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MISCELLANEOUS FIELD STUDIES
MAP MF – 333
SHEET 1 OF 2

DRIFT OF SURFACE AND NEAR-BOTTOM WATERS OF THE SAN FRANCISCO BAY SYSTEM, CALIFORNIA: MARCH 1970 THROUGH APRIL 1971

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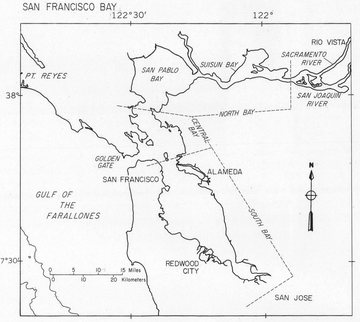
INTRODUCTION

The San Francisco Bay system [1/] is a complex estuary in which there is an interplay between natural chemical and physical processes, and changes resulting from the works of man. The bay is used for recreation, water-borne commerce, fishing, domestic and industrial waste disposal, and esthetic pleasure. Because some of these uses are competitive, it is desirable to adequately predict the impact of man's activities on this natural system. The reliability of such predictions will be strengthened by long-term observations directed toward understanding the natural processes occurring in the bay. This study is a compilation of one aspect of the U. S. Geological Survey's continuing investigations of the San Francisco bay system.

INDEX MAP
SAN FRANCISCO BAY



STUDY

This study presents a description of the seasonal changes in the water circulation within the San Francisco Bay system and the adjacent Pacific Ocean, observed from March 1970 to April 1971. Since March 1970, the Geological Survey has been releasing drifters every 2 months from a network of stations in San Francisco Bay and the Pacific Ocean (Conomos and others, 1970, fig. 1). The drifter used in this study (Woodhead and Lee, 1960) is a saucer-like plastic disc on a plastic stem that has a serial number, return address, and a statement of reward to be paid with the return of the serial number, and the date and place at which the drifter was found. A brass weight attached to each drifter carries it to the bottom where it is moved with the near-bottom water. Without the weight the drifter floats and indicates the movement of the surface water.

This report summarizes the movement of the drifters with a series of maps. Surface water drift has been observed only during two periods, but will be part of the ongoing study. Because these data are presented for the use of those interested in problems related to the patterns of water circulation, emphasis is placed upon data presentation rather than discussion of circulation mechanisms.

SEASONAL DRIFTER MOVEMENTS

Drifter release and recovery information is summarized on table 1. The recovery rate of bottom drifters, released approximately bimonthly (table 1), ranged from about 10 to 21 percent; the greatest recovery occurred during the winter months. The surface drifter releases, which were begun in December 1970, yielded higher recovery percentages (27 to 33 percent).

The principal directions of drifter movement are plotted on figures 1 through 8. The arrows are drawn from release points to recovery locations typical of that release point, and portray simplified paths of movement. Table 1 indicates the number of returns determining the drift arrows on each figure.

Near-bottom drifter movements on the continental shelf showed a pronounced eastward movement into the bay system for offshore releases less than 35 km from the Golden Gate. The eastward drift into the bay system persisted throughout the year.

Within the bay system, the drifter movements define three dominant flow patterns: (1) a permanent drift westward from Rio Vista to eastern San Pablo Bay; (2) a permanent drift eastward through the Golden Gate, with virtually all drifters turning north into San Pablo Bay; (3) a seasonally reversing drift in south bay, that is dominantly northward during summer and southward during winter.

Surface drifter movements on the continental shelf during the winter and spring months were characterized by a longshore pattern (>25 km from the Golden Gate) and a nearshore (<25 km from the Golden Gate) pattern. The offshore drift set northward during December–February (fig. 6) and was relatively well defined; during March–April 1971, however, the north and south components were relatively equal (fig. 8). The nearshore pattern was fanlike, radiating from the Golden Gate, but during both periods, the northward drift was dominant.

Within the bay system, the surface drift in the northern reaches was seaward from Rio Vista throughout the 4 months observed. During December–February 1971 (fig. 6), the south and central bay drift was northward and seaward through the Golden Gate; during March–April 1971, however, the northern part of south bay showed a northward drift, while the southern part of the south bay showed a southward drift (fig. 8).

Excluding several drifters which were released at the Golden Gate, no near-bottom drifter released within the bay system has ever been recovered on the ocean beaches; conversely, no surface drifter released seaward of the Golden Gate has been recovered within the bay system.

The average speeds of near-bottom drifter movements for the entire year are summarized according to dominant drift directions on table 2. Drift speeds averaged 2 km per day from Rio Vista to San Pablo Bay and 4 km per day from the Gulf of Farallones to San Pablo Bay. By contrast, the south bay drift speeds were only 1 km per day. Although there was a suggestion of greater speeds during the winter period, the present data are inadequate to quantify the changes of speed. Surface drift speeds appear to average in excess of 5 km per day during the 4-month period.

1/ In this report, we refer to three informal subdivisions of the San Francisco Bay system as the north, central, and south bays (index map).

Table 1.--Drifter release data[a]

Release information[b]			Recovery information[c]			
	Numbers released		Total recoveries		Percent recoveries	
Release dates	Bottom	Surface	Bottom	Surface	Bottom	Surface
5-6 March 1970	1475		311		21.1	
4-5 June 1970	1325		143		10.8	
27 July-3 August 1970	1275		130		10.2	
1-3 October 1970	1150		183		15.9	
21-23 December 1970	1200	1030	175	275	14.6	26.7
2-6 March 1971	1425	925	136[d]	309	9.5	33.4

[a]Compiled 25 April 1971
[b]Excluding Davenport and Farallon Islands stations
[c]Including only recoveries within 60 days of each release date
[d]Recoveries as of 25 April 1971

Table 2.--Comparison of net nontidal speeds of near-bottom water

Area	Representative Speeds (km per day)[a] Average	Range	Methods	Reference
San Francisco Bay			Drifters	This report
Rio Vista-San Pablo Bay	2	0.3-4.5		
Gulf of Farallones-San Pablo Bay	4	0.3-4.5		
South bay	1	0.25-1.2		
Nearshore measurements				
Middle Atlantic Continental Shelf	-	0.3-0.9	Drifters	Bumpus, 1965
Pacific Northwest Continental Shelf			Drifters	Gross and others, 1969
Toward Columbia estuary	1.4	--		
Toward Strait of Juan de Fuca	0.3	0.1-2.8		
Inner Continental Shelf	1.6	0.7-2.5		
California Continental Shelf			Drifters	Squire, 1969
Monterey Bay	-	0.07-0.8		
Inshore measurements				
James Estuary	6	--	Field Measurement	Pritchard, 1956
Silver Bay			Field Measurement	McAlister and others, 1959
Mid-depth, July	-	0.9-3.5		
Near-bottom, March	-	0.7-1.7		
Mersey estuary	7	--	Field Measurement	Bowden, 1960
East Sound[b]	6	--	Field Measurement	Rattray, 1967

[a]1 km per day = 1.2 cm per sec = 0.62 mi per day
[b]Wholly wind-induced near-bottom circulation

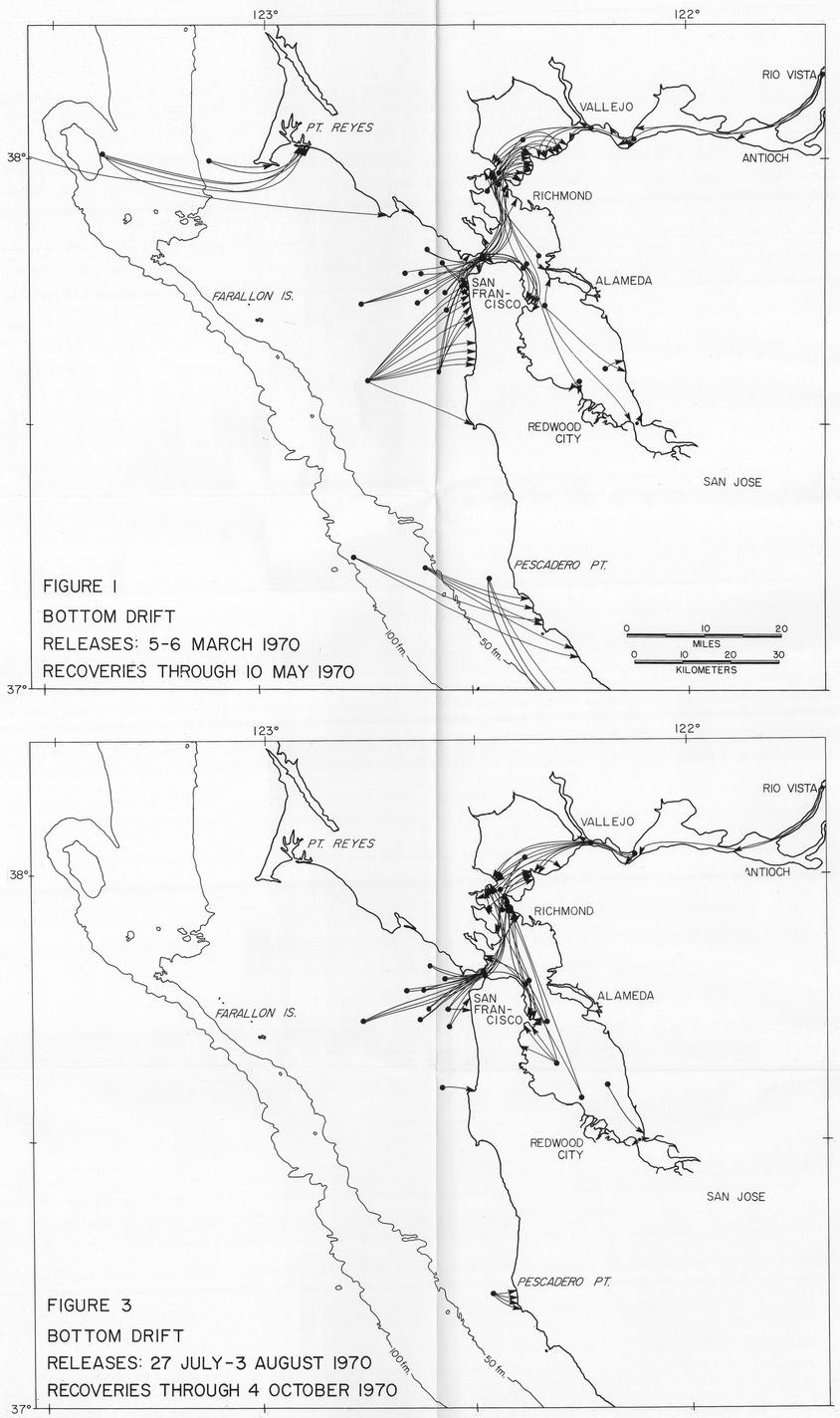


FIGURE 1
BOTTOM DRIFT
RELEASES: 5-6 MARCH 1970
RECOVERIES THROUGH 10 MAY 1970

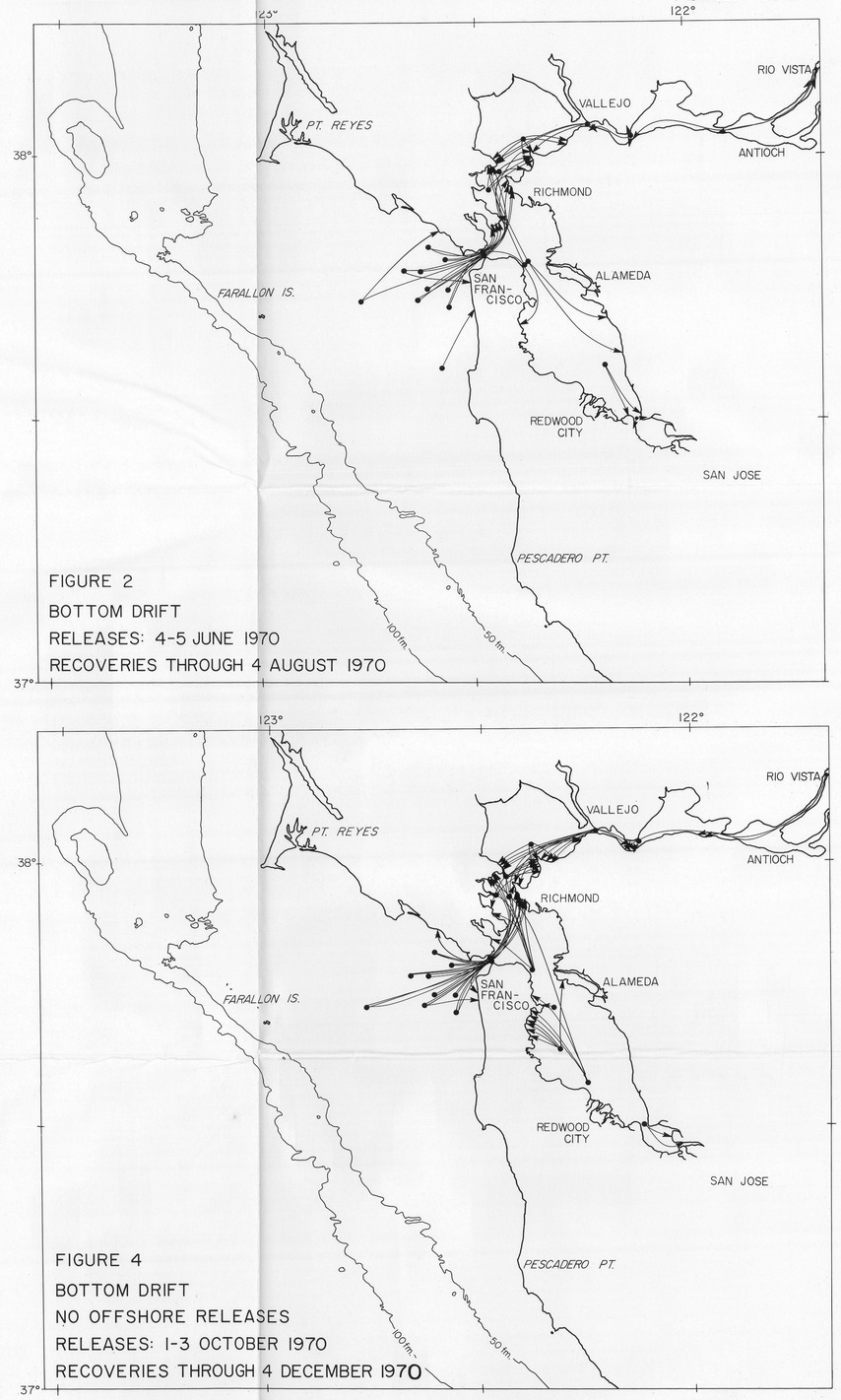


FIGURE 2
BOTTOM DRIFT
RELEASES: 4-5 JUNE 1970
RECOVERIES THROUGH 4 AUGUST 1970

FIGURE 3
BOTTOM DRIFT
RELEASES: 27 JULY-3 AUGUST 1970
RECOVERIES THROUGH 4 OCTOBER 1970

FIGURE 4
BOTTOM DRIFT
NO OFFSHORE RELEASES
RELEASES: 1-3 OCTOBER 1970
RECOVERIES THROUGH 4 DECEMBER 1970