 degree F.) that seasonally evolves in the eastern north Pacific (US. HO., 1948). When this feature develops early in the albacore season and moves inshore to the north, an early fishery usually commences off Oregon and Washington.

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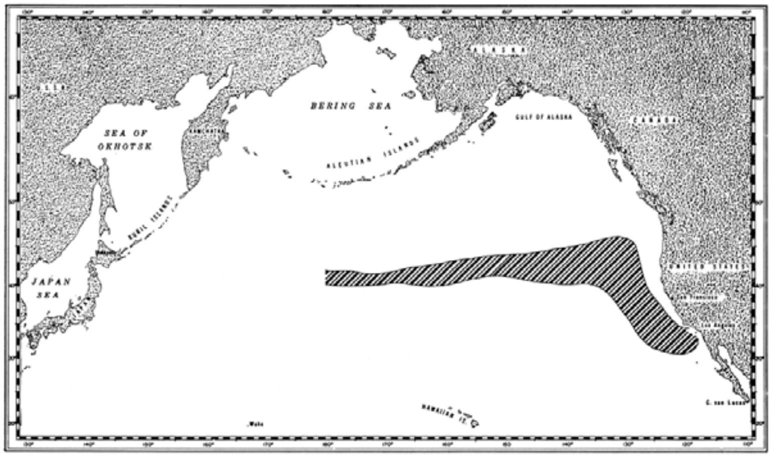

FIGURE 51. "Albacore water" (60-65 degrees F.) extending offshore during September-October (US. HO., 1948). This is the migration route used in the fall by albacore departing from the eastern north Pacific.

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the Pacific into the Japanese winter longline fishing area. The route of this westward journey also lies mainly between the 57 and 68 degree isotherms (Figure 51).

During an ocean-spanning migration, albacore are scattered over a considerable distance; large concentrations seldom are found. Experimental trolling several hundred miles offshore, within the inbound and outbound migration routes, consistently has failed to produce large catches similar to those on the fishing grounds; often fewer than 10 fish are caught per successful day's trolling (Figure 52). Longline fishing at depths, and gillnet fishing near the surface also have resulted in comparatively small catches. Thus with the fishing gear now in use, the American fishery probably cannot be improved substantially by fishing considerable distances offshore on the widely scattered fish—even with weather permitting. Present information shows that until new skills, knowledge, and equipment are developed it would be more profitable for individual captains to wait for fish to concentrate on the grounds before attempting to harvest them.

Since the annual migration is influenced by environmental conditions, which in turn are subject to large seasonal variations, in the future we can expect fluctuations in the location of the albacore eastward migration route; their point of entry into the fishing grounds, the coastal migration route northward, their point of departure from the grounds, and the position of the westward migration route. In fact, wide fluctuation should be considered normal.

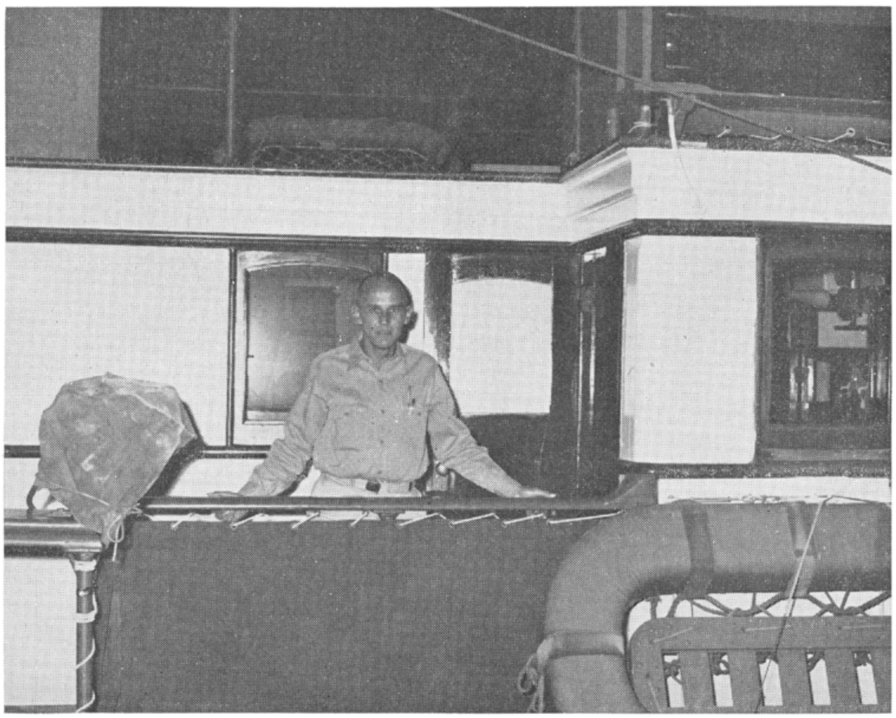

FIGURE 52. William L. Craig aboard the *N. B. Scofield* prior to departing on an albacore research cruise to gather fishing and oceanographic data. *Photograph by Robert A. Iselin.*

FIGURE 52. William L. Craig aboard the N. B. Scofield prior to departing on an albacore research cruise to gather fishing and oceanographic data. Photograph by Robert A. Iselin

10.3. Migrations (On the Fishing Grounds)

Knowledge and understanding of detailed albacore-environment relationships, schooling behavior, and general migratory patterns on the fishing grounds have immediate practical importance because, if properly utilized, a more efficient harvest can result (Figure 53).

By mid-August most albacore school groups destined for the California fishery have arrived on the southern grounds. They are not uniformly distributed; instead, large and small seasonally shifting cumulations (school groups) of different fish sizes are found. It is these school-group concentrations that provide fishermen with worthwhile catches, and an understanding of the mechanisms that regulate their longevity and cause such aggregations to build up and disappear is of prime importance.

10.3.1. Surface Temperature

During the early part of the 1951 through 1957 seasons, most albacore were north of Cape San Lazaro, Baja California and south of Point Conception within a broad general area bordered by 59 degree F. water to the north, 69 degree water on the south, and offshore from the very cold upwelled water along the coast. Usually by the season's peak the fishing ground has changed: the southern border sometimes encompasses 70 to 71 degrees F. water on the south and southeast, and the northern border extends farther to the north. The size and position of this broad fishing region fluctuates tremendously, and these variations

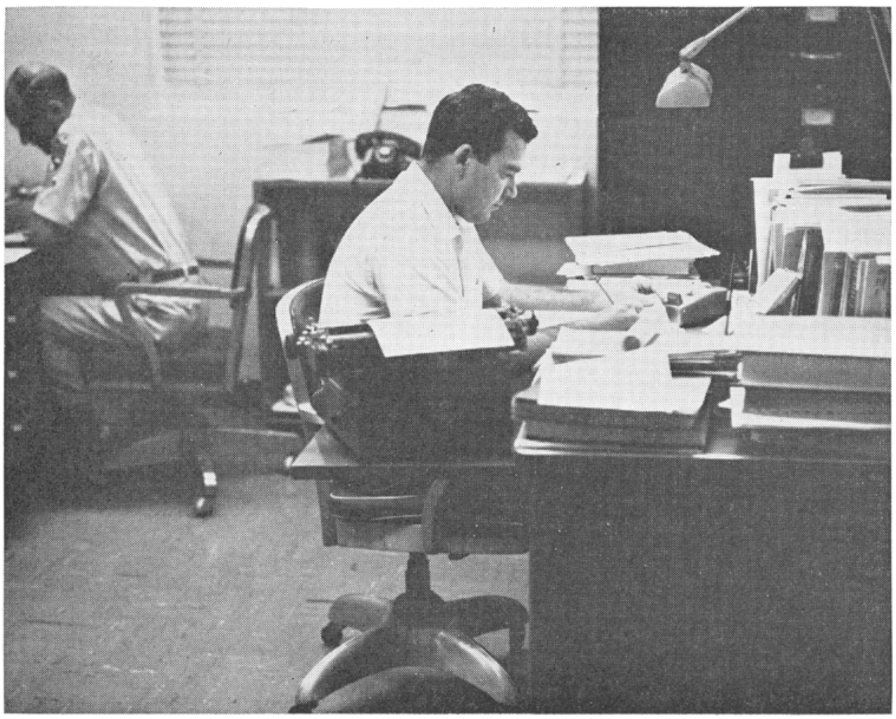

FIGURE 53. Harold B. Clemens at the California State Fisheries Laboratory, Terminal Island, analyzing data concerning tuna biology, oceanography, and the activities of the fishing fleet. *Photograph by Robert A. Iselin.*

FIGURE 53. Harold B. Clemens at the California State Fisheries Laboratory, Terminal Island, analyzing data concerning tuna biology, oceanography, and the activities of the fishing fleet. Photograph by Robert A. Iselin.

tend to regulate the locale of albacore concentrations primarily by increasing and limiting, or both, their northern and southern extensions.

California's research vessel *N. B. Scofield* sailed June 3, 1957, on a pre-season cruise designed to locate and chart the albacore coastward migration route, and to study albacore-environment relationships (Mais, 1957; Clemens, 1958). Based on past experience, an area southwest of Guadalupe Island, between latitudes 27 and 29 degrees north and longitudes 119 and 121 degrees west, was chosen as the survey area. Unusually warm sea-surface temperatures, in excess of 67 degrees F., were encountered immediately south of the island and caused us to shift the survey area north where the season's first albacore were caught on the trolling lines, and the migration route discovered in 62.6 to 64.8 degree water. Several commercial vessels scouting with trolling gear, in the area between Guadalupe Island and the mainland, also found unseasonally warm sea temperatures and failed to catch fish until they had turned back into cooler water some 60 miles north. Subsequently albacore were found in heavy commercial quantities north of the island, while only a few tons were taken during the season in the warm water to the south. By the end of August, this area had become too warm even for the larger albacore, and thus bait fishing south of the island also failed. During the winter, when the sea temperatures had cooled, a small fishery developed south of Guadalupe Island and produced almost 20,000 pounds of albacore during December and January. Thus a heavy-producing fishery, encompassing thousands of square miles and seasonally providing several million pounds of albacore, first disappeared and then partially reappeared in conjunction with warming and cooling sea temperatures, although the run virtually had ended during the winter reappearance.

This general warming that began in 1957 continued, and in 1958 surface temperatures on the familiar southern albacore fishing grounds ranged between 2 and 4 degrees F. warmer than was typical for the previous 10 or more years. In 1959, sea temperatures again were warm (Radovich, 1960, 1961). This temperature increase had a profound effect on the albacore fishery. The usually heavy-producing Baja California fishing grounds (south of about 32 degrees N. latitude), that yielded an annual average of about 20 million pounds of albacore during the seven years 1951 through 1957, failed during these warm-water years and fishermen had to fish more northern areas—areas frequently subjected to violent storms.

When the seasonal south-north warming of the coastal sea surface is slow compared to the albacore northward migration rate, the boundary between the northern cold water and the warmer southern water acts as a barrier, and the albacore tend to slow down and concentrate behind it. During August 1957, the sea-temperature anomaly dropped from warm to almost normal (Figure 54); at the same time the albacore schools abruptly ceased their unusually rapid northward migration. Most of the schools remained within 150 miles of the coast between Point Conception and San Francisco during September and part of October, and then gradually continued their upcoast journey as the temperature anomaly rose again from October through December. Fishermen enjoyed excellent fishing on the heavily concentrated schools and took roughly 20 million pounds—double their usual catch. As a result, the 1957 season, which by the end of August had looked as if it would be only a fair to poor one, turned out to be the best since 1952 and the fourth largest on record (Clemens, 1958).

Additional information concerning albacore behavior with respect to sea temperatures also has been obtained from fishermen's logbooks. These data reveal that albacore avoid coastal areas where upwelling has introduced cold, green, rich waters into the surface layers, but good catches are made where fish have concentrated along the warmer edges of these upwelling areas (Godsil, 1949). Good albacore catches are made all along the margin of the large upwelling area extending offshore from Point Conception to the Columbia River; almost no albacore are taken in the cold upwelled water, and only fair to poor catches are made farther offshore. In addition, for many years we have received reports that albacore frequently abound offshore along the edges of cold tongues or fingers of water and along the margins of currents and eddies. Also, we have found that albacore often avoid the usually warm, nearshore surface layers around the Channel Islands off southern California. These "sportfishing grounds" lie eastward of the relatively cool southeasterly-flowing California current, and are partly protected from northwest winds. The circulation on these fishing grounds is typically sluggish, and in the summer the water becomes warm by comparison with offshore temperatures.

Albacore tend to avoid an area where the surface temperatures become warmer than about 69 degrees F.; however, a few may still be taken there in deep cooler water. During the 1955 sportfishing season, fishermen

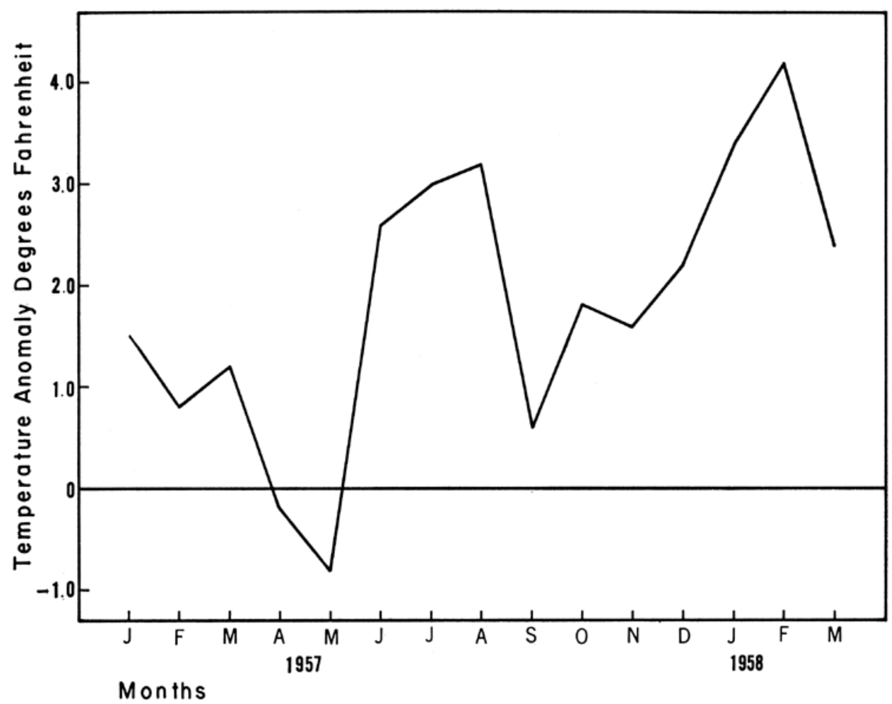

FIGURE 54. Los Angeles Harbor sea-temperature anomalies January 1957-March 1958 (data from Stewart, 1960).

FIGURE 54. Los Angeles Harbor sea-temperature anomalies January 1957-March 1958 (data from Stewart, 1960)

operating in relatively warm water between Santa Catalina and Santa Barbara Islands found poor surface fishing, but had fair success in the cooler water 100 to 300 feet down.

Further evidence demonstrating an albacore-temperature relationship in the California fishery was obtained during the winter of 1957. Detailed log records from a dozen vessels revealed fair December fishing in the 60 to 63 degree F. water surrounding Guadalupe Island. In January the area extending from northwest to southeast of the island cooled to between 58 and 59 degrees F., and successful fishing was confined to the westward side where the temperatures were warmer. By the end of January only small bands of warm water remained, but these were still producing fish although the cold water surrounding them had failed.

Finally, fishermen frequently report finding large (some over 60 miles in diameter), irregular, 60 to 65 degree F. "pools" of water well-offshore in areas of either warmer or cooler water. The albacore in these pools seem to have been cut off from the main migration and linger in the area, hesitating to enter the surrounding water. Eventually these pools become smaller and the albacore more concentrated and fishermen sometimes find they are very productive.

10.3.2. Subsurface Temperatures

At present there is little information concerning albacore-subsurface temperature relationships in the California fishery. Our oceanographic and exploratory fishing data indicate that most fish are confined to the oceanic realm above the 57-degree F. subsurface zone. Thus the albacore habitat lies within the oxygen-rich, lighted, mixed layer of the ocean where organic production is high. Beneath the mixed layer, at the thermocline, the water becomes quite cold. off California the thermocline varies seasonally in thickness and depth. When it is shallow the temperature at its top may be warmer than our so-called albacore-limiting 57-degree water. In general the thermocline is shallowest in the spring and summer and deepest in the winter. Beneath it the water is relatively low in oxygen and in many cases too cold for albacore to endure voluntarily for any length of time. Mais and Jow (1960) reported that tropical tunas in the eastern Pacific avoid subsurface water that is cold and low in oxygen. Rivas (1953) reported that albacore have a well-developed "pineal apparatus" that may be a light receptor partially controlling vertical movements.

The 57-degree F. subsurface area apparently acts like a "floor" in the albacore's living space. The floor is uneven and variable and its depth is subject to natural fluctuations. This causes large seasonal changes in the amount of vertical living space—a fact of considerable importance to the distribution of albacore on the fishing grounds.

Japanese workers at the Nankai Fisheries Research Laboratory have reported good albacore catches in the winter longline fishery at depths of 475 to 490 feet. During March 1950, the Sagami Maru found that the sea temperatures in these depths ranged between 59 and 64 degrees F., while the surface temperatures were 63 to 68 degrees F. During March 1953, the Nisso Maru made good catches at 475 feet where the temperatures were between 63 and 70 degrees F., while at the surface it was 63 to 77 degrees F.

By contrast, on fishing grounds off northern Baja California and southern California, during the height of a season's fishing, the albacore floor has been reported less than 328 feet (100 meters) deep. Where it approaches the surface deep-swimming fish may be guided upward—thus increasing their availability to the fishermen. Near Monterey, 57-degree F. water frequently lies at the surface, leaving the albacore without living space. Thus their coastal migration halts, or they move farther offshore before continuing their northward journey. Outside of the coastal fishing grounds, 57-degree F. water is at considerably greater depths (Figure 55) (Reid, *et al.*, 1958).

10.3.3. Albacore Size

Small one-, two-, and three-year-old albacore (the backbone of the California fishery) travel primarily in the shallow layers. These youngsters rapidly advance northward behind the 57-degree F. isotherm, and at the season's peak sometimes are scattered along a south-north area exceeding 1,000 miles in length. Large fish three or four years of age and older inhabit the surface and the deeper layers of suitable environment.

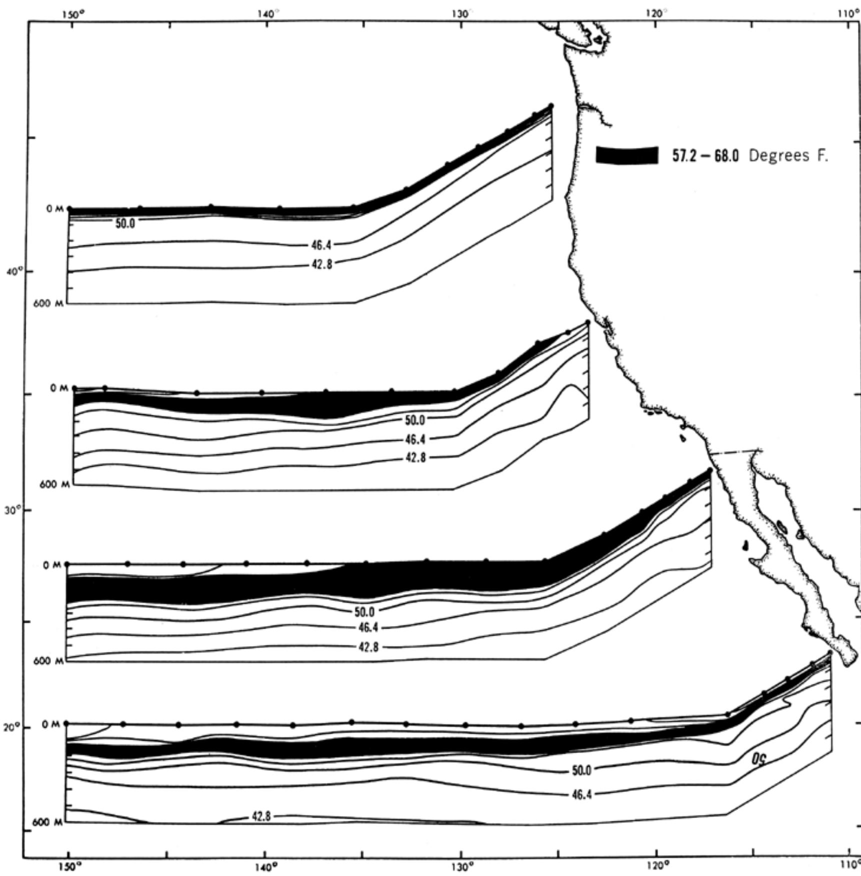

FIGURE 55. Vertical profiles of ocean temperature from the surface to 600 meters, August 1955 (data from Reid, *et al,* 1958).

FIGURE 55. Vertical profiles of ocean temperature from the surface to 600 meters, August 1955 (data from Reid, et al, 1958)

Experimental fishing, conducted off Southern California and northern Baja California during the 1955 season's peak, resulted in catches of small fish on surface trolling gear and larger ones on deep-fishing longline gear (Pinkas, 1955; Clemens, 1955). Commercial and sport boats sometimes find good bait fishing south of Point Conception, where large albacore periodically enter the surface layers and feed voraciously (Figure 56). Jig boats, by comparison, land few large fish. Albacore weighing 45 pounds and more, rarely enter the American fishery.

10.3.4. Food Habits

The discovery of the albacore's far-ranging migratory habits has led to considerable speculation as to why they undertake such long journeys from the central Pacific. The consensus of opinion is that they are performing a seasonal feeding migration into the rich, productive coastal areas.

FIGURE 56. Happy sportfisherman landing a highly-prized Pacific albacore off Southern California. Note the long extended pectoral fins; the reason they are called "dragonfly" tuna in the Orient. *Photograph courtesy of Pierpoint Landing.*

FIGURE 56. Happy sportfisherman landing a highly-prized Pacific albacore off Southern California. Note the long extended pectoral fins; the reason they are called "dragonfly" tuna in the Orient. Photograph courtesy of Pierpoint Landing.

After albacore have arrived on the fishing grounds, fluctuations in location, quantity, and availability of desirable food items play an important role in regulating both horizontal and vertical albacore movements (Clemens, 1957). For example their migratory rate is slower and they tend to linger and become concentrated near the surface in a few regions that vary considerably in size both within and between seasons. South of Eureka, California, these are:

(1) the Guadalupe Island area;

(2) the coastal area between central Baja California and San Clemente Island;

(3) the Point Conception area;

(4) the coastal area between Morro Bay and San Francisco.

These four regions are important surface-feeding grounds, and albacore taken in them usually are gorged with local food items. Stomachs from albacore caught outside these areas typically are empty.

Fishermen operating in these surface-feeding areas are never assured of profitable catches, however, unless they take advantage of the rhythm or periodicity of albacore feeding. Commonly there are alternating periods of good and poor fishing throughout most of the grounds, and although highly variable, each period usually lasts about 10 days. Some fishing vessels have arrived on the grounds at the end of a good run. After experiencing about 10 days of poor fishing they have returned to port for supplies and thus missed the start of another good fishing period. The more successful fishermen were those who were on the grounds during the good fishing days and in port for repairs, supplies, etc., through slack periods. During intervals of poor fishing, there are times when albacore are plentiful in the surface layers, but pay little or no attention to the offered lures. At other times they either have left the surface layers to feed on deep-living organisms or have departed from the area.

Early-season catches south of Point Conception generally are made throughout the day. To the north and later in the season there is a daily rhythm to fishing and best catches usually are made in the morning or late afternoon or both. When this occurs, the vessel captains who return to port each evening are en route to and from the fishing grounds while fishing is best.

Albacore are fast-traveling, opportunistic feeders, with high metabolic rates and they need quantities of food. Thus they continually adjust their swimming depth and speed to take advantage of local food conditions within the lighted layers of the sea. In the southern fishing grounds they feed primarily on pelagic, surface-living organisms and on diurnal migrants from the depths (organisms from the scattering layer). To the north, however, they seem to eat fewer surface organisms.

11. SUMMARY

1. The Pacific albacore is a migratory species preferring a deep, oxygen-rich, oceanic realm throughout much of the temperate south and north Pacific Oceans. Typically they remain offshore from cold, dirty coastal areas and there are major fisheries for them in the western, west-central and eastern North Pacific.

2. In the eastern Pacific, albacore have been recorded from the Revilla Gigedo Islands off Mexico and north into the Gulf of Alaska; however, the richest fishing grounds lie between central Baja California and the Columbia River.

3. The California fishery, which was the first on the Pacific coast, usually begins in June; develops rapidly in July; peaks in August; gradually declines during September, October, and November and ends by December or January—some years a few albacore are caught almost every month.

4. During 1950 through 1959, commercial fishermen landed 191,000 tons and sport fishermen 4,000 tons of albacore in California. These were valued at about 71.5 million dollars.

5. In 1951, the California Department of Fish and Game launched a continuing scientific program, designed to improve the albacore fishery through biological research.

6. The first successful tuna tag was developed by Department scientists at the California State Fisheries Laboratory, Terminal Island, in January 1952. It was made from polyvinylchloride plastic tubing that resembles spaghetti and became known as the California spaghetti tag.

7. During the six seasons, 1952 through 1957, 4,585 albacore were tagged and liberated between central Baja California and San Francisco on 15 cruises aboard 9 vessels : 5 commercial, 3 research and 1 sport.

8. Instructions printed on each tag with special ink, a port-contact man at California ports, posters written in Spanish, Japanese and English, commendation cards, and a nominal monetary reward, have all aided in our tag-recovery program.

9. Seventy-three tagged albacore, representing 1.6 percent of the total releases, were recovered in the eastern Pacific, mid-Pacific and western Pacific.

10. Eighteen albacore (25 percent of the recoveries) were captured in our fishery the season following tagging, and over four percent during a third season. Those tagged one season and recaptured the next, within a month of the comparable release date, were close to the release location, indicating that during the period 1952 through 1956 albacore migrations occurred with good precision.

11. About 88 percent of the tagged fish, for which minimum distance traveled could be computed, were recovered within five months and had traveled less than 700 miles. Ninety-five percent of the albacore recovered during the tagging season were north of the release point.

12. The minimum northward migration rate was six nautical miles per day (24 hours); those traveling within 90 to 100 miles of the coast averaged at least four nautical miles daily, while offshore migrants swam at a 15-mile-per-day rate.

13. A tagged albacore released August 4, 1952, between Santa Catalina Island and Long Beach, California,

migration record. Subsequently six tags have been recovered off Japan and two in the central Pacific.

14. Albacore enroute from our fishery to the central Pacific area averaged 17 nautical miles per day (fastest 18) and those swimming to Japan, 16 (fastest 23) miles daily. These fish can travel over 500 miles per month with ease.

15. Albacore migrations were determined from tag returns, by exploratory fishing, by analyzing fishing fleet activities, and by plotting monthly catch-locality data for certain albacore size groups.

16. Their coastward (entering) migration route varies considerably from year to year, and while on the fishing grounds they travel varying courses and at different rates upcoast as the season progresses.

17. Although no albacore tagged off Baja California or California have been recovered off Oregon or Washington, it is the albacore that move northward from Baja California and southern California that periodically play a major role in the northern fisheries.

18. Most albacore have migrated out of the eastern Pacific by the end of December. Sea-surface temperatures, location and abundance of desirable food items, and albacore size and sexual maturity are the most important factors regulating their movements and distribution.

19. There is a definite albacore catch-temperature relationship. Almost 90 percent of 1.3 million fish sampled were caught where surface temperatures were 60 to 67 degrees F.; catch-effort estimates show that they were most abundant in these temperatures. Also, there is an albacore size-temperature relationship; fish weighing less than 20 pounds were harvested in 65 degree F. and cooler water by trolling vessels, while larger fish predominated in warmer water and were taken primarily by live-bait boats.

20. A similar catch-temperature relationship exists in the western Pacific. The Japanese live-bait fishery harvests large fish in the warm coastal water; they do not have a coastal troll fishery such as ours, that takes smaller fish in cool water.

21. Based upon the albacore temperature relationship, we discovered their coastward migration route from the central Pacific. Also we accurately predicted large seasonal changes in the migration route.

22. The commerical albacore fishery failed from 1928 through 1934 because of major shifts in the coastal migration routes. The seasonal "runs" occurred outside the range of the fishing fleets, which made short trips primarily in the southern California Channel-Island area.

23. The albacore stocks in the major north Pacific fishing areas are closely related and perhaps are a single population.

24. Albacore schools travel northward along the American coast in the spring and fall and into the west-central Pacific during the fall and winter. In this area they move southward as the season progresses; some probably remain in the west-central Pacific but others migrate on to Japan. Within these three major areas, any

journeys is likely to occur : half way, all the way, or round trip—some albacore may even remain put.

25. At times a few albacore will overwinter near Guadalupe Island. These fish probably arrive late in the season and have their northward migration halted by undesirable oceanographic conditions. In the following late spring or early summer they start to move upcoast ahead of the main migration and create a "false run".

26. Recaptured fish ranged from 55 to 91 cm at time of tagging and were at liberty from 6 to 761 days. When change-in-length was plotted against days-at-liberty for each fish, a linear trend $Y = -11.83 + 0.309 X$; was obtained.

27. Data from 21 tagged albacore (545 to 770 mm long), that had been at liberty from 9 to 15 months, were used to calculate an annual growth curve. Based upon the growth equation $Y = 210.31 + 0.845 X$, the average maximum size attained by albacore was calculated as 135.6 cm—7.6 centimeters longer than the largest actually measured.

28. Our growth data show that albacore averaging 52 cm fork length in June would grow to 65 cm in one year; 65 cm fish would grow to 76 cm, 76 cm fish to 85, 85 cm fish to 93, and 93 cm fish would measure 100 cm a year later.

29. The natural albacore size groups in the California fishery are year-classes.

30. Running-ripe albacore never have been recorded in the eastern North Pacific, but five- and six-year-old fish in the 93 and 100 cm size groups (37 and 46 pounds) had recently spawned.

31. Albacore apparently spawn within the period January through June in the vicinity of the Subtropical Convergence and south over an area extending from the longitude of Japan to the Hawaiian Islands. There is a possibility that some of the overwintering adults, in the eastern Pacific, spawn south of Guadalupe Island in the spring or summer.

32. If spawning and hatching peaks in April and the first winter ring is formed in February, the smallest size group (52 cm) fish would be 14 months old in June and have one winter ring on their scales or body hard parts; the second size group (65 cm) would consist of two-year-old fish, the third group (76 cm) would be three years old etc.

33. A weight-length relationship was determined from fish landed in 1952, 1955, and 1960. There were no differences between sexes, so the data were combined and the relationship calculated : $W = 4.936 \times 10^{-8} L^{2.99}$.

34. Our growth calculations fitted to von Bertalanffy's growth equation become : $l_t = 1356 [1 - e^{-0.17 (t + 1.87)}]$.

35. After hatching, the youngsters grow at a rate of four centimeters per month during their first year and probably move into the central Pacific surface layers north of the Subtropical Convergence.

36. The once-productive Baja California fishing grounds failed during the three seasons 1958 through 1960, in conjunction with ocean temperatures which were several degrees warmer than typical for the past 10 or more years.

37. Most of the albacore in the California fishery are confined to the oceanic realm above the 57 degree F. subsurface zone. This area is oxygen-rich, lighted, and high in organic production. During the height of a season, the albacore "floor" may be between 160 and 325 feet deep.

38. Near Monterey, 57-degree water frequently lies at the surface at season's peak, leaving the albacore without living space. Thus the northward migrating fish are stopped or they move seaward. offshore from the fishing grounds the 57 degree F. layer is considerably deeper, and the Japanese longline fishery commonly catches fish at 490 feet or more.

39. Small one-, two-, and three-year-old albacore (the backbone of the California fishery) travel primarily in the shallow layers. These youngsters rapidly advance northward up our coast behind the 57 degree F. isotherm, and sometimes at the season's peak they are scattered for 1,000 miles or more along a south-north area. Large fish three or four years old and older inhabit the surface and the deeper layers of suitable environment—albacore weighing over 45 pounds rarely enter our fishery.

40. Albacore travel coastward from the central Pacific on a feeding migration. After they arrive on the grounds, fluctuations in location, quantity, and availability of food play a significant role in regulating their horizontal and vertical movements.

41. There is a rhythm or periodicity in albacore feeding behavior; it frequently lasts for about 10 days and plays an important part in fishing success. Early-season catches south of Point Conception generally are made

throughout the day. Later in the season and to the north there is a daily rhythm to fishing, and best catches usually are made in the morning or late afternoon or both.

42. Albacore in the southern fishing grounds feed primarily on pelagic. surface-living organisms and on diurnal migrants from the depths. To the north, however, they seem to eat fewer surface organisms.

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APPENDIX A

Number of Albacore Tagged by One Degree Square by Month 1952 Through 1957. Subsequent Recoveries are Indicated in Parenthesis Opposite the Lot With Which Tagged.

One-Degree Square		June	July					August						
Latitude	Longitude	'57	'52	'55	'56	'57	Total July	'52	'53	'54	'55	'56	'57	Total August
27	119	--	--	--	--	--	--	--	28	--	--	--	--	28
	120	--	--	--	--	--	--	--	424(10)	--	--	--	--	424(10)
	121	--	--	--	--	--	--	--	22(1)	--	--	--	--	22(1)
28	116	--	--	--	--	--	--	--	--	86	--	--	--	86
	118	--	--	--	--	--	--	--	5	--	--	--	--	5
	119	--	--	--	--	--	--	--	--	--	5	--	--	5
	120	--	--	--	--	--	--	--	228(3)	--	--	--	--	228(3)
	121	--	--	--	--	--	--	--	22	--	--	--	--	22
29	115	--	--	--	10	--	10	--	--	--	--	--	--	--
	116	--	--	--	108(6)	--	108(6)	--	--	--	--	--	--	--
	117	--	--	--	--	--	--	--	--	18	3	--	--	21
	119	2(1)	--	--	--	--	--	--	--	--	--	--	--	--
	120	--	--	--	--	--	--	--	1	4	5	--	--	10
	121	--	--	--	--	--	--	--	--	--	1	--	--	1
30	116	25(1)	--	--	31	252(7)	283(7)	--	--	--	11(2)	--	--	11(2)
	117	48(1)	--	--	21(1)	21	42(1)	--	--	--	--	--	--	--
	118	1	--	1	--	--	1	--	--	--	5	--	--	5
	119	--	--	--	--	--	--	--	--	35	--	--	--	35
	120	--	--	--	--	--	--	--	--	--	2	--	--	2
31	116	--	--	--	103(5)	4	107(5)	--	--	--	--	--	--	--
	117	14	--	22(6)	117(4)	98(2)	237(12)	--	3	--	17	--	--	20
	118	9	--	--	12	119(2)	131(2)	--	5	--	19	--	1	25
	119	--	--	--	--	--	--	--	8	--	--	--	--	8
	120	--	--	--	--	--	--	--	--	320(1)	--	--	--	320(1)
	122	--	--	--	--	--	--	--	--	--	30(1)	--	--	30(1)
32	117	--	3	4	2	1	10	--	2	--	22(1)	--	--	24(1)
	118	--	--	14	5	26(2)	45(2)	--	2	--	7(1)	--	--	9(1)
	119	--	--	--	--	--	--	--	--	87	--	6	--	93
	120	--	--	--	--	10(1)	10(1)	--	--	30	--	--	--	30
	122	--	--	--	--	--	--	--	--	--	5	--	--	5
33	118	--	--	--	6(1)	--	6(1)	214(3)	--	--	--	45	--	259(3)
	119	--	--	--	--	--	--	1	--	1	--	115(1)	--	117(1)
	120	--	--	--	--	--	--	--	--	12	--	--	--	12
	121	--	--	--	--	--	--	--	--	4	7	--	--	11
	122	--	--	--	--	--	--	--	--	--	--	--	1	1
	123	--	--	--	--	--	--	--	--	--	4	--	--	4
34	121	--	--	--	--	--	--	--	--	--	--	--	--	--
	122	--	--	--	--	--	--	--	--	--	--	--	--	--
	123	--	--	--	--	--	--	--	--	--	--	--	--	--
35	121	--	--	--	--	--	--	--	--	--	--	--	--	--
	122	--	--	--	--	--	--	--	--	--	--	--	--	--
	123	--	--	--	--	--	--	--	--	--	--	--	--	--
36	122	--	--	--	--	--	--	--	--	--	--	--	--	--
	123	--	--	--	--	--	--	--	--	--	--	--	--	--
	124	--	--	--	--	--	--	--	--	--	--	--	--	--
	125	--	--	--	--	--	--	--	--	--	--	--	--	--
37	123	--	--	--	--	--	--	--	--	--	--	--	--	--
	125	--	--	--	--	--	--	--	--	--	--	--	--	--
Total	--	99(3)	3(0)	41(6)	415(17)	531(14)	990(37)	215(3)	750(14)	597(1)	143(5)	166(1)	2	1873(24)

APPENDIX A
Number of Albacore Tagged by One Degree Square by Month 1952 Through 1957. Subsequent Recoveries are Indicated in Parenthesis Opposite the Lot With Which Tagged

APPENDIX A—Continued

Number of Albacore Tagged by One Degree Square by Month 1952 Through 1957. Subsequent Recoveries are Indicated in Parenthesis Opposite the Lot With Which Tagged.

One-Degree Square		September						October					Annual Totals						
Latitude	Longitude	'52	'54	'55	'56	'57	Total September	'53	'54	'55	'57	Total October	Total '52	Total '53	Total '54	Total '55	Total '56	Total '57	Total 1952-1957
27	119	-	--	-	--	-	--	--	-	--	-	--	--	28	--	--	--	--	28
	120	-	--	-	--	-	--	--	-	--	-	--	--	424(10)	--	--	--	--	424(10)
	121	-	--	-	--	-	--	--	-	--	-	--	--	22(1)	--	--	--	--	22(1)
28	116	-	--	-	--	-	--	--	-	--	-	--	--	--	86	--	--	--	86
	118	-	--	-	--	-	--	--	-	--	-	--	--	5	--	--	--	--	5
	119	-	--	-	--	-	--	--	1	--	-	1	--	--	1	5	--	--	6
	120	-	--	-	--	-	--	--	-	--	-	--	--	228(3)	--	--	--	--	228(3)
	121	-	--	-	--	-	--	--	-	--	-	--	--	22	--	--	--	--	22
29	115	-	--	-	--	-	--	--	-	--	-	--	--	--	--	--	10	--	10
	116	-	--	-	--	-	--	--	-	--	-	--	--	--	--	--	108(6)	--	108(6)
	117	-	--	-	--	-	--	--	-	--	-	--	--	--	18	3	--	--	21
	119	-	--	-	--	-	--	--	-	--	-	--	--	--	--	--	--	2(1)	2(1)
	120	-	--	-	--	-	--	--	-	--	-	--	--	1	4	5	--	--	10
	121	-	--	-	--	-	--	--	-	--	-	--	--	--	--	1	--	--	1
30	116	-	--	-	--	-	--	--	-	--	-	--	--	--	--	11(2)	31	277(8)	319(10)
	117	-	--	-	--	-	--	--	-	--	-	--	--	--	--	--	21(1)	69(1)	90(2)
	118	-	--	-	--	-	--	--	-	--	-	--	--	--	--	6	--	1	7
	119	-	192	-	--	-	192	--	-	--	-	--	--	--	227	--	--	--	227
	120	-	--	-	--	-	--	--	-	--	-	--	--	--	--	2	--	--	2
31	116	-	--	-	--	-	--	--	-	--	-	--	--	--	--	--	103(5)	4	107(5)
	117	-	--	-	--	-	--	--	-	--	-	--	--	3	--	39(6)	117(4)	112(2)	271(12)
	118	-	--	-	--	-	--	--	-	--	-	--	--	5	--	19	12	129(2)	165(2)
	119	-	--	-	--	-	--	--	-	--	-	--	--	8	--	--	--	--	8
	120	-	--	-	--	-	--	--	-	--	-	--	--	--	320(1)	--	--	--	320(1)
	122	-	--	-	--	-	--	--	-	--	-	--	--	--	--	30(1)	--	--	30(1)
32	117	-	--	-	--	-	--	--	-	--	-	--	3	2	--	26(1)	2	1	34(1)
	118	-	--	-	--	-	--	--	-	--	-	--	--	2	--	21(1)	5	26(2)	54(3)
	119	-	--	-	--	-	--	--	-	--	-	--	--	--	87	--	6	--	93
	120	-	50	-	--	-	50	--	-	--	-	--	--	--	80	--	--	10(1)	90(1)
	122	-	--	16	--	-	16	--	-	--	-	--	--	--	--	21	--	--	21
33	118	2	--	-	--	-	2	--	-	--	-	--	216(3)	--	--	--	51(1)	--	267(4)
	119	-	--	-	--	-	--	--	-	--	-	--	1	--	1	--	115(1)	--	117(1)
	120	-	24	-	--	-	24	--	-	--	-	--	--	--	36	--	--	--	36
	121	-	357(2)	-	--	-	357(2)	--	-	--	-	--	--	--	361(2)	7	--	--	368(2)
	122	-	73	10	--	-	83	--	-	--	-	--	--	--	73	10	--	1	84
	123	-	--	20	--	-	20	--	-	--	-	--	--	--	--	24	--	--	24
34	121	-	71	-	--	5	76	--	-	--	-	--	--	--	71	--	--	5	76
	122	-	62	-	--	11	73	--	-	--	-	--	--	--	62	--	--	11	73
	123	-	9	-	--	-	9	--	-	--	-	--	--	--	9	--	--	--	9
35	121	-	--	-	32	-	32	--	-	--	-	--	--	--	--	--	32	--	32
	122	-	15	-	--	8	23	50	-	--	2	52	--	50	15	--	--	10	75
	123	-	1	-	--	4	5	--	-	--	-	--	--	--	1	--	--	4	5
36	122	-	--	-	12	8	20	1	-	--	-	1	--	1	--	--	12	8	21
	123	-	--	-	126(5)	3	129(5)	--	-	--	-	--	--	--	--	--	126(5)	3	129(5)
	124	-	4	-	--	-	4	--	-	53(1)	-	53(1)	--	--	4	53(1)	--	--	57(1)
	125	-	--	13	--	-	13	--	-	22	-	22	--	--	--	35	--	--	35
37	123	-	--	-	23	-	23	311	-	--	-	311	--	311	--	--	23	--	334
	125	-	--	19	--	-	19	--	-	13(1)	-	13(1)	--	--	--	32(1)	--	--	32(1)
Total	----	2	858(2)	78	193(5)	39	1170(7)	362	1	88(2)	2	453(2)	220(3)	1112(14)	1456(3)	350(13)	774(23)	673(17)	4585(73)

APPENDIX A

Number of Albacore Tagged by One Degree Square by Month 1952 Through 1957. Subsequent Recoveries are Indicated in Parenthesis Opposite the Lot With Which Tagged

APPENDIX B

Lengths of 4,538 Albacore Tagged in the Eastern North Pacific 1952 Through 1957. Subsequent Recoveries are Indicated in Parenthesis Opposite the Length at Time of Tagging.

Length (Centimeters)	June '57	July '52	July '55	July '56	July '57	August '52	August '53	August '54	August '55	August '56	August '57	September '52	September '54	September '55	September '56	September '57	October '53	October '54	October '55	October '57	Total '52	Total '53	Total '54	Total '55	Total '56	Total '57	Total '52-'57
50	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	1	--	--	--	1
51	--	--	--	0	--	0	--	--	0	--	--	--	4	0	--	--	--	--	--	--	0	--	4	0	0	--	4
52	--	--	--	1	--	2	--	0	1	--	--	--	22	1	--	0	0	--	0	--	2	0	22	2	1	0	27
53	--	--	--	0	--	0	--	1	1	--	0	--	52	7	--	1	1	--	7	--	0	1	53	15	0	1	70
54	--	--	--	0	--	0	--	6	4	--	1	--	39	10	0	3	3	--	6	--	0	3	45	20	0	4	72
55	--	0	--	2	--	0	0	10	8(1)	--	0	--	20	9	1	9	4	--	8	0	0	4	30	25(1)	3	9	71(1)
56	--	1	0	1	0	0	2	4	10(2)	--	0	--	19	12	4	10	5	--	2	1	1	7	23	24(2)	5	11	71(2)
57	--	0	1	0	1	3	1	6	9	--	0	--	5	7	3	9	10	--	4	1	3	11	11	21	3	11	60
58	--	2	1	0	0	1	1	9	9	--	0	--	8	5	2	4	5	--	0	0	3	6	17	15	2	4	47
59	--	0	0	2	1	2	1	7	3	--	0	--	5	5	2	2	3	--	3	--	2	4	12	11	4	3	36
60	--	--	0	0	0	1	2	10	5(2)	--	0	--	11	2	0	0	4	--	7	--	1	6	21	14(2)	0	0	42(2)
61	--	--	6	0	0	4	0	10	5	--	0	--	13	14	4(1)	1	1	--	14(1)	--	4	1	23	39(1)	4(1)	1	72(2)
62	0	--	6(2)	1	1	10	2	5	11	--	0	--	16	6	0	0	5	--	17	--	10	7	21	40(2)	1	1	80(2)
63	1	--	8(1)	1	13	29	4	8	19	--	0	--	18	0	2	--	6	--	10(1)	--	29	10	26	37(2)	3	14	119(2)
64	1	--	7(2)	21(2)	14(3)	25	0	18	24	0	0	--	13	--	2	--	9	--	8	--	25	9	31	39(2)	23(2)	15(3)	142(7)
65	4	--	7	21	27	37(1)	3	39	11	2	1	--	33	--	17	--	17	--	1	--	37(1)	20	72	19	40	32	220(1)
66	6	--	2(1)	25	32(1)	23	1	66	4	4	0	--	27	--	18(1)	--	29	--	1	--	23	30	93	7(1)	47(1)	38(1)	238(3)
67	10(1)	--	3	29(1)	30(2)	15	2	74	4	3	--	--	62	--	22(1)	--	40	--	0	--	15	42	136	7	54(2)	40(3)	294(5)
68	6	--	0	16	26	13	3	70	0	4	--	--	81	--	21(2)	--	42	--	--	--	13	45	151	0	41(2)	32	282(2)
69	6(1)	--	--	17	27	6	3	46	0	2	--	0	68	--	12	--	35	--	--	--	6	38	114	0	31	33(1)	222(1)
70	13	--	--	10	13	4	3	37(1)	0	1	--	1	51(1)	--	8	--	28	--	--	--	5	31	88(2)	0	19	26	169(2)
71	4	--	--	11	8	9	1	21	0	4	--	0	44	--	1	--	6	--	--	--	9	7	65	0	16	12	109
72	1	--	--	9(1)	7(1)	6	0	11	0	6	--	0	20	--	5	--	9	--	--	--	6	9	31	0	20(1)	8(1)	74(2)
73	2	--	--	23	4	1	2	4	0	7	--	0	4	--	7	--	7	--	--	--	1	9	8	0	37	6	61
74	1	--	--	36(3)	13	1	11	4	0	10	--	0	2	--	13	--	8	--	--	--	1	19	6	0	59(3)	14	59(3)

APPENDIX B

Lengths of 4,538 Albacore Tagged in the Eastern North Pacific 1952 Through 1957. Subsequent Recoveries are Indicated in Parenthesis Opposite the Length at Time of Tagging

75	5	--	--	50(3)	12	3	10	2	0	12	--	1	2	--	9	--	1	--	--	--	4	11	4	0	71(3)	17	107(3)
76	5	--	--	36(2)	34(1)	1(1)	19	7	2	32	--	0	5(1)	--	14	--	5	--	--	--	1(1)	24	12(1)	2	82(2)	39(1)	160(5)
77	4	--	--	46(2)	42(1)	1	34(1)	6	1	21(1)	--	--	4	--	7	--	7	--	--	--	1	41(1)	10	1	74(3)	46(1)	173(5)
78	6	--	--	25	48(4)	0	48(2)	4	1	21	--	--	4	--	11	--	3	--	--	--	0	51(2)	8	1	57	54(4)	171(6)
79	3(1)	--	--	10(1)	34	1(1)	65(1)	11	2	10	--	--	8	--	3	--	8	--	--	--	1(1)	73(1)	19	2	23(1)	37(1)	155(4)
80	4	--	--	14(2)	23	0	80(1)	18	0	9	--	--	10	--	4	--	8	--	--	--	0	88(1)	28	0	27(2)	27	170(3)
81	2	--	--	2	17	--	65(2)	15	2	6	--	--	19	--	1	--	8	--	--	--	--	73(2)	34	2	9	19	137(2)
82	0	--	--	3	17	--	60(1)	9	2	1	--	--	19	--	0	--	11	--	--	--	--	71(1)	28	2	4	17	122(1)
83	2	--	--	1	12	--	52	27	3	2	--	--	26	--	--	--	5	--	--	--	--	57	53	3	3	14	130
84	0	--	--	2	4	--	48	9	1	0	--	--	27	--	--	--	5	--	--	--	--	53	36	1	2	4	96
85	1	--	--	0	16	--	49(1)	10	0	0	--	--	24	--	--	--	5	0	--	--	--	54(1)	34	0	0	17	105(1)
86	0	--	--	--	15(1)	--	36(3)	3	0	2	--	--	33	--	--	--	7	1	--	--	--	43(3)	37	0	2	15(1)	97(4)
87	0	--	--	--	7	--	32	2	0	2	--	--	17	--	--	--	2	0	--	--	--	34	19	0	2	7	62
88	0	--	--	--	5	--	26(1)	1	0	1	--	--	15	--	--	--	4	--	--	--	--	30(1)	16	0	1	5	52(1)
89	0	--	--	--	6	--	20	1	1	0	--	--	3	--	--	--	2	--	--	--	--	22	4	1	0	6	33
90	1	--	--	--	4	--	8	0	0	--	--	--	2	--	--	--	2	--	--	--	--	10	2	0	--	5	17
91	0	--	--	--	4	--	15(1)	1	--	--	--	--	0	--	--	--	0	--	--	--	--	15(1)	1	--	--	4	20(1)
92	--	--	--	--	1	--	13	0	--	--	--	--	0	--	--	--	1	--	--	--	--	14	0	--	--	1	15
93	--	--	--	--	3	--	9	--	--	--	--	--	0	--	--	--	0	--	--	--	--	9	0	--	--	3	12
94	--	--	--	--	2	--	7	--	--	--	--	--	1	--	--	--	1	--	--	--	--	8	1	--	--	2	11
95	--	--	--	--	1	--	3	--	--	--	--	--	0	--	--	--	0	--	--	--	--	3	0	--	--	1	4
96	--	--	--	--	2	--	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2	--	--	--	2	4
97	--	--	--	--	0	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	0	1
98	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	1
99	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	1
Total	88(3)	3(0)	41(6)	415(17)	326(14)	198(3)	746(14)	592(1)	143(5)	162(1)	2(0)	2(0)	857(2)	78(0)	193(5)	39(0)	362(0)	1(0)	88(2)	2(0)	203(3)	1108(14)	1450(3)	350(13)	770(22)	657(17)	4538(73)

APPENDIX B

Lengths of 4,538 Albacore Tagged in the Eastern North Pacific 1952 Through 1957. Subsequent Recoveries are Indicated in Parenthesis Opposite the Length at Time of Tagging

APPENDIX C

Monthly Commercial Albacore Catch 1954 to 1959 by Surface Temperature, Numbers, and Pounds (1,300,182 Albacore)

Date		Surface Temp. Degrees F.	Albacore	
Year	Month		Numbers	Pounds
		1954-55 Season		
1954	June	62	180	2,273
		63	2	24
	July	58	3	40
		60	191	2,045
		61	41	605
		62	711	7,299
		63	798	10,256
		64	1,157	15,192
		65	1,214	14,237
		66	2,330	28,490
		67	234	2,918
	Aug.	60	1,234	13,754
		61	1,797	21,683
		62	1,612	18,915
		63	2,091	24,102
		64	1,899	22,890
		65	180	2,237
		66	521	11,138
		70	3	78
	Sept.	57	64	911
		58	109	1,322
		59	567	7,481
		60	7,307	94,018
		61	10,919	139,400
		62	9,008	124,313
		63	1,533	20,914
		64	1,095	14,567
		65	165	2,356
		66	477	12,396
		67	15	192
	Oct.	55	23	275
		57	35	421
		58	413	5,327
		59	588	7,594
		60	1,852	24,681
		61	3,063	41,044
		62	1,409	17,681
		63	120	1,459
		72	20	148
	Nov.	60	1,070	20,102
		61	864	9,681
	Dec.	60	295	2,401
Totals			57,209	746,860

APPENDIX C
Monthly Commercial Albacore Catch 1954 to 1959 by Surface Temperature, Numbers, and Pounds (1,300,182 Albacore)

APPENDIX C—Continued

Monthly Commercial Albacore Catch 1954 to 1959 by Surface Temperature, Numbers, and Pounds (1,300,182 Albacore)

Date		Surface Temp. Degrees F.	Albacore	
Year	Month		Numbers	Pounds
		1955-56 Season		
1955	June	61	197	2,064
		62	1,874	19,389
	July	58	30	312
		59	54	572
		60	1,085	11,222
		61	6,903	72,147
		62	12,378	130,987
		63	8,139	84,547
		64	13,386	140,058
		65	4,495	47,869
		66	1,600	17,105
		67	1,059	11,001
		68	323	3,078
		69	127	1,299
		70	369	3,491
		71	470	4,447
		72	409	3,870
	Aug.	57	22	232
		58	49	503
		59	390	4,093
		60	6,218	65,424
		61	4,416	46,550
		62	863	8,945
		63	1,948	20,063
		64	1,103	11,078
		65	1,281	13,279
		66	7,463	77,798
		67	9,638	98,972
		68	14,115	150,113
		69	6,209	64,236
		70	11,297	123,641
		71	2,122	22,458
		72	2,733	29,941
		73	81	860
		74	355	4,156
		77	615	7,072
	Sept.	53		
		54		
		55	5	58
		56	25	280
		57	118	1,288
		58	1,085	11,206
		59	508	5,355
		60	3,797	38,538
		61	10,132	104,123
		62	6,380	68,108
		63	860	9,216
		64	321	4,052
		65	595	6,659
		66	369	4,086
		67	5,115	61,865
		68	4,411	51,439
		69	1,415	14,935
		70	6,509	72,776
		71	1,155	15,431
		72	278	3,445
		73	70	697
	Oct.	56	1	9
		57	14	143
		58	658	7,088
		59	805	8,653
		60	8,251	88,808
		61	10,484	113,158
		62	4,662	48,266
		63	482	5,137
		64	1,163	16,105
		65	431	5,856
		66	2,901	32,022
		68	52	770
	Nov.	54		
		55	1	12
		57		
		58	35	404
		59	18	205
		60	632	6,676
		61	884	9,868
		62	3,492	40,660
		63	1,335	15,369
		64	4,657	56,722
		65	624	7,359
		67	43	575
	Dec.	56		
		57		
		58		
		59	2	25
		61	560	6,843
		62	2,242	27,325
		63	634	7,171
		64	323	3,653
1956	Jan.	56		
		57		
		59	294	3,866
		60	636	8,420
		61	1,259	16,187
		62	3,773	50,175
Totals			218,312	2,363,959

APPENDIX C
Monthly Commercial Albacore Catch 1954 to 1959 by Surface Temperature, Numbers, and Pounds (1,300,182 Albacore)

APPENDIX C—Continued

Monthly Commercial Albacore Catch 1954 to 1959 by Surface Temperature, Numbers, and Pounds (1,300,182 Albacore)

Date		Surface Temp. Degrees F.	Albacore	
Year	Month		Numbers	Pounds
		1956-57 Season		
1956	June	61	417	5,224
		62	2,109	28,860
		63	4,414	64,573
		64	12,201	168,459
		65	3,657	53,311
		66	4,510	64,207
		67	774	11,114
		68	1,186	18,226
		69	173	2,602
		70	208	3,124
	July	56	92	1,581
		57	59	854
		58	4	46
		59	75	1,101
		60	4,107	60,701
		61	596	8,619
		62	1,980	28,064
		63	4,880	71,881
		64	40,040	600,452
		65	28,095	439,367
		66	21,456	347,607
		67	8,063	129,048
		68	5,731	94,238
		69	524	8,791
		70	218	3,333
	Aug.	56	91	1,358
		58	85	1,249
		59	1,855	25,472
		60	13,295	177,482
		61	12,461	159,345
		62	23,941	322,878
		63	7,271	99,864
		64	19,396	276,579
		65	14,249	215,678
		66	12,895	215,447
		67	13,259	227,282
		68	12,831	219,475
		69	1,678	28,324
		70	1,220	19,695
		71	186	3,054
	Sept.	56	1	12
		57	18	240
		58	26	406
		59	999	13,084
		60	11,227	143,960
		61	11,702	155,126
		62	38,938	506,554
		63	16,295	210,795
		64	25,772	334,474
		65	4,246	59,810
		66	2,911	40,765
		67	1,005	15,292
		68	600	10,630
		69	596	9,651
		70	483	8,323
	Oct.	57	26	377
		58	458	6,687
		59	2,938	44,007
		60	5,161	73,230
		61	1,827	23,198
		62	7,489	97,841
		63	3,462	41,828
		64	844	11,565
		65	259	3,701
		66	683	12,204
		67	19	405
		68	459	7,836
		69	189	3,394
		70	227	3,938
	Nov.	54	1	15
		55	1	13
		56	109	1,613
		57	25	346
		58	507	7,045
		59	1,820	24,751
		60	3,863	56,487
		61	1,433	22,207
		62	1,608	26,314
		63	171	2,892
		64	373	6,015
		65	90	1,478
		66	4	76
		67	11	208
	Dec.	58	155	2,197
		59	488	6,661
		60	1,496	20,751
		61	704	8,098
		62	860	11,844
		63	325	5,878
		64	949	14,299
		65	170	2,487
		66	37	535
1957	Jan.	59	1	19
		61	8	111
		62	879	12,555
		63	663	9,132
		64	2,071	28,480
		65	533	6,966
	Feb.	62	149	2,775
		63	175	2,414
		64	278	3,830
	March	62	16	213
Totals			439,115	6,336,603

APPENDIX C
Monthly Commercial Albacore Catch 1954 to 1959 by Surface Temperature, Numbers, and Pounds (1,300,182 Albacore)

APPENDIX C—Continued

Monthly Commercial Albacore Catch 1954 to 1959 by Surface Temperature, Numbers, and Pounds (1,300,182 Albacore)

Date		Surface Temp. Degrees F.	Albacore	
Year	Month		Numbers	Pounds
		1957-58 Season		
1957	June	60	1	10
		61	2	21
		62	46	665
		63	786	12,037
		64	2,113	35,441
		65	2,158	40,226
		66	4,346	73,247
		67	1,449	24,320
		68	412	6,694
		69	337	5,627
		70	329	5,446
		72	315	4,485
	July	56		
		57		
		58	49	632
		59	60	715
		60	359	4,715
		61	2,923	42,882
		62	9,499	132,731
		63	4,284	63,264
		64	6,825	108,198
		65	15,610	279,113
		66	39,004	686,819
		67	21,843	384,660
		68	14,605	271,912
		69	2,995	58,392
		70	692	14,543
		71	71	1,075
		72	11	157
	Aug.	56		
		57	62	950
		58	197	2,724
		59	98	1,332
		60	2,366	33,335
		61	2,394	33,148
		62	6,703	92,366
		63	4,220	61,252
		64	7,951	126,330
		65	7,540	147,024
		66	17,622	369,380
		67	11,816	252,227
		68	9,794	206,117
		69	3,976	82,822
		70	571	11,641
		71	151	3,337
		72	696	16,345
		73	27	551
		74	81	1,963
		75	106	1,959
		76	1	21
	Sept.	59		
		60	309	4,632
		61	1,908	29,315
		62	12,643	180,475
		63	25,978	377,423
		64	53,711	805,871
		65	20,169	303,920
		66	13,582	213,345
		67	2,761	47,534
		68	1,535	23,443
		69	503	8,080
		70	99	2,325
	Oct.	56		
		59	7	103
		60	411	6,019
		61	1,156	18,894
		62	4,682	80,243
		63	3,289	57,349
		64	5,152	89,585
		65	1,316	20,523
		66	467	8,911
		67	202	3,533
		68	84	1,495
		69	4	59
	Nov.	57	6	80
		58	24	333
		59	78	1,776
		60	517	10,001
		61	1,153	23,655
		62	1,336	25,410
		63	1,121	16,925
		64	2,580	36,309
		65	190	2,579
		66		
		67	4	123
	Dec.	61	1	14
		62	28	567
		63	354	5,789
		64	932	12,630
		65	6	100
		66	166	3,158
		67	19	315
1958	Jan.	62		
		63	8	138
		64	21	364
Totals			366,008	6,126,696

APPENDIX C
Monthly Commercial Albacore Catch 1954 to 1959 by Surface Temperature, Numbers, and Pounds (1,300,182 Albacore)

APPENDIX C—Continued

Monthly Commercial Albacore Catch 1954 to 1959 by Surface Temperature, Numbers, and Pounds (1,300,182 Albacore)

Date: Year	Date: Month	Surface Temp. Degrees F.	Albacore: Numbers	Albacore: Pounds
		1958-59 Season		
1958	June	58	12	163
		61	18	203
		62	1	14
		63	161	2,167
		64	189	3,099
		65	96	2,498
		66	3	91
		67	55	1,634
		68		
		69		
	July	57	1	13
		58	38	545
		59	193	2,656
		60	1,536	21,873
		61	6,324	89,018
		62	34,210	476,444
		63	22,614	317,278
		64	42,902	622,456
		65	22,978	362,947
		66	9,626	176,431
		67	1,279	19,845
		68	659	10,118
		69	105	1,503
		70	221	3,680
	Aug.	58	17	408
		59	28	397
		60	111	1,601
		61	1,007	15,350
		62	3,639	54,497
		63	6,882	105,412
		64	10,768	170,178
		65	9,351	195,482
		66	15,046	351,270
		67	3,907	97,346
		68	219	4,042
		69		
	Sept.	54	5	88
		58	3	46
		59	1	10
		60	423	6,352
		61	306	4,500
		62	2,215	33,095
		63	4,591	62,527
		64	3,457	52,291
		65	1,881	29,685
		66	2,279	47,810
		67		
		68	337	4,915
	Oct.	58	2	31
		60	270	3,901
		61	398	5,311
		62	2,636	32,218
		63	4,426	53,638
		64	1,313	14,585
	Nov.	56	6	64
		60	18	167
		61	43	447
		62	732	6,822
		64		
		66		
Totals			219,538	3,469,162
Grand totals			1,300,182	19,043,280

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APPENDIX C
Monthly Commercial Albacore Catch 1954 to 1959 by Surface Temperature, Numbers, and Pounds (1,300,182 Albacore)