UNITED STATES DEPARTMENT OF INTERIOR

GEOLOGICAL SURVEY

DISTRIBUTION OF MACROBENTHIC INFAUNA IN TIDAL FLAT DEPOSITS, WILLAPA, BAY, WASHINGTON - SUMMER, 1978

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INTRODUCTION

This paper reports observations made by the authors on macrobenthic infauna occurring in tidal flats in Willapa Bay, Washington during the summer of 1978. Features of the macrobenthic infauna observed include diversity, density, and distribution. These observations are part of a larger study of depositional processes and facies characteristics of modern estuarine deposits.

Geologists from the U. S. Geological Survey have been conducting studies of modern and ancient environments in or near Willapa Bay during the last several years. Results of these studies are reported in Clifton and others (1976), Clifton and Phillips (1978, 1980), Hill and Chin (1979, 1981), Anima (1979), Luepke and Clifton (1979), Hill (1980), and Chin and Hill (1982).

ENVIRONMENTAL SETTING

The following description of the study area is mainly a synthesis of information contained in Garrett and others (1962), Andrews (1965), Clifton and Phillips (1978), Anima (1979), and Hill (1980).

Willapa Bay, a coastal plains estuary, is located on the southwestern Washington coast approximately 47 km north of the Columbia River mouth (Fig. 1). The Bay is a complex estuary composed of three large and several small estuaries forming a water area of about 375 km^2. The single bay resulted from the formation of a 32 km long sand bar (North Beach Peninsula) extending northward from the mainland.

The Bay entrance is about 8 km across and generally obstructed by large sand shoals. Two main channels occur within Willapa Bay (Fig. 2). The south channel (Nahcotta), about 29 km long, is protected from open water by the North Beach Peninsula. The other channel runs east from the Bay mouth for approximately 19 km and is the mouth of the Willapa River, the largest tributary flowing into the bay. Water depths in the main channels vary from about 6 to 25 m; widths range approximately from 90 to 2200 m. Both channels show a somewhat sinuous configuration which is influenced by the tides.

Extensive tidal flats represent more than half the bay area, extending up to a kilometer offshore locally. Two main environments compose the tidal flats (Clifton and Phillips, 1980): (1) intertidal flats which are inundated by astronomical tides, and (2) supratidal flats which are inundated by a combination of astronomical and meteorlogical tides. Locally, salt marsh environments occur between intertidal and supratidal flats. Runoff channels cross the tidal flats. Sediments on the flats range from well sorted sand near the main channels to clay toward the upper reaches of the tide flats (Fig. 3). In the southern part of the Bay, tidal flats are muddier due to decreases in water circulation and well developed salt marshes. Sections of the north Bay also have dense vegetation on the flats.

The main controls over climate in the North Pacific are the semipermanent high and low pressure regions, terrain, and the ocean. During the summer, when a semipermanent high pressure cell predominates, air flow is northwesterly, cool, and relatively dry. In the winter, the Aleutian low pressure replaces the high. Air flow becomes southwesterly and brings moist air onshore. Willapa Bay experiences gale force winds during winter storms.

Mean annual precipitation is about 220 cm. Monthly precipitation is least in July/August (4 cm) and greatest in December (38 cm). However, only a few precipitation records are available for the basin with only rare records from higher elevations. The mean annual air temperature varies from approximately 11 ^{o}C (July) to 4.5 ^{o}C (January). Extreme temperatures are infrequent and of short duration; overall, the moderating influence of the ocean is noticed in the air temperatures of the area. Relatively high humidities (70-85% in winter, 25-70% in summer) result in low water losses to evaporation. The annual evaporation is about 51-64 cm.

Characteristic of mixed tides on the Pacific coast, tides in the Bay show diurnal inequality. Between mean high high water and mean lower low water, the diurnal variance is 2.5 m at the Bay mouth to 3.1 m at Nahcotta. Willapa Bay at mean high tide has a water-covered area of about 375 km^2; at low tide only 178 km^2 is covered with water. The result is approximately 197 km^2 of broad tidal flats (Fig. 2).

Average current velocity during ebb and flood tides is about 2.5 knots. The greatest currents (4-6 knots) occur on the ebb tide at the bay mouth. Even greater velocites may occur during periods of strong south winds due to the northward flow of the ebbing tide coupled with the wind effects. Waves generated offshore have little effect on the inner Bay because of the protection afforded by North Beach Peninsula. An exception is at the Bay entrance where bottom sediment is intensively reworked by waves. Local winds are the most significant agent generating waves in the inner Bay.

Water characteristics in Willapa Bay may change rapidly. On an outgoing tide, about 65% of the water leaves the Bay. If this water is caught up in a littoral drift, it is swept away and replaced with ocean water on the incoming tide. On the average, water temperatures range from 7-9 ^{o}C in the winter to 14-20 ^{o}C in the summer.

The fall season is a period of relatively high salinity (30 parts per thousand). This results when the Columbia River plume shifts to the south and water offshore of the Bay mouth is replaced with more saline ocean water. During winter, salinity can drop as low as five parts per thousand due to (1) increased runoff from winter precipitation and (2) the Columbia River plume swinging to the north. With decreases in the amount of runoff during the spring, the salinity begins to increase (approximately 20 parts per thousand). Summer salinities (about 25 parts per thousand) result from much reduced rainfall and the influx of more ocean water. The salt water wedge is sharpest in the summer and fall.

Willapa Bay receives runoff from about 2400 km^2 of land (principally the west flank of the Willapa Hills). Due to seasonal variation in precipitation and lack of snow or other surface storage to maintain summer flow, runoff is variable. During July to September, runoff accounts for less than 2% of the average annual runoff. Runoff maps show a large variation in average runoff between tributary basins. For example, average runoff for the North River basin is about 150 cm, whereas it is over 250 cm in the Naselle River bain. Overall, the runoff figures are generally higher than would be anticipated from available precipitation records.

Sediments in the Bay are supplied by the Pacific Ocean, terrace deposits, rivers, and aeolian sand deposits. The Pacific ocean supplies most of the sand deposited in the Bay and on the tidal delta at the Bay entrance (Fig. 3). A combination of littoral drift and tides causes extensive erosion along Cape Shoalwater. The eroded sediment is carried onto the tidal delta and into the Bay; in the Bay it is deposited along Toke Spit and Ellen Sands.

Large amounts of mud and sand are derived by erosional processes from the Quaternary terraces around the Bay. During high tides (especially in the winter and /or associated with storms), wave action undercuts the vertical cliffs and stacks causing slumping or slides of the deposits.

Nine rivers supply sediment to Willapa Bay. The majority of clay and silt (minor amounts of gravel and sands) deposited in the Bay come from these rivers.

Sand flats along North Beach Peninsula are composed mainly of sediment blown from aeolian deposits on the barrier spit. Some sediment is also provided by subtidal channels eroding into beach and nearshore sands.

The specific study area for this report is located on the intertidal flats between approximately Goose Point and Pickernell

Creek on the east side of Willapa Bay (Fig. 4). Geographically, this area occupies a mid-estuary position. The width of the flat varies from a few hundred meters up to a kilometer. Limited salt marsh and supratidal flat environments occur near the Palix River and Pickernell Creek. Indurated terrace deposits occur along the entire shoreline adjacent to the flats.

Within the specific study area, the average textural characteristics are best described as poorly sorted, fine-grained sand with strongly-fine skewed leptokurtic distributions. Distribution patterns of textural parameters (Fig. 5) show consistent trends of sediments fining upslope and up-estuary reflecting a response to decreasing hydraulic energy and increasing distance from the main sand source (the tidal inlet).

Composition of sediments on the intertidal flats between Goose Point and Pickernell Creek are mainly (greater than 90%) light minerals, mostly quartz with small amounts of lithic fragments, pumice, vegetation, and biogenic shell fragments. Heavy minerals make up about 4% of the sediment. The most common heavy minerals are clinopyroxene, orthopyroxene, hornblende, epidote, and opaque. Clay minerals comprise less than 5% of the sediment. The principal clay minerals are montmorillonite, illite, and chlorite. Fossils (micro + macro) make up less than one percent of the sediment.

Within the specific study area, bed forms range from large sandwaves to small-scale ripples. Due to low sedimentation rates on the flats, the sediment experiences extensive biogenic reworking except where local conditions preclude infaunal activity. Therefore, bioturbate-textured sediments are characteristic of these mid-estuary intertidal deposits.

Reconnaisance of the tidal flats between Goose Point and Pickernell Creek suggest the following major trends relative to prominant seagrasses: (1) **Z. marina** (lwf) was most dense in subtidal and continually ponded areas of the flats, (2) **Z. marina** (int.) was found mixed with **Z. noltii** on the mid-tidal flat and to a lesser extent with **Z. marina** (lwf) on the lower tide flats, (3) **Z. noltii** was limited primarily to the upper and mid-tidal flats. **Z. noltii** was the most ubiquitous of the three varieties present. Major factors controlling distribution of seagrasses are relative lengths of subaerial versus tidal inundation, effectiveness of tidal circulation, and relative elevation of the tide flat surface.

Salt marshes within the study area occur primarily in small circular clumps directly seaward of topographic lows in the Pleistocene terrace topography. Salt marsh grasses show a distinct increase in density and diversity from the upper intertidal into terrestrial marshes (upslope). **Triglochin** occurs in pure stands on the upper intertidal flats and in mixed stands with **Scirpus** or **Salicornia** in supratidal flat areas. Controlling physical factors appear to be water salinity, substrate salinity, and elevation. Recent salt marsh geographic distribution from Goose Point to Pickernell Creek seems to be controlled by antecedent Holocene topographic lows in the Pleistocene terraces.

METHODS

Box cores (20 X 20 X 50 cm) were used to collect bottom samples from 36 stations on the tidal flats (Fig. 4). The sediment was washed through a 0.5-mm-mesh sieve. Organisms recovered were fixed in 10% formalin, preserved in 45% isopropyl alcohol, and later identified and counted in the laboratory. These samples were collected in July-August, 1978.

MACROBENTHIC INFAUNA

The following macrobenthic infauna were collected within the study area (distribution and density shown in Figs. 6-29):

Arthropoda (Crustacea)

- **Upogebia pugettensis** (Fig. 6)
- **Callianassa californiensis** (Fig. 7)
- **Eohaustorius** sp. (Fig. 8)
- **Idotea** sp. (Fig. 9)
- **Corophium** sp. (Fig. 10)
- **Ampithoe** sp. (Fig. 11)
- Cumacea (one species, Fig. 12)
- gammarid amphipod (one species [?], Fig. 13)
- copepod (one species, Fig. 14)
- isopod (one species, Fig. 15)

Mollusca

- **Mya arenaria** (Fig. 16)
- **Cryptomya california** (Fig. 17)
- **Macoma balthica** (Fig. 18)
- **Tapes japonica** (Fig. 19)
- ?**Musculus senhousia** (Fig. 20)
- ?**Polinices** sp. (Fig. 21)
- ?**Clinocardium** sp. (Fig. 22)

Annelida (Polychaeta)

Abarenicola pacifica (Fig. 23)

Eteone sp. (Fig. 24)

Nephtys spp. (Fig. 25)

Capitellidae (one species, Fig. 26)

Orbiniidae (one species, Fig. 27)

Phyllodocidae (one species, Fig. 28)

The sampling technique was not adequate for collecting deep burrowing organisms such as **Callianassa californiensis**. This species commonly burrows to a meter or more below the sediment-water interface. A comparison of the number of **Callianassa** burrow openings (Fig. 29) at the sediment surface indicate this species is much more common and abundant than indicated by the actual number of animals collected (Fig. 7).

SUMMARY

During the summer of 1978, samples from 36 intertidal stations between Goose Point and Pickernell Creek in Willapa Bay, Washington were collected to examine the diversity, distribution, and density of macrobenthic infauna. All the fauna collected belonged to one of 3 major groups: Arthropoda (Crustacea - 10 species; 3,002 individuals, Fig. 30), Mollusca (7 species; 1,359 individuals, Fig. 31), and Annelida (Polychaeta - 6 species; 314 individuals, Fig. 32). Overall, 4,675 individual organisms (Fig. 33) representing 23 species were collected.

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LIST OF FIGURES

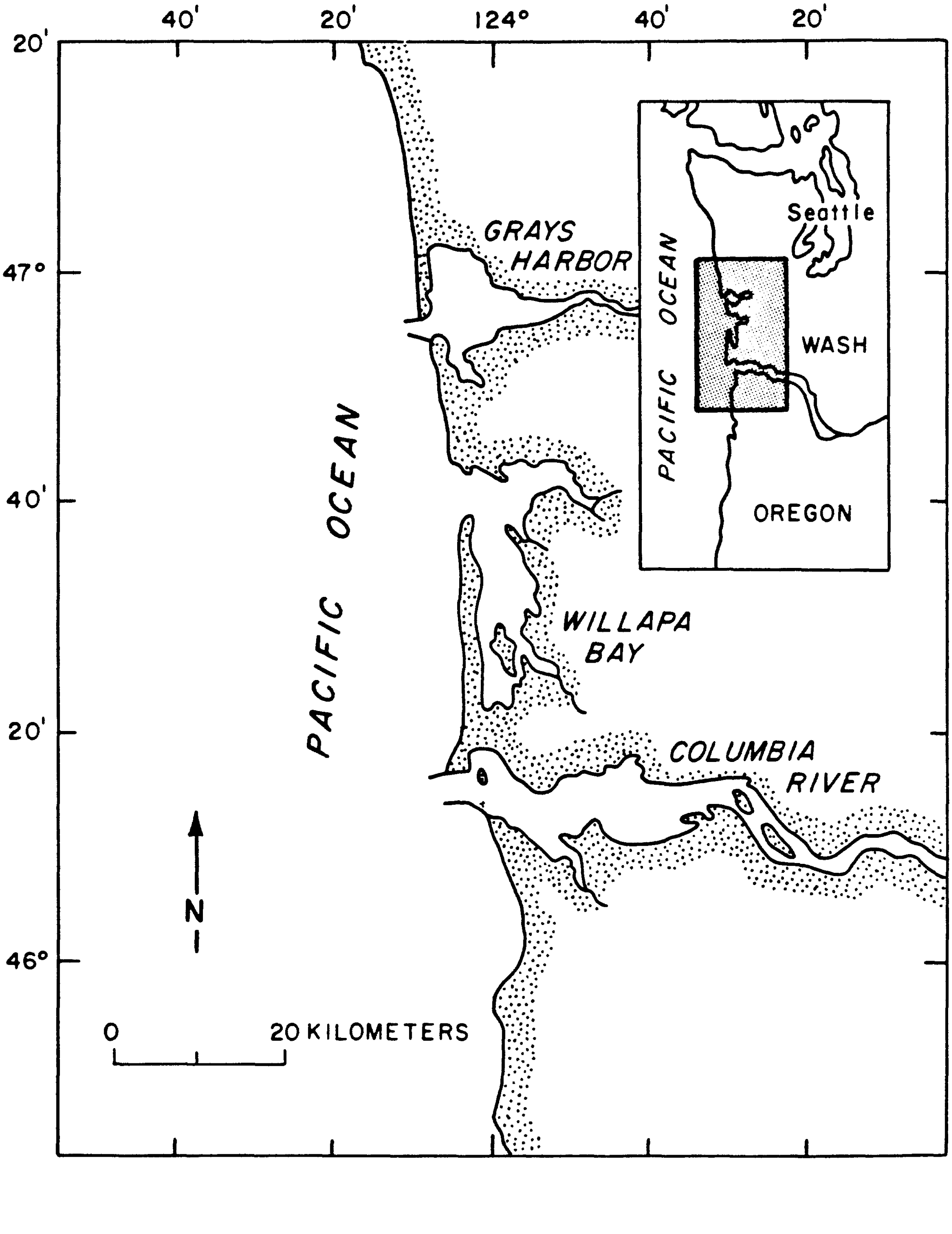

40'
20'
124°
40'
20'
20'
47°
40'
20'
46°
GRAYS HARBOR
PACIFIC OCEAN
WILLAPA BAY
COLUMBIA RIVER
N
0
20 KILOMETERS
Seattle
PACIFIC OCEAN
WASH
OREGON

FIG. 1

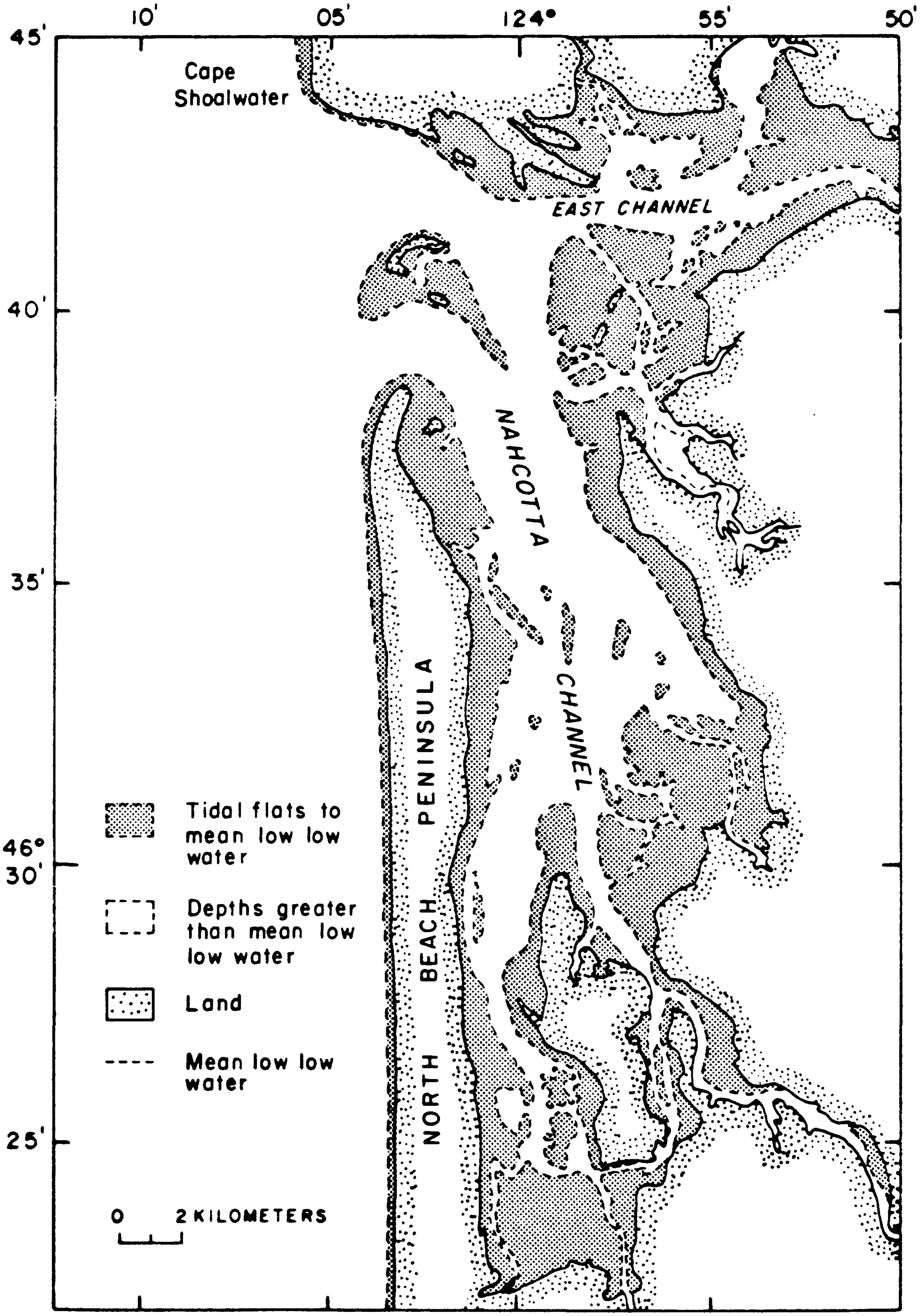
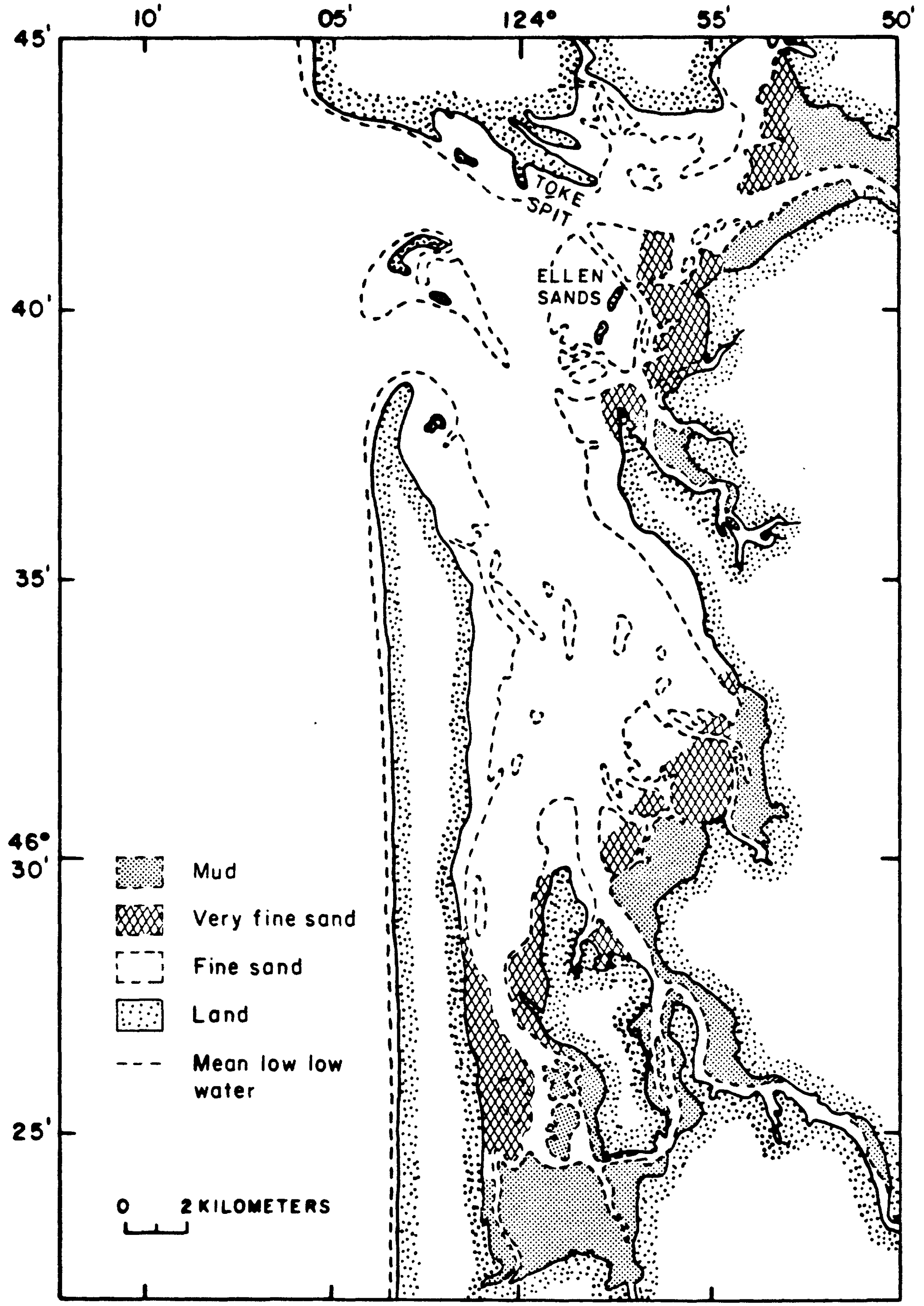

10'
05'
124°
55'
50'
45'
40'
35'
46°
30'
25'
Cape
Shoalwater
EAST CHANNEL
NAHCOTTA
CHANNEL
NORTH BEACH PENINSULA
Tidal flats to
mean low low
water
Depths greater
than mean low
low water
Land
Mean low low
water
0 2 KILOMETERS

FIG.2



10'
05'
124°
55'
50'
45'
40'
35'
46°
30'
25'
TOKE SPIT
ELLEN SANDS
Mud
Very fine sand
Fine sand
Land
Mean low low water
0
2 KILOMETERS

FIG

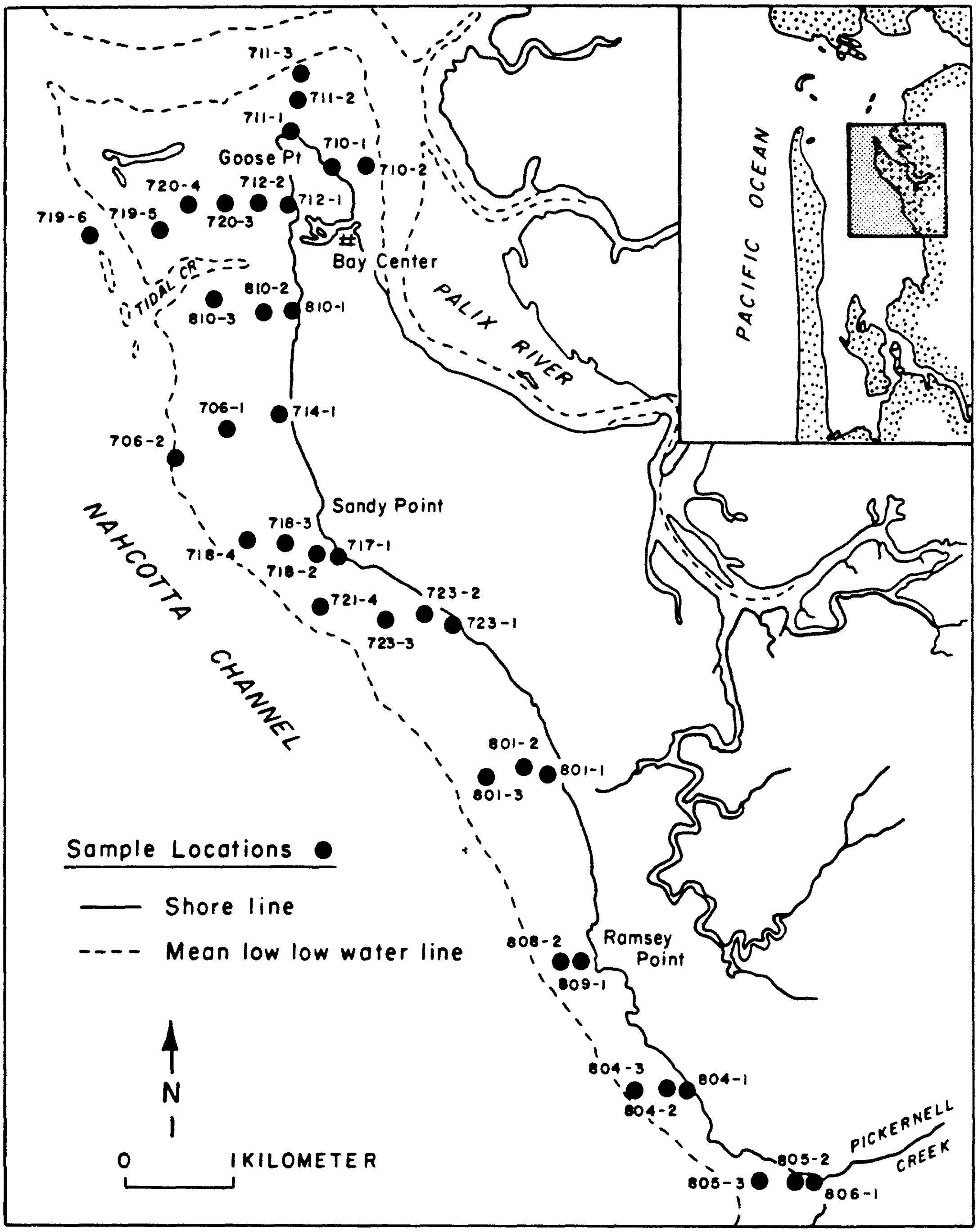

711-3
711-2
711-1
710-1
710-2
Goose Pt
720-4
712-2
712-1
719-6
719-5
720-3
Bay Center
TIDAL CR
810-2
810-3
810-1
PALIX RIVER
PACIFIC OCEAN
706-1
714-1
706-2
Sandy Point
NAHCOTTA CHANNEL
718-3
717-1
718-4
718-2
721-4
723-2
723-1
723-3
801-2
801-1
801-3
Sample Locations
Shore line
Mean low low water line
808-2
Ramsey Point
809-1
N
804-3
804-1
804-2
0 1 KILOMETER
805-2
805-3
806-1
PICKERNELL CREEK

FIG.

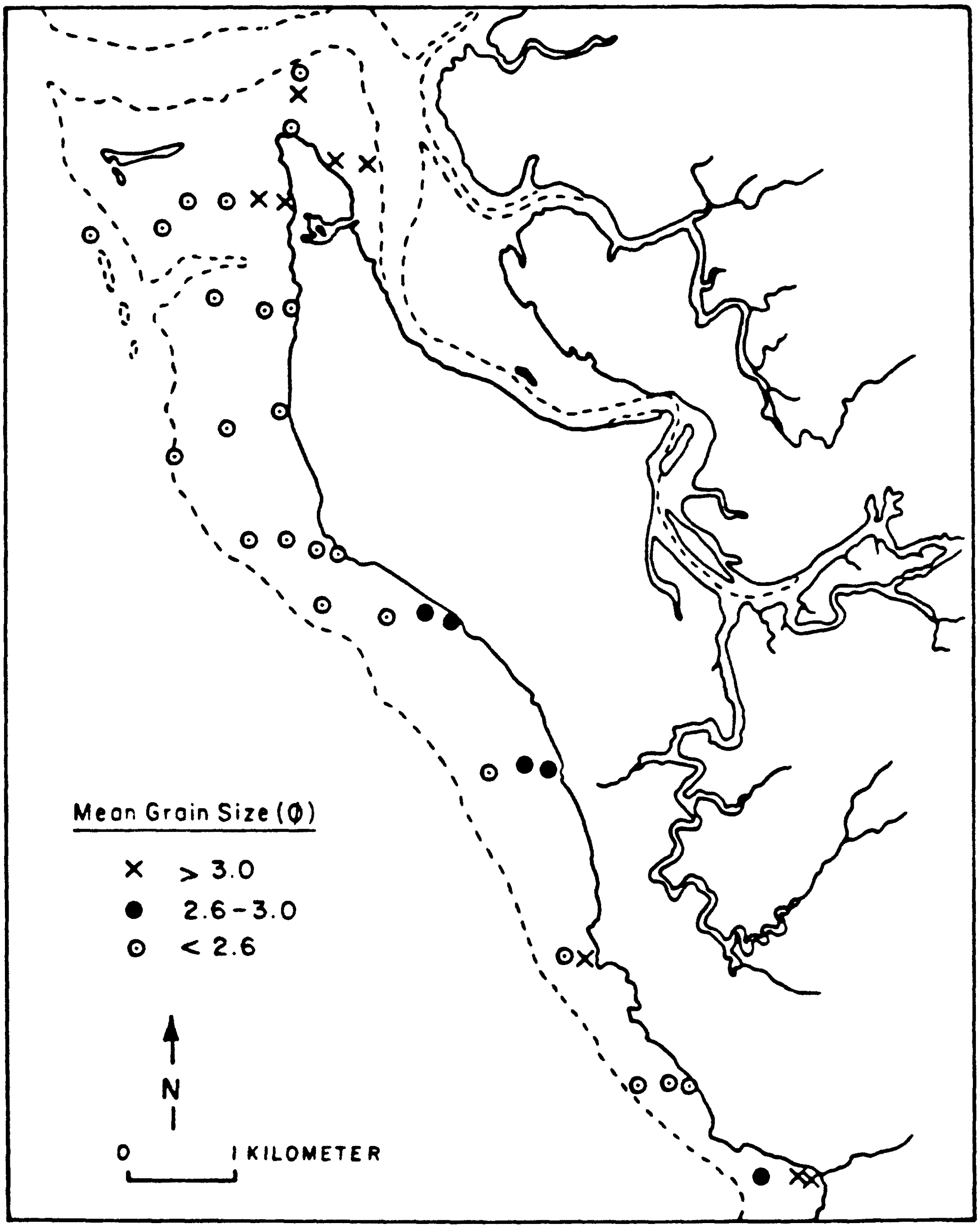


FIG.5

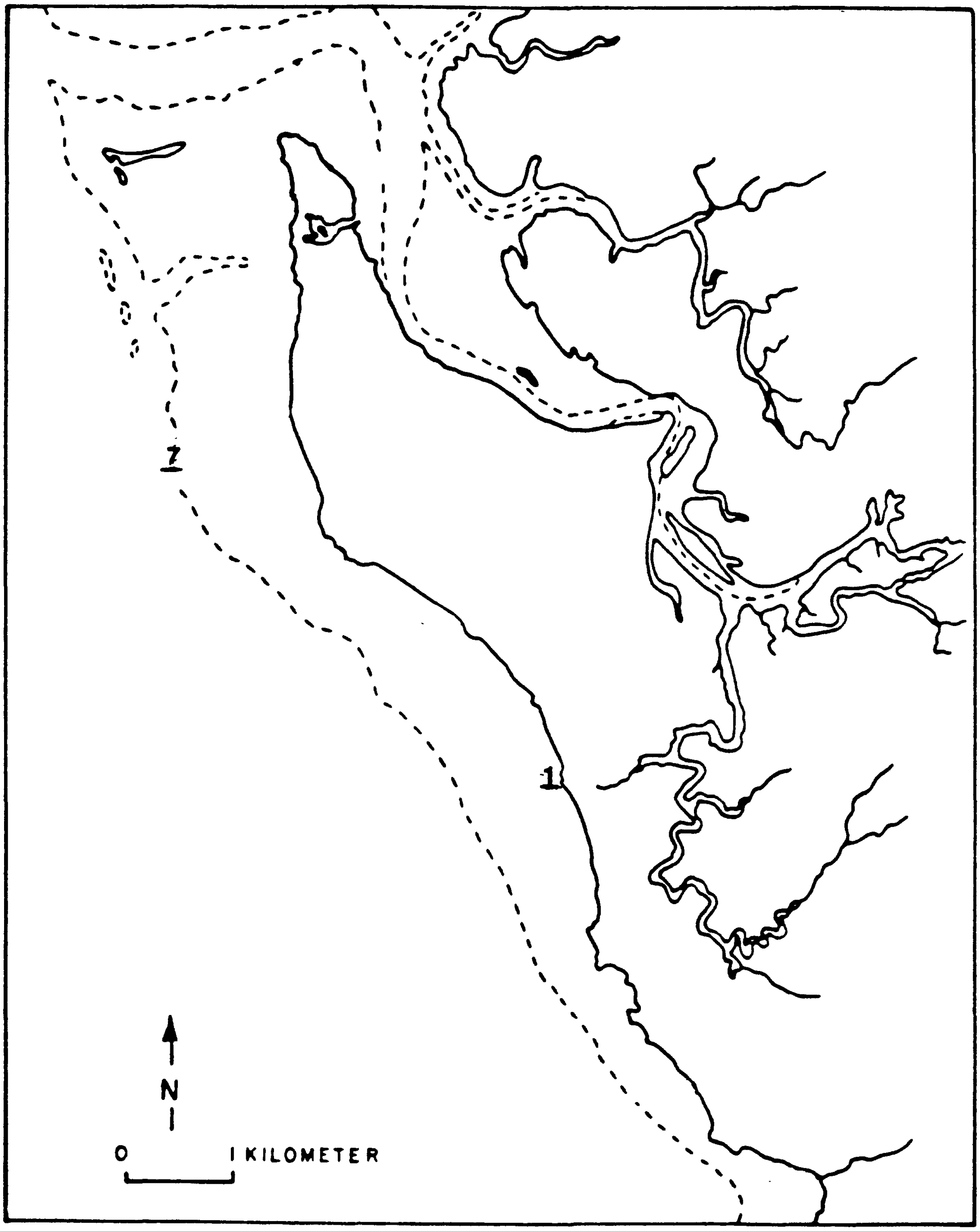
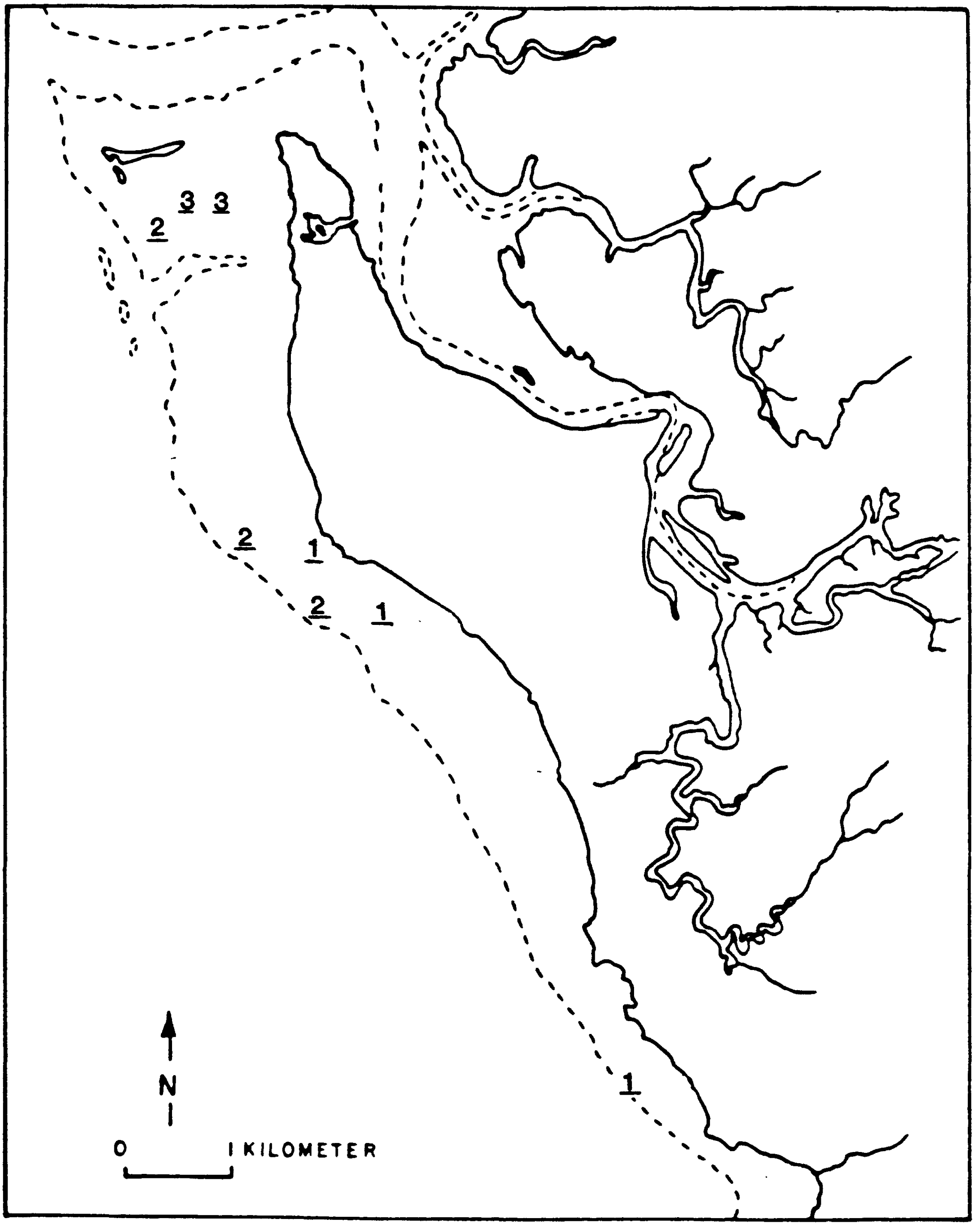


FIG.6



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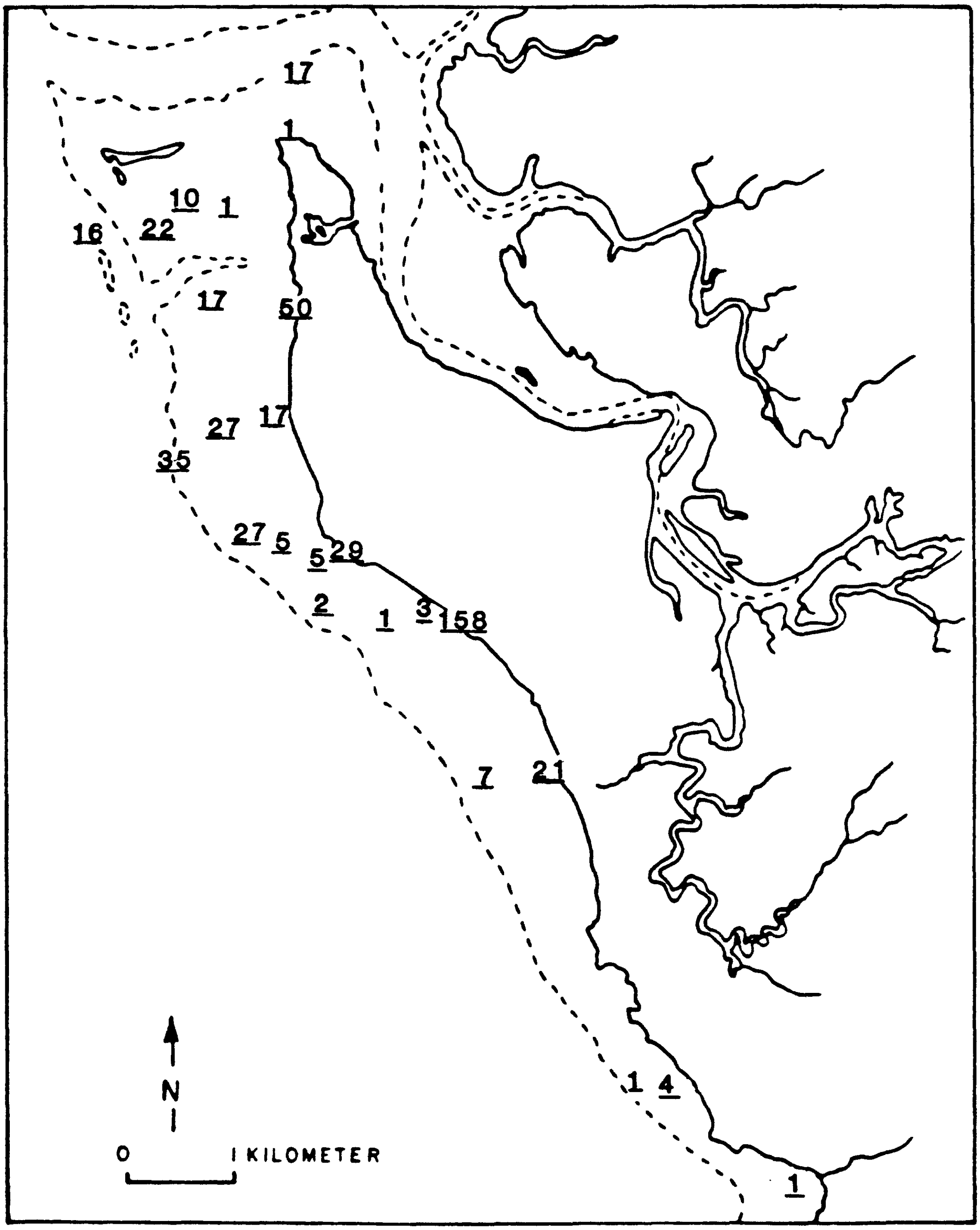

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FIG.8

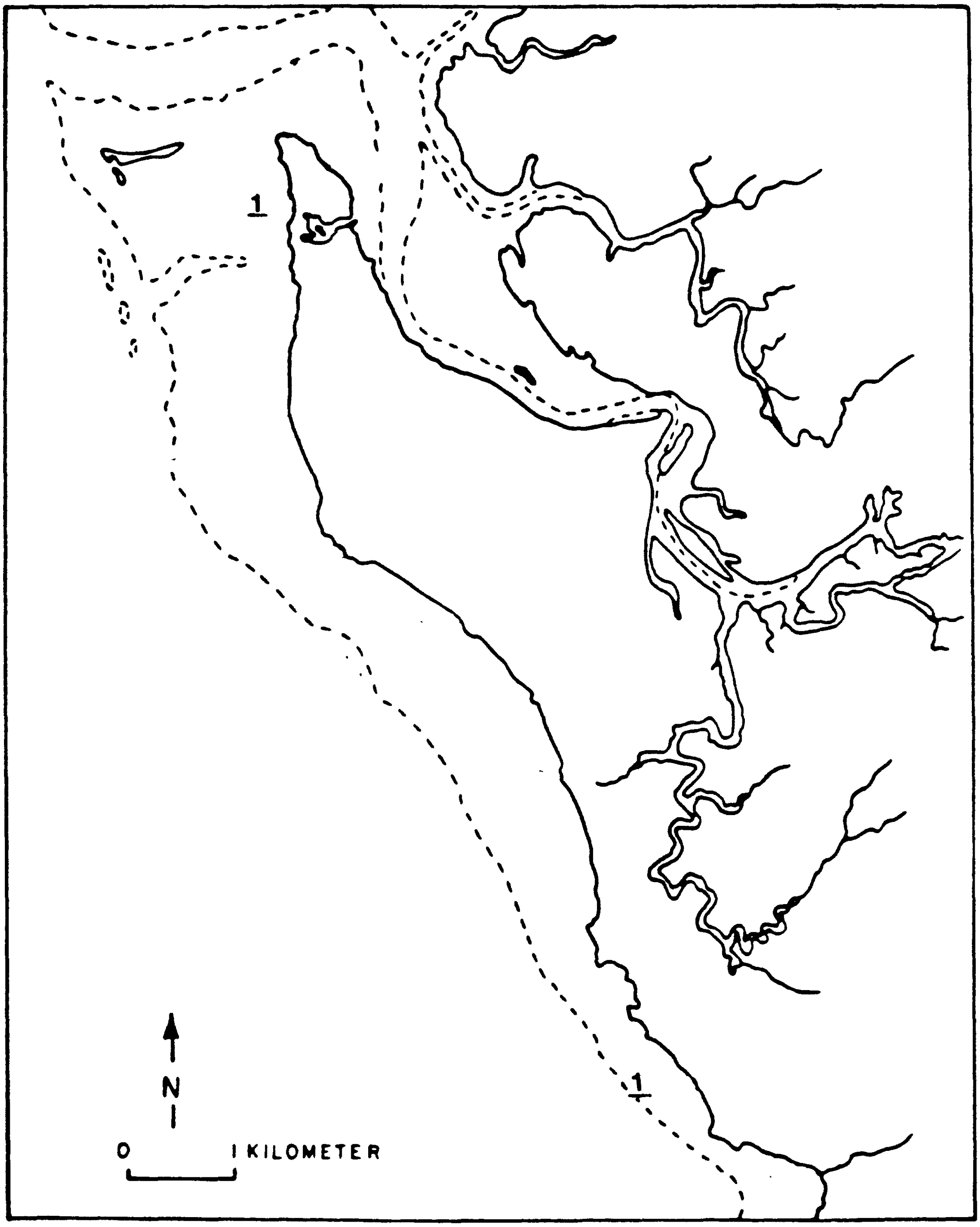


FIG.9

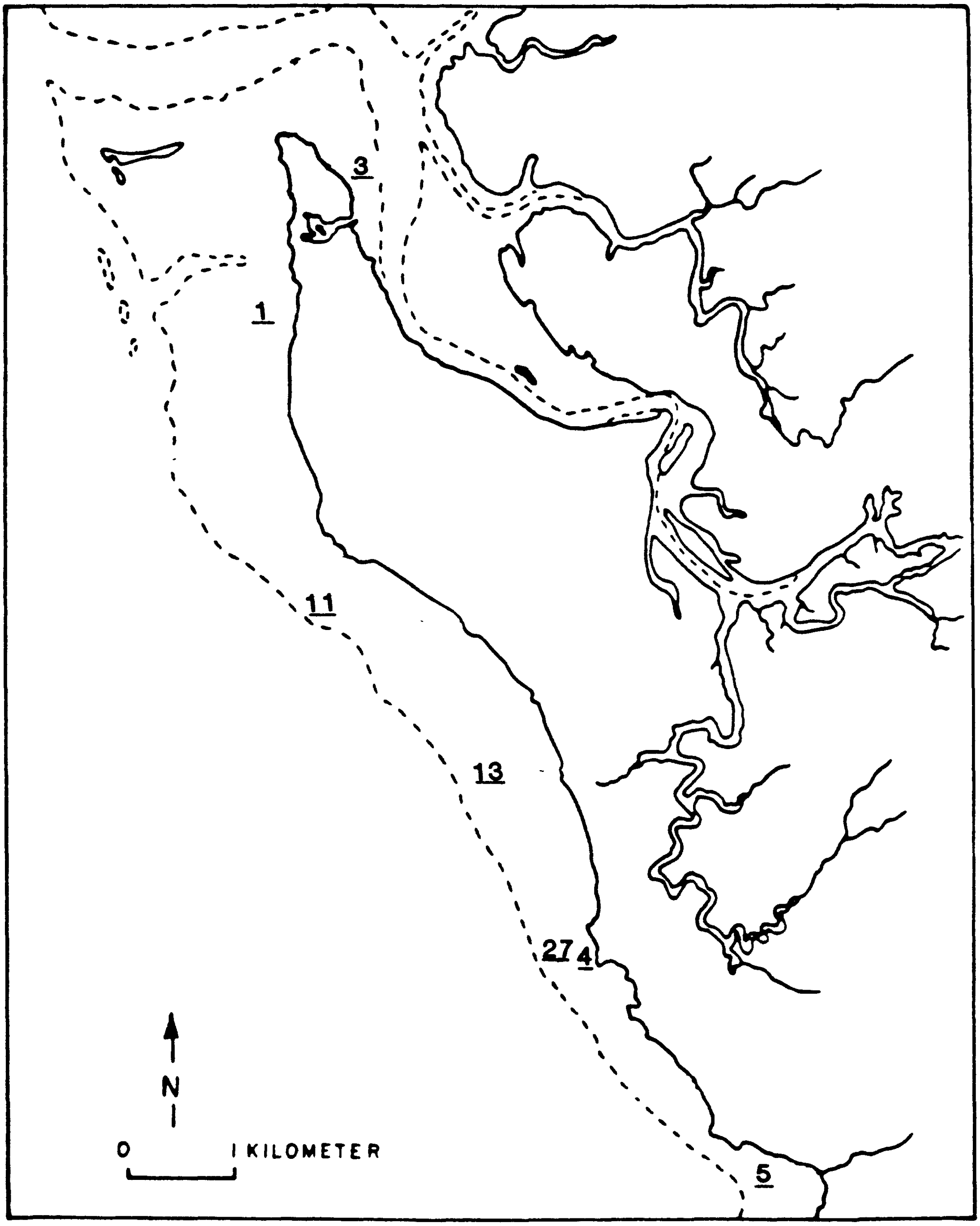


FIG.10

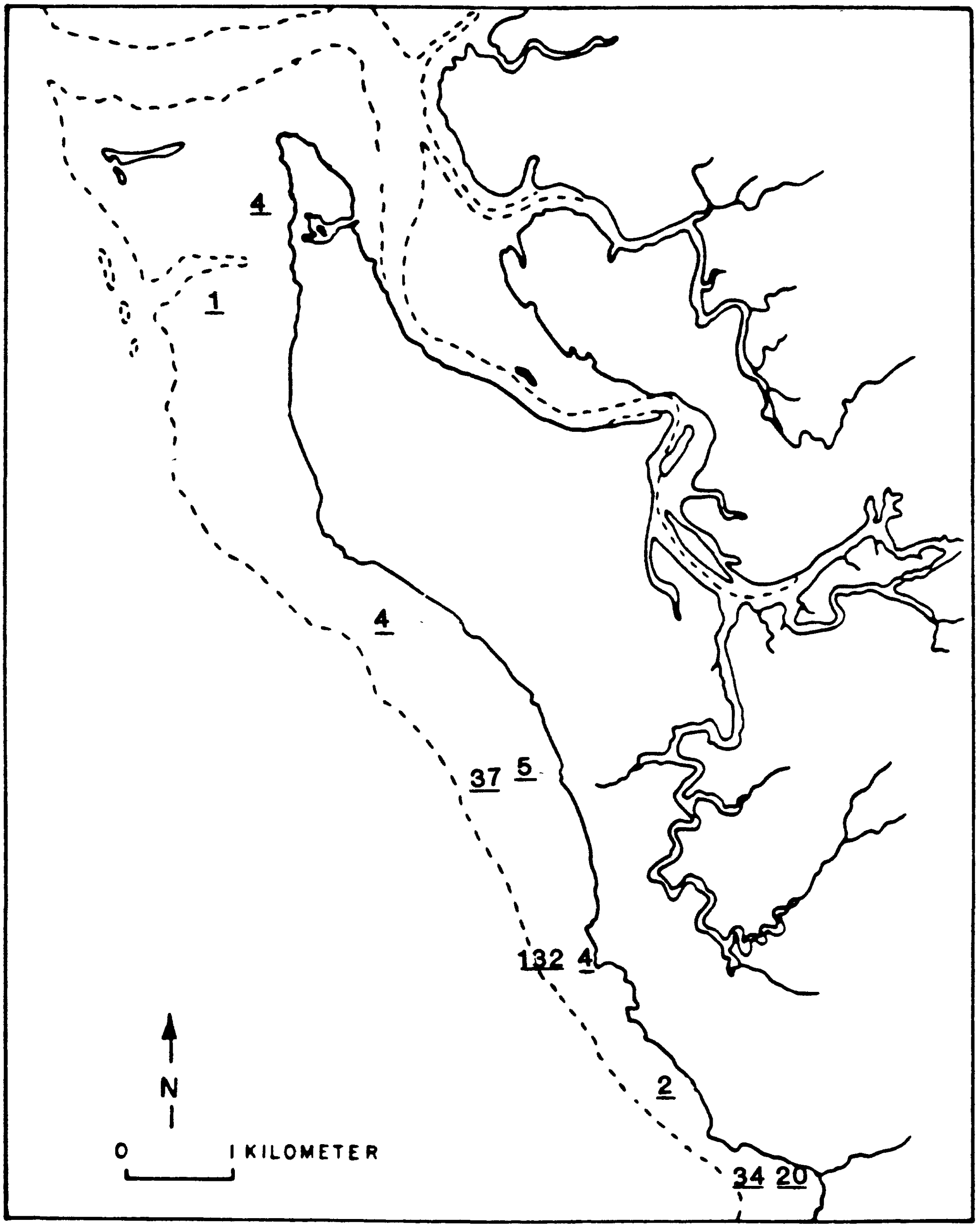
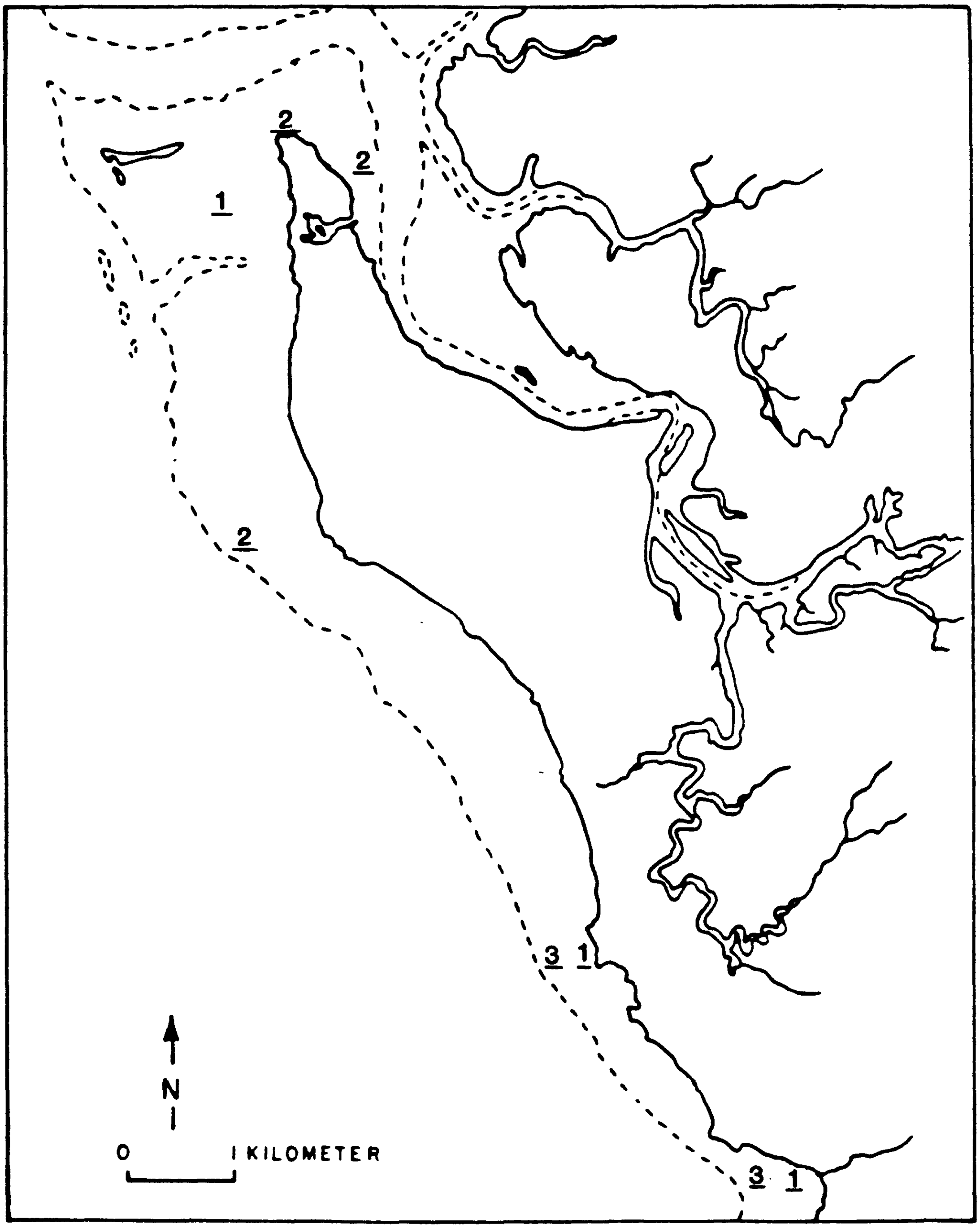


FIG.11



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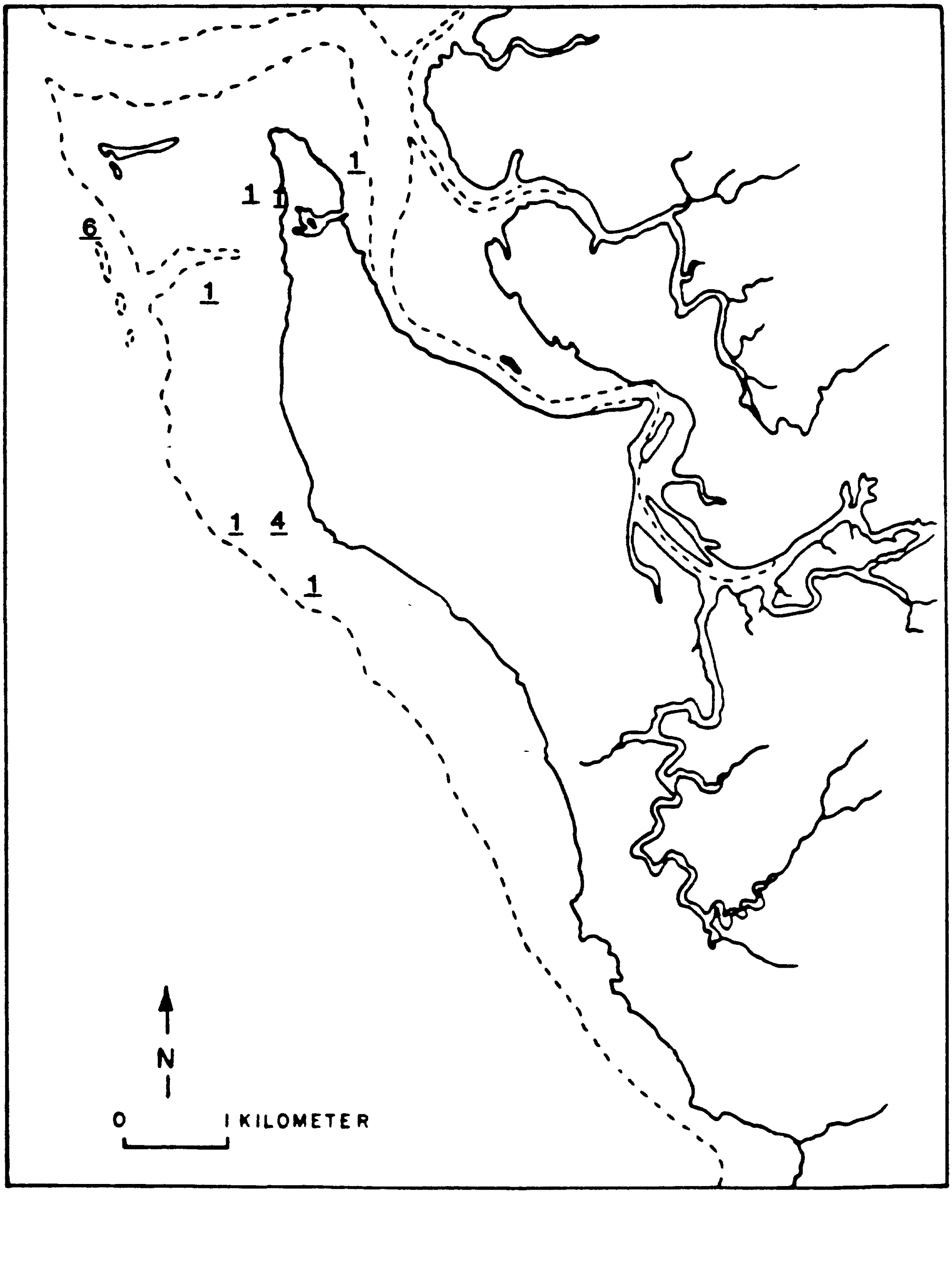

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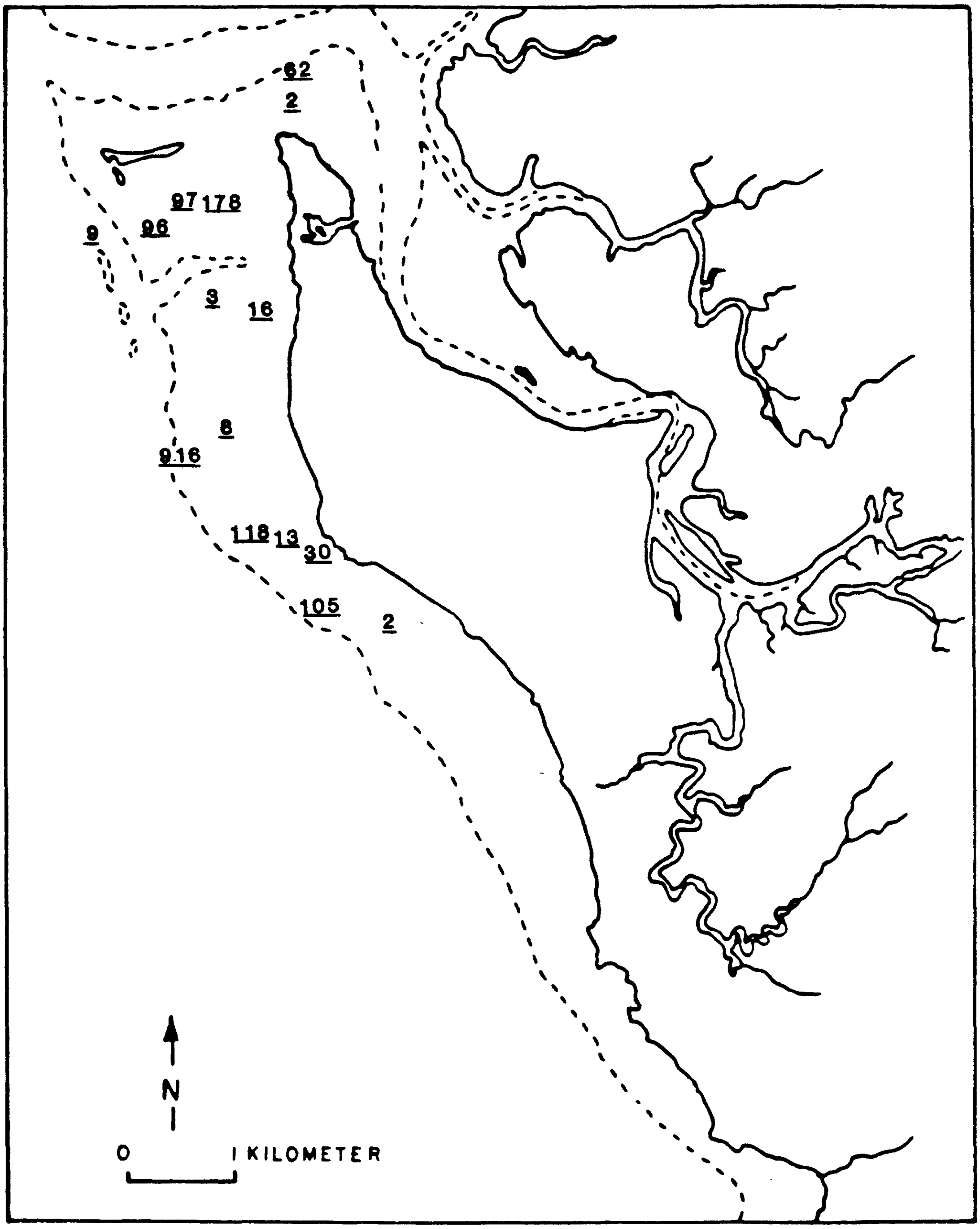
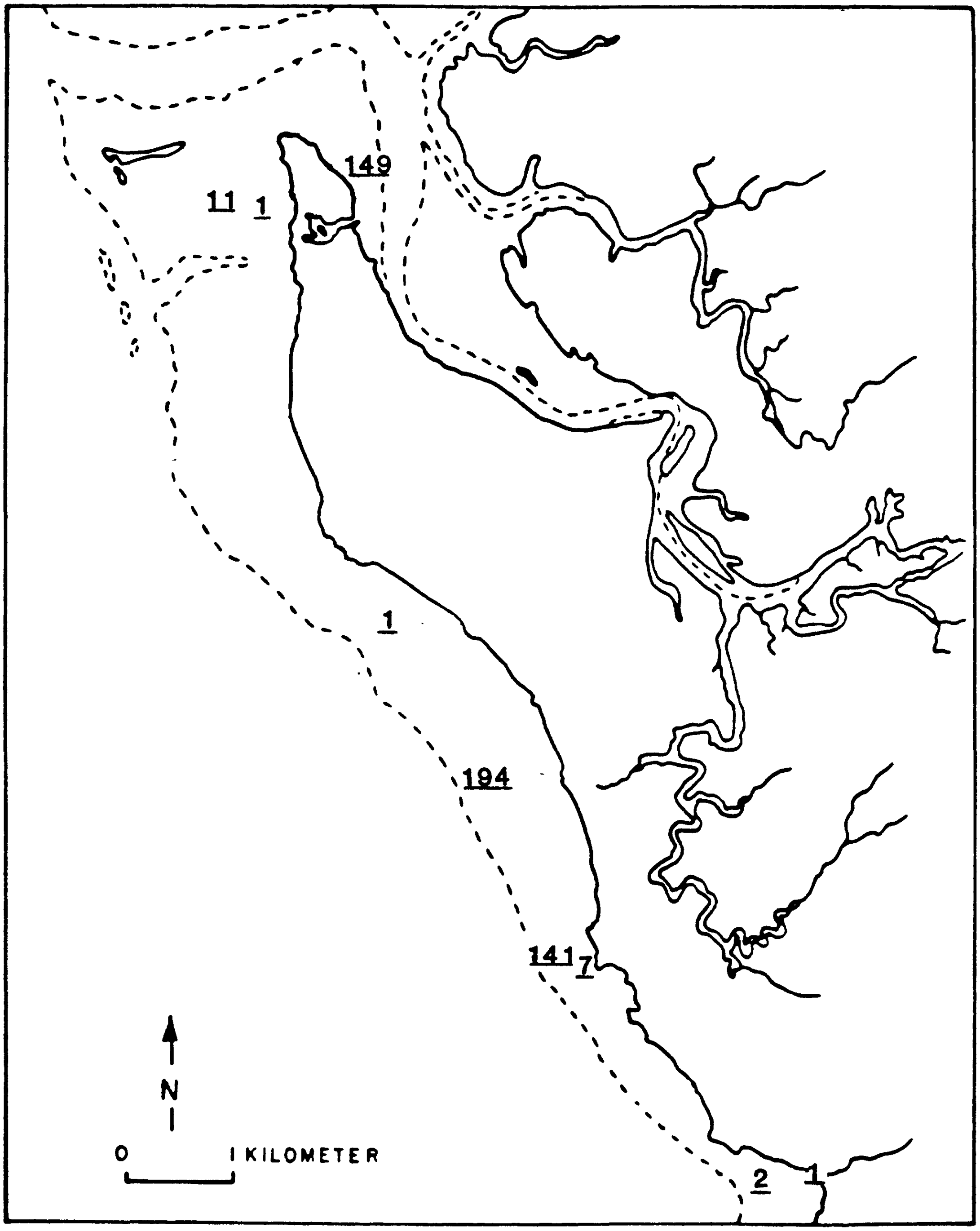


FIG.14



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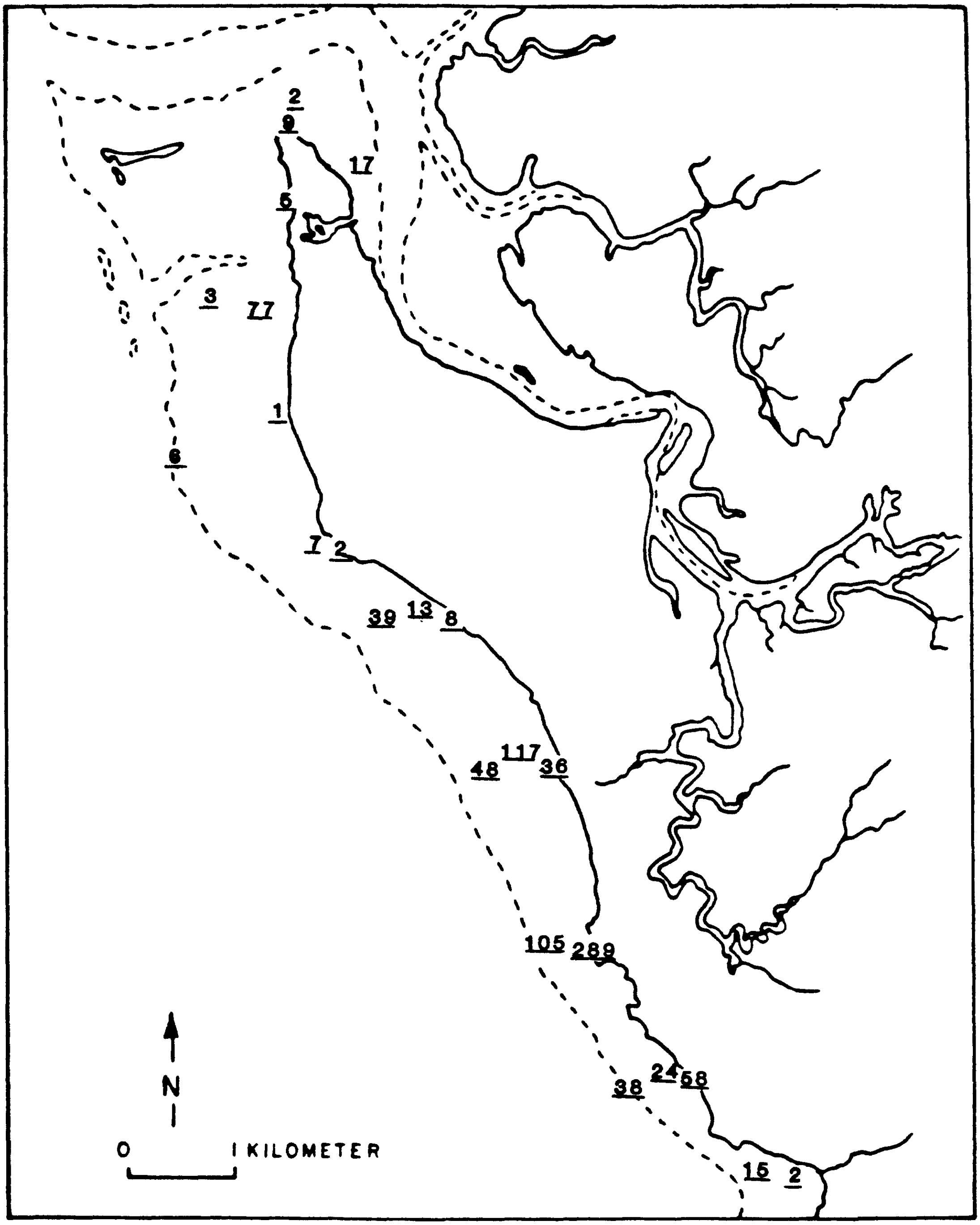
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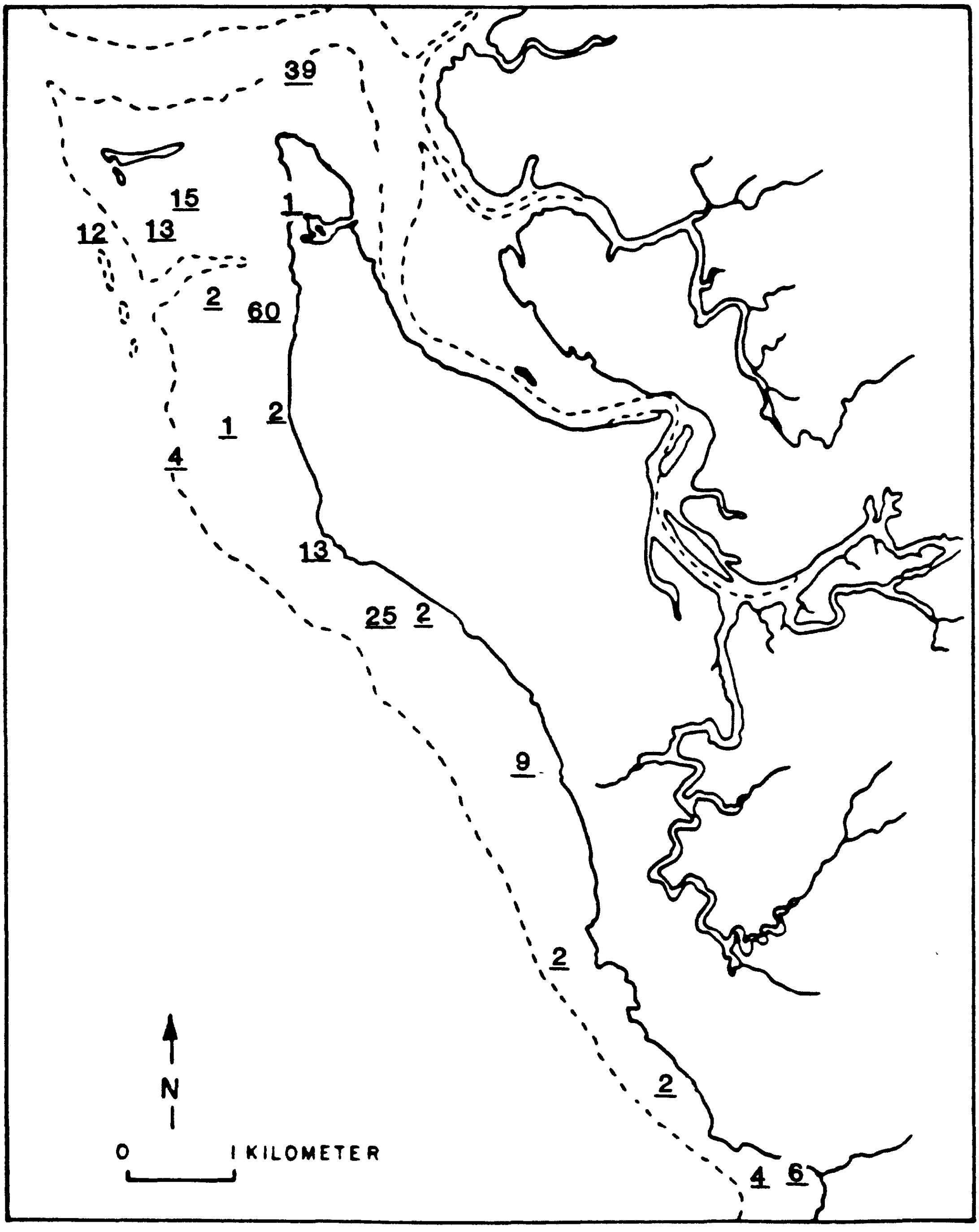
1 KILOMETER

FIG. 16



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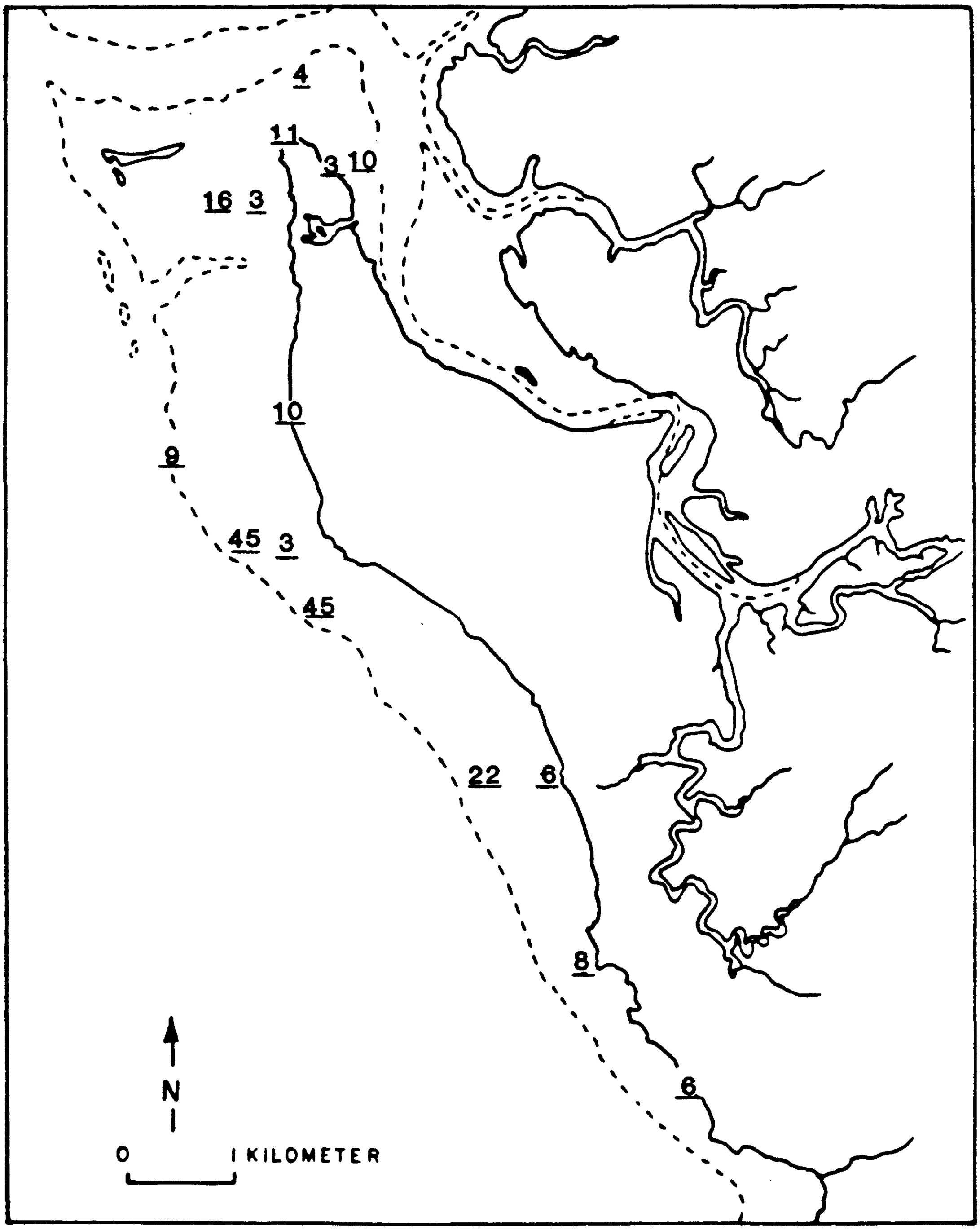


FIG. 18

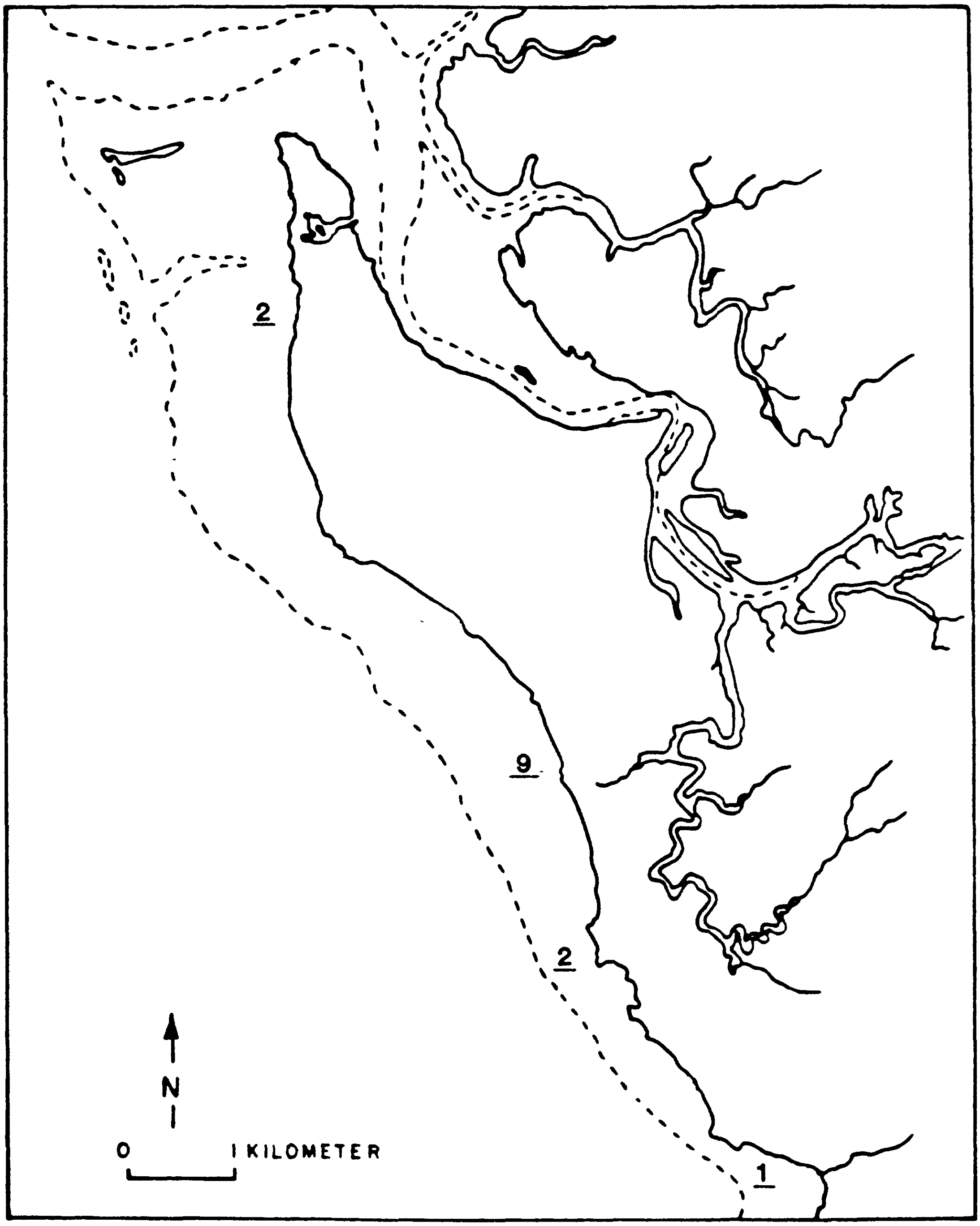


FIG. 19

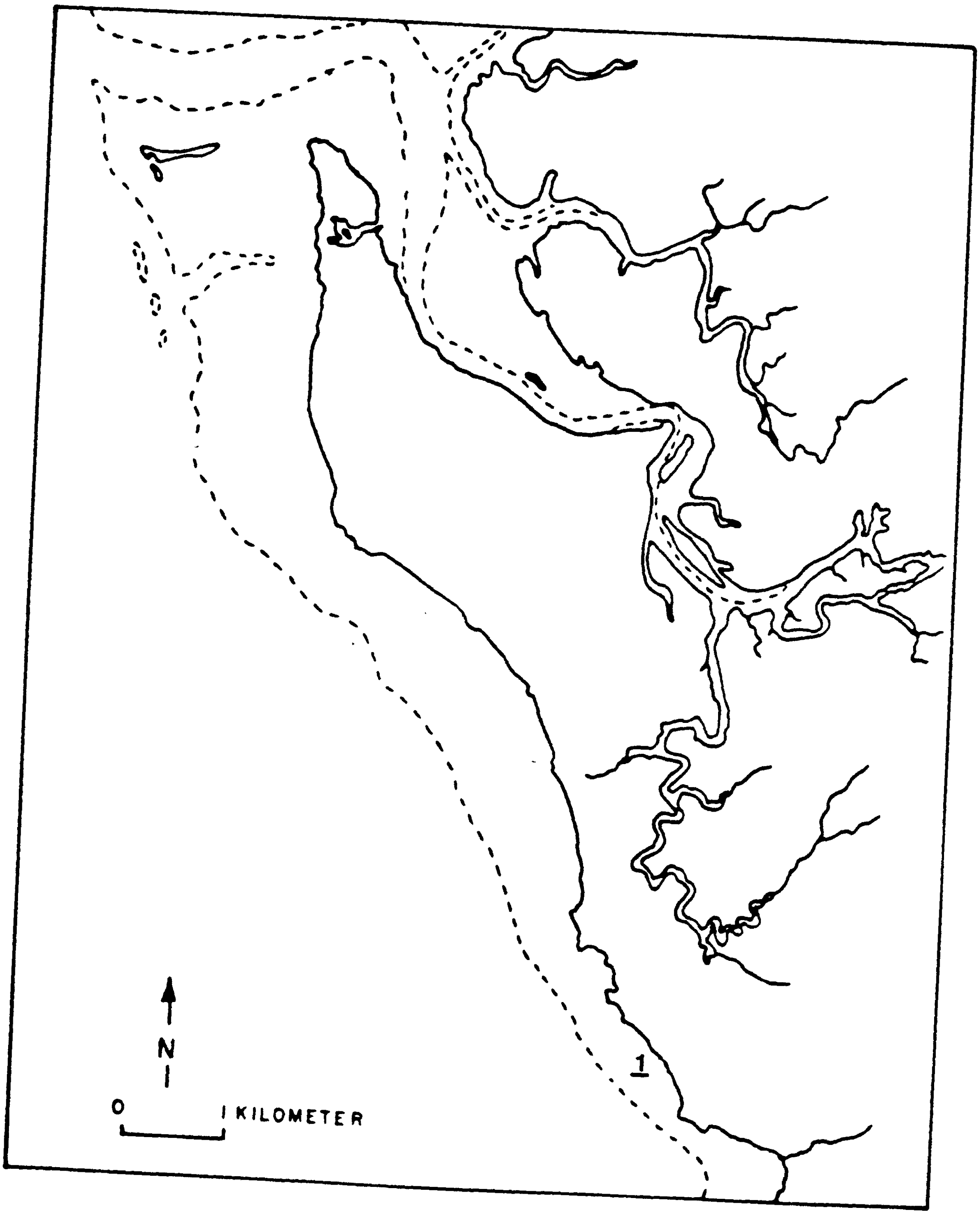
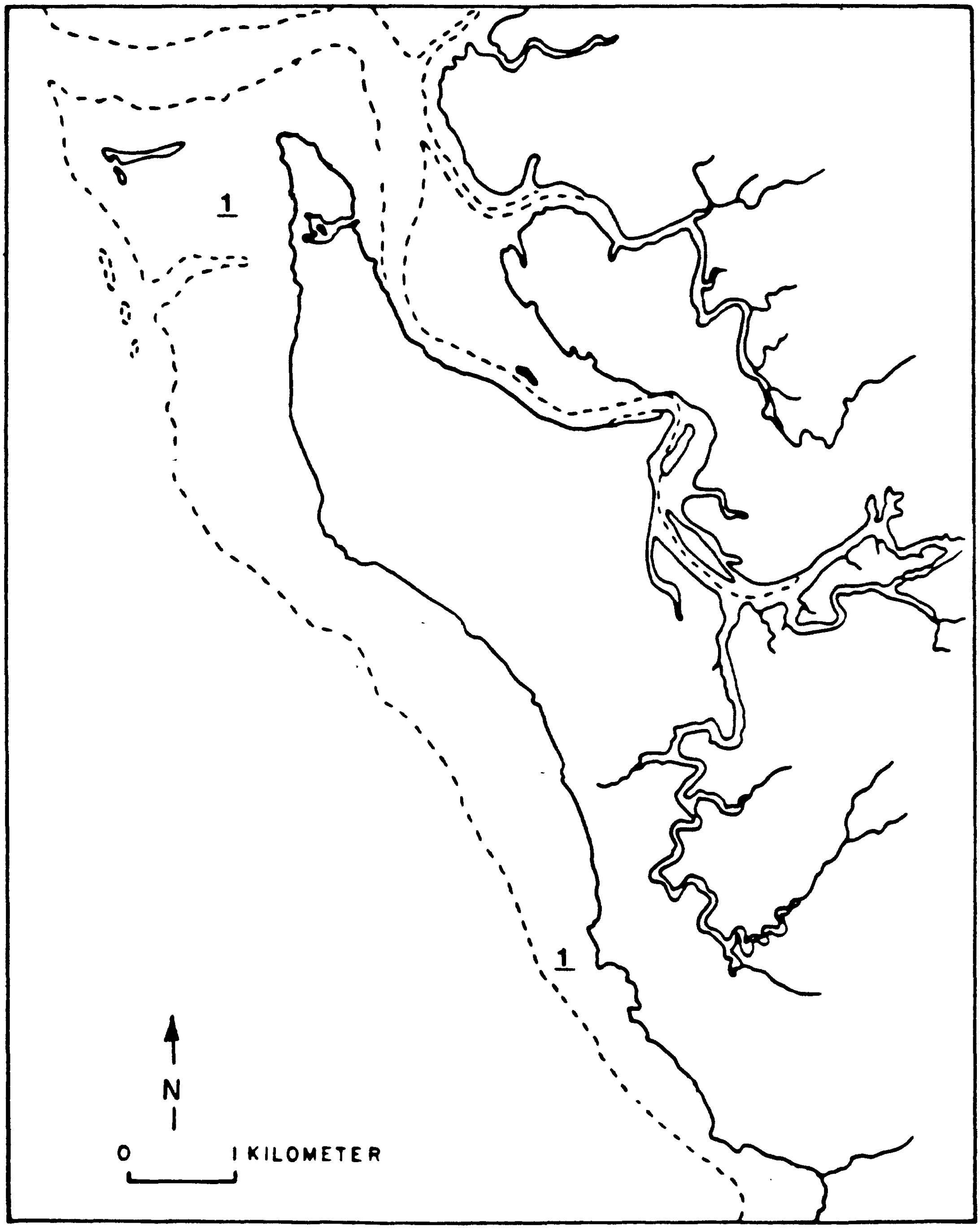


FIG.20



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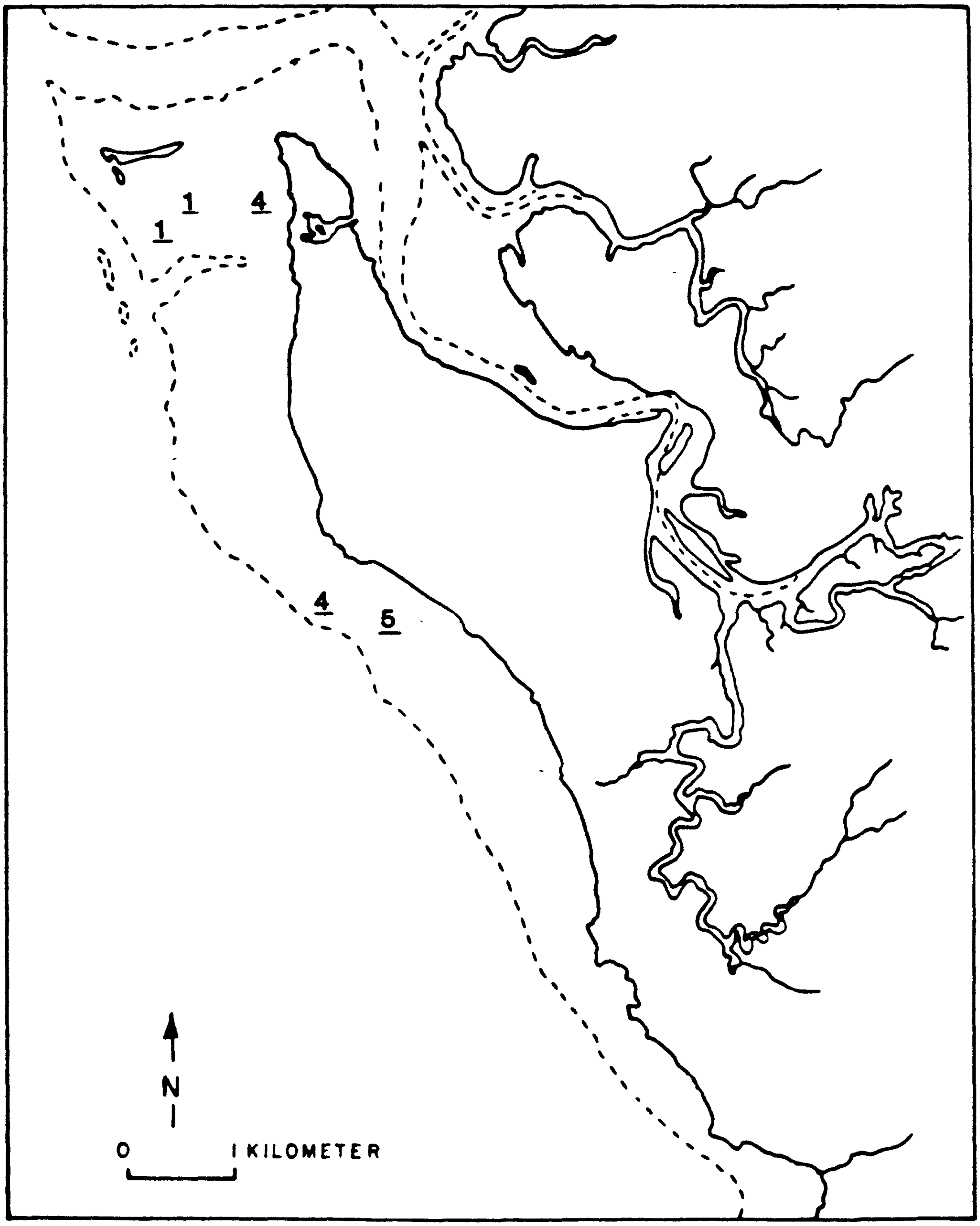

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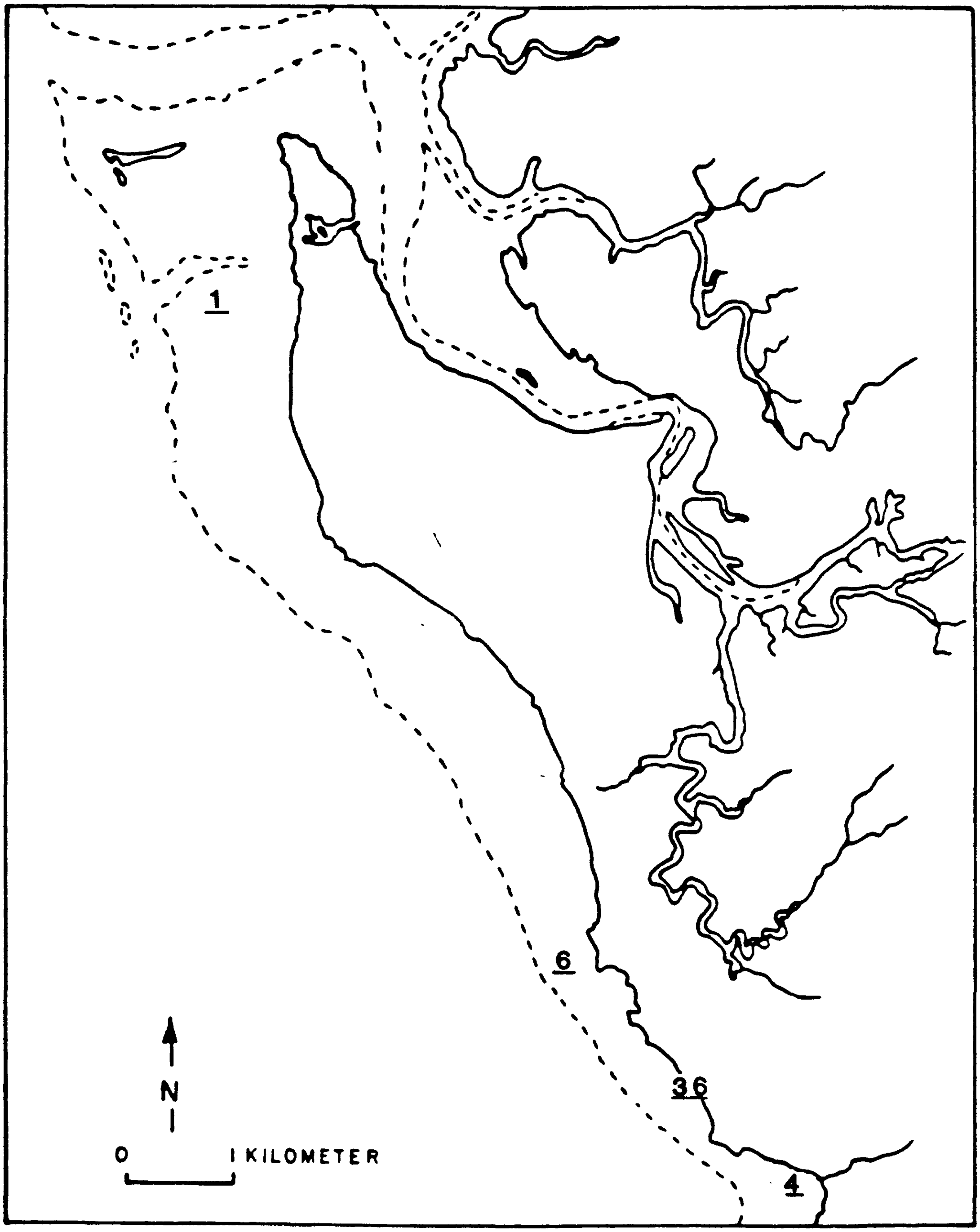


FIG.23

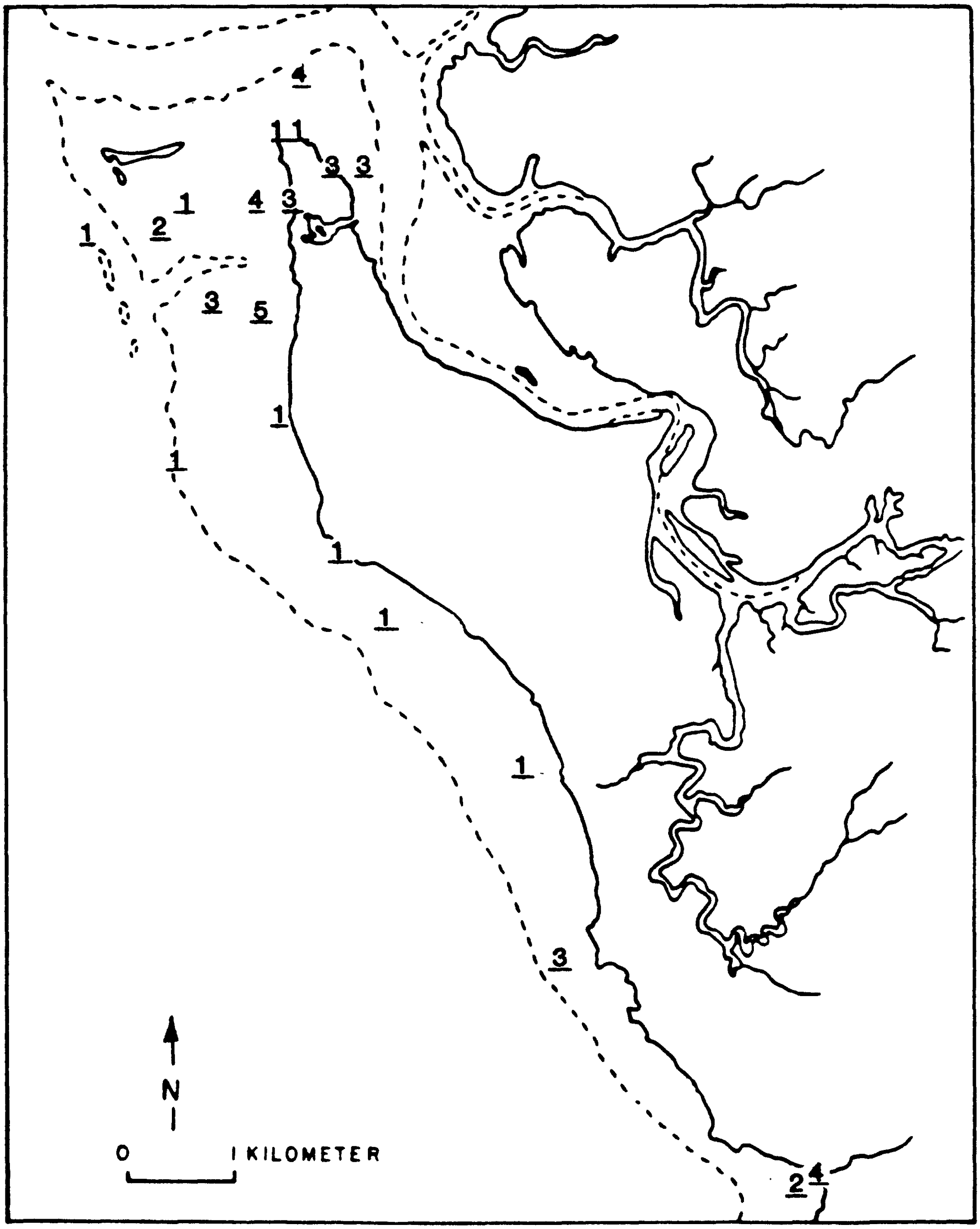


FIG.24

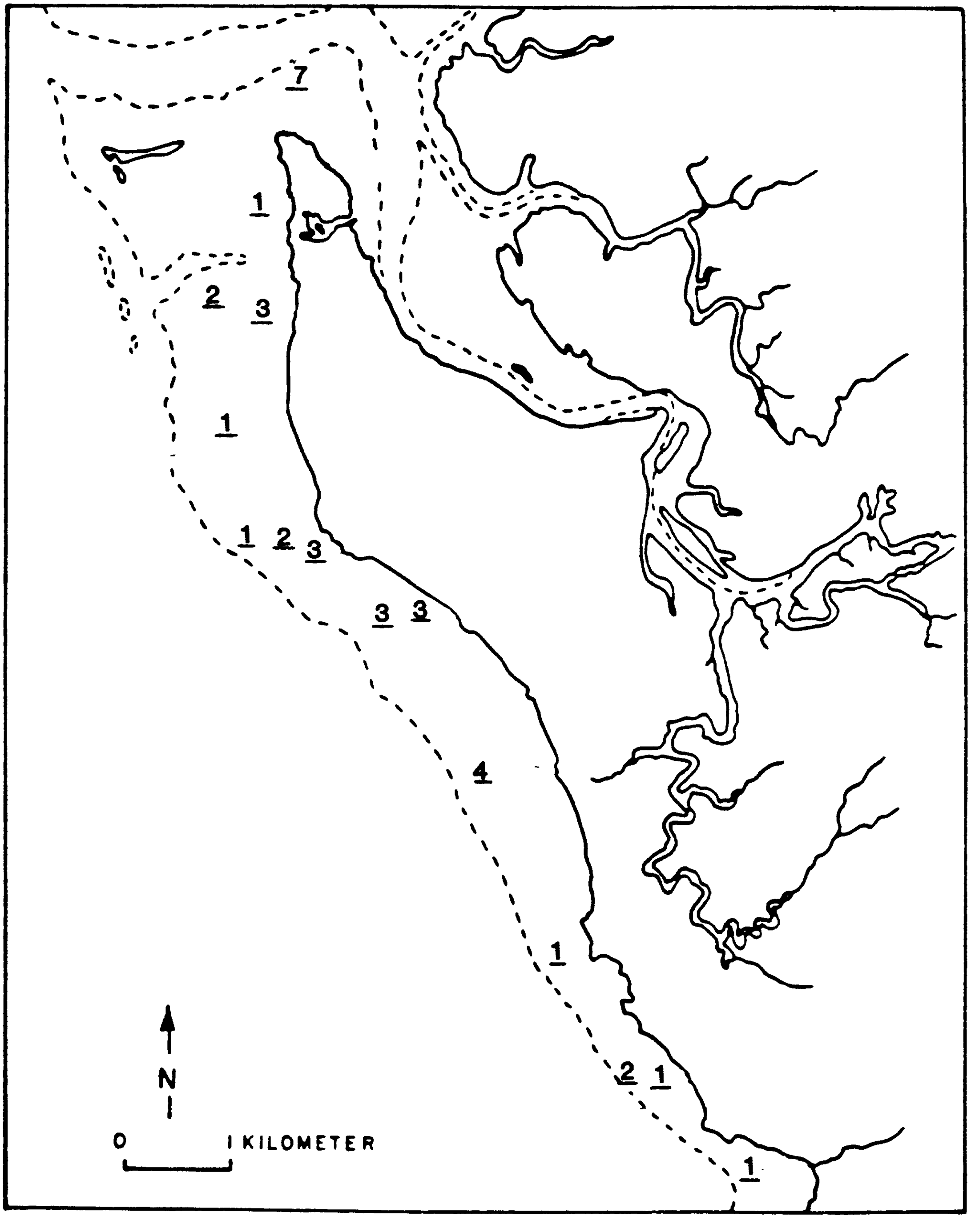


FIG.25

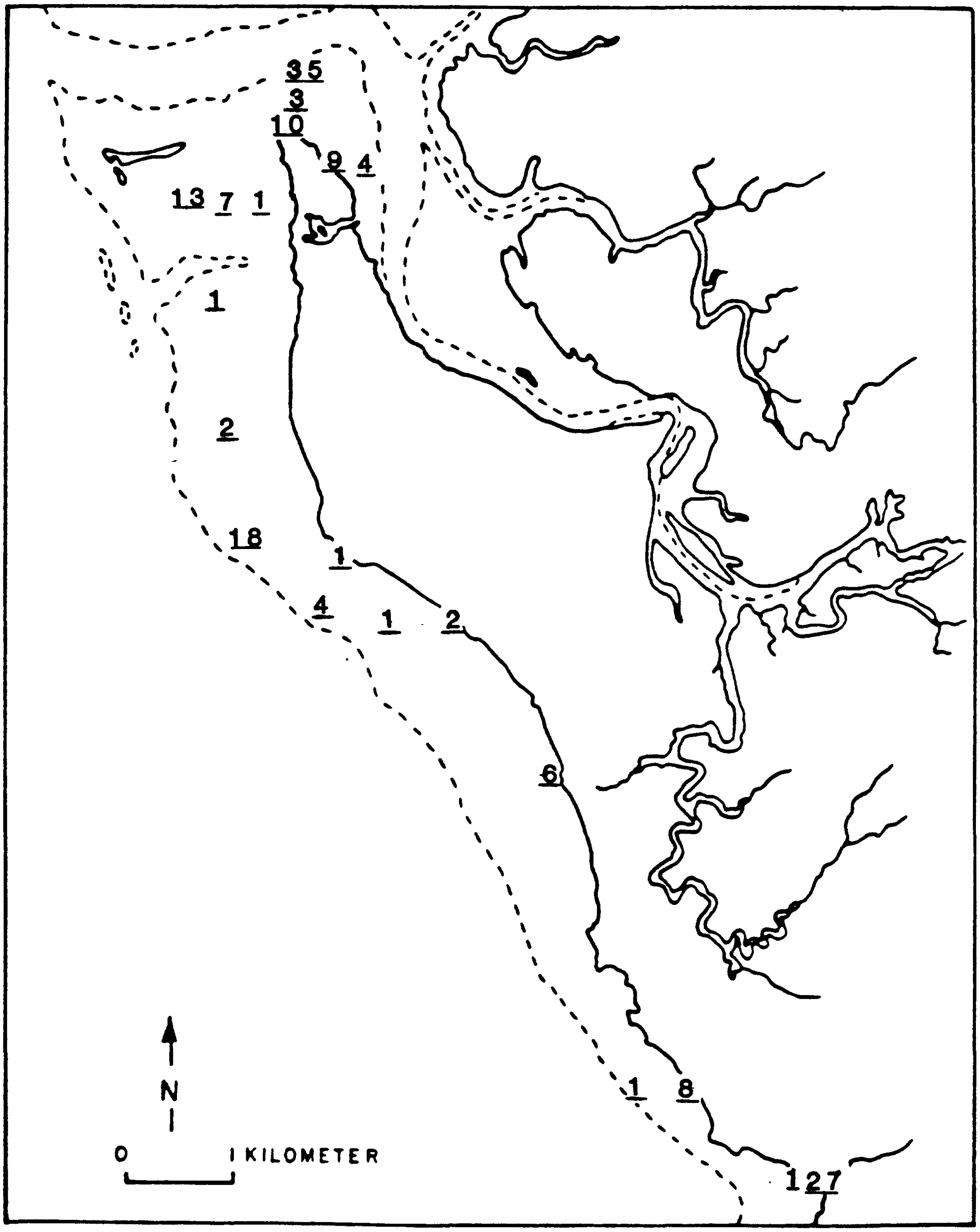


FIG.26

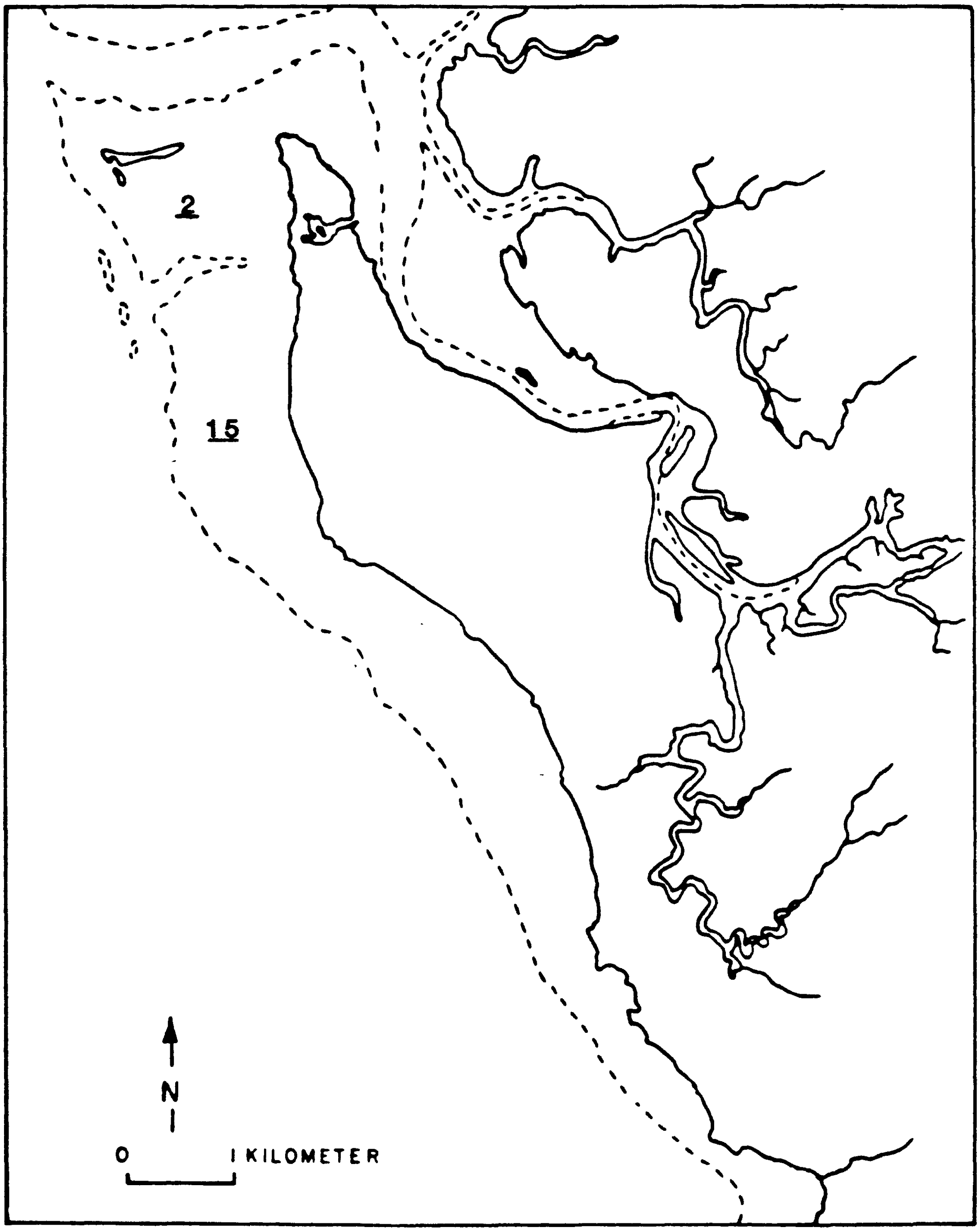


FIG.27

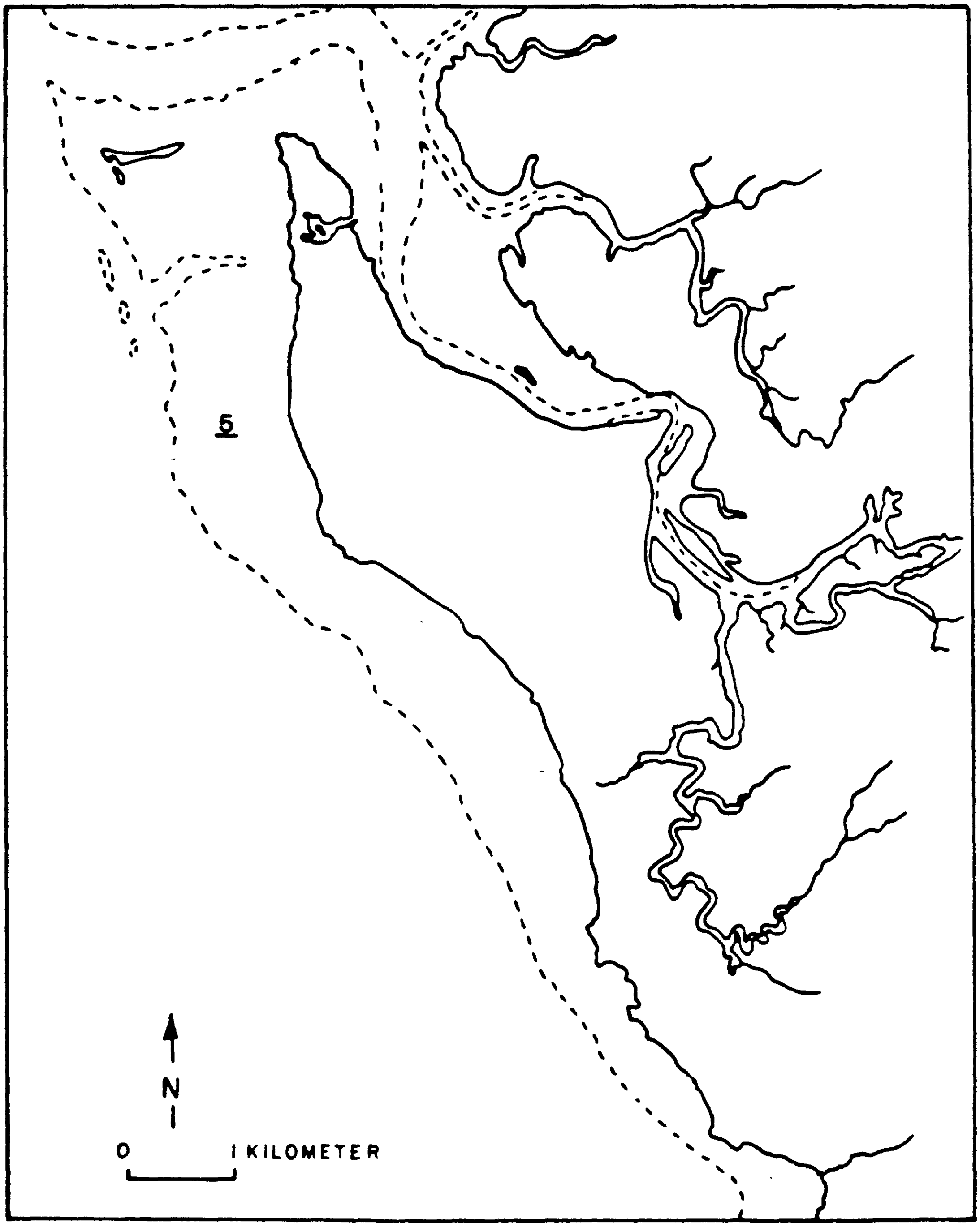
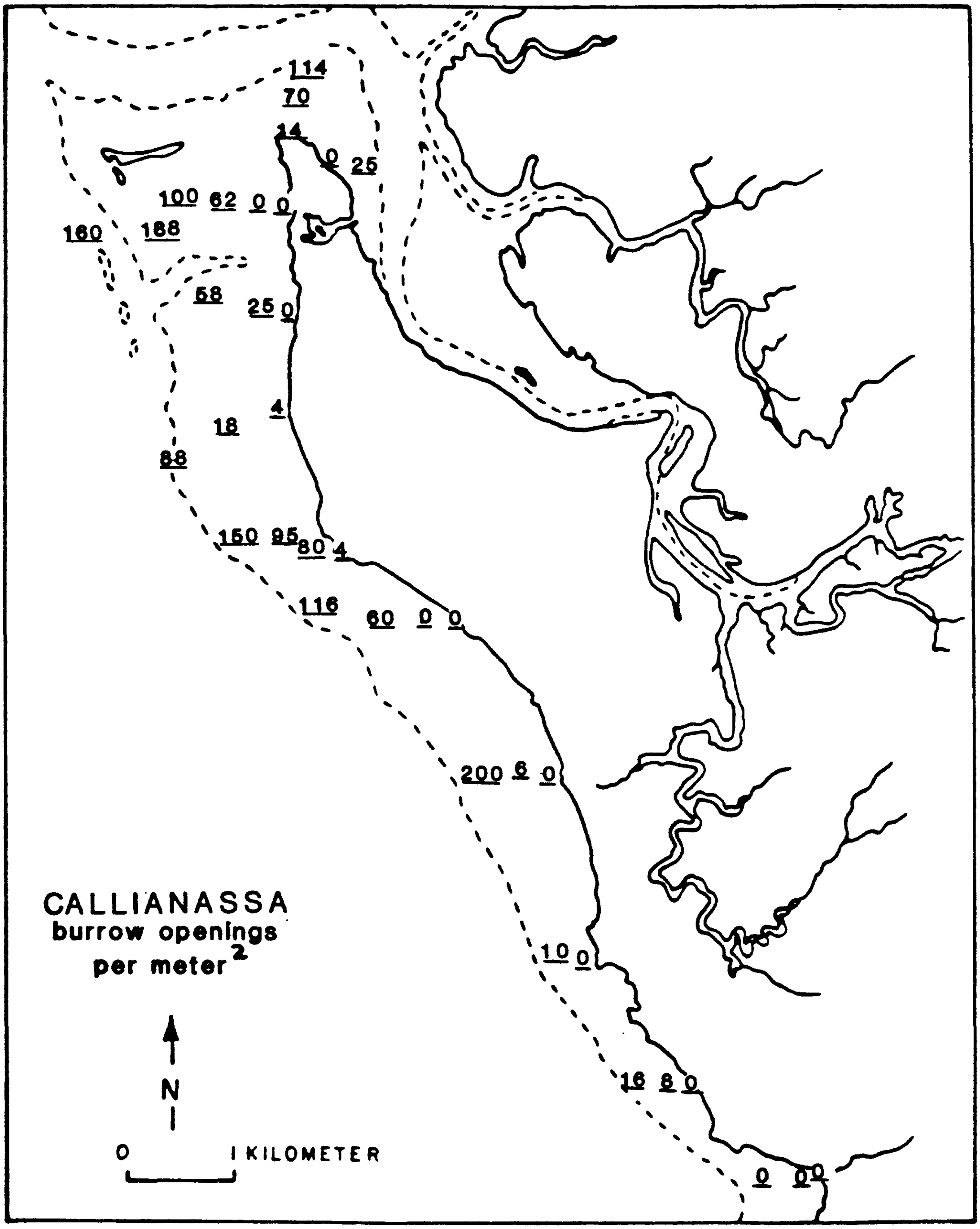


FIG.2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6
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10
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16
8
0
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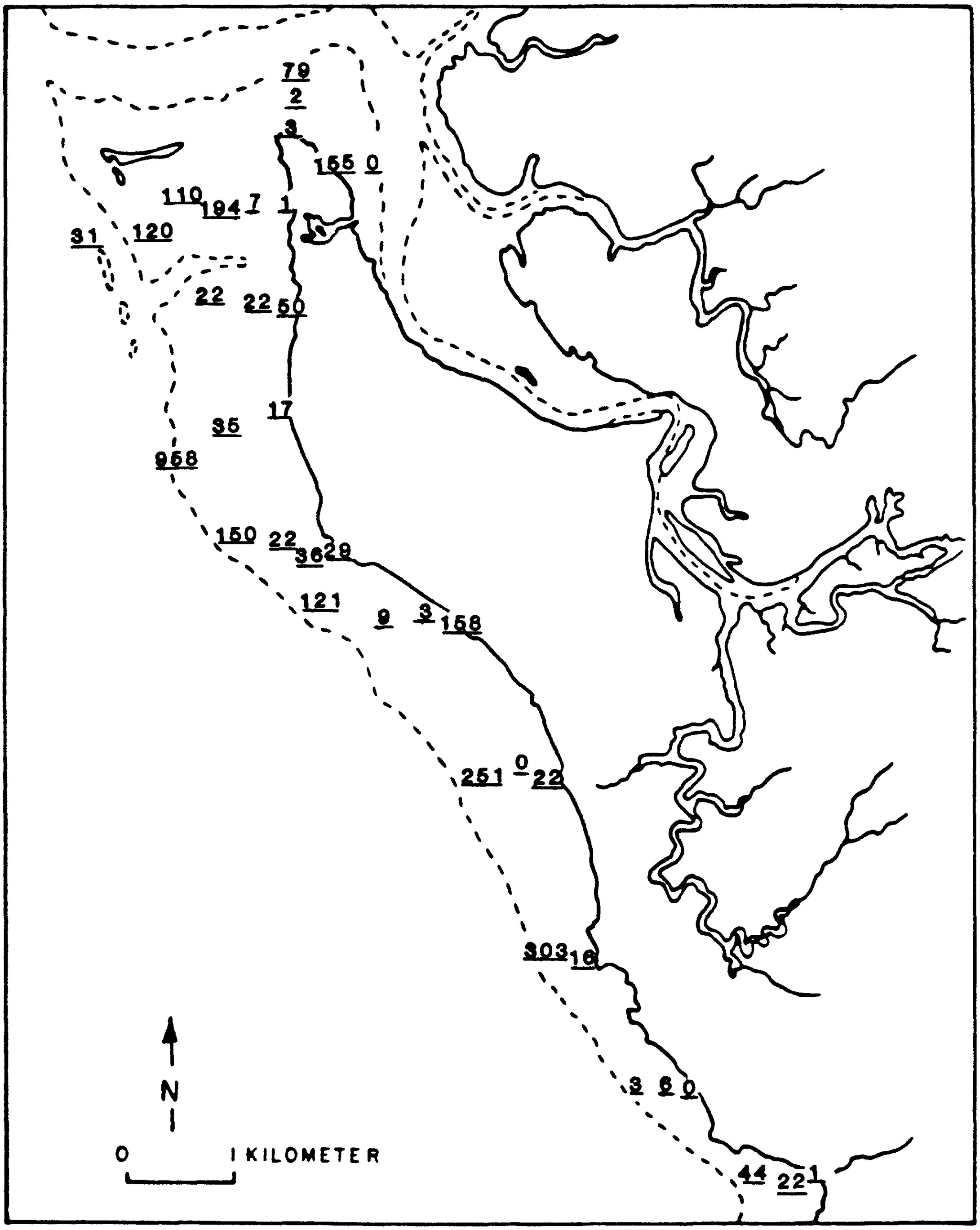
CALLIANASSA
burrow openings
per meter²
N
0
1 KILOMETER

FIG.29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22
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958
150
22
36
29
121
9
3
158
251
0
22
303
16
N
3
6
0
0
1 KILOMETER
44
22
1

FIG.30

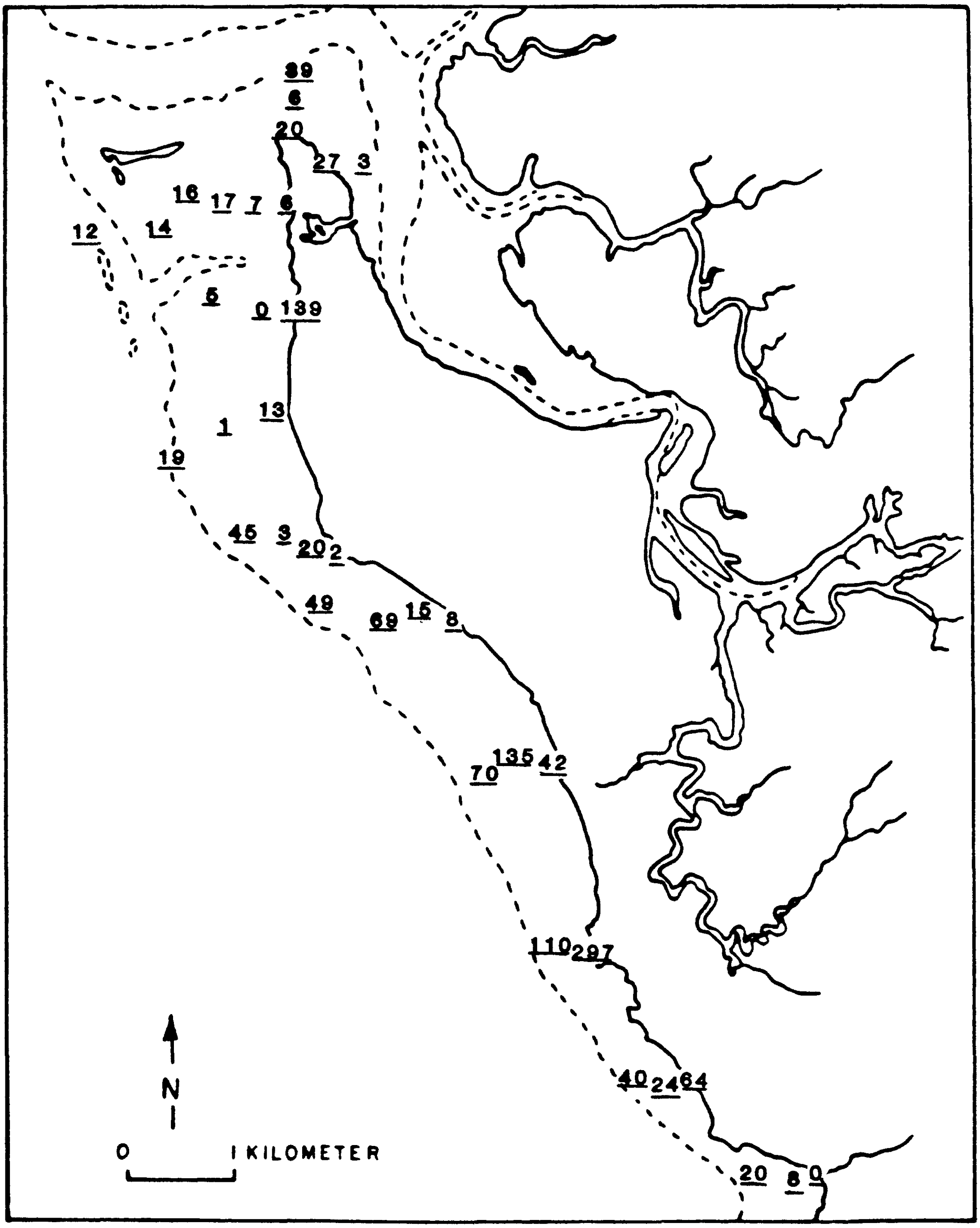
39
6
20
27
3
16
17
7
6
12
14
5
0
139
13
1
19
45
3
20
2
49
69
15
8
70
135
42
110
297
40
24
64
20
8
0
N
0
1 KILOMETER

FIG.31

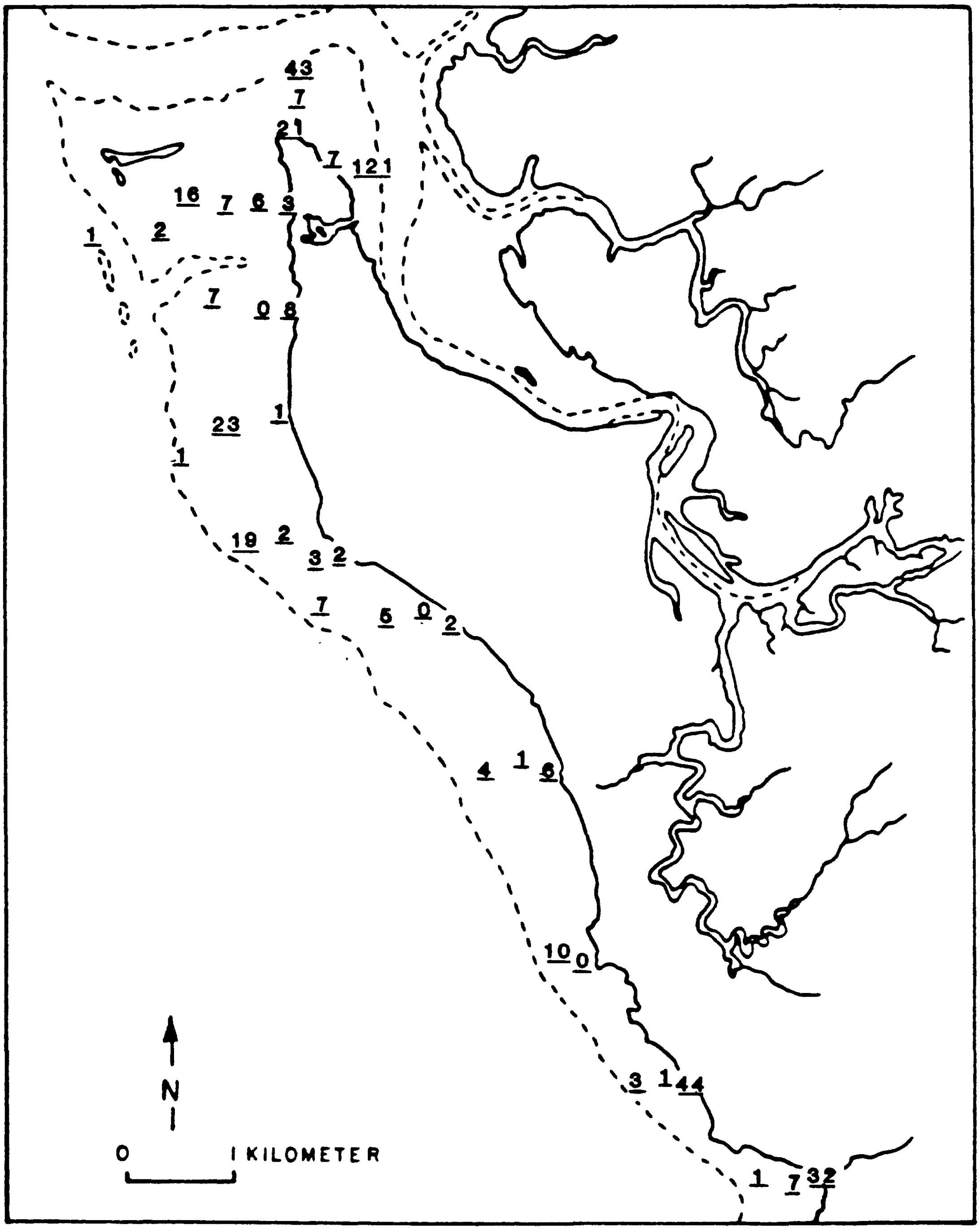
43
7
21
7
121
16
7
6
3
1
2
7
0
8
23
1
1
19
2
3
2
7
5
0
2
4
1
6
10
0
3
1
44
1
7
32
N
0
1 KILOMETER

FIG.32

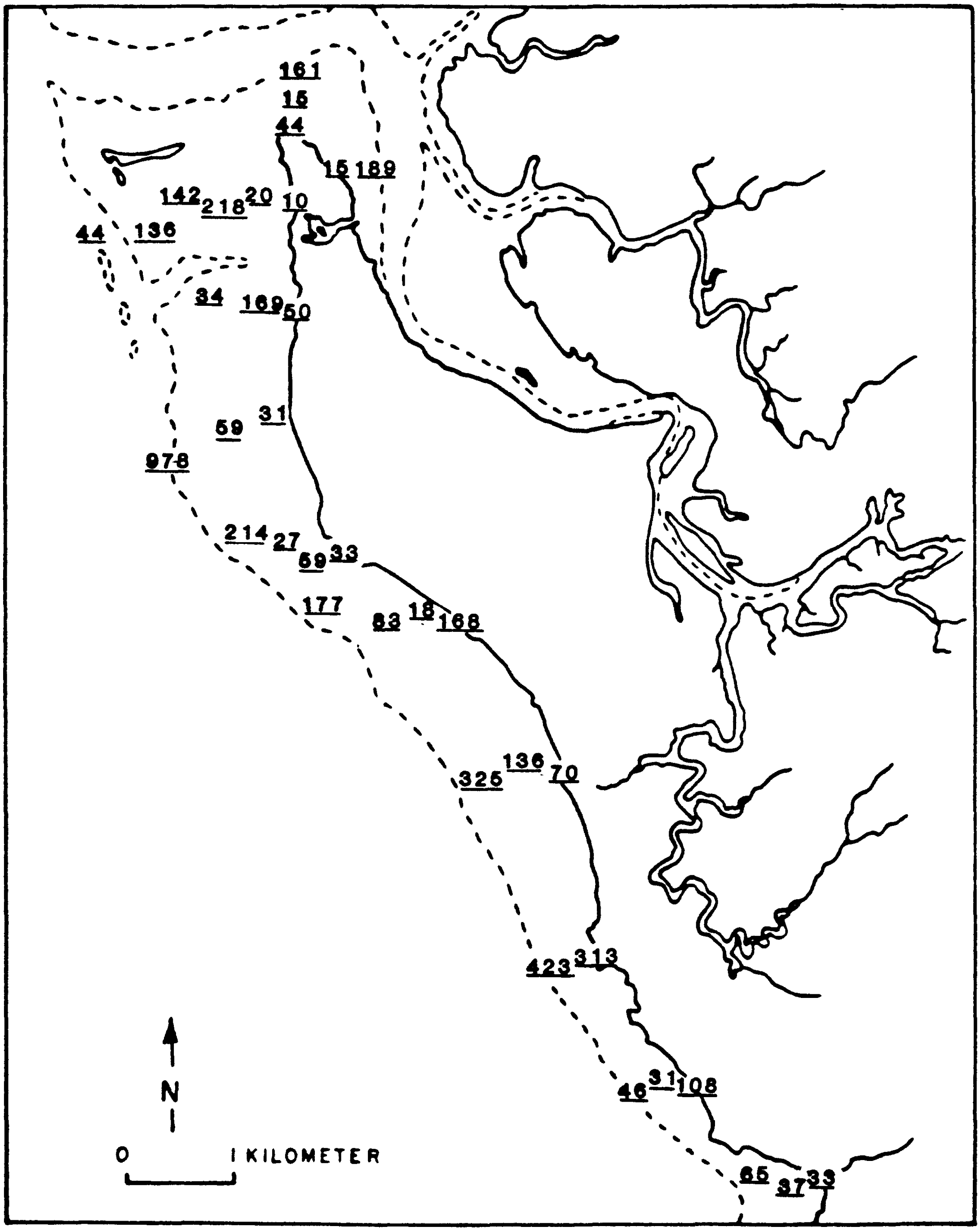
161
15
44
15
189
142
218
20
10
44
136
34
169
50
31
59
978
214
27
59
33
177
83
18
168
325
136
70
423
313
46
31
108
65
37
33
N
0
1 KILOMETER

FIG.33