Surface Currents as Determined by Drift Card Releases Over the Continental Shelf Off Central and Southern California

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ABSTRACT

During March 1964 through February 1966, 8,320 plastic drift cards were released at selected points from an aircraft to measure surface current drift over two areas: from the coast to about 48 n.mi. off central California between Point Arena and Point Sur; and from the coast to about 90 n.mi. off southern California between Point Arguello and Punta Salsipuedes, Baja California, Mexico. The recovery rate was 3.5% in the central area and 5.7% in the southern area. An average 79.4% of the recoveries were found within 2 wk following the date of release. Results lend support to studies concluded by earlier investigators. The distribution of the directions from which drift cards were returned increased the evidence for the presence of an eddy off the coast between San Francisco and Monterey Bay during May through July, and of the large gyre and associated southern California countercurrent south of Point Conception during April through August and to a lesser extent in October and December.

INTRODUCTION

Dispersal and survival of the planktonic eggs and larvae of marine fishes in the ocean euphotic zone is affected by surface currents. The purpose of this study was to develop additional information on the drift patterns to which surface planktonic forms are subjected over the continental shelf of the west coast of the United States. The general direction of surface drift was determined and is compared with wind velocity during the survey period to expose any general relationship between wind direction and inshore surface currents. Johnson and Squire (1970) published the results found along the northwestern coast of the United States. This paper covers the central area from Point Arena to Point Sur, Calif., and the southern area from Point Arguello, Calif., to Punta Salsipuedes, Baja California, Mexico.

Field work for the study was carried out concurrently with an airborne infrared sea surface temperature survey of the continental shelf conducted with the cooperation of the U.S. Coast Guard (Squire 1971).

Increased interest in coastal surface currents as they may pertain to the drift of surface pollutants, such as petroleum, has prompted the documentation of this drift study.

METHODS

Talbot (1964) showed that specially prepared drift bottles could be successfully dropped from an aircraft; however, drift cards were chosen for this study due to the ease of handling and the limited space available in the aircraft. The individual drift cards are identical to those described by Johnson and Squire (1970) and were a 4 × 5¼-in, numbered, postage paid, self-addressed, fluorescent red postcard. A plain fluorescent red card was used as backing, and both were sealed in a clear plastic envelope with a steel washer as ballast. This study was conducted from March 1964 through February 1966, during which period 16 drift card releases were made off southern California and central California. From March 1964 through February 1965, airborne releases of drift cards were made once each 3 mo. Beginning in March 1965 and continuing until the end of the study, the frequency of drift card releases increased to one per month. Ten cards were released at each drop station.

The U.S. Coast Guard aircraft were flown at an average altitude of 500 ft over a prescribed pattern covering the central area to about 48 n.mi. offshore and the southern area to about 90 n.mi. offshore. Twenty-five release stations were located on the flight transects over the central area, and 27 release stations over the southern area. Dead-reckoning techniques, aided by the aircraft's tacan, loran, and radar navigation equipment were used to locate release points.

For visual comparison of wind direction, average wind speed, and the direction of surface drift, a wind rose symbol developed by Tabata (1961) was used on each drift chart (Figs. 1, 2). The symbols give the percent frequencies for the prevailing winds and calms (wind velocity 1 kn) based on eight points of the compass and the average wind speed in knots for a 2-wk period—1 wk before release and 1 wk after (drift cards were released on the last day of the first week of the 2-wk period). Wind data were obtained for geographical locations as near the

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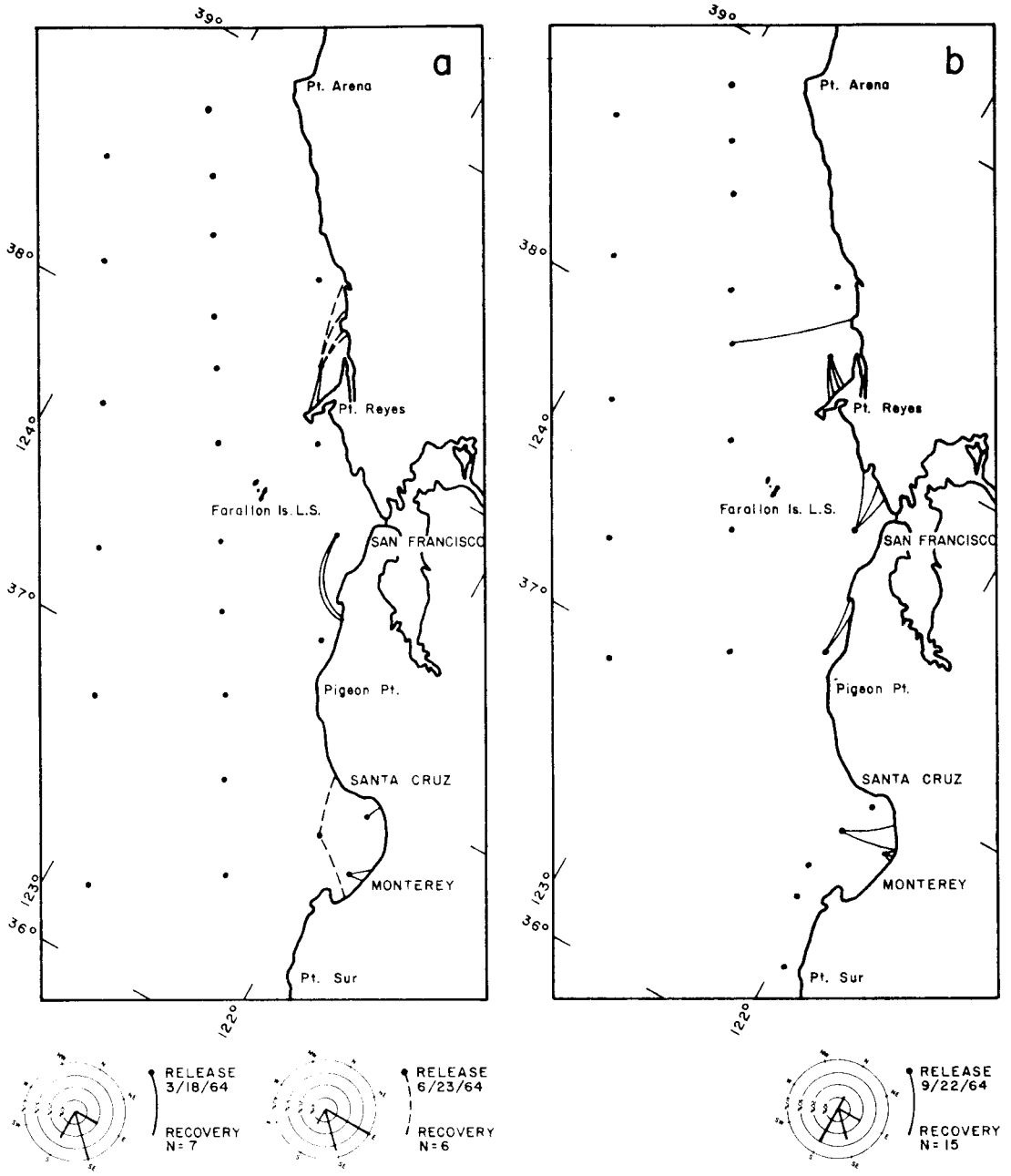
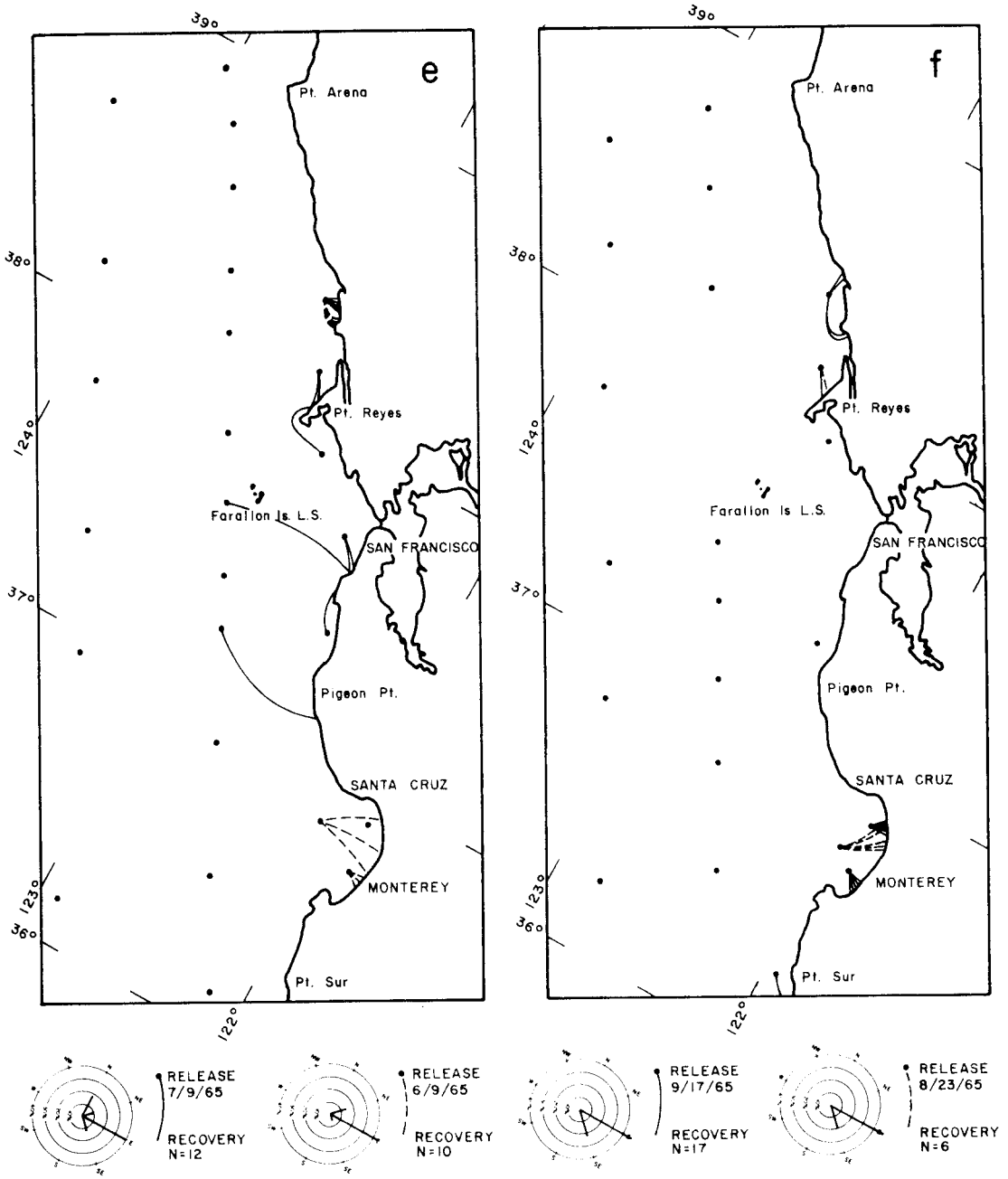


Figure 1.—Drift card release and recovery points off the central area of California: a) March and June 1964; b) September 1964; c) December 1964 and March 1965; d) April and May 1965; e) June and July 1965; f) August and September 1965; g) October and November 1965; h) December 1965 and February 1966.



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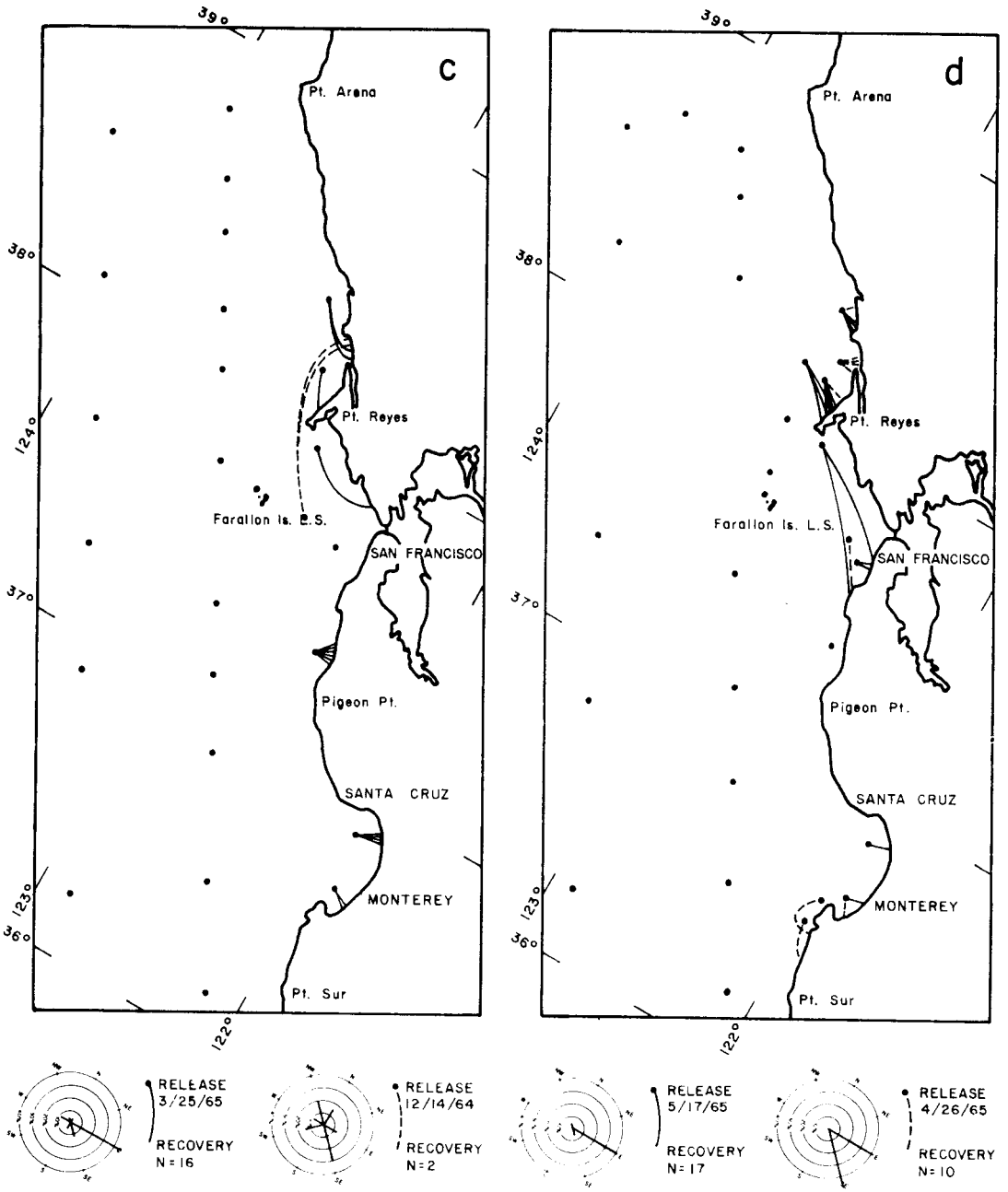

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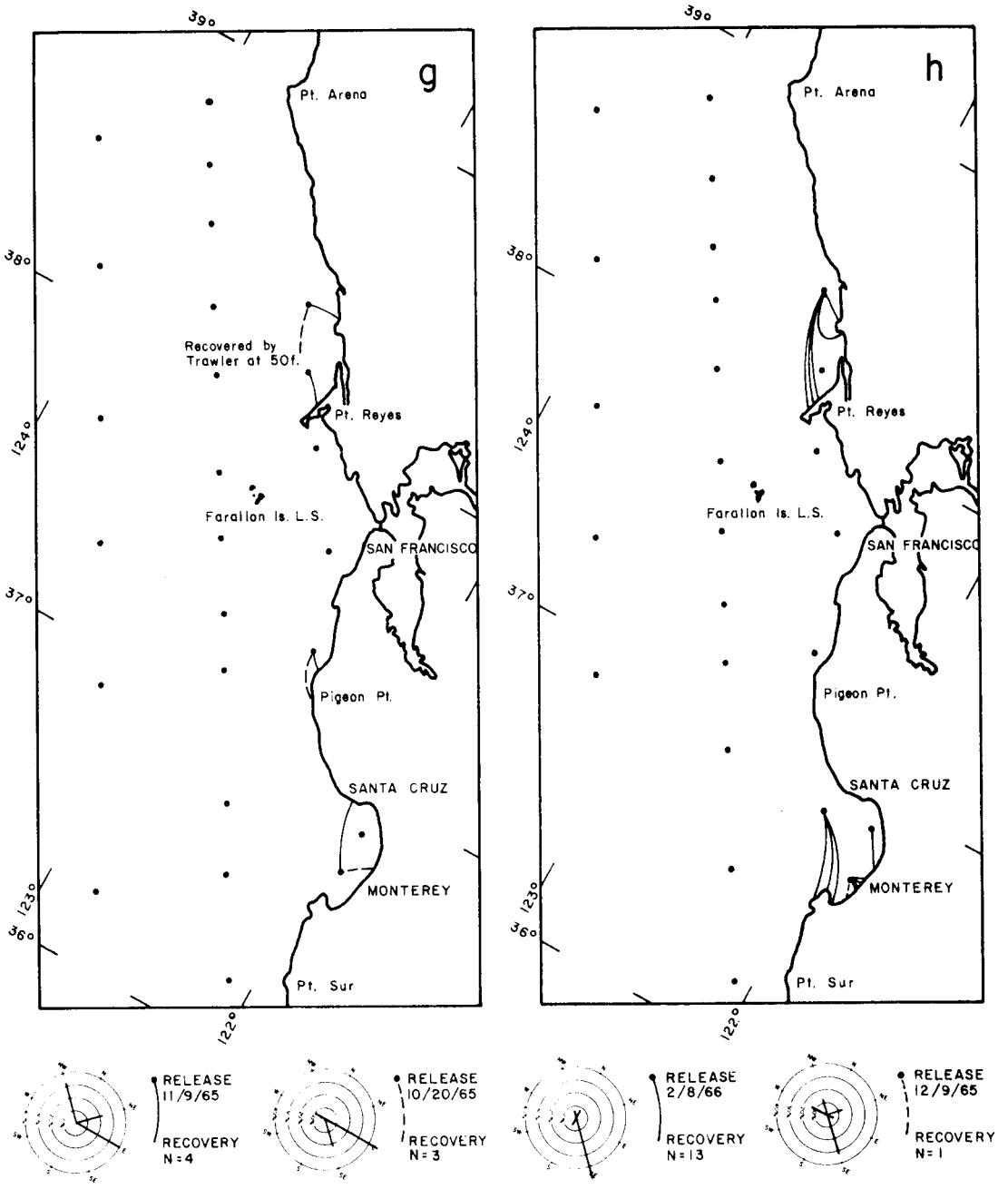

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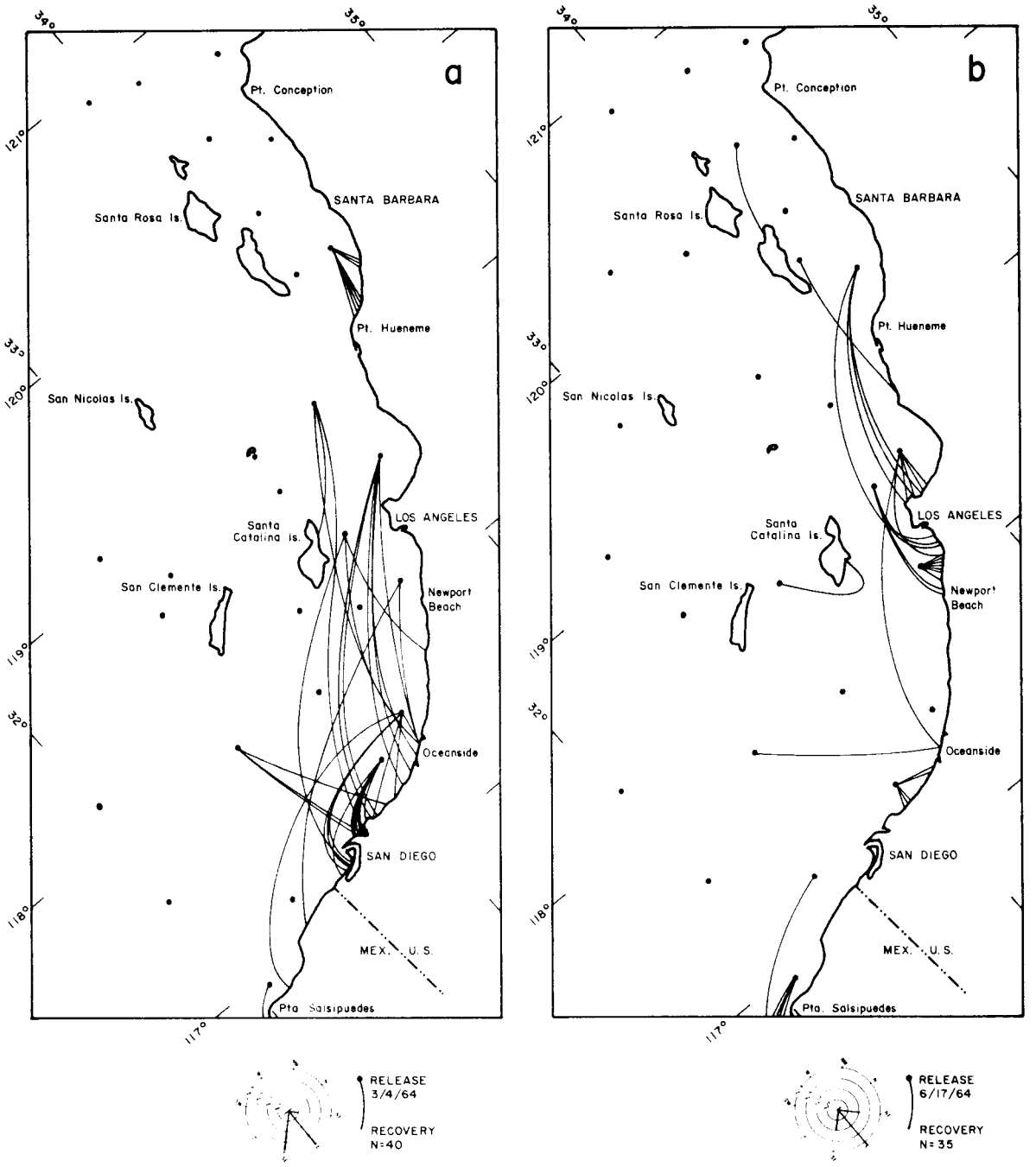
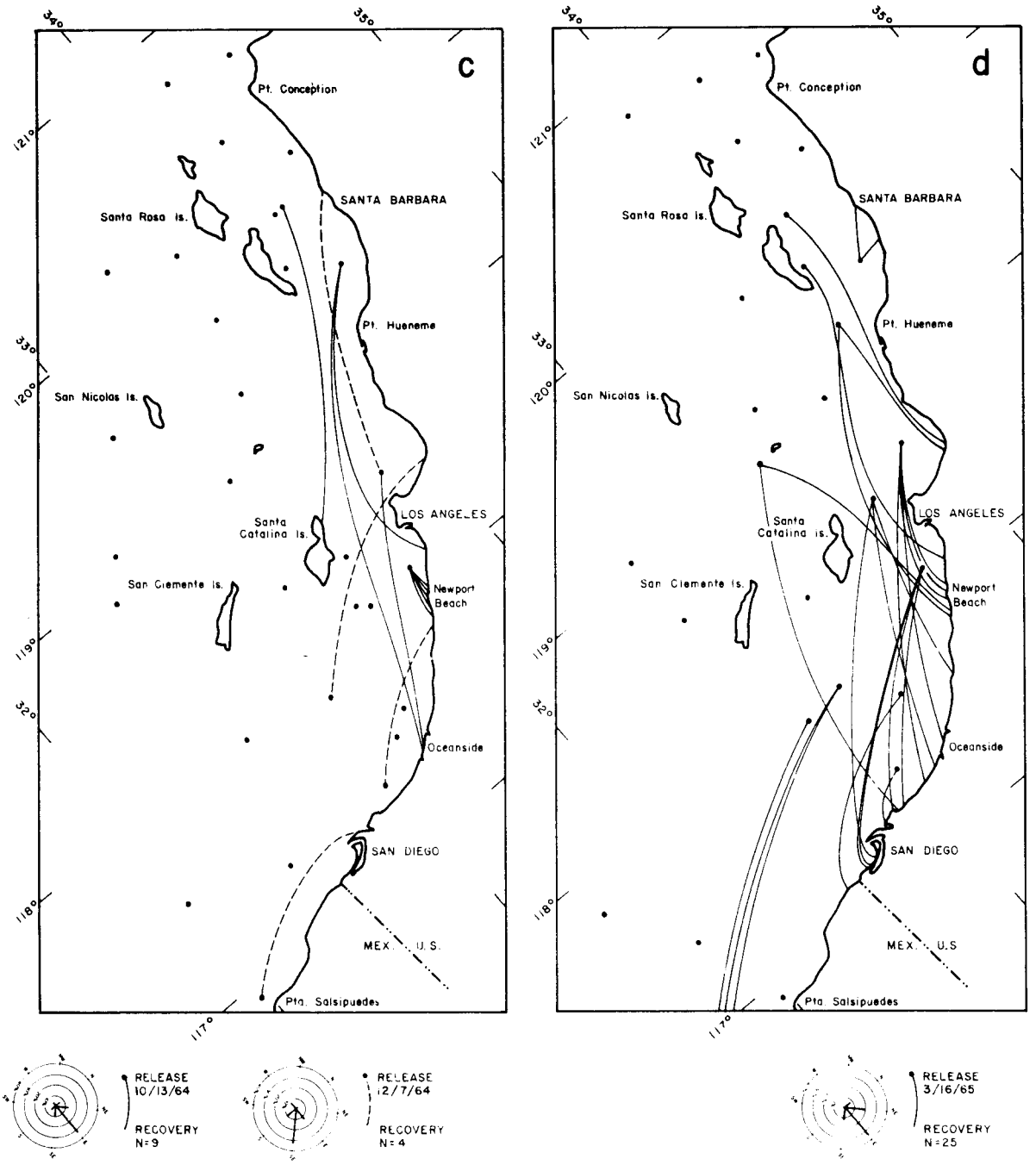


Figure 2.—Drift card release and recovery points off southern California: a) March 1964; b) June 1964; c) October and December 1964; d) March 1965; e) April 1965; f) May 1965; g) June 1965; i) August 1965; j) September and October 1965.



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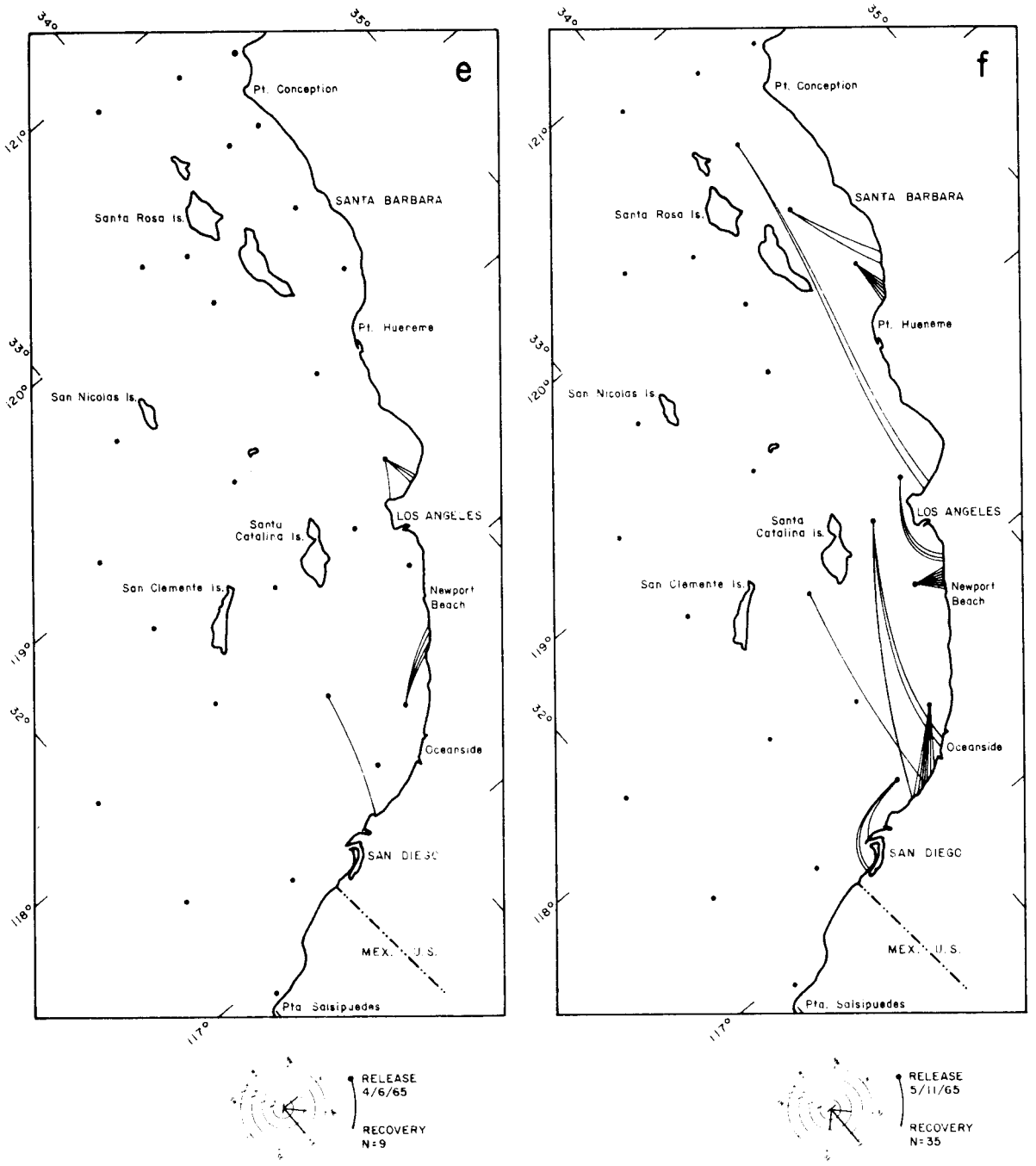

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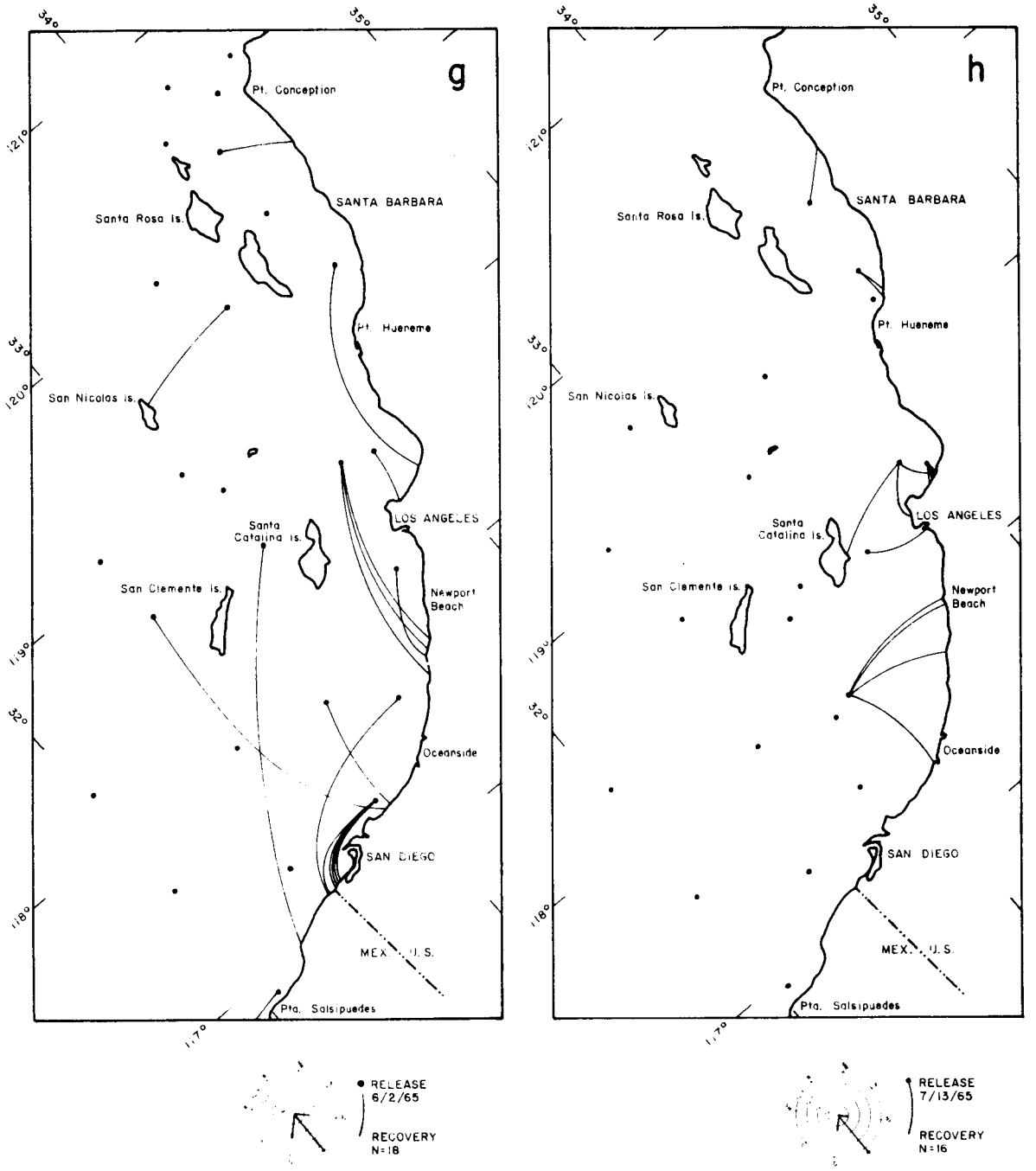

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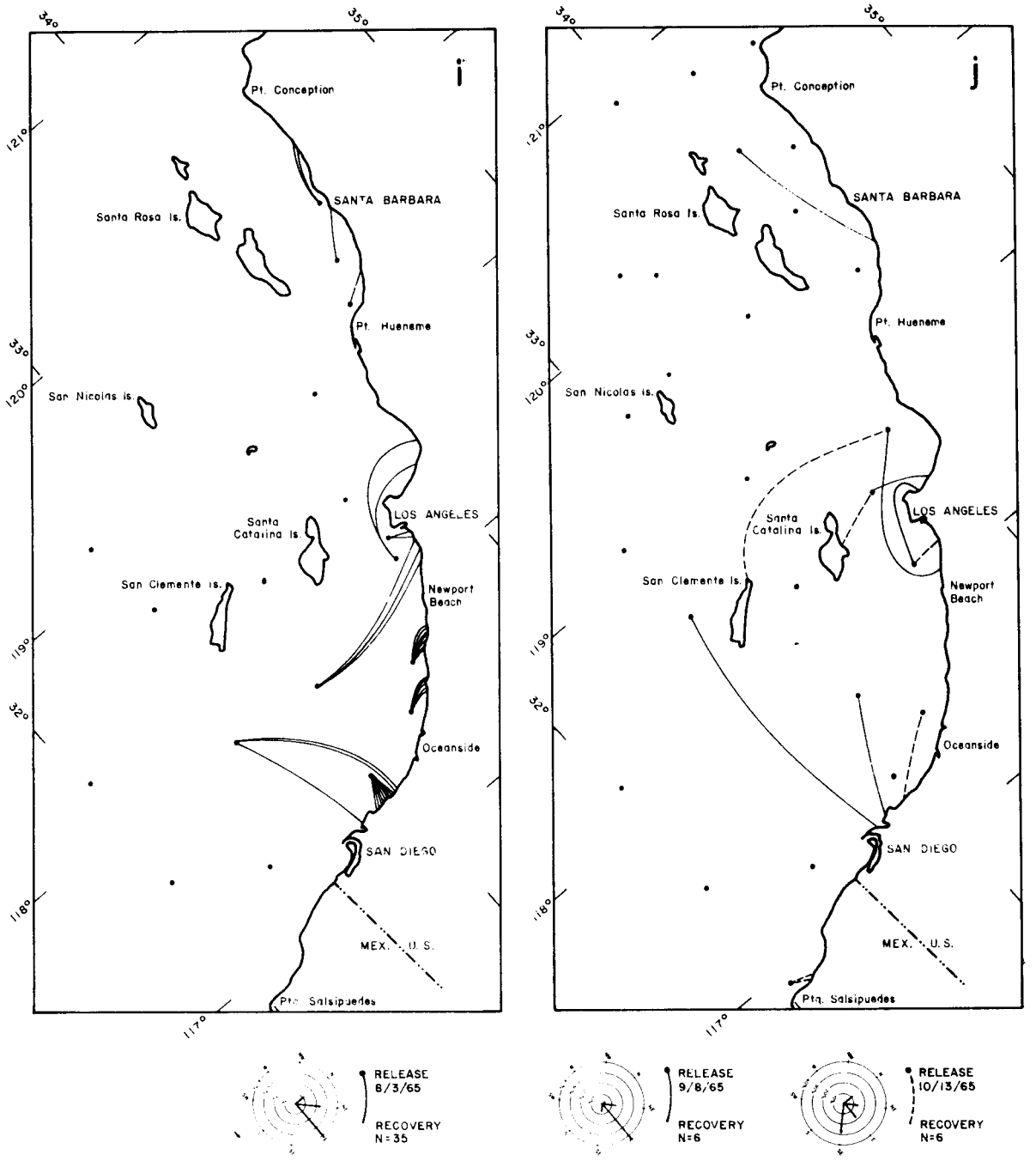

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center of each survey area as possible. Data for the central area was obtained for the U.S. Coast Guard Farallon Island Light Station, 28 mi west of the entrance to San Francisco Bay, and in the southern area for the U.S. Navy San Clemente Island Naval Air Station. These data were made available by the National Weather Records Center, Asheville, N.C.

RESULTS

Of the 8,320 cards released over both study areas, 4.5% (377) were recovered. This recovery rate compares closely with those found by previous investigators using drift bottles and drift cards along the west coast of the United States (Tibby 1939; Schwartzlose 1964) and near Hawaii (Barkley et al. 1964). In the central area, 3.5% of the cards were returned, whereas 5.7% of the cards were recovered in the southern area. An average 59.8% of all cards recovered were found within 1 wk following the date of release, and 79.4% were found within 2 wk. The percentage of recoveries made during the first week after the drop in the central area was 72.1%, and in the southern area 52.7%. By the end of 2 wk, the percentage of recoveries in the central area was 86.8% and in the southern area 75.1%.

Charts (Fig. 1a to 1h central area, Fig. 2a to 2j southern area) giving the date and location of release and recovery and the average wind velocity were prepared for each quarterly and monthly drifter releases. The average wind speed was derived by averaging all values recorded during the 2-wk period. The rate of drift and trajectory of the card cannot be determined from the recoveries because of the lack of information between time of release and recovery. Original data to determine the time between release and recovery is not available. No recoveries were made and no charts were drawn for southern area releases in November and December 1965 and January and February 1966; nor for the central area during January 1966.

DISCUSSION AND CONCLUSIONS

The patterns of current flow associated with the California Current along the North American west coast have been examined by a number of scientists (e.g., Tibby 1939; Sverdrup et al. 1942; Reid et al. 1958; Burt and Wyatt 1964; Schwartzlose 1964; Tully 1964). We would expect the surface drift in the nearshore areas generally to be in agreement with the findings of these scientists.

Drift card recovery rates probably bear a relationship to the amount of shore activity by people. Many areas of the coast in the central area are rocky and not easily accessible. This, and the fact that the coastal population is small, would account for reduced returns when compared with southern California. The southern California coast is easily accessible, except for the island areas, and there is a high population level along most of the coast and from this a higher recovery rate would be expected.

Most of the recoveries in the central area were from drop stations relatively close to shore. Only three recoveries were from the line of drop stations located about 25 mi offshore, and none were recovered from the outer line of stations, about 50 mi offshore.

Southern California recoveries were mostly from stations near the coast, between the coast and Catalina, and the Santa Barbara Channel Islands; few recoveries were from the offshore drop stations.

Drift cards recovered along the coasts of central and southern California gave evidence of some surface drift toward the east and/or southeast through most of the year. Only in December 1966 did neither area have at least one return from either direction. Five of the 15 mo in the central area and 6 of the 12 mo in the southern area had a significantly greater proportion of the recoveries from the east and/or southeast than from all other directions combined.

Off the central area, little evidence of a strong Davidson Current can be observed along the open coast during the late fall, winter, or early spring months [Fig. 1a, 1c (March), 1g (November), 1h (December, February)]. Only in December 1964 (Fig. 1c) does evidence of the coastal countercurrent exist, with recoveries from off Bodega Bay from drift cards dropped near the San Francisco light vessel. Schwartzlose (1964) had indications from his work that an eddy flowed counterclockwise during the summer between San Francisco and the north edge of Monterey Bay. In July 1965 (Fig. 1e), off Halfmoon Bay and south of Point Reyes, some of the recoveries indicated a northward flowing coastal current during this period. During the remainder of the year, most of the recoveries showed drift to the east and/or southeast.

In the southern area between Point Conception and northern Baja California, an average 69% of the drift cards recovered had moved in an east and/or southeast direction. These observations reflect the combined influence of northwest winds and the relatively permanent southerly flowing current reported by Schwartzlose (1964) off the southern California and Baja California coasts.

Evidence for the gyre south off southern California was found during the late spring and summer (Fig. 2b, 2e, 2h, 2i). Some of the returns from coastal areas were recovered northeast to northwest of release points and these recoveries were most evident along the coast from San Diego northward and offshore to the San Clemente and Catalina Islands and the Los Angeles area. During these months Tibby (1939) reported that south flowing offshore currents return along shore as the north flowing Southern California Countercurrent. Forty percent of the returns from the August 1965 (Fig. 2i) releases drifted north or northwest nearly 90° from the prevailing winds flowing toward the east-northeast. Returns from the December 1964 (Fig. 2c) drift cards lend support to the conclusion by Reid et al. (1958), that the northerly flowing countercurrent associated with the large eddy off southern California is present in some measure through the late fall and winter.

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LITERATURE CITED

BARKLEY, R. A., B. M. ITO, and R. P. BROWN.
1964. Releases and recoveries of drift bottles and cards in the central Pacific. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 492, 31 p.

BURT, W. V., and B. WYATT.
1964. Drift bottle observations of the Davidson Current off Oregon. *In* K. Yoshida (editor), Studies on oceanography, p. 156-165. Univ. Tokyo Press, Tokyo.

JOHNSON, S. I., and J. L. SQUIRE, JR.
1970. Surface currents as determined by drift card releases on the continental shelf off the northwestern United States. U.S. Fish Wildl. Serv., Tech. Pap. 48, 12 p.

REID, J. L., JR., G. I. RODEN, and J. G. WYLLIE.
1958. Studies of the California Current System. Calif. Coop. Oceanic Fish. Invest. Prog. Rep. 1 July 1956-1 January 1958, p. 27-56.

SCHWARTZLOSE, R. A.
1964. Nearshore currents of the western United States and Baja California as measured by drift bottles. Calif. Coop. Oceanic Fish. Invest. Rep. 9:15-22.

SQUIRE, J. L.
1971. Measurements of sea surface temperature on the eastern Pacific continental shelf using airborne infrared radiometry, August 1963-July 1968. U.S. Coast Guard Ocean. Rep. 47 (CG373-47), 229 p.

SVERDRUP, H. U., M. W. JOHNSON, and R. H. FLEMING.
1942. The oceans, their physics, chemistry and general biology. Prentice-Hall, Inc., Englewood Cliffs, N.J., 1087 p.

TABATA, S.
1961. Temporal changes of salinity, temperature and dissolved oxygen content of the water at Station "P" in the northeast Pacific Ocean and some of their determining factors. J. Fish. Res. Board Can. 18:1073-1174.

TALBOT, G. B.
1964. Drift bottle modifications for air drops. Trans. Am. Fish. Soc. 93:203-204.

TIBBY, R. B.
1939. Report on returns of drift bottles released off southern California, 1937. Calif. Dep. Fish Game, Fish Bull. 55, 36 p.

TULLY, J. P.
1964. Oceanographic regions and processes in the seasonal zone of the North Pacific Ocean. *In* K. Yoshida (editor), Studies on oceanography, p. 68-84. Univ. Tokyo Press, Tokyo.

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