Title
Fish Bulletin No. 55. Report on returns of drift bottles released off southern California, 1937

Author
Tibby, Richard B

Publication Date
1939

DIVISION OF FISH AND GAME OF CALIFORNIA
BUREAU OF MARINE FISHERIES
FISH BULLETIN No. 55
Report on Returns of Drift Bottles Released off Southern California, 1937[1]

By

RICHARD B. TIBBY

1939

[1] Submitted for publication, January, 1939.

TABLE OF CONTENTS

1. INTRODUCTION

The use of drift bottles as a means of charting ocean currents is an old one, and their use in fisheries research is not without precedent. In the North Sea, particularly, investigations of the oceanic circulation have been carried on over a number of years by this means and have shed light on a great variety of fisheries problems. The circulation of the waters off the coast of southern California was, at the beginning of the present survey, very incompletely charted. It was felt that a more detailed knowledge of hydrographic conditions would materially assist in the interpretation of some of the problems relating to the life-history of the sardine (Sardinops caerulea) and some of the other commercial fishes.

The present survey was designed to chart surface circulation throughout the region of maximum spawning of the sardine. As the California State Fisheries Laboratory possessed neither the equipment nor the personnel for a detailed hydrographic survey of the region, it was decided that drift bottles should be used as the most convenient method of obtaining data on the surface circulation. Drift methods have two distinct advantages: the bottles are inexpensive to prepare and no special training or equipment is necessary to carry out their release. After Dr. H. U. Sverdrup, Director of the Scripps Institution of Oceanography, was consulted concerning the plans for the drift bottle investigation, it was proposed that the Scripps Institution, which was then seriously handicapped by the loss of their research vessel, carry on a program of water sampling concurrently with the drift bottle releases as an additional means of obtaining data on the circulation of the region in question. This arrangement proved to be most satisfactory as the information obtained by dynamic methods was more detailed and provided a much better picture of conditions than would have been possible by the drift bottles alone. As it turned out, the main value of the drift bottles lay in confirming the results of the dynamic computations. As the Scripps Institution of Oceanography is now in a position to continue their hydrographic work and as the information they obtain will be available to the California Division of Fish and Game, the drift bottle work need not be continued.

2. ACKNOWLEDGMENTS

The use of drift bottles as a means of determining the drift of eggs and larvae of the California sardine was first proposed by Dr. Frances N. Clark of the California State Fisheries Laboratory, and her enthusiasm in a large part was responsible for the initiation of this program. Its continuation would not have been possible without the active support and the interest of Mr. W. L. Scofield, Supervisor of the Laboratory.

I wish especially to thank Dr. H. U. Sverdrup, Director of the Scripps Institution of Oceanography, whose freely given advice was sought on many occasions, and under whose direction the circulation of the entire area was established by means of an intensive hydrographic program. The assistance of Dr. Richard H. Fleming and Dr. Eric G. Moberg of the Scripps Institution of Oceanography, during the oftentimes arduous days at sea is very much appreciated.

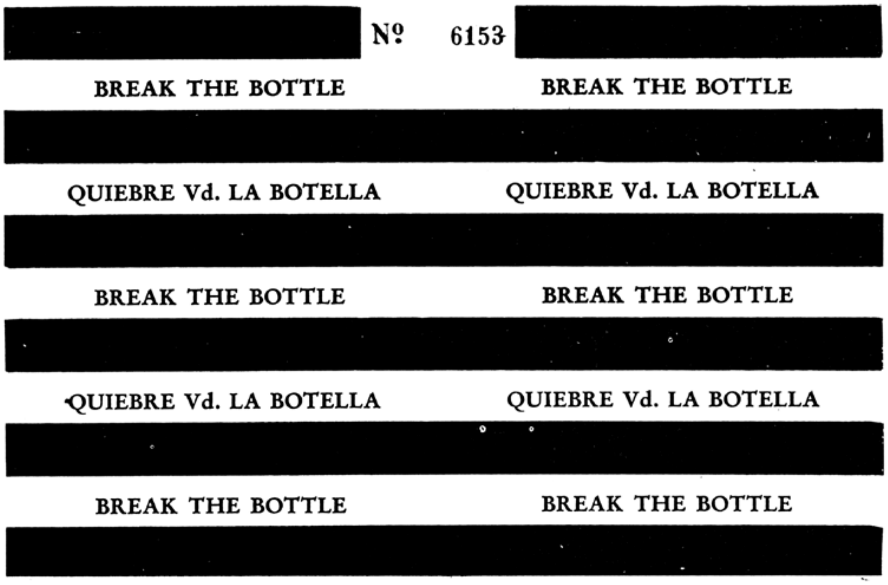
My thanks are extended to Captain Walter Engelke and to the crew of the California Division of Fish and Game patrol boat *Bluefin*, from which the bottles were released.

To all whom I have mentioned and to the members of the staff of the California State Fisheries Laboratory who assisted in the preparation of the drift bottles, I wish to tender my grateful acknowledgments.

3. PREPARATION OF THE DRIFT BOTTLES

The type of drift bottle to be used was determined by two considerations: the area of the region to be covered was large and the available funds were limited. It seemed expedient, therefore, to use a large number of bottles of a simple type rather than a lesser number of more elaborate ones, even though the former are less efficient and are more liable to be directly affected by the wind. The choice was also governed by the fact that the experiment was to be in the nature of a preliminary survey, as little was known of the surface circulation in the region to be investigated, and it was felt that the disadvantages inherent in the simpler type of bottle would be more than offset by the increased number of returns. The results have shown that the choice was a wise one.

The bottles used were 12-ounce wine bottles of rather heavy, clear glass. Three sheets of printed matter were placed inside each bottle. The first, which was visible from the outside, was a sheet of paper printed with alternate red and white bands and bearing on it instructions to "break the bottle." (See Fig. 1.) The second was addressed "to the finder" (see Fig. 2), telling him what the bottle was and requesting him to fill out and mail the third insert, a postpaid postal card. (See Fig. 3.) This postal card asked where the bottle had been found, the date, and the name and address of the finder. No reward was offered for the return of the card, but a letter was written upon receipt of each card thanking the sender for his interest and informing him when and where the bottle had been released. All printed matter was in both English and Spanish, as it was believed some of the bottles would come ashore along the coast of Lower California.



№ 6153

BREAK THE BOTTLE BREAK THE BOTTLE

QUIEBRE Vd. LA BOTELLA QUIEBRE Vd. LA BOTELLA

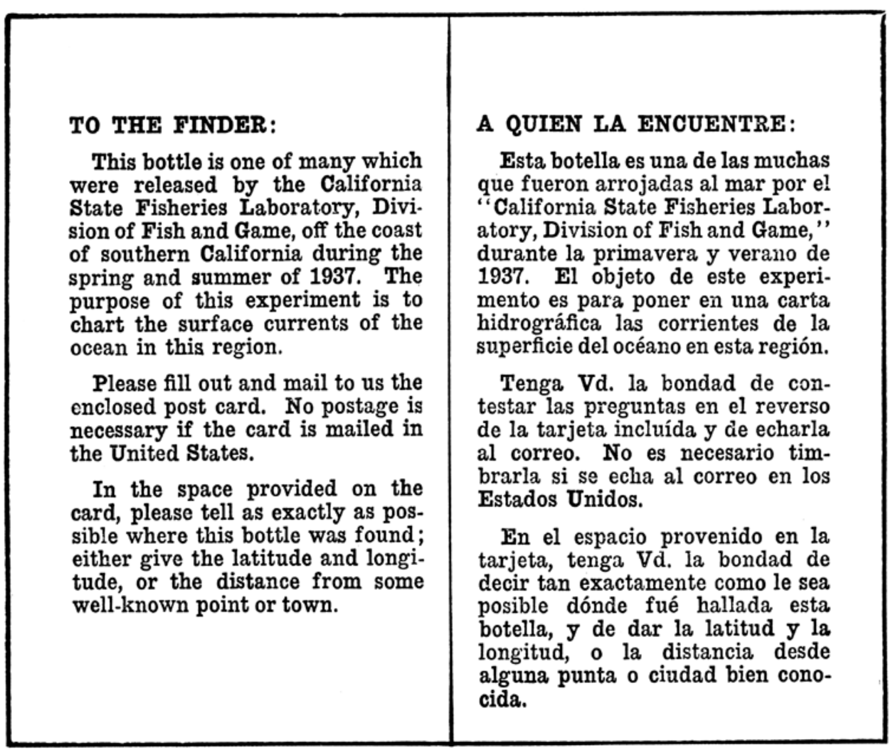
BREAK THE BOTTLE BREAK THE BOTTLE

QUIEBRE Vd. LA BOTELLA QUIEBRE Vd. LA BOTELLA

BREAK THE BOTTLE BREAK THE BOTTLE

FIG. 1. Label for drift bottle, visible from outside.

FIG. 1. Label for drift bottle, visible from outside



TO THE FINDER:

This bottle is one of many which were released by the California State Fisheries Laboratory, Division of Fish and Game, off the coast of southern California during the spring and summer of 1937. The purpose of this experiment is to chart the surface currents of the ocean in this region.

Please fill out and mail to us the enclosed post card. No postage is necessary if the card is mailed in the United States.

In the space provided on the card, please tell as exactly as possible where this bottle was found; either give the latitude and longitude, or the distance from some well-known point or town.

A QUIEN LA ENCUENTRE:

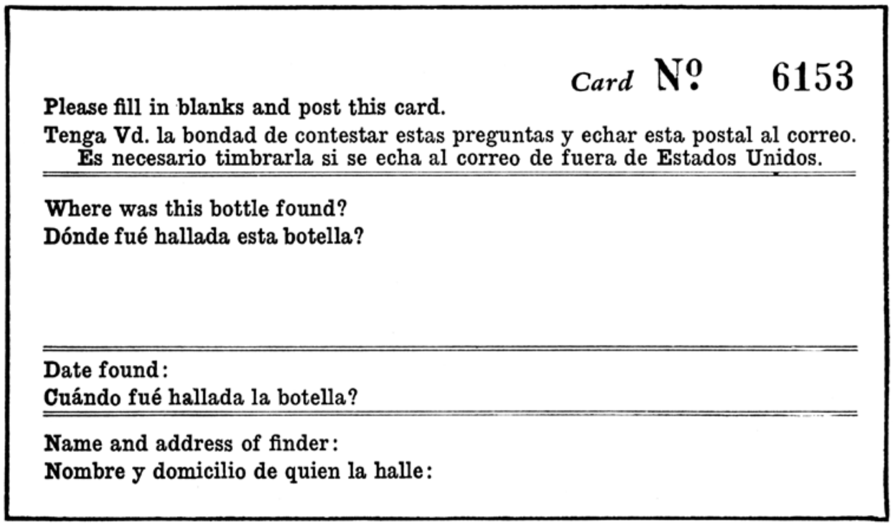
Esta botella es una de las muchas que fueron arrojadas al mar por el "California State Fisheries Laboratory, Division of Fish and Game," durante la primavera y verano de 1937. El objeto de este experimento es para poner en una carta hidrográfica las corrientes de la superficie del océano en esta región.

Tenga Vd. la bondad de contestar las preguntas en el reverso de la tarjeta incluída y de echarla al correo. No es necesario timbrarla si se echa al correo en los Estados Unidos.

En el espacio provenido en la tarjeta, tenga Vd. la bondad de decir tan exactamente como le sea posible dónde fué hallada esta botella, y de dar la latitud y la longitud, o la distancia desde alguna punta o ciudad bien conocida.

FIG. 2. Sheet enclosed in drift bottle addressed "To the Finder."

FIG. 2. Sheet enclosed in drift bottle addressed "To the Finder."



Card No. 6153

Please fill in blanks and post this card.

Tenga Vd. la bondad de contestar estas preguntas y echar esta postal al correo.
Es necesario timbrarla si se echa al correo de fuera de Estados Unidos.

Where was this bottle found?
Dónde fué hallada esta botella?

Date found:
Cuándo fué hallada la botella?

Name and address of finder:
Nombre y domicilio de quien la halle:

FIG. 3. Back of post-paid reply card enclosed in drift bottle.

FIG. 3. Back of post-paid reply card enclosed in drift bottle

The preparation of the bottles required three operators, one to insert the labels, one to ballast the bottles and one to insert the corks. The labels were so arranged that they could be picked up quickly, rolled around a piece of doweling and inserted in the bottle so that the striped label was on the outside. Each bottle was floated in fresh water and ballasted with dry sand until it almost sank, so that when the cork was inserted and the neck was dipped in marine glue, the bottle floated in sea water with but one or two inches of the neck protruding above the surface. The method was rapid and convenient and could be carried out as fast as the labels could be placed in the bottles.

The corks were soaked in water for several hours to make them flexible and were then forced into the bottles by means of a small hand-corking machine. The bottles were set aside for twenty-four hours to allow a partial drying out of the corks. If wet corks were dipped into the hot glue, large thin bubbles formed which often broke, exposing the tops of the corks. Three operators could prepare an average of four hundred bottles per day.

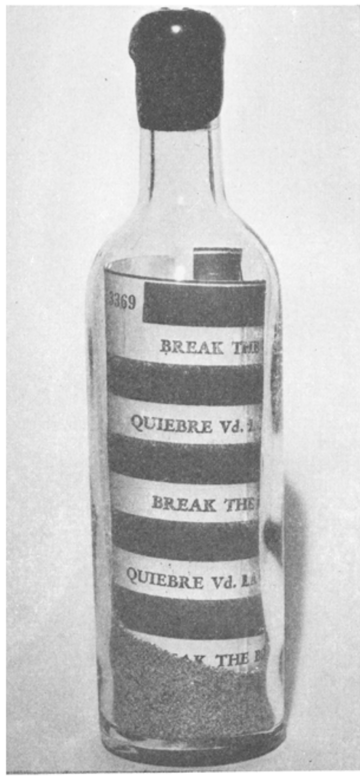


FIG. 4. Drift bottle as it appeared when released.

FIG. 4. Drift bottle as it appeared when released

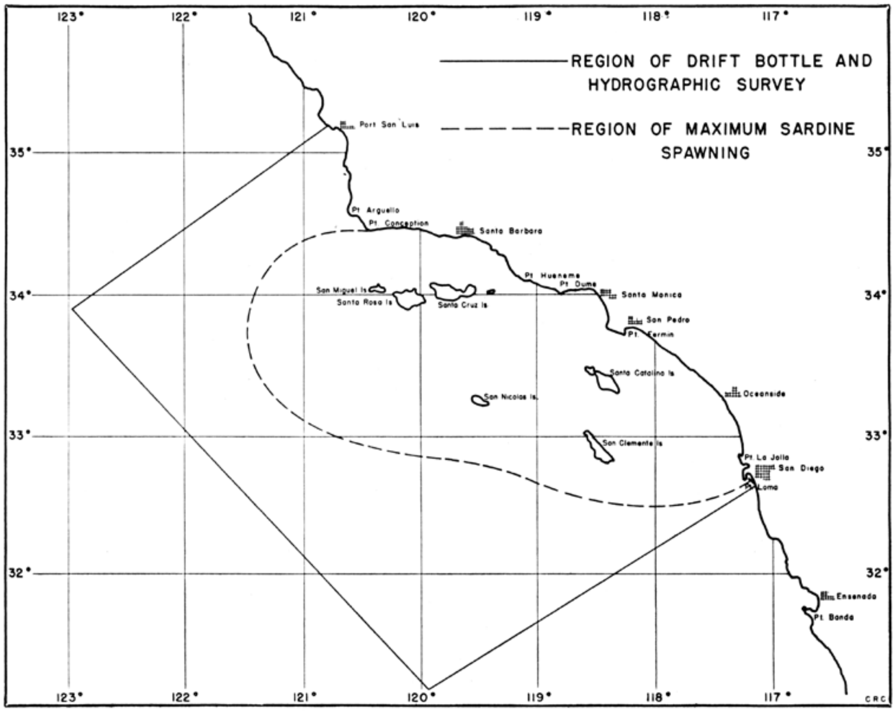


FIG. 5. Chart showing the region of maximum spawning of the sardine and the region of the drift bottle and hydrographic survey.

FIG. 5. Chart showing the region of maximum spawning of the sardine and the region of the drift bottle and hydrographic survey

4. DRIFT BOTTLE STATIONS

A survey by Scofield (1934) showed the main spawning area of the sardine to be between Point Conception and San Diego and offshore for about one hundred miles. The drift bottle experiment was designed to include this area and to extend somewhat beyond its boundaries, particularly to the south. (See Fig. 5.) Surface circulation to the south of the main spawning area is of especial interest since inshore waters from San Diego south provide extensive "nursery grounds" for young sardines. Accordingly, four station lines were laid out as follows:

Section I

From the buoy off breakwater at Port San Luis lay course at 235° true to 33° 50' N., 122° 59' W. Distance, 135 miles.

Section II

From 32° 59' N., 122° 01' W., lay course at 55° true to shore just below Santa Barbara. This line will run through the San Miguel Passage. Distance, 150 miles.

Section III

From Point Fermin Light lay course at 235° true to 31° 58' N., 121° 12' W. Distance, 180 miles.

Section IV

From 31° 10' N., 119° 56' W., lay course at 55° true to a point one mile north of Point La Jolla. Distance, 165 miles.

These lines were approximately 70 miles apart. Their length was modified slightly during the progress of the investigation. A total of 27 stations was planned for the four lines, but this also was changed somewhat due to adverse weather conditions. The general rule followed in locating the stations was that they should be 15 miles apart along each section in inshore waters and 30 miles apart in offshore waters.

Since the sardines spawn during the months of March to July, it was planned to make three cruises during the spawning period at intervals of four or five weeks, each trip occupying ten days or two weeks. On each trip approximately 2000 bottles were released. The first cruise was from March 25 to April 4, the second from May 5 to May 13, and the third from June 22 to July 2, 1937. On cruises I and III the planned work could be only partly completed because of bad weather.

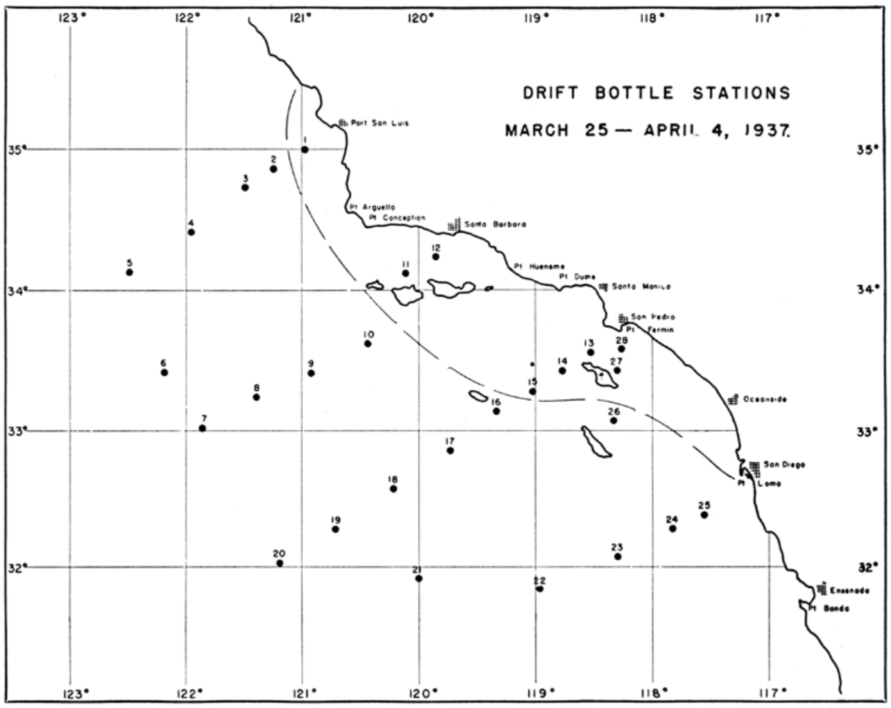


FIG. 6. Drift bottle stations, first cruise. Broken line indicates region within which stations lie from which recoveries were made, and the general region of recovery.

FIG. 6. Drift bottle stations, first cruise. Broken line indicates region within which stations lie from which recoveries were made, and the general region of recovery

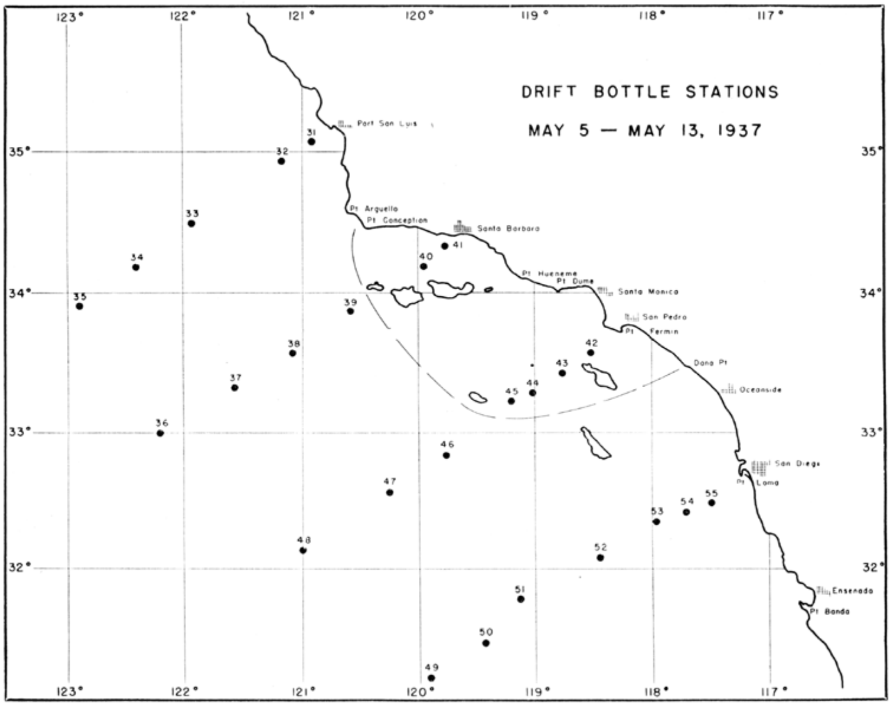


FIG. 7. Drift bottle stations, second cruise. Broken line indicates region within which stations lie from which recoveries were made, and the general region of recovery.

FIG. 7. Drift bottle stations, second cruise. Broken line indicates region within which stations lie from which recoveries were made, and the general region of recovery

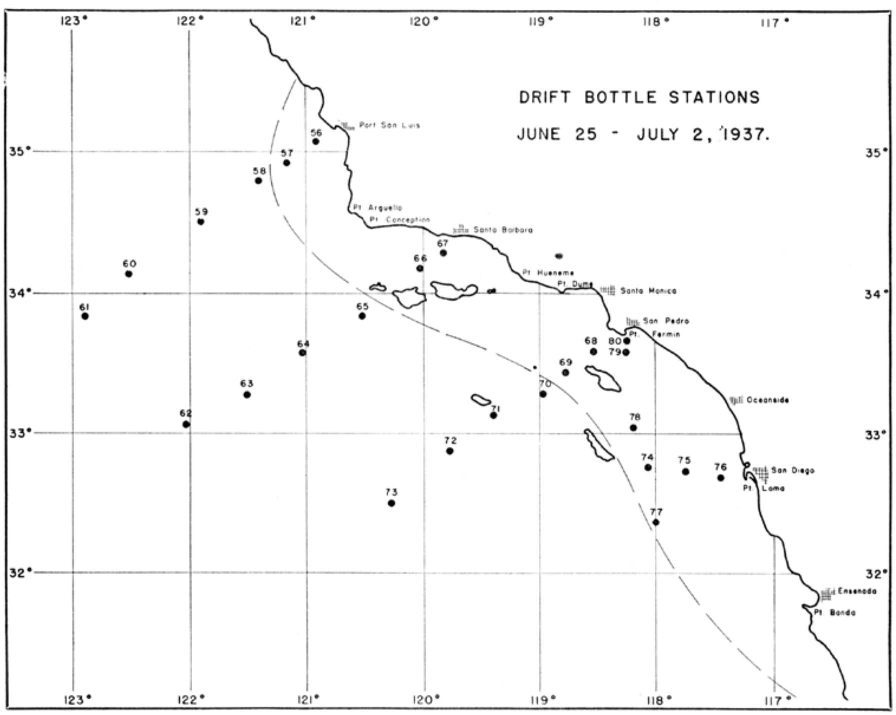


FIG. 8. Drift bottle stations, third cruise. Broken line indicates region within which stations lie from which recoveries were made, and the general region of recovery.

FIG. 8. Drift bottle stations, third cruise. Broken line indicates region within which stations lie from which recoveries were made, and the general region of recovery

5. ANALYSIS OF DRIFT BOTTLE RETURNS

Figures 9, 10 and 11 represent the dynamic topography of the surface referred to the 500 decibar surface of the region of the survey. These charts were prepared at the Scripps Institution of Oceanography and are part of a yet unpublished manuscript (Sverdrup and Fleming), describing the results of the hydrographic survey carried on by the Scripps Institution concurrently with the drift bottle releases. On these charts the dynamic height anomalies are shown with contour intervals of 0.01 dynamic meters. Arrows indicate the direction of flow.

In order to compare the drift velocities of the bottles with the velocities corresponding to the dynamic topography on these charts, it was found convenient to prepare a table from which, given the distance in nautical miles between the dynamic contours, it would be possible to read off directly the speed of flow in nautical miles per day. (Hereafter, whenever distances are referred to as being in miles, it is

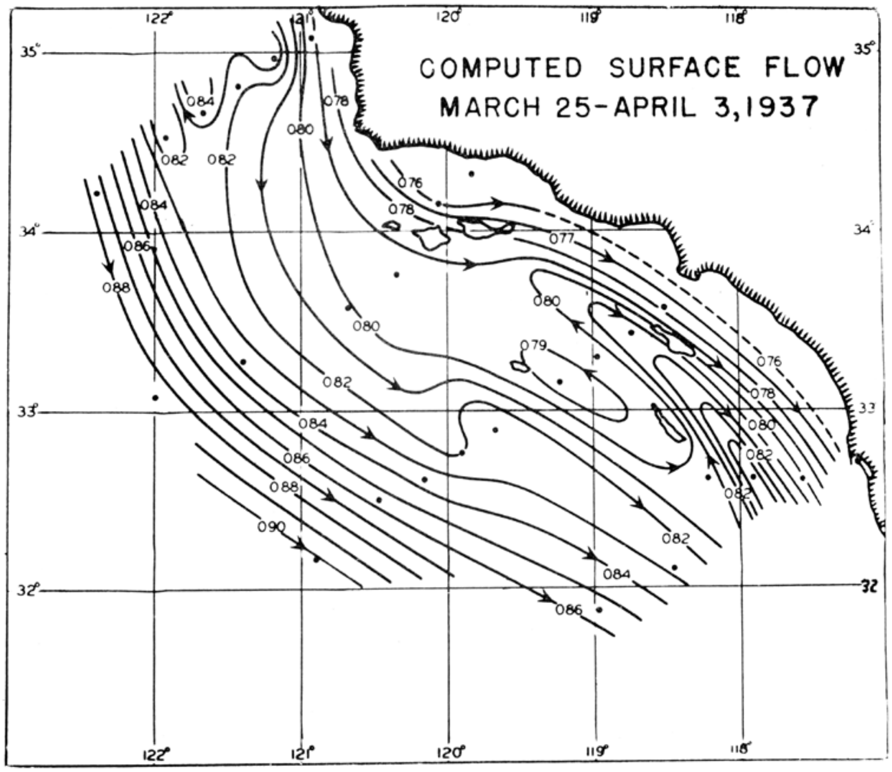


FIG. 9. Chart showing dynamic topography on first cruise. Contour interval 0.01 dynamic meter. Arrows indicate direction of flow.

FIG. 9. Chart showing dynamic topography on first cruise. Contour interval 0.01 dynamic meter. Arrows indicate direction of flow

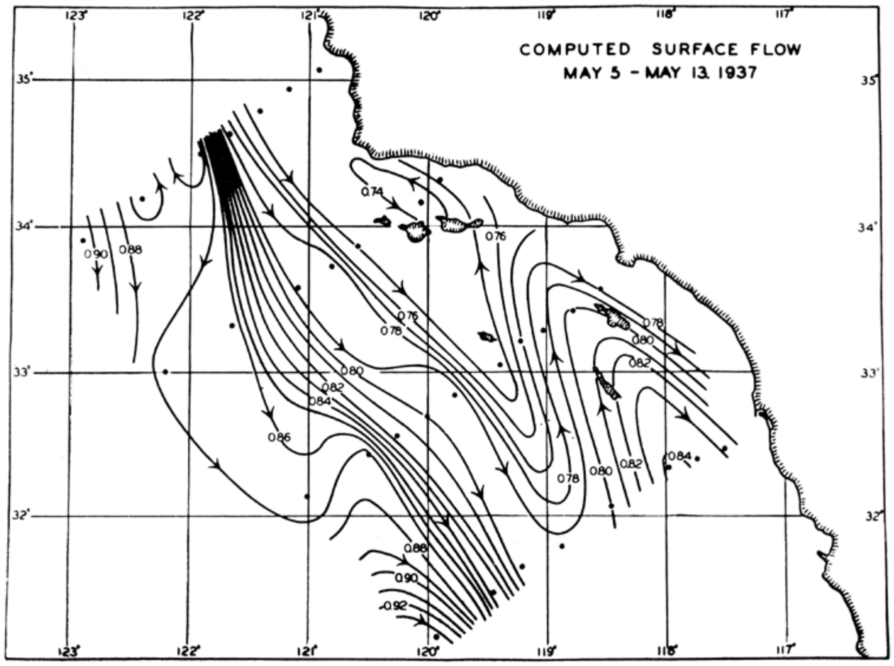


FIG. 10. Chart showing dynamic topography on second cruise. Contour interval 0.01 dynamic meter. Arrows indicate direction of flow.

FIG. 10. Chart showing dynamic topography on second cruise. Contour interval 0.01 dynamic meter. Arrows indicate direction of flow

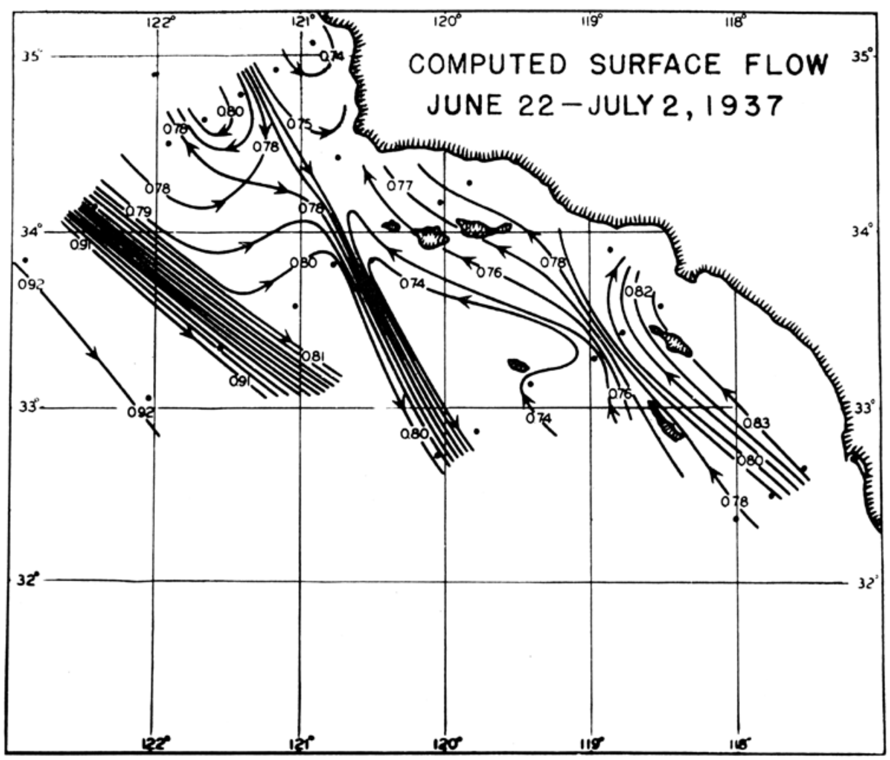


FIG. 11. Chart showing dynamic topography on third cruise. Contour interval 0.01 dynamic meter. Arrows indicate direction of flow.

FIG. 11. Chart showing dynamic topography on third cruise. Contour interval 0.01 dynamic meter. Arrows indicate direction of flow

understood that nautical miles are meant.) Surface velocities were calculated from the following formula:

$$v = \frac{(D_a - D_b)\ 10^5}{14.58\ \sin\ \phi\ L}$$

where

v = surface velocity in centimeters per second,

$(D_a - D_b)$ = difference in dynamic height between contours, expressed in meters,

ϕ = mean latitude of observation, and

L = distance between contours expressed in kilometers.

FORMULA

In the figures which follow, showing the analysis of recoveries, each station is numbered and the paths of drift are denoted by solid, broken or dotted lines. Arrows indicate the direction of drift, and the small numbers at the termination of each line refer to the number of bottles recovered at that particular point. Along the lower left hand margin of each figure is a scale of nautical miles, each division representing a distance of 10 miles.

5.1. Cruise I

5.1.1. Station 1

From this station, 15 miles off Port San Luis, only one bottle was recovered, but it is of especial interest. It was found floating in the water alongside a fishing vessel lying at anchor at the north end of Guadalupe Island, Lower California. The interval between release and recovery was 39 days, the airline distance that it had traveled was 400 miles in a southeasterly direction, which meant a rate of drift of about 10 miles per day. The significance of this single return from the standpoint of the sardine egg and larval investigation lies in the fact that the inshore waters to the north of Point Conception during March and April, 1937, drifted down the coast of Lower California some distance offshore. This will be discussed in detail later. It is one of the two long distance recoveries made to date (October 1, 1938). As the dynamic topography charts of the Scripps Institution do not extend beyond a point approximately due west of Ensenada, Lower California, it is not possible to compare accurately the observed rate of drift with that which may be derived from dynamical computations. However, over the 200 miles in which the bottle traveled within the region of the survey its average computed rate was about 5 miles per day.

There are several ways in which the difference between observed and computed rates may be accounted for. In the first place, the speed of flow to the south of the region may very possibly have been greater than that within the region itself. Also, conditions as depicted by the dynamic charts are not stationary but are continually and rapidly changing. In addition, the currents shown on these diagrams represent stream lines, and not trajectories of water masses, and the velocities of flow may be somewhat different than the indicated values.

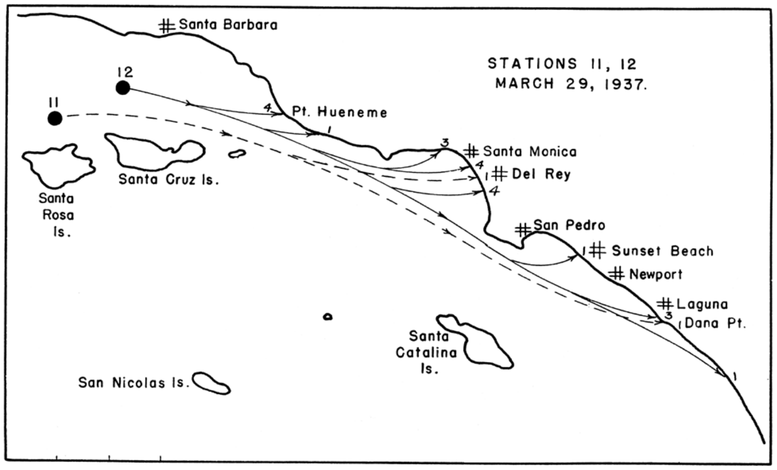

STATIONS 11, 12
MARCH 29, 1937.
Santa Barbara
12
11
Pt. Hueneme
Santa Monica
Del Rey
San Pedro
Sunset Beach
Newport
Laguna
Dana Pt.
Santa Cruz Is.
Santa Rosa Is.
Santa Catalina Is.
San Nicolas Is.

Fig. 12.

FIG. 12

But that the charts are, in general, valid is adequately borne out by the returns from stations 11, 12, 15, 69, 74, 75, 76 and 78, where the actual trajectories of groups of bottles may be seen.

5.1.2. Stations 11, 12

The two recoveries from station 11 were made, one at Del Rey Beach and one at Dana Point, 29 and 43 days after release. Even though the average speed of drift was somewhat slower that that for recoveries from station 12 these returns show that the path of drift from the two stations was much the same.

For the purposes of analysis the returns from station 12 were divided into four groups, as follows:

Group	General region of recovery	Number of bottles found	Days elapsed between release and recovery
I	Hueneme	2	4
		3	5
II	Santa Monica Bay	1	15
		1	19
		1	20
		1	21
		4	22
		1	23
		1	25
		1	27
III	Sunset Beach	1	19
IV	South of Laguna Beach	1	27
		1	34
		1	47
		1	48

TABLE

As an indication of the speed of drift we may take the short time recoveries, and the maximum rates are made out to be:

Group I.	7.5 miles per day
Group II.	4.3 miles per day
Group III.	5.0 miles per day
Group IV.	4.5 miles per day

These results are entirely consistent and are in good agreement with the values taken from the charts of dynamic topography. The paths of drift from stations 11 and 12 are straightforward, down-wind, and in the direction of the inshore currents, with no indications of significant swirls or eddies.

5.1.3. Stations 13, 14, 15

In figure 9 is shown a current which flows from the south just inside San Clemente Island. This is known as the Southern California Counter-Current. In the Scripps Institution manuscript (Sverdrup and Fleming) from which figures 9, 10 and 11 were taken, it is stated that this Counter-Current is part of the system of circulation whereby a portion of the southeasterly offshore current (the inner edge of the California Current) turns back on itself somewhere in the region north of Sebastian Viscaino Bay, Lower California, flows in a northwesterly direction to the Santa Barbara Islands, and then again turns and runs southeast and inshore. The northerly flow of this current is the Counter-Current, in which station 15 was located. The path of flow is shown by the remarkably clean-cut trajectory of the bottles, and substantiates in some detail the results of the dynamic computations.

There were two returns from station 13, one from station 14, and four from station 15. The two short-time returns were both from station 15 and indicate a drift velocity of 5.4 miles per day. This is approximately the same as the computed value.

5.1.4. Stations 27, 28, 29, 30

Returns from station 27 confirm the analysis of a southerly inshore drift. The shortest time-interval between release and recovery does not give a satisfactory value for drift velocity.

At stations 29 and 30 just outside the San Pedro breakwater a number of bottles were released for a newsreel company. Twenty-seven were recovered in the general vicinity.

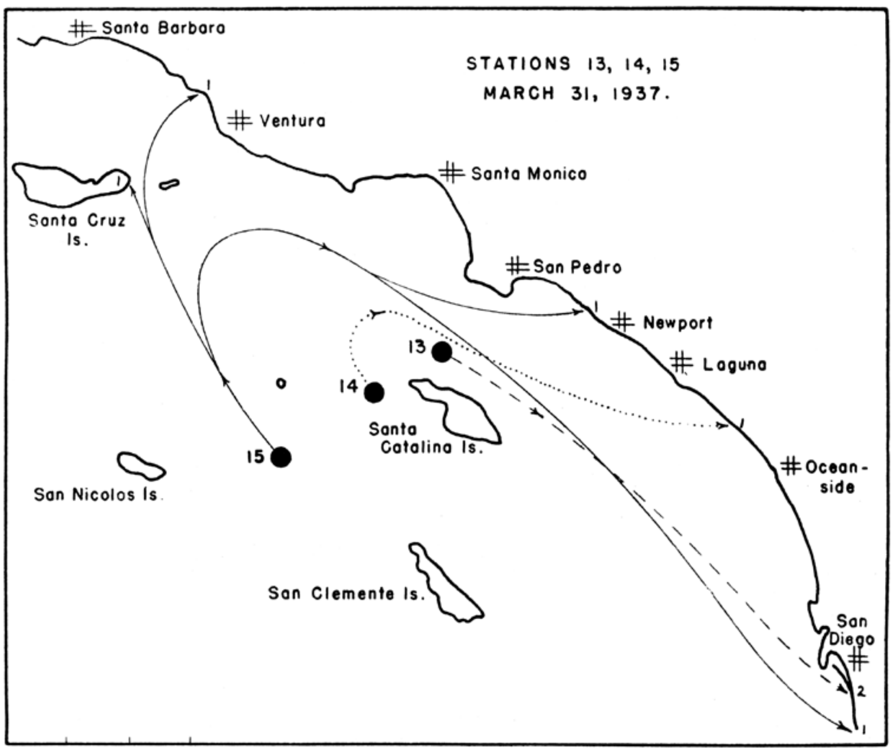


Fig. 13.

FIG. 13

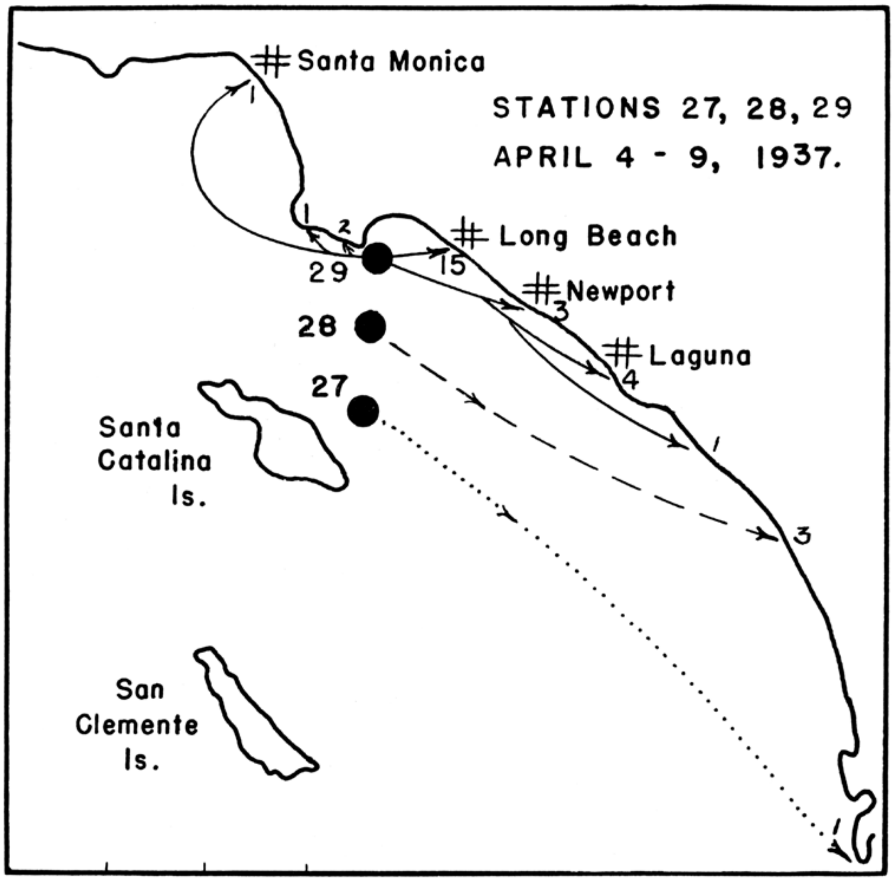


FIG. 14.

FIG. 14

5.2. Cruise II

In figure 7 are shown the stations occupied on the second cruise. This is the only cruise on which the full program was completed. In the figure is also shown the region within which stations lay from which recoveries were made and the general region of recovery. For the dynamic topography of the region during the time of release, refer to figure 10.

Returns from this cruise were very meager, although more bottles were released than on either of the other two. It is remarkable that the region of recovery was very much smaller, being confined, roughly, to the triangular area between Point Conception, San Nicolas Island, and Dana Point. No explanation can be offered for the small number of recoveries.

5.2.1. Stations 40, 41

The returns from these two stations are not easily reconciled with the drift shown in figure 10.

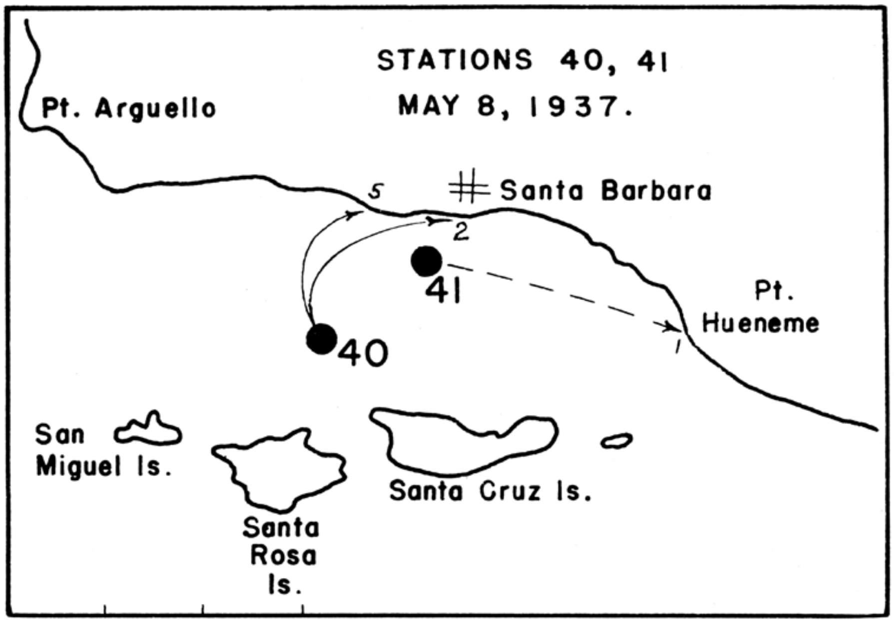


FIG. 15.

FIG. 15

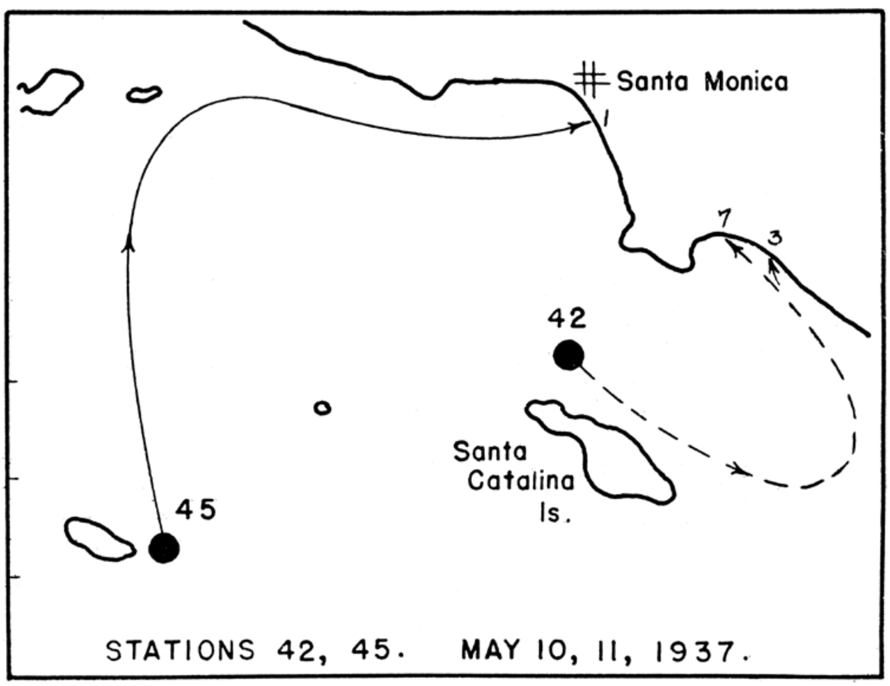


FIG. 16.

FIG. 16

5.2.2. Stations 42, 45

These two stations are similar to 13 and 15, cruise I (see Fig. 13). The general features of surface circulation are much the same as they were at the time stations 13 and 15 were occupied except for a northerly current (indicated by the drift bottle returns) close in along the shore as far north as Point Fermin. Observed maximum velocities compare favorably with computed average velocities. The former were 6 and 3.5 miles per day from stations 42 and 45, respectively, and the corresponding computed values were approximately 5 and 3 miles per day for the trajectories.

5.3. Cruise III

In figure 8 are shown the stations occupied on the third cruise. Some of the planned stations were omitted because of inclement weather. In figure 8 are also shown the region within which stations lay from which recoveries were made and the general region of recovery. This region is comparable to that shown for cruise I (see Fig. 6) except that it is extended somewhat farther to the south. For the dynamic topography of the region during the time of release refer to figure 11.

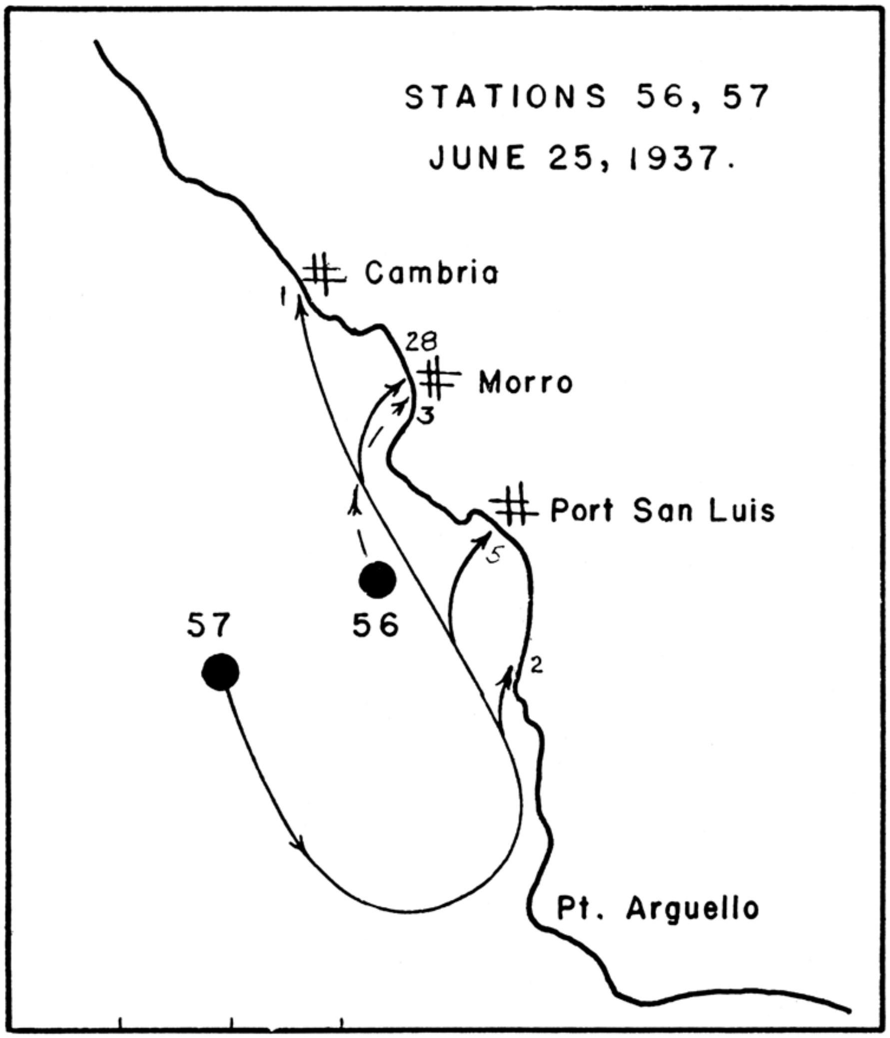


FIG. 17.

FIG. 17

5.3.1. Stations 56, 57

The value of the returns from these stations lies in that they confirm the dynamic computations. Station 57 is interesting because there was a 43 per cent recovery—36 bottles from the 83 released.

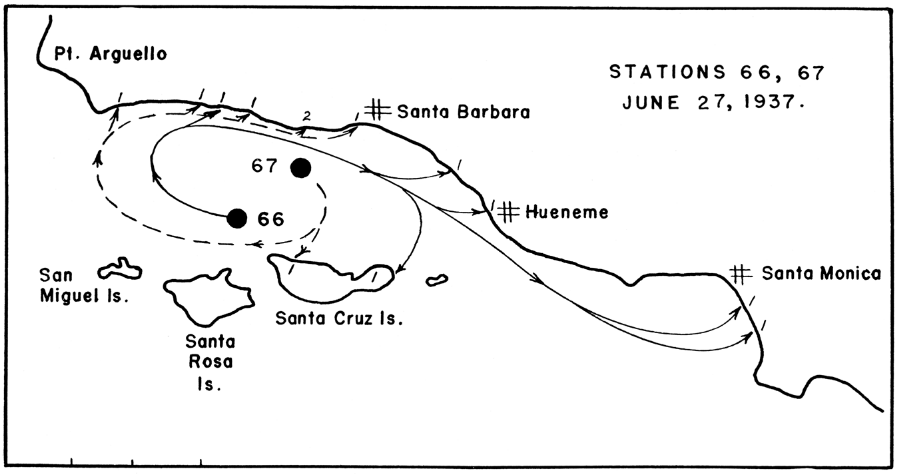


Fig. 18.

FIG. 18

5.3.2. Stations 66, 67

Figure 18 was drawn to indicate the most likely drift. It was not possible to give much weight to the time interval between release and recovery as the airline distance was short and the coast line relatively unfrequented.

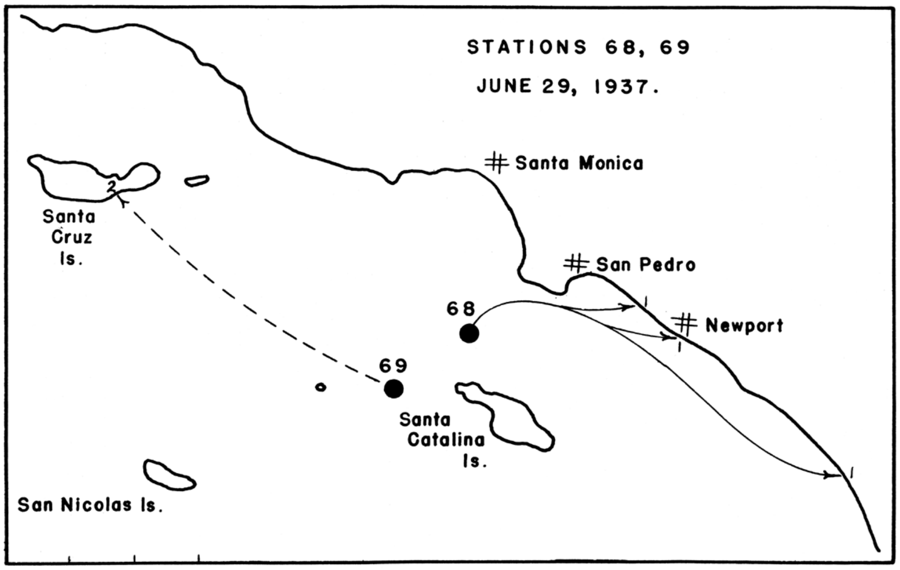


FIG. 19.

FIG. 19

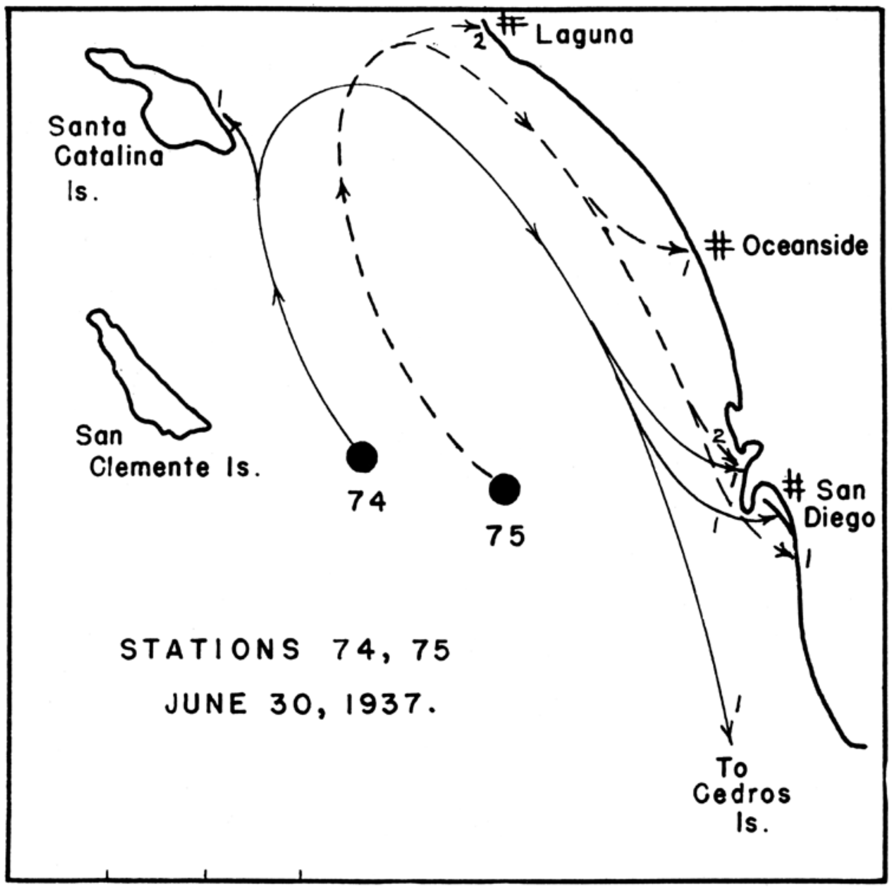


FIG. 20.

FIG. 20

5.3.3. Stations 68, 69, 74, 75

Stations 74 and 75 were located in the water flowing in from the south (the Southern California Counter-Current). This current turned in the Catalina Channel and ran south inshore (see Fig. 11). Short-time returns indicate a drift velocity of 5.7 and 4.8 miles per day from stations 74 and 75, respectively. Dynamic data are not available for the southerly part of the drift, but in the northerly leg of the journey the corresponding computed speeds were 7.8 and 5.2 miles per day. A single return that gave an observed velocity of 5.2 miles per day was one which was recovered on Cedros Island, Lower California. This bottle had traveled a distance of about 425 miles and the interval between release and recovery was 81 days. Although no hydrographic work has been done south of Ensenada, from what has been observed of currents in this region it is most probable that the bottle drifted directly down the coast, around the south shore of Sebastian Viscaino Bay, and washed ashore on the east side of Cedros Island, where it was recovered.

The returns from these two stations, together with that from station 69, establish trajectories of flow for the coastal waters below the Santa Barbara Islands and inshore.

5.3.4. Stations 76, 77

Returns from these two stations were very similar to those from stations 74 and 75, except that the observed drift velocities were somewhat less, being about 3.8 miles per day. The drift in figure 21 is based on an analysis of stations 69, 74 and 75 and on the dynamic topographic charts.

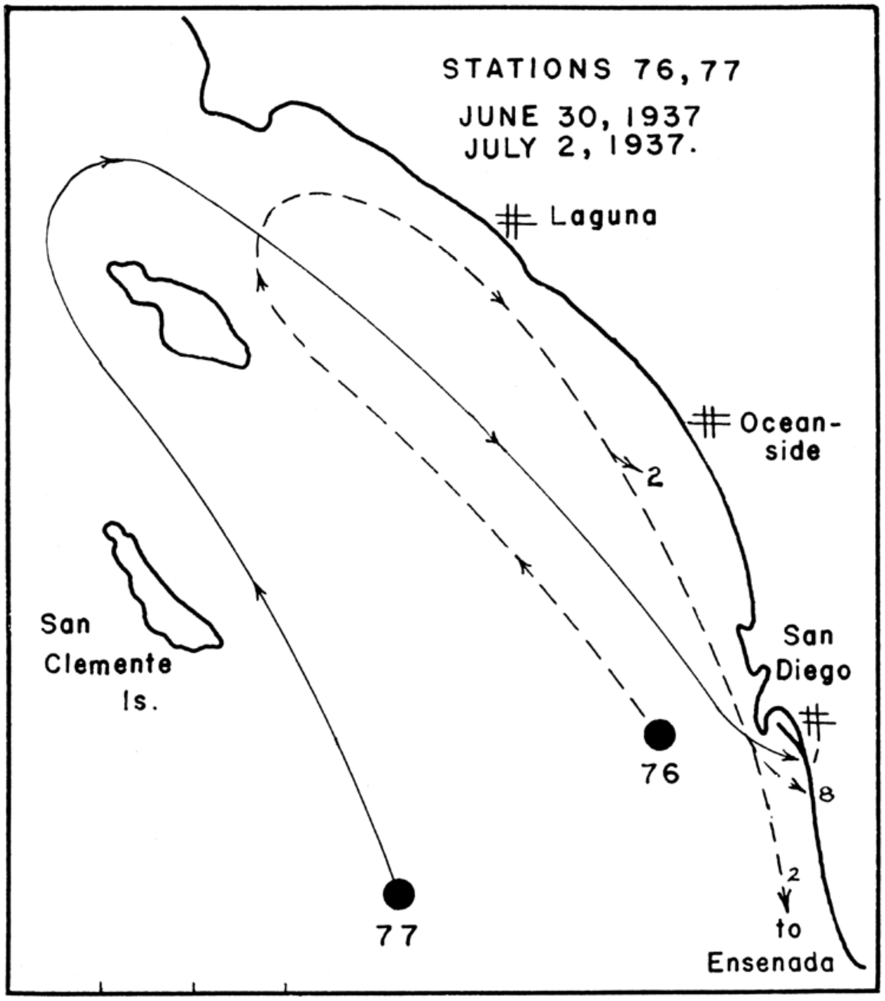


FIG. 21.

FIG. 21

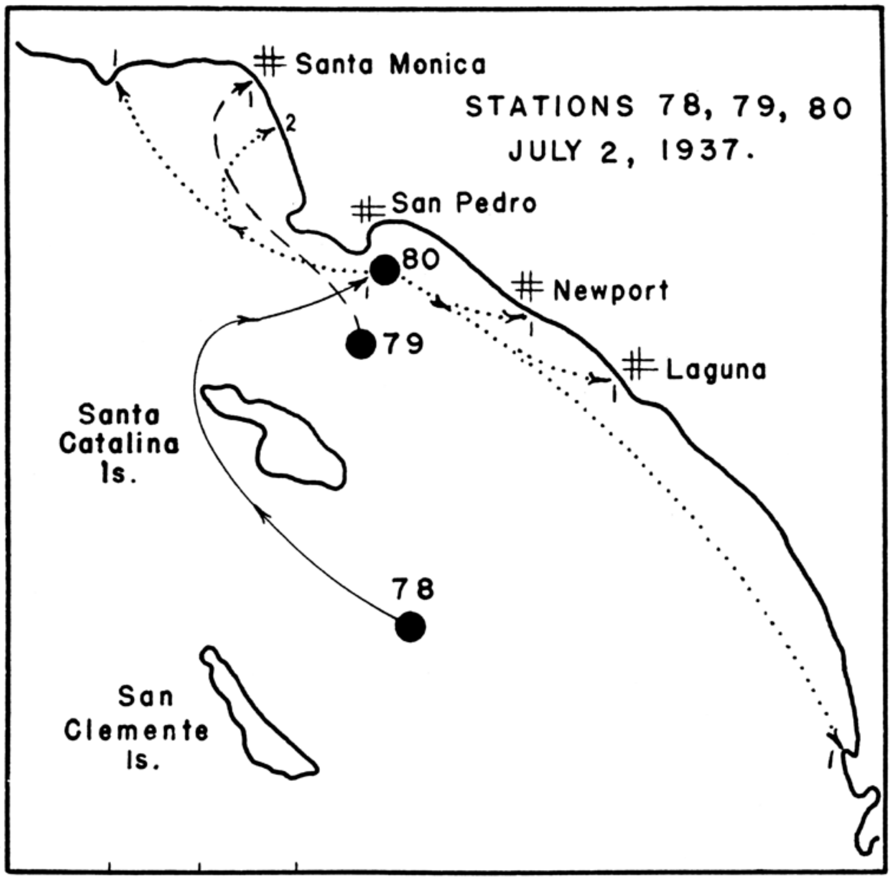


FIG. 22.

FIG. 22

5.3.5. Stations 78, 79, 80

Returns from these three stations are so irregular that it has been impossible to deduce their probable courses from release-recovery intervals. There is also considerable discrepancy between the supposed actual drift and the drift indicated by the dynamic topography. (See Fig. 11.) One return from station 80 recovered on San Nicolas Island can not be accounted for at all. Its drift was probably exceedingly erratic and can not be plotted with any assurance of accuracy.

6. DISCUSSION

The results of this investigation show that drift bottle methods are not the most practicable means of determining surface flow in the southern California region. This is due to two factors, first that the coast of Lower California, where many of the bottles probably came ashore, is largely uninhabited, and second that the nature of the circulation is such that bottles from possibly half of the region (see Figs. 6, 7 and 8) would not come ashore at all, at least not along the immediate coast. Out of a total of 5943 bottles released, only 185 have been recovered (3.2 per cent). It is believed that about half of the bottles released drifted directly down the coast of Mexico and offshore and are now on their way across the Pacific Ocean, following roughly the path of the Northern Equatorial Currents. Some of these may perhaps be recovered on the other side of the Pacific or even in the Indian Ocean.

In preparing the charts showing the bottle drifts, the probable paths of drift were first laid out according to the flow shown on the charts of the dynamic topography. The paths were then checked in two ways, first by plotting trajectories from the six stations in which such trajectories were well defined, and second by comparing the drift velocities with those obtained from the dynamical computations. In all cases where the trajectories of the several groups of bottles were well marked, those trajectories were almost identical with the stream lines indicated on the topographical charts. This in itself is significant as it shows that the stream lines indicated on those charts are good representations of the actual *path of flow*, a conclusion that would not necessarily have been possible if the data from dynamic computations were the only ones available. While the drift velocities did not in every instance have the same values as the computed velocities, the discrepancies were small; in fact, the agreement between the two was remarkably good. In many of the short-time recovery analyses the observed drift was somewhat greater than that calculated for the path of flow along which the bottle traveled. The difference was not, however, large, and may be explained by the fact that the bottles, by the very nature of their construction, were affected somewhat by the wind. The following table shows some of the comparisons between observed and computed velocities:

Station	Maximum observed velocity (miles per day)	Approximate computed velocity (miles per day)
1	10.0	5.0
12	7.5	6.0
	4.3	6.0
	5.0	6.0
	4.5	6.0
15	5.4	6.0
42	6.0	5.0
45	3.5	3.0
74	5.7	7.8
75	4.8	5.2
Average	5.67	5.60

TABLE

With the exception of station 12, in all cases where the observed was less than the computed velocity, at least part of the drift was against the wind. This shows again the influence of wind, and, when this effect is taken into consideration, confirms further the agreement between the results of the drift methods and those of the dynamic computations. A rather large discrepancy may be noted in station 1. However, the value given for the computed velocity is applicable only to the northern half of the drift of this bottle and no current data are available for the southern 200 miles of its journey.

A reasonably adequate surface-flow diagram could have been constructed from the drift bottle returns alone, but only for the first and third trips and only within the restricted area lying between Santa Cruz Island and San Diego and well inside San Nicolas Island. This area includes approximately one-half of the region of maximum sardine spawning and one-fourth of the region of the hydrographic survey. The main value of the drift bottles lay in confirming in some detail the results of the dynamic computations of the Scripps Institution.

Figures 9, 10 and 11, showing the computed surface flow, are very suggestive when considered in connection with the sardine spawning problem. During the period from March to July there was a progressive development of the Southern California Counter-Current, an offshore movement of the eastern boundary of the southerly offshore current, and a greatly increased velocity of flow in certain regions. The offshore movement referred to was associated with upwelling along the coast above Point Conception, and during the course of the southward flow of the offshore water and its return as the Southern California Counter-Current, mixing took place between it and the upwelled water. It is known that regions of upwelling are relatively rich in both phyto- and zoo-plankton by virtue of the nutrients that are brought to the surface. From this we may expect that the region to the south and inshore from Point Conception may prove to be an especially favorable area for the growth of large plankton populations which would, in turn, provide food in abundance for pelagic larval and young fish.

The pattern of flow is probably the result of the combined effects of the prevailing winds, the peculiar bottom configuration off the coast and the sudden cutting in of the coast line at Point Conception.

It is possible, with the data now available, to explain something of the method of transport of sardine larvae and young fish to the so-called "nursery grounds." Very small sardines of the current year's spawning (5 to 10 cm., standard length) are to be found largely in shallow water immediately adjacent to the coast from Point Conception south to Cape San Lucas. The larger part of the young fish are found from Point Conception to Turtle Bay, Lower California, which region probably constitutes the major nursery grounds. Within these grounds there are concentrations of small fish at several places, notably at Santa Monica Bay, along the Coronado Strand, at Ensenada Bay, San Quentin Bay, Sebastian Viscaino Bay (Cedros Island), and Turtle Bay. There are also a number of other points of lesser importance including the Channel Islands and most of the many small bays scattered along the west coast of Lower California.

We may deduce from the drift bottle returns and from the dynamic computations that objects at or near the surface from somewhat less than half of the region of maximum spawning will eventually be carried inshore to the coast of southern California below Point Conception, and south and inshore along the coast of Lower California at least as far as Sebastian Viscaino Bay. This drift corresponds to what has been considered that of the sardine larvae and young fish to the nursery grounds. There has been in the past considerable speculation as to the method of transport of the larvae. Scofield (1934), referring to the circulation as shown on the U. S. Hydrographic office charts, makes this statement: “"From these current data it would appear that the eggs deposited well off Point Conception in the California current would be swept to the south and southwest and eventually lost in the broad expanse of the Pacific. Data secured by the author on the localities of larvae apparently disprove this theory. One alternative is that these tiny larvae are capable of movement as a result of their swimming ability. It has been shown that the larvae move from the spawning ground to the southeast and inshore. This movement takes place within the upper 25 fathoms of water, for numerous vertical hauls revealed that the larvae occur in greatest quantities above this depth. The U. S. Hydrographic office bases its current results on data collected by vessels as recorded from their daily set. This, of course, represents surface drift. Such drift oftentimes extends down as deep as 400 meters. But south of Point Conception we may have a subsurface drift quite different from that at the surface. It may be possible that this subsurface drift is only a few meters down. South of Point Conception the sloping front of the continental shelf extends well out into the edge of the California current. North of Point Conception the front of the shelf sinks rather abruptly. Here the lower edge of the shelf, or the 1000-fathom line, lies within five or six miles of land; whereas to the south this line extends out as far as 150 miles. This rather marked change in bottom contour from the north to the south might result in peculiar subsurface drifts of which we know nothing at the present time. It may be such a subsurface drift that is taking these larvae from the spawning grounds to the southeast and inshore. This larval movement, then, may not be the result of free swimming."”

Such conclusions regarding the circulation were the only ones possible with the data then available; nothing was known of conditions below the surface and the charts of surface flow were inadequate for interpreting the drift of eggs and larvae and young fish. However, the results of the present hydrographic survey show clearly that subsurface circulation at 100 meters followed closely the surface drift throughout the period from March to July, 1937. As the larvae are not found in any numbers below about 50 meters even during the day (they have a diurnal migration) the surface circulation may be taken as representing the drift of the larvae. This being the case the developing larvae from about half of the region of maximum spawning would be transported inshore along the entire coast from Point Conception south at least to Sebastian Viscaino Bay.

The outer part of the region of maximum spawning presents yet another problem since conditions west of Point Conception are quite different from what they are farther inshore. In the March drift bottle experiment, a group of bottles was released 15 miles off Port San Luis and about 30 miles northwest of Point Conception (station 1). of these bottles one was recovered at Guadalupe Island, some 145 miles off the coast of Lower California and about 280 miles south of San Diego. This indicates that any larvae from west of Point Conception would have been carried directly down the coast and offshore. Although no detailed surface-flow data are available for the region south of

San Diego there is no reason to assume that the water of which this southerly offshore current (the California Current) is composed would go anywhere except directly down the coast. It will be seen from figures 9, 10 and 11 that the California Current is not at all the well-defined body of water that has previously been supposed. The term has been rather loosely used to include all the southerly offshore currents. During March and April the eastern (inshore) boundary of the part of this southerly current that continues its flow down the coast without turning back lay close in above Point Conception, and it was in this part of the California Current that the drift bottle from Station 1 was carried. During May and June the boundary probably moved offshore some 40 or 50 miles.

There are three possible fates for fish larvae that are found within this California Current to the west of the portion that turns north as the Southern California Counter-Current:

1. They are carried south and offshore and are lost,

2. Conditions to the south of Guadalupe Island are such that there is a definite inshore set to the California Current, and

3. The larvae metamorphose during their period of southerly drift and make their own way inshore off Lower California.

Both the second and the third of these possibilities seem most unlikely. Both eggs and larvae have been found some distance to sea, but in only relatively small numbers. The reason for this scarcity is not at present apparent. It is not a question of temperature alone since temperature conditions are as favorable for spawning within the California Current as they are inshore (Tibby, 1937), and it is probably not directly one of salinity (Clark, 1934). The implication of these data and those from the hydrographic survey is that local or widespread yearly variation in either temperature or salinity are not of any great importance in determining the distribution of spawning or the survival of young fish *except in so far as they are indicative of changes in the general pattern of circulation* and the associated phenomena of upwelling and abundance of planktonic food organisms. One other consideration that must be included is that the yearly variation in the character of the California Current and especially in the limits of its inshore boundary must be of great importance in determining the success or failure of any given year-class.

No adequate conclusion can be made at present as to the relative importance of these factors; more data must be available. It will most likely be found that there is a definite correlation between the physical factors of circulation, upwelling and mixing, the development of large populations of phyto- and zoo-plankton, and the success of spawning and the survival of young fish. What natural factors govern abundance and survival it is not now possible to state, since no correlative data are available on physical conditions, plankton and sardine eggs and larvae. Already, however, from the results of this work, the movements of larvae and young fish to the "nursery grounds" have been explained. Intensive, complete and concurrent studies on physical and chemical conditions, on phyto- and zoo-plankton, and on abundance and distribution of eggs, larvae and young sardines, will go far toward explaining and perhaps predicting the relative survival of young sardines from year to year and the abundance of fish that will be available for the commercial fisheries.

7. SUMMARY

1. The surface circulation of the ocean in the area between Port San Luis and San Diego and approximately 150 miles to sea for the period, March to July, 1937, was established by means of drift bottles and a hydrographic survey.

2. Twelve-ounce wine bottles, corked and sealed with marine glue, were used. These bottles were so weighted with sand that one or two inches of the neck protruded above the surface. Each bottle carried instructions and a postal card to be returned by the finder.

3. Three cruises were made, approximately 2000 bottles being released on each cruise. Out of a total of 5943 bottles released, 185 (3.2 per cent) were recovered.

4. Analysis of recoveries showed that surface circulation over only a limited area could be demonstrated by drift bottles alone.

5. Because of the nature of the circulation and the character of the coast line the percentage of recoveries was small, and it is shown that drift bottles are not an adequate means of charting surface flow over the entire region of maximum spawning of the sardine, but that they are an invaluable check on the dynamic computations, and that they made possible some conclusions pertaining to the drift of larvae and young fish that could not have been obtained from the dynamic computations alone.

6. Sardine larvae and young fish if spawned inside the California Current will be carried to the nursery grounds along the coast of southern and Lower California. The fate of those spawned within the California Current is not completely clarified by the study.

7. The yearly variations in the California Current may have profound influences on the survival of sardine spawn.

8. LITERATURE CITED

Clark, Frances N. 1934. Maturity of the California sardine (Sardina caerulea), determined by ova diameter measurements. California. Division of Fish and Game. Fish Bulletin, no. 42, 49 pp.

England. Ministry of Agriculture and Fisheries. 1931. Drift bottles. England. Ministry of Agriculture and Fisheries. Fisheries Notice, no. 16, 24 pp.

Godsil, H. C. 1930. A discussion of the localities in which the California sardine (Sardina caerulea) was taken in the San Diego region, 1928–1929. California. Division of Fish and Game. Fish Bulletin, no. 25, pp. 40–44.

Lewis, Ralph C. 1929. The food habits of the California sardine in relation to the seasonal distribution of the microplankton. Scripps Institution of Oceanography. Bulletin, tech. ser., vol. 2, no. 3, pp. 155–180.

McEwen, George F. 1932. A summary of basic principles underlying modern methods of dynamical oceanography. *In* Physics of the earth—V. Oceanography. National Research Council. Bulletin, no. 85, pp. 310–357.

Schmidt, Johannes 1913. Experiments with drift-bottles. (First report.) Danish Oceanographical Expeditions 1908–10 to the Mediterranean and Adjacent Seas. Report, no. 2, vol. 3, 13 pp.

Scofield, Eugene C. 1934. Early life history of the California sardine (Sardina caerulea), with special reference to distribution of eggs and larvae. California. Division of Fish and Game. Fish Bulletin, no. 41, 48 pp.

Smith, Edward H. 1926. A practical method for determining ocean currents. U. S. Coast Guard. Bulletin, no. 14, 50 pp.

Sverdrup, H. U. 1938. On the process of upwelling. Journal of Marine Research, vol. 1, 1937–38, no. 2, pp. 155–164.

Sverdrup, H. U., and Fleming, Richard H. The waters off the coast of southern California, March to July, 1937. Scripps Institution of Oceanography. Bulletin, tech. ser.; *submitted for publication*.

Tait, John B. 1930–37. The surface water drift in the northern and middle areas of the North Sea and in the Faroe-Shetland Channel. Scotland. Fishery Board. Scientific Investigations, 1930, no. 2, 4; 1931, no. 3; 1937, no. 1.

Tibby, Richard B. 1937. Drift bottles released off coast of southern California. Science, vol. 86, no. 2232, pp. 328–329.

1937. The relation between surface water temperature and the distribution of spawn of the California sardine, Sardinops caerulea. California Fish and Game, vol. 23, pp. 132–137.

TABLE 1

RECORD OF LIBERATIONS AND RECOVERIES OF DRIFT BOTTLES, 1937

Liberations					Recoveries			
Station	Date	Position		Serial No. of bottles released	Serial No. of bottles recovered	Place of recovery	Date	Number of days drift
		Latitude	Longitude					
1	3/25	35° 00′ N.	120° 59′ W.	1– 84	84	Guadalupe Island, Lower California	5/3	39
2	3/26	34° 52′ N.	121° 14′ W.	85– 165	None			
3	3/26	34° 44′ N.	121° 29′ W.	166– 249	None			
4	3/26	34° 25′ N.	121° 58′ W.	250– 333	None			
5	3/26	34° 08′ N.	122° 29′ W.	334– 417	None			
6	3/27	33° 25′ N.	122° 11′ W.	418– 501	None			
7	3/27	33° 01′ N.	121° 52′ W.	502– 585	None			
8	3/27	33° 15′ N.	121° 23′ W.	586– 668	None			
9	3/27	33° 25′ N.	120° 55′ W.	669– 751	None			
10	3/28	33° 37′ N.	120° 26′ W.	752– 831	None			
11	3/29	34° 07′ N.	120° 06′ W.	832– 912	888	Del Rey Beach	4/27	29
					895	Dana Point	5/11	43
12	3/29	34° 16′ N.	119° 51′ W.	913– 995	913	Venice	4/20	22
					920	El Segundo	4/17	19
					923	Venice	4/19	21
					924	Between El Segundo and Manhattan	4/18	20
					928	Point Hueneme	4/ 3	5
					929	Point Hueneme	4/ 3	5
					937	Dana Strand	5/ 2	34
					949	Santa Margarita River, near Oceanside	5/15	47
					952	Santa Monica	4/21	23
					954	Point Mugu Fish Camp	4/ 3	5
					957	Point Hueneme	4/ 2	4
					958	Salt Creek Camp, North of Dana Point	4/25	27
					965	Dana Point Strand	5/16	48
					966	Point Hueneme Light	4/ 2	4
					968	Sunset Beach	4/17	19
					969	El Segundo	4/20	22
					971	Del Rey Beach	4/23	25
					973	Playa Del Rey Lagoon	4/25	27
					977	Crystal Pier, Santa Monica	4/20	22
					978	Manhattan Beach	4/20	22
					983	Las Flores Canyon, west of Santa Monica	4/13	15
13	3/31	33° 34′ N.	118° 32′ W.	996–1079	1027	Coronado	4/24	24
					1041	Imperial Beach	4/25	25
14	3/31	33° 26′ N.	118° 46′ W.	1080–1135 1248–1275	1267	Capistrano Beach	5/ 6	36
15	3/31	33° 17′ N.	119° 01′ W.	1136–1219	1172	Santa Cruz Island	4/20	20
					1174	Carpinteria	5/23	53
					1180	Rosarito Beach, Lower California	5/ 7	37
					1189	Huntington Beach	4/23	23
16	3/31	33° 09′ N.	119° 20′ W.	1220–1247 1276–1331	None			
17	4/ 1	32° 51′ N.	119° 44′ W.	1332–1415	None			
18	4/ 1	32° 34′ N.	120° 13′ W.	1416–1499	None			
19	4/ 1	32° 16′ N.	120° 43′ W.	1500–1569	None			
20	4/ 1	32° 02′ N.	121° 11′ W.	1570–1637	None			
21	4/ 1	31° 55′ N.	120° 00′ W.	1638–1692	None			
22	4/ 2	31° 51′ N.	118° 58′ W.	1693–1748	None			
23	4/ 2	32° 05′ N.	118° 18′ W.	1749–1804	None			
24	4/ 2	32° 17′ N.	117° 50′ W.	1805–1860	None			
25	4/ 2	32° 22′ N.	117° 34′ W.	1861–1916	None			
26	4/ 4	33° 05′ N.	118° 20′ W.	1917–1944	None			
27	4/ 4	33° 27′ N.	118° 18′ W.	1945–1972	1959	Mission Beach	4/28	24
28	4/ 4	33° 34′ N.	118° 16′ W.	1973–2000	1979	Carlsbad	5/ 5	31
					1986	Oceanside	5/ 1	27
					1988	Oceanside	4/28	24
29	4/ 9	33° 42′ N.	118° 10′ W.	2003–2028	2003	Huntington Beach	8/23	136
					2007	Long Beach	4/19	10
					2008	San Clemente Beach	5/16	37
					2009	False return		
					2010	Sunset Beach	4/15	6
					2013	Long Beach Breakwater	4/ 9	1
					2014	Long Beach Breakwater	4/11	2
					2017	Long Beach	4/15	6
					2020	Sunset Beach	4/20	11
					2023	Long Beach	4/16	7
					2024	Seal Beach Pier	4/15	6
					2026	Laguna Beach	5/22	43

TABLE 1

RECORD OF LIBERATIONS AND RECOVERIES OF DRIFT BOTTLES, 1937

TABLE 1—Continued

RECORD OF LIBERATIONS AND RECOVERIES OF DRIFT BOTTLES, 1937

Liberations					Recoveries			
Station	Date	Position: Latitude	Position: Longitude	Serial No. of bottles released	Serial No. of bottles recovered	Place of recovery	Date	Number of days drift
30	4/ 9	33° 41′ N.	118° 14′ W.	2029–2084	2036	Sunset Beach	5/ 2	23
					2039	Bet. Newport and Laguna	9/20	164
					2040	Point Fermin	4/27	18
					2042	White's Point	5/10	31
					2046	Dana Point Strand	5/ 9	30
					2047	Ocean Park	5/12	33
					2048	Seal Beach	5/16	37
					2051	Sunset Beach	5/ 2	23
					2056	Pt. Vincente Light	4/18	9
					2057	Capistrano Beach	5/29	50
					2059	Newport Harbor	8/20	133
					2063	Sunset Beach	4/29	20
					2065	Newport	4/25	16
					2071	Seal Beach	5/ 4	25
					2077	Long Beach	10/24	198
					2079	Laguna Beach	5/23	44
31	5/ 5	35° 04′ N.	120° 55′ W.	2085–2168	None			
32	5/ 5	34° 56′ N.	121° 10′ W.	2169–2252	None			
33	5/ 6	34° 30′ N.	121° 55′ W.	2253–2336	None			
34	5/ 6	34° 11′ N.	122° 24′ W.	2337–2420	None			
35	5/ 7	33° 54′ N.	122° 54′ W.	2421–2504	None			
36	5/ 7	33° 00′ N.	122° 12′ W.	2505–2588	None			
37	5/ 7	33° 19′ N.	121° 33′ W.	2589–2672	None			
38	5/ 7	33° 34′ N.	121° 05′ W.	2701–2784	None			
39	5/ 8	33° 52′ N.	120° 35′ W.	2785–2868	None			
40	5/ 8	34° 10′ N.	120° 03′ W.	2869–2952	2878	Goleta Beach	6/17	40
					2880	15 mi. W. of Santa Barbara	6/13	36
					2887	Santa Barbara Light	5/18	10
					2888	Goleta	5/29	21
					2892	Carpinteria	6/18	41
					2930	18 mi. W. of Santa Barbara	5/22	14
					2945	El Capitan Resort, nr. Goleta	5/22	14
41	5/ 8	34° 19′ N.	119° 46′ W.	2953–3036	2967	Hueneme Light	6/14	37
42	5/10	33° 34′ N.	118° 31′ W.	3037–3120	3063	Terminal Island	5/24	14
					3066	Huntington Beach	5/20	10
					3072	Long Beach	5/23	13
					3073	Long Beach	6/ 2	23
					3077	Huntington Beach	5/26	16
					3089	Terminal Island	5/24	14
					3102	Long Beach	5/17	7
					3108	Long Beach	5/23	13
					3115	Sunset Beach	5/15	5
					3118	Long Beach	5/15	5
43	5/10	33° 25′ N.	118° 46′ W.	3121–3204	None			
44	5/11	33° 17′ N.	119° 01′ W.	3205–3288	None			
45	5/11	33° 13′ N.	119° 12′ W.	3289–3372	3339	Venice	6/ 6	26
46	5/11	32° 50′ N.	119° 46′ W.	3373–3456	None			
47	5/12	32° 33′ N.	120° 15′ W.	3457–3540	None			
48	5/12	32° 08′ N.	121° 00′ W.	3541–3624	None			
49	5/12	31° 10′ N.	119° 55′ W.	3625–3680	None			
50	5/13	31° 28′ N.	119° 26′ W.	3681–3736	None			
51	5/13	31° 47′ N.	118° 52′ W.	3737–3792	None			
52	5/13	32° 04′ N.	118° 27′ W.	3793–3848	None			
53	5/13	32° 20′ N.	117° 58′ W.	3849–3904	None			
54	5/13	32° 24′ N.	117° 30′ W.	3905–3960	None			
55	5/13	32° 28′ N.	117° 30′ W.	3961–4016	None			
56	6/25	35° 04′ N.	120° 55′ W.	2673–2700 4017–4072	2685	Morro Rock	6/29	4
					2692	Morro Rock	12/13	5½ months
					4063	Morro Rock	7/25	30
57	6/25	34° 55′ N.	121° 10′ W.	4073–4156	4074	Morro Rock	7/ 7	12
					4076	Estero Bay, above Morro Rock	7/10	15
					4079	Morro Bay	7/ 1	6
					4084	15 miles south of Pismo Beach	8/ 4	40
					4086	Morro Rock	12/23	6 months
					4087	Morro Bay	7/21	26
					4088	Morro Rock	7/ 7	12
					4089	Morro Rock	7/ 3	8
					4091	Morro Rock	7/ 7	12
					4094	Morro Rock	6/29	4
					4095	Oceano Beach	7/10	15
					4096	Morro Rock	12/13	5½ months

TABLE 1
RECORD OF LIBERATIONS AND RECOVERIES OF DRIFT BOTTLES, 1937

TABLE 1—Continued

RECORD OF LIBERATIONS AND RECOVERIES OF DRIFT BOTTLES, 1937

Liberations					Recoveries			
Station	Date	Position: Latitude	Position: Longitude	Serial No. of bottles released	Serial No. of bottles recovered	Place of recovery	Date	Number of days drift
					4098	Cambria	7/22	27
					4103	Morro Rock	7/ 2	7
					4108	Morro Rock	7/ 1	6
					4116	Morro Bay	7/ 4	9
					4119	Morro Rock	7/ 7	12
					4122	Pismo Beach	7/12	17
					4123	Morro Rock	7/ 7	12
					4126	Morro Rock	7/ 5	10
					4129	Morro Rock	7/ 2	7
					4130	Morro Rock	7/ 7	12
					4133	Morro Bay	7/ 4	9
					4134	Morro Beach	6/30	5
					4135	Pismo Beach	7/ 9	14
					4136	Morro Bay	8/19	55
					4137	Pismo Beach	7/ 7	12
					4142	Oceano Beach	7/ 9	14
					4143	Morro Rock	7/ 5	10
					4144	Morro Rock	7/ 7	12
					4145	Morro Bay	7/ 4	9
					4147	Morro Bay	7/15	20
					4150	Mussel Rock Beach, Guadalupe	7/13	18
					4151	Morro Bay	7/ 5	10
					4152	Morro Rock	6/29	4
					4153	Morro Rock	7/ 4	9
58	6/25	34° 47′ N.	121° 25′ W.	4157–4240	None			
59	6/25	34° 30′ N.	121° 55′ W.	4241–4324	None			
60	6/26	34° 08′ N.	122° 26′ W.	4325–4380	None			
61	6/26	33° 50′ N.	122° 54′ W.	4381–4436	None			
62	6/26	33° 03′ N.	122° 02′ W.	4437–4520	None			
63	6/26	33° 17′ N.	121° 31′ W.	4521–4604	None			
64	6/27	33° 34′ N.	121° 02′ W.	4605–4688	None			
65	6/27	33° 50′ N.	120° 31′ W.	4689–4772	None			
66	6/27	34° 10′ N.	120° 02′ W.	4773–4856	4775	Smuggler's Cove, Santa Cruz Island	7/31	34
					4805	Ventura	7/26	29
					4826	Hueneme Beach	7/14	17
					4834	Manhattan Beach	7/16	19
					4836	Del Rey Pier	7/15	18
					4848	Refugio Beach	8/15	49
67	6/27	34° 17′ N.	119° 50′ W.	4857–4940	4874	Carpinteria	7/13	16
					4879	San Augustin, near Pt. Conception	8/26	60
					4914	17 miles west of Santa Barbara	7/24	27
					4926	16 miles west of Goleta	7/31	34
					4928	Near Goleta	7/11	14
					4936	Ladies Harbor, Santa Cruz Island	7/21	24
					4940	Tecolote Beach, Goleta	7/13	16
68	6/29	33° 35′ N.	118° 31′ W.	4941–5024	4975	Corona Del Mar	7/22	23
					4993	Sunset Beach	7/ 8	9
					5006	Carlsbad	7/16	17
69	6/29	33° 26′ N.	118° 47′ W.	5025–5108	5076	Albert's Anch., Santa Cruz Island	7/ 9	10
					5095	Albert's Anch., Santa Cruz Island	7/ 6	7
70	6/30	33° 17′ N.	118° 58′ W.	5109–5192	None			
71	6/30	33° 08′ N.	119° 24′ W.	5193–5276	None			
72	6/30	32° 52′ N.	119° 47′ W.	5277–5360	None			
73	6/30	32° 31′ N.	120° 17′ W.	5361–5432	None			
74	6/30	32° 46′ N.	118° 03′ W.	5433–5498	5455	Cedros Island, Lower California	9/19	81
					5466	Coronado	8/25	56
					5467	Mission Beach	8/20	51
					5474	Avalon, Catalina Island	7/25	25
75	6/30	32° 44′ N.	117° 45′ W.	5568–5639	5570	Mission Beach	7/31	31
					5572	Imperial Beach	8/ 2	33
					5590	Oceanside	7/31	31
					5592	Laguna	8/16	47
					5622	Laguna	8/23	54
					5636	Pacific Beach	8/15	46

TABLE 1
RECORD OF LIBERATIONS AND RECOVERIES OF DRIFT BOTTLES, 1937

TABLE 1—Continued

RECORD OF LIBERATIONS AND RECOVERIES OF DRIFT BOTTLES, 1937

Liberations					Recoveries			
Station	Date	Position		Serial No. of bottles released	Serial No. of bottles recovered	Place of recovery	Date	Number of days drift
		Latitude	Longitude					
76	6/30	32° 41′ N.	117° 27′ W.	5712–5783	5735	Ensenada, LowerCalifornia	7/ 1	1
					5738	Imperial Beach	7/27	27
					5740	Five miles below California-Mexican border	7/17	17
					5747	Tijuana Slough	7/23	23
					5752	California-Mexican border	7/31	31
					5753	Ensenada, Lower California	8/15	46
					5759	Coronado	7/15	15
					5764	California-Mexican border	7/21	21
					5766	Coronado	7/17	17
					5771	Ten miles off Oceanside	7/ 8	8
					5772	Imperial City	7/18	18
					5778	Fourteen miles west southwest of Oceanside	7/ 6	6
77	7/ 2	32° 22′ N.	118° 00′ W.	5856–5927	5879	Imperial Beach	8/23	52
78	7/ 2	33° 07′ N.	118° 11′ W.	5784–5855	5839	Horseshoe Kelp, San Pedro	7/21	19
79	7/ 2	33° 28′ N.	118° 15′ W.	5640–5711	5695	Venice	9/ 6	66
80	7/ 2	33° 38′ N.	118° 15′ W.	5499–5567	5506	Laguna	7/22	20
					5512	Balboa Pier	7/21	19
					5513	La Jolla	9/ 4	64
					5523	Manhattan Beach	7/18	16
					5533	Pt. Dume	7/23	21
					5544	Manhattan Beach	7/29	27
					5550	San Nicolas Island	9/13	73
81	7/10	34° 00′ N.	118° 48′ W.	5928–5950	5929	Del Rey Beach	7/15	5
					5930	Malibu	7/11	1
					5932	Malibu	7/14	4
					5934	Santa Monica Canyon	7/14	4
					5936	Malibu	7/21	11
					5938	Malibu	7/11	1
					5939	Del Rey	7/15	5
					5940	Venice	7/16	6
					5941	Malibu	7/11	1
					5942	Del Rey Pier	7/15	5
					5943	Malibu	7/18	8
					5944	Del Rey	7/20	10
					5945	Malibu	7/11	1
					5946	Malibu	7/11	1

Nos. 575, 2075, 2076, 2687, 2697, 4779, 5634 not released—used for demonstration.

TABLE 1
RECORD OF LIBERATIONS AND RECOVERIES OF DRIFT BOTTLES, 1937

DIVISION OF FISH AND GAME OF CALIFORNIA
BUREAU OF MARINE FISHERIES
FISH BULLETINS

* No. 1. Report on Fish Conditions. 1913; 48 pp., 3 figs.

* No. 2. The Scientific Investigation of Marine Fisheries, as Related to the Work of the Fish and Game Commission in Southern California. By Will F. Thompson. 1919; 27 pp., 4 figs.

* No. 3. The Spawning of the Grunion (Leuresthes tenuis). By Will F. Thompson, assisted by Julia Bell Thompson. 1919; 29 pp., 9 figs.

* No. 4. The Edible Clams, Mussels and Scallops of California. By Frank W. Weymouth. 1921; 74 pp., 19 pls., 26 figs.

* No. 5. A Key to the Families of Marine Fishes of the West Coast. By Edwin C. Starks. 1921; 16 pp., 4 figs.

* No. 6. A History of California Shore Whaling. By Edwin C. Starks. 1922; 38 pp., 22 figs.

* No. 7. The Life History and Growth of the Pismo Clam. By Frank W. Weymouth. 1923; 120 pp., 15 figs., 18 graphs.

* No. 8. Racial and Seasonal Variation in the Pacific Herring, California Sardine and California Anchovy. By Carl L. Hubbs. 1925; 23 pp., 4 pls.

* No. 9. Preliminary Investigation of the Purse Seine Industry of Southern California. By Tage Skogsberg. 1925; 95 pp., 23 figs.

* No. 10. The Life History of Leuresthes tenuis, an Atherine Fish with Tide Controlled Spawning Habits. By Frances N. Clark. 1925; 51 pp. 6 graphs, 7 pls.

* No. 11. The California Sardine. By the Staff of the California State Fisheries Laboratory. 1926; 221 pp., 74 figs.

No. 12. The Weight-Length Relationship of the California Sardine (Sardina caerulea) at San Pedro. By Frances N. Clark. 1928; 58 pp., 11 figs.

No. 13. The Seasonal Average Length Trends at Monterey of the California Sardine (Sardina caerulea). By Carroll B. Andrews. 1928; 13 pp., 6 figs.

* No. 14. Report on the Seals and Sea Lions of California. By Paul Bonnot. 1928; 61 pp., 38 figs.

* No. 15. The Commercial Fish Catch of California for the years 1926 and 1927. By the Bureau of Commercial Fisheries. 1929; 94 pp., 52 figs.

No. 16. The Life-History of the California Jack Smelt (Atherinopsis californiensis.) By Frances N. Clark. 1929; 22 pp., 12 figs.

* No. 17. Sacramento-San Joaquin Salmon (Oncorhynchus tschawytscha) Fishery of California. By G. H. Clark. 1929; 73 pp., 32 figs.

* No. 18. The Pismo Clam: Further Studies of its Life History and Depletion. By William C. Herrington. 1930; 67 pp., 16 figs.

* No. 19. Sardine Fishing Methods at Monterey, California. By W. L. Scofield. 1929; 61 pp., 27 figs.

* No. 20. The Commercial Fish Catch of California for the Year 1928. By the Staff of the Bureau of Commercial Fisheries. 1930; 109 pp., 62 figs.

* No. 21. Analysis of Boat Catches of White Sea Bass (Cynoscion nobilis) at San Pedro, California. By S. S. Whitehead. 1930; 26 pp., 20 figs.

* No. 22. A Bibliography of the Tunas. By Genevieve Corwin. 1930; 103 pp.

No. 23. Success of the Purse Seine Boat in the Sardine Fishery at Monterey, California (1929–1930 Fishing Season). By J. B. Phillips. 1930; 28 pp., 19 figs.

No. 24. An Analysis of the Catch Statistics of the Striped Bass (Roccus lineatus) Fishery of California. By J. A. Craig. 1930; 41 pp., 22 figs.

* No. 25. Fishing Areas Along the California Coast for the Sardine (Sardina caerulea). By the California State Fisheries Laboratory. 1930; 44 pp., 25 figs.

No. 26. Seasonal Changes in the Daily Average Length of the California Sardine (Sardina caerulea). By Frances N. Clark. 1930; 22 pp., 11 figs.

* No. 27. The Ring Net, Half Ring Net, or Purse Lampara in the Fisheries of California. By Donald H. Fry, Jr. 1930; 65 pp., 28 figs.

No. 28. Handbook of Common Commercial and Game Fishes of California. By Lionel A. Walford. 1931; 183 pp., 137 figs.

* No. 29. The Striped Bass of California. By Eugene C. Scofield. 1931; 82 pp., 46 figs.

* No. 30. The Commercial Fish Catch of California for the Year 1929. By the Staff of the Bureau of Commercial Fisheries. 1931; 133 pp., 75 figs.

No. 31. Studies of the Length Frequencies of the California Sardine (Sardina caerulea). By the California State Fisheries Laboratory. 1931; 53 pp., 24 figs.

* No. 32. The California Halibut (Paralichthys californicus) and an Analysis of the Boat Catches. By G. H. Clark. 1931; 52 pp., 25 figs.

* No. 33. Fishing Methods for the Bluefin Tuna (Thunnus thynnus) and an Analysis of the Catches. By S. S. Whitehead. 1931; 32 pp., 22 figs.

No. 34. Salmon of the Klamath River, California. By John O. Snyder. 1931; 130 pp. 44 figs.

* No. 35. A Distributional List of the Species of Fresh Water Fishes Known to Occur in California. By Barton W. Evermann and Howard Walton Clark. 1931; 67 pp.

No. 36. A Bibliography of the Sardines. By Genevieve C. Wheeler. 1931; 133 pp.

No. 37. The California Barracuda (Sphyraena argentea). By Lionel A. Walford. 1932; 120 pp., 32 figs., 6 pls.

No. 38. The California Shrimp Industry. By Paul Bonnot. 1932; 20 pp., 11 figs.

No. 39. Fluctuations in the Abundance of Striped Bass (Roccus lineatus) in California. By G. H. Clark. 1933; 18 pp., 7 figs.

No. 40. The California Mackerel Fishery. By Richard S. Croker. 1933; 149 pp., 73 figs.

No. 41. Early Life History of the California Sardine (Sardina caerulea), with Special Reference to Distribution of Eggs and Larvae. By Eugene C. Scofield. 1934; 48 pp., 24 figs.

No. 42. Maturity of the California Sardine (Sardina caerulea), Determined by Ova Diameter Measurements. By Frances N. Clark. 1934; 49 pp., 19 figs.

No. 43. The Sizes of California Sardines Caught by the Different Fishing Gear and in the Different Localities of the Monterey and San Pedro Regions. By the California State Fisheries Laboratory. 1935; 59 pp., 27 figs.

No. 44. The Commercial Fish Catch of California for the Years 1930–1934, inclusive. By the Staff of the Bureau of Commercial Fisheries. 1935; 124 pp., 19 figs.

No. 45. The Sharks and Rays of California. By Lionel A. Walford. 1935; 66 pp., 58 figs.

No. 46. A contribution toward the Life Histories of Two California Shrimps, Crago franciscorum (Stimpson) and Crago nigricauda (Stimpson). By Hugh R. Israel. 1935; 28 pp., 9 figs.

No. 47. Interseasonal and Intraseasonal Changes in Size of the California Sardine (Sardinops caerulea). By Frances N. Clark. 1936; 28 pp., 11 figs.

No. 48. Fishing Localities for the California Sardine, Sardinops caerulea, 1928–1936. By Frances N. Clark. 1937; 11 pp., 5 figs.

No. 49. The Commercial Fish Catch of California for the Year 1935. By the Bureau of Commercial Fisheries. 1937; 170 pp., 114 figs.

No. 50. Sizes of California Sardines Caught in the Different Areas of the Monterey and San Pedro Regions. By J. B. Phillips. 1937; 31 pp., 12 figs.

No. 51. The High Seas Tuna Fishery of California. By H. C. Godsil. 1938; 41 pp., 20 figs.

No. 52. Historical Account of the Los Angeles Mackerel Fishery. By Richard S. Croker. 1938; 62 pp., 37 figs.

No. 53. Measures of Abundance of the Sardine, Sardinops caerulea, in California Waters. By Frances N. Clark. 1939; 45 pp., 19 figs.

No. 54. The Fishes of the Family Sciaenidae (Croakers) of California. By Tage Skogsberg. 1939.

No. 55. Report on Returns of Drift Bottles Released off Southern California, 1937. By Richard B. Tibby. 1939; 36 pp., 22 figs.

* Out of print.

These bulletins are offered free of charge in exchange for the publications of other bodies engaged in marine research and to other interested persons at a nominal cost. Address: California State Fisheries Laboratory, Terminal Island, California.