Moss Landing Marine Laboratories

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THE RESULTS OF AN EXPLORATORY FISHING CRUISE FOR *LOLIGO OPALESCENS* IN SOUTHERN AND CENTRAL CALIFORNIA JUNE 5-25, 1974

by

J.R. Raymond Ally, Ronald G. Evans, and Thomas W. Thompson

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ABSTRACT

During June 1974 the California Department of Fish and Game, in cooperation with the Sea Grant program at Moss Landing Marine Laboratories, conducted an exploratory fishing cruise that extended from La Jolla to Santa Cruz and included the Channel Islands, concentrating on inshore waters. The cruise was preliminary to the initiation of a major program of squid research and had six objectives:

1) To gather samples of market squid (Loligo opalescens) for population, growth, aging and food chain studies.
2) To locate potential new fishing grounds.
3) To investigate methods for determining spawning intensity.
4) To gather data on oceanographic parameters of the spawning grounds.
5) To make incidental collections as requested by other investigators.
6) To familiarize Sea Grant personnel with the capabilities of the Department's largest research vessel, ALASKA, with respect to squid.

Especially good weather and oceanographic conditions persisting throughout the cruise enabled us to make 66 nightlight stations, 17 midwater trawls and eight bottom trawls. Fishable concentrations of squid were discovered in the areas between Cape San Martin and Partington Point, between Pfeiffer Point and Point Sur, and in Carmel Bay, heretofore unfished. Squid spawning off Santa Cruz Island was observed utilizing an underwater observation chamber aboard the vessel. Mating and feeding behavior were observed in shipboard aquaria.

THE RESULTS OF AN EXPLORATORY FISHING CRUISE FOR *LOLIGO OPALESCENS* IN SOUTHERN AND CENTRAL CALIFORNIA

INTRODUCTION

During June 1974, the California Department of Fish and Game, in cooperation with Moss Landing Marine Laboratories, conducted cruise 74A5 in the inshore waters off the California coast between La Jolla and Santa Cruz, including the Santa Barbara Channel Islands. This cruise, carried out aboard the research vessel ALASKA, had six objectives:

1. To gather samples of market squid, *Loligo opalescens*, for population, growth, aging and food chain studies.
2. To locate potential new fishing grounds.
3. To investigate different methods for determining spawning intensity.
4. To gather data on oceanographic parameters of squid spawning grounds.
5. To make incidental collections as requested by other investigators.
6. To familiarize personnel from Moss Landing Marine Laboratories with the characteristics, limitations, and operating procedures of the ALASKA in preparation for future squid cruises under the auspices of the Sea Grant program.

METHODS AND MATERIALS

ALASKA is a large research vessel, originally designed as a tuna clipper and completely described in the first volume of *Fishing Boats of the World* (Traung, 1955). Since acquisition by the Department of Fish and Game, the boat has been modified by conversion of much of the refrigerated fish hold space for gear storage, the addition of scientist's quarters and laboratories, the installation of an underwater observation chamber, and rigging for almost all conceivable types of commercial fishing operations. The boat is unusually stable and spacious, particularly for a coastal research vessel.

Fishing methods employed on Cruise 74A5 included night-lighting, combined with hook and line jigging and brailing for squid; and the employment of a large (100-ft., or 30.48-m, mouth) midwater trawl, in conjunction with a Simrad sonar and fathometer operating at 30/38 kHz. The duration of the night-light stations ranged from 30 to 210 minutes, averaging 45 to 60 minutes. Midwater trawls ranged from 4 to 20 minutes in duration at depths of 30 to 60 feet. Eight bottom trawls were accomplished immediately off Monterey with a 42-ft. (12.8-m) bottom trawl in order to sample squid egg masses.

The cruise track (Figures 1-7) extended from La Jolla north through the Channel Islands and thence along the coast from Point Conception north to Monterey. Extensive sampling was carried out in Monterey Bay. After 5 days there, the vessel reversed its track, continuing the sampling program south to Point Sal and Santa Cruz Island and returning to San Pedro.

A total of 17 midwater trawls and 66 night-light stations was completed under unusually good weather conditions. The coast between Points Sal and Pescadero was sampled intensively because of the relatively unexplored nature of these waters, especially with respect to the squid resource. Night-light stations were located only 2 to 3 miles apart along this stretch of coastline. The cruise track differed from that of most previous

Fish and Game cruises, as well as the CalCOFI cruises, largely in its concentration on areas north of Point Conception and close to shore. A major reason for this was the criticism of CalCOFI cruise tracks in Okutani and McGowan's (1969) analysis of larval squid distribution.

Squid were jigged employing the Japanese lures described in Flores (1972) and Voss (1973), which generally do not damage captured animals severely. Thus, aquarium experiments employed jigged animals as well as animals taken by brailing from a spawning aggregation off Santa Cruz Island. Morphometric analyses were accomplished using animals preserved by freezing and in 10% seawater formalin. Specimens of squid and other species captured in the midwater trawl were identified immediately; and representative samples were preserved in seawater formalin or by freezing for subsequent examination. Lights employed in the sampling program were a 1500 watt incandescent bulb suspended approximately 6 ft. (1.8 m) from the water's surface and a 650 watt movie light arranged so as to shine through the underwater observation port located about 3 ft. (.91 m) beneath the water line of the vessel.

RESULTS

Squid were observed at 53 of 66 night-light stations and were captured in 16 of 17 midwater trawls. Fishable concentrations of squid were noted at Santa Cruz and San Clemente Islands and in Monterey Bay, areas presently exploited by commercial fishermen. Large concentrations were also found between Cape San Martin and Partington Point, between Pfeiffer Point and Point Sur, and between Yankee and Pescadero Points.

The latter three areas are not traditionally fished and, with the exception of Carmel Bay, had not been explored for squid fishery potential.

Squid taken under the lights had dorsal mantle lengths averaging 161.18 mm (6.35 in.). Unusually large squid were taken between Cape San Martin and Partington Point and between Pfeiffer Point and Point Sur (130-192 mm, or 5.1-7.5 in.), as well as at Santa Cruz Island and in the Carmel Bay area. Moreover, squid captured in these locales were in stages of gonadal maturity indicating imminent spawning. Spawning was actually observed at Santa Cruz Island. Thus it seems probable that the Cape San Martin-Partington Point, Pfeiffer Point-Point Sur, and Carmel Bay sampling sites represent heretofore uncharted spawning areas (Figure 9). The squid taken in the traditionally fished spawning grounds off Monterey and San Clemente Island were somewhat smaller (100-170 mm, or 3.9-6.6 in.) but were also in advanced stages of gonadal maturity.

As expected, almost all of the squid taken on the jigs were sexually mature, demonstrating the sexual size dimorphism described by Fields (1965).

For many years commercial fishermen have maintained that the squid taken off Monterey are larger than those obtained elsewhere in the state. In order to investigate this reported size difference, dorsal mantle lengths of squid taken from seven stations in the Monterey area were compared with dorsal mantle lengths of samples from seven stations south of Point Conception. The mean of the Monterey area dorsal mantle lengths was 165.08 mm (6.5 in.) as opposed to a mean of 158.76 mm (6.25 in.) for animals from south of Point Conception. This difference amounts to only 3.8%, which we do not regard as significant for the time period of the cruise.

On June 8 an unusually large spawning school of squid was encountered off Santa Cruz Island. There we were able to carry out detailed observations of squid spawning behavior. We observed only one mating position, namely that in which the male squid positions himself below the female. The head to head position reported by Fields (1965) was not recorded at this station. However, what could have been interpreted as a head to head position was sometimes observed during the male's attempts to capture a female. In the successful matings we observed, a head to head confrontation always resulted in a rapid shift to the dorsal-ventral position.

Commencing on June 7 we held live adult squid in an aquarium aboard the vessel in a continuously running seawater system. Two jigged squid were placed in the tank and observed feeding upon juvenile rockfish which had been taken in the midwater trawl that evening. On June 8 ten additional squid, the majority of which (7) were taken from the spawning aggregation previously mentioned, were added to the same aquarium. Mating behavior and egg deposition were filmed. We attempted to maintain live squid in the aquarium until June 11, at which time the surviving five animals were sacrificed. During this period squid in the aquarium fed on rockfish and anchovies both before and after mating. This observation interested us inasmuch as the majority of the literature reports that spawning squid do not feed. The average fecundity of a female squid was 24 fingers of eggs per animal. At the termination of the experiment, 4 days after the last of the spawning animals had been introduced to the aquarium, one completely spent male and four completely spent females were still alive and feeding. This was interesting since the literature (Fields, 1965) leads one to believe that squid die shortly after spawning and egg deposition.

The results of the midwater trawls (Table 1) are relatively unique for two reasons. The first is the extremely large size of the trawl employed. The second is the fact that the trawl was deployed at shallow depths close to shore. As a result of the series of trawls completed in June 1974, we feel we are beginning to develop an understanding of the communities of organisms which coinhabit inshore waters with schools of *Loligo opalescens*.

Squid are remarkably abundant in the shallow scattering layer sensed with the sonar equipment aboard ALASKA and were obtained in 16 of 17 trawls. South of Estero Point squid were taken in 7 of 8 trawls and were present in large numbers in all trawls north of Estero Point. The most abundant co-occurring organism was *Sebastes*. Enormous quantities of juvenile *Sebastes* were taken in trawls north of Estero Point. Juvenile rockfish were also present in about a quarter of the stations south of Estero Point. Anchovies were more frequent co-occurrers with squid south of Estero Point, and their importance declined as we moved north. The jellyfish *Pelagia* and *Chrysoara* were taken frequently with squid and were so abundant north of Estero Bay that our trawls had to be shortened drastically in order to avoid damage to the net. Euphausiids were important in trawl catches north of Estero Point. (Squid have been observed feeding on euphausiids in Monterey Bay -- G. Victor Morejohn, Moss Landing Marine Laboratories, personal communication.)

A number of other species were common co-occurrers with *Loligo opalescens*, as indicated by the midwater trawl data, although in relatively small numbers. These organisms included the medusa fish, *Icichthys lockingtoni*; midshipman, *Porichthys notatus*; hake, *Merluccius productus*; juvenile flatfish; and *Cancer* crabs. We anticipate that the accumulation of more data with the large midwater trawl, combined with observations on the feeding habits of *Loligo opalescens*, will enable us to better determine the role played by this species in the food chains of the California Current system.

Squid were abundant on night-light stations (Table 2), occurring on 80% of the stations throughout the cruise. Observations of organisms co-occurring with *Loligo* at night-light stations tended to indicate more pronounced differences between Central and Southern California than did the midwater trawls. However, these observations should be regarded as reinforcing those obtained with the midwater trawl since the night-light tends to be selective and since it is difficult to identify many organisms in the water under the light. Generally, juvenile *Sebastes* increased north of Estero Point, while anchovies decreased, and euphausiids were more abundant in the northern areas sampled than in the southern, as revealed by the midwater trawls.

One of the objectives of cruise 74A5 was to investigate methods for determining spawning intensity utilizing traditional methods. The midwater trawl and the squid jig produce quite different results. The trawl is relatively unselective with respect to age or sex. Mean dorsal mantle length of trawled squid was 68.86 mm (2.71 in.), with a standard deviation of 23.13 mm (.91 in.), and the ratio of males to females was 1.5:1. The squid jig, however, appears to be selective for adult animals (mean DML = 161.18 mm, or 6.35 in., S.D. = 8.84 mm, or .35 in.) and highly selective for males. The sex ratio observed in standard 1,000 gram samples was 7.68 males per female. The reason for this selectivity is presently unknown. We hypothesize that it is likely that adult male squid have a more positive phototropism than do females, are more aggressive in their feeding behavior, or are sexually attracted to the jigs.

We had far more success on the night-light stations in calm water than in rough seas. This is only partly due to the fact that we were drifting on these stations. It was only in periods of dead calm that we could attract squid close enough to the surface to brail or make observations of mating behavior. This is perhaps due to the squids' ability to sense surface surge or, alternatively, to actually hear the sound produced by a chop.

While we had good success in locating squid for the midwater trawl with the Simrad sonar system aboard ALASKA, we were unable to obtain squid in the absence of small fish whose swim bladders could provide a positive echo. A consideration of the literature (Flores, 1972; Shibata and Flores, 1972; Kawaguchi and Nazumi, 1972; and Matsui, Taramoto and Kaneko, 1972) leads us to believe that the 30/38 kHz frequency range of this system is too low to sense squid schools unless they are mixed with fish. The same literature indicates that operating frequencies between 160 and 200 kHz are more appropriate for this work.

DISCUSSION

We should like to emphasize the fact that the results of cruise 74A5 are preliminary and apply only for the period encompassed by the cruise dates (June 5-25, 1974). Three weeks is indeed a limited time frame from which to draw conclusions about an area so extensive and a resource so large. In future years we plan to seek potential squid fishing grounds between Santa Cruz and the Oregon border, to conduct more detailed investigations of newly discovered potential fishing grounds, and to attempt to deploy newly developed mechanisms for estimating the squid resource.

Among the failures of this cruise was the attempt to gather data on oceanographic parameters of the spawning grounds. As the result of a malfunction of the XBT, we were unable to obtain more than surface water temperatures at any of our sampling stations. We will attempt to remedy this problem in future years and to coordinate the ALASKA cruise with small-scale water sampling experiments to be conducted from the research vessel operated by Moss Landing Marine Laboratories.

The bottom trawls were less than satisfactory, a result of our ability to locate large rock reefs in an otherwise featureless sand bottom. In the future we intend to experiment with drop cameras or a TV camera/monitor system to estimate per cent cover of egg masses on the bottom. Hopefully, acoustic sensing techniques can also be devised and developed to the point that the same tools employed in estimating anchovy populations can be applied to squid populations.

The squid resource is apparently very large and could possibly support a considerably expanded fishery. Estimates of the ultimate potential sustained yield harvest from the California Current system range from 50,000 to ~~600,000~~ 300,000 tons annually (Frey, 1971; Gulland, 1971). Cruise 74A5 represents the first serious attempt to estimate the size of this fishery.

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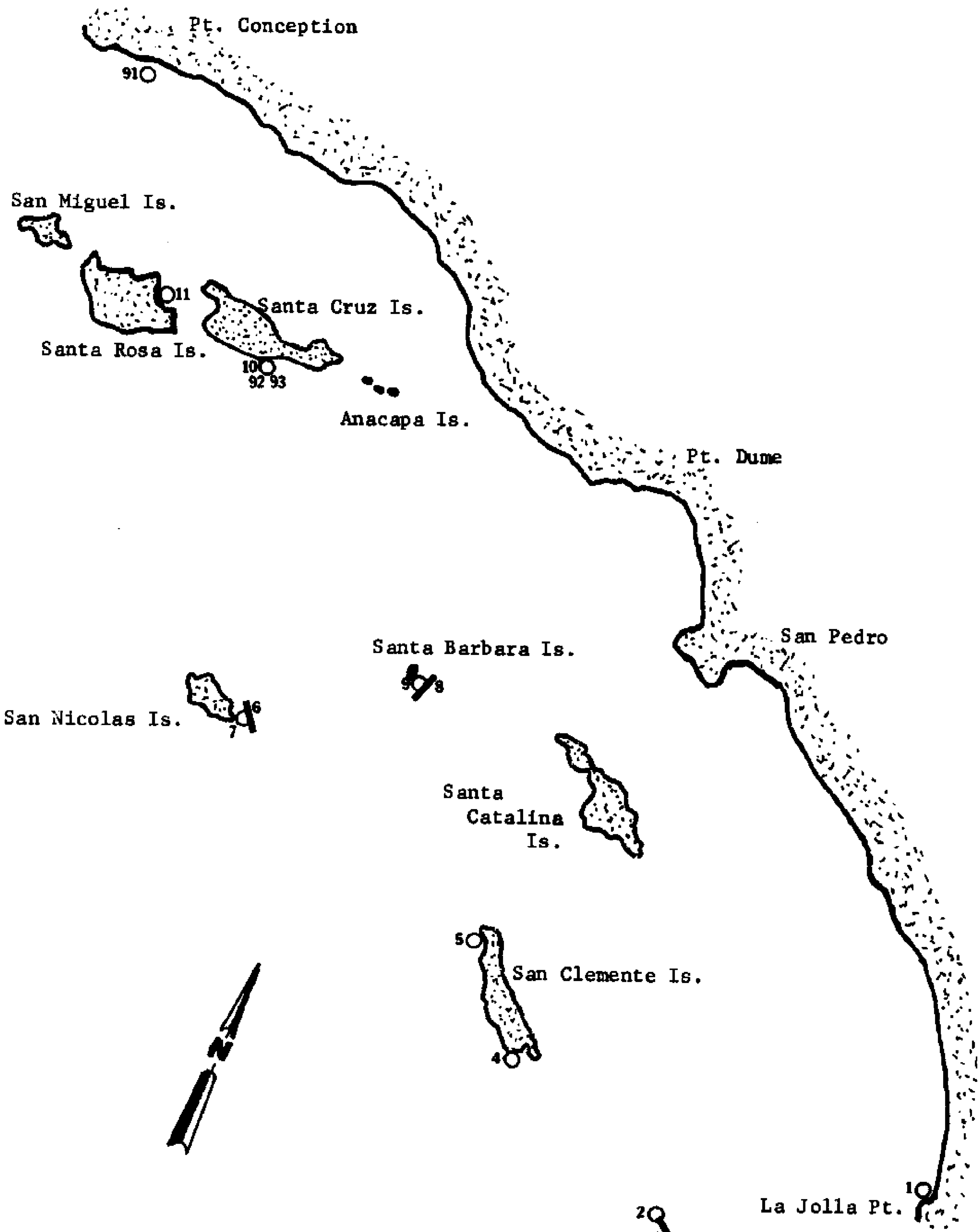

FIGURE 1. Cruise 74-A-5: O = night-light stations; ▬ = midwater trawl stations.

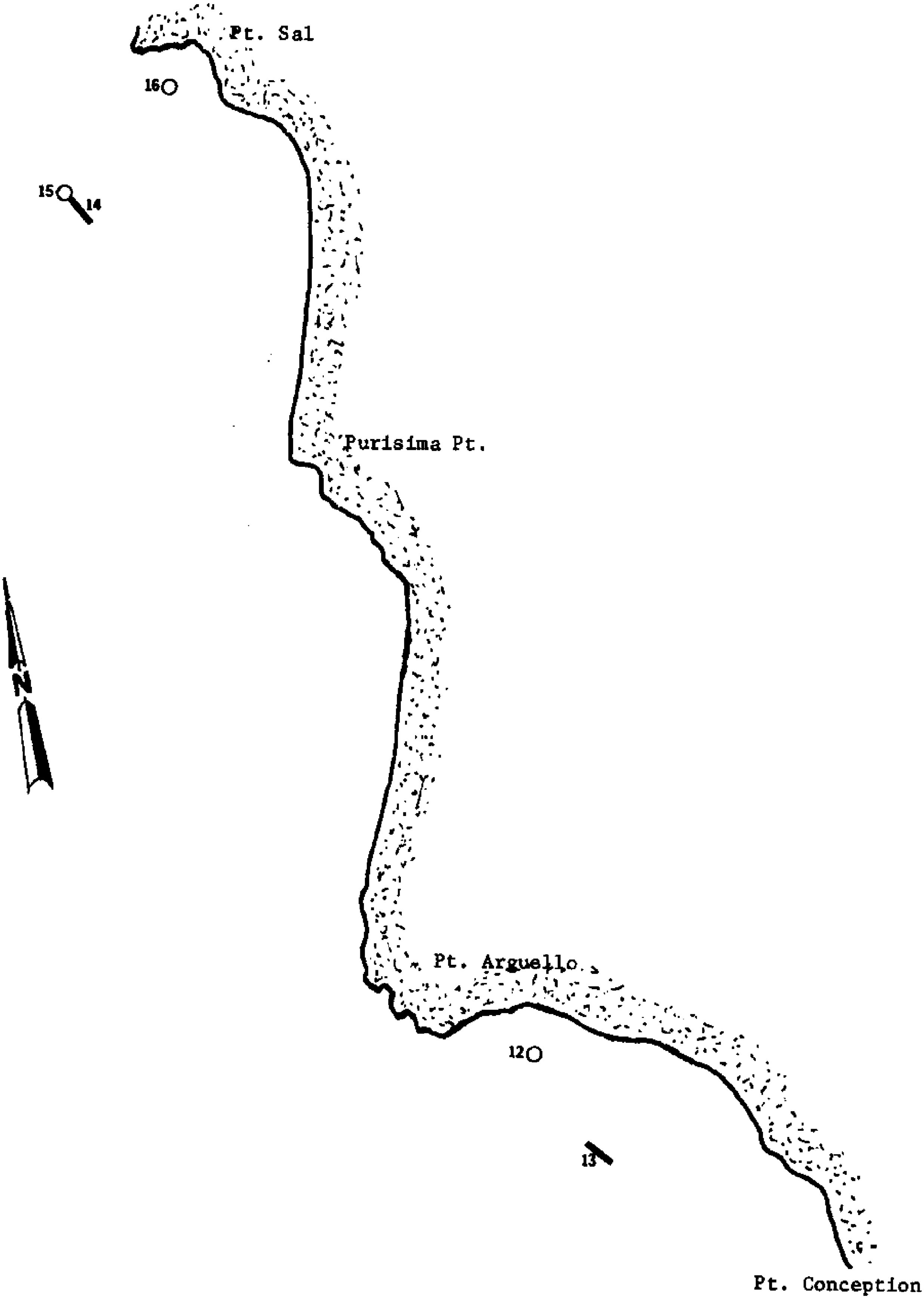

FIGURE 2. Cruise 74-A-5: O = night-light stations; ▬ = midwater trawl stations.

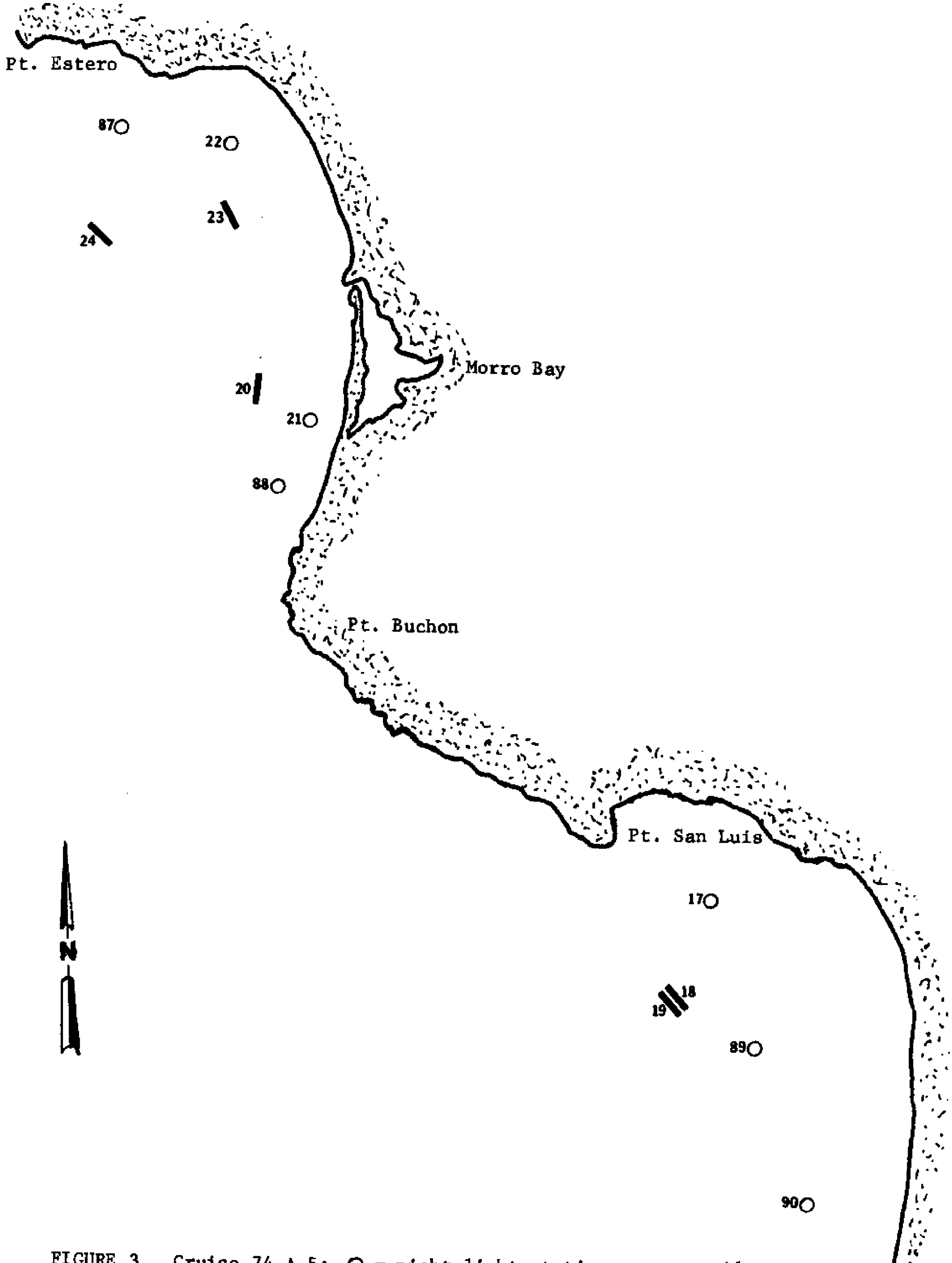

FIGURE 3. Cruise 74-A-5: O = night-light stations; ▬ = midwater trawl stations.

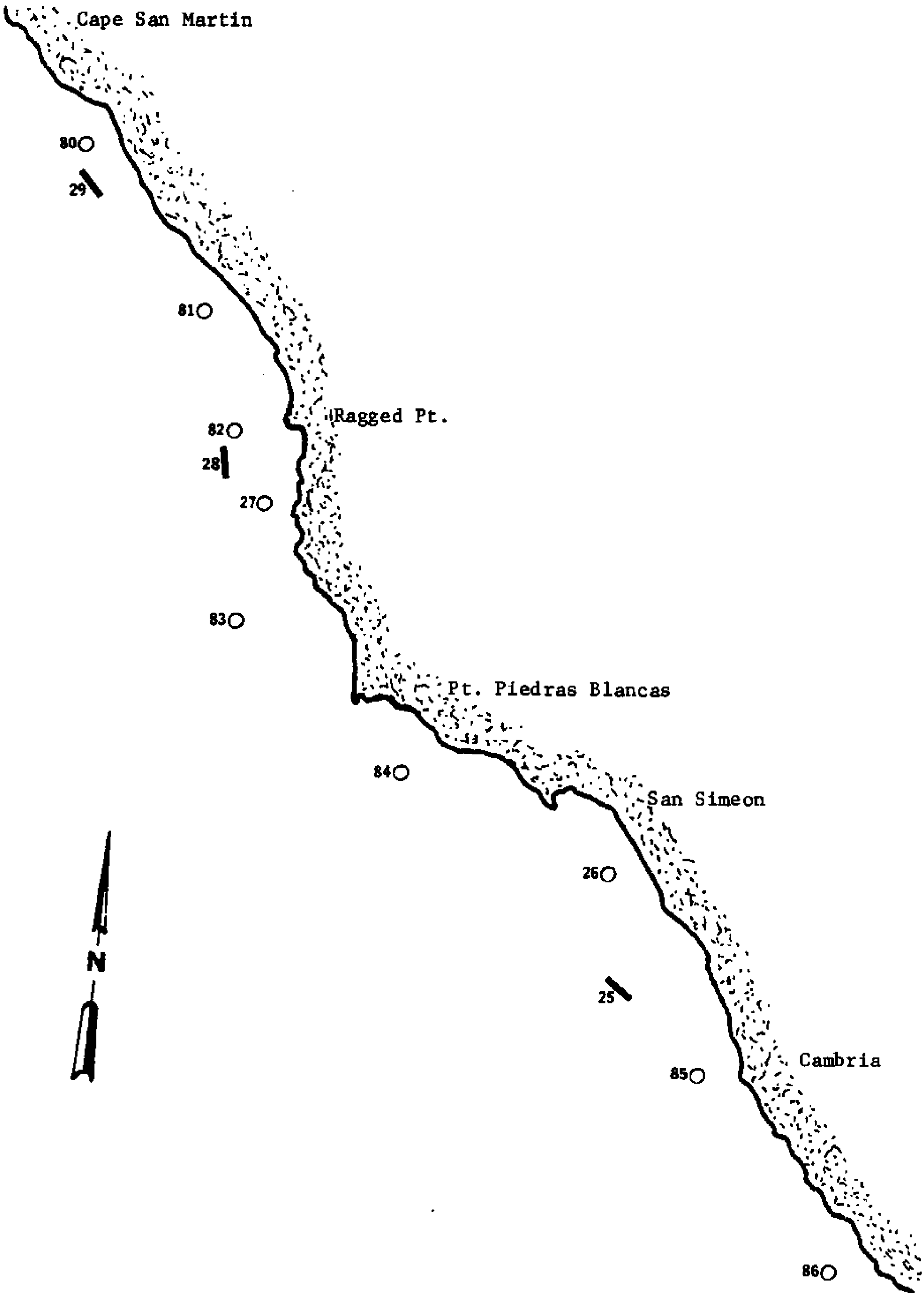

FIGURE 4. Cruise 74-A-5: O = night-light stations; ▬ = midwater trawl stations.

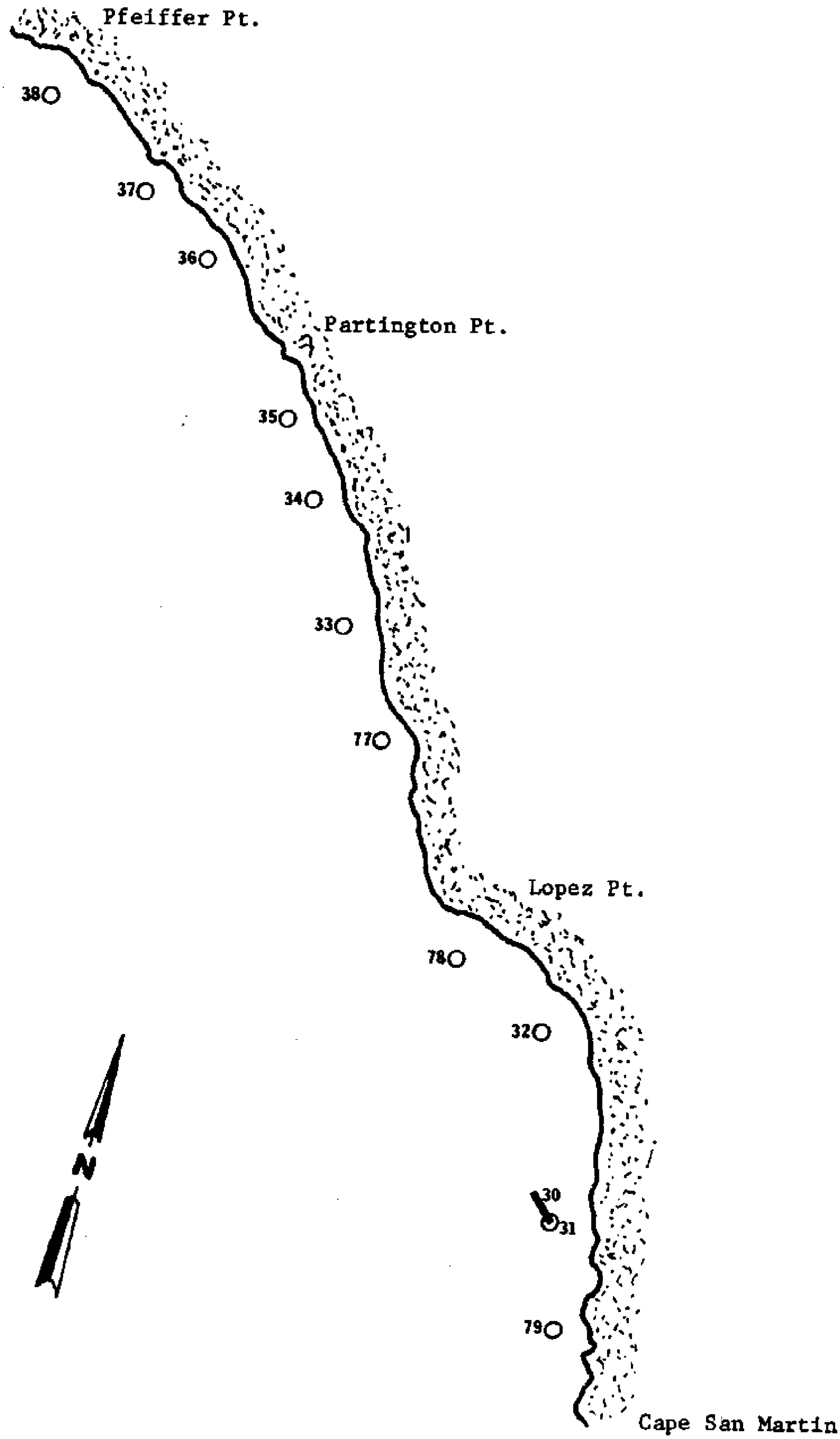

FIGURE 5. Cruise 74-A-5: O = night-light stations; ▬ = midwater trawl stations.

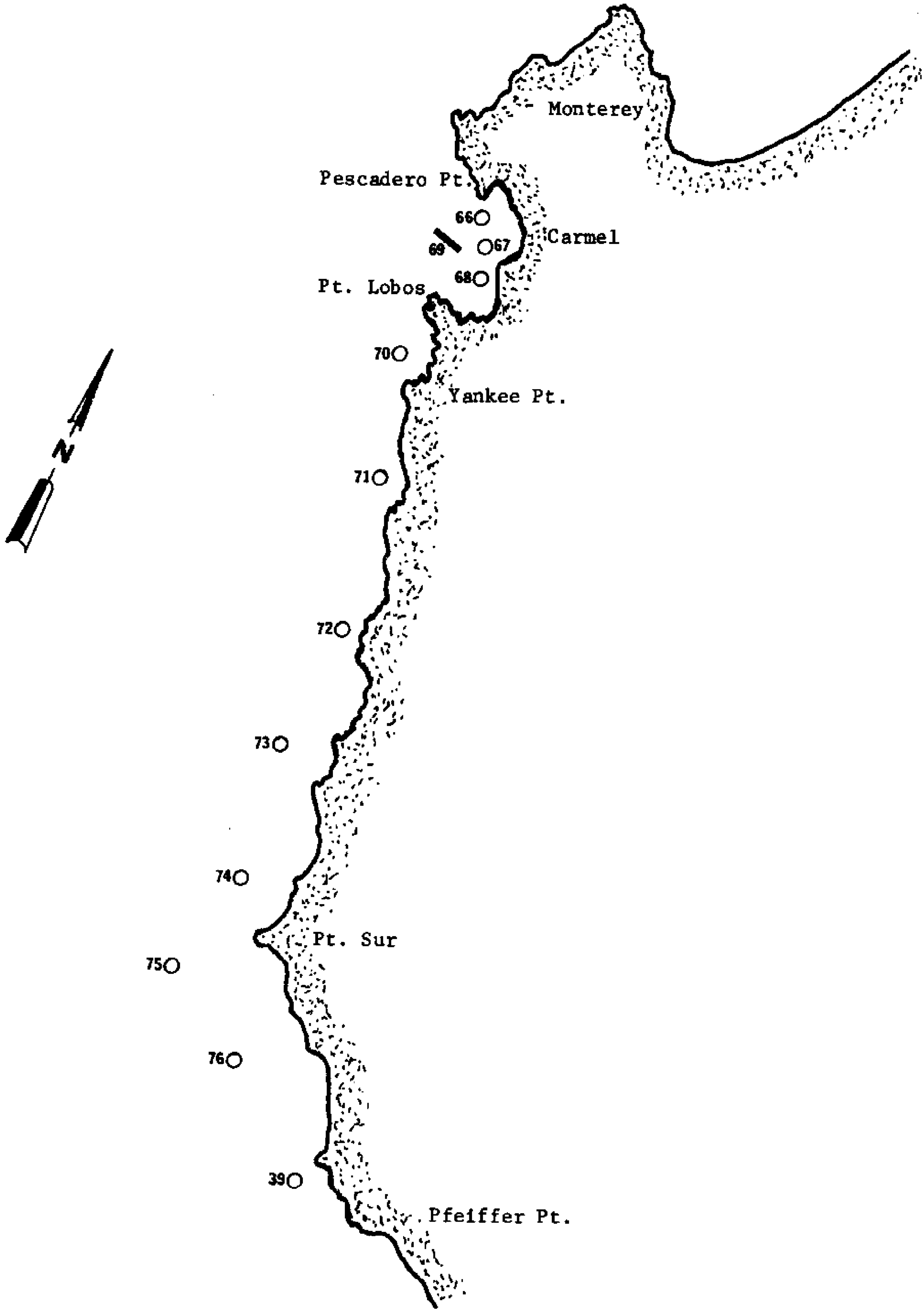

FIGURE 6. Cruise 74-A-5: O = night-light stations; ▬ = midwater trawl stations.

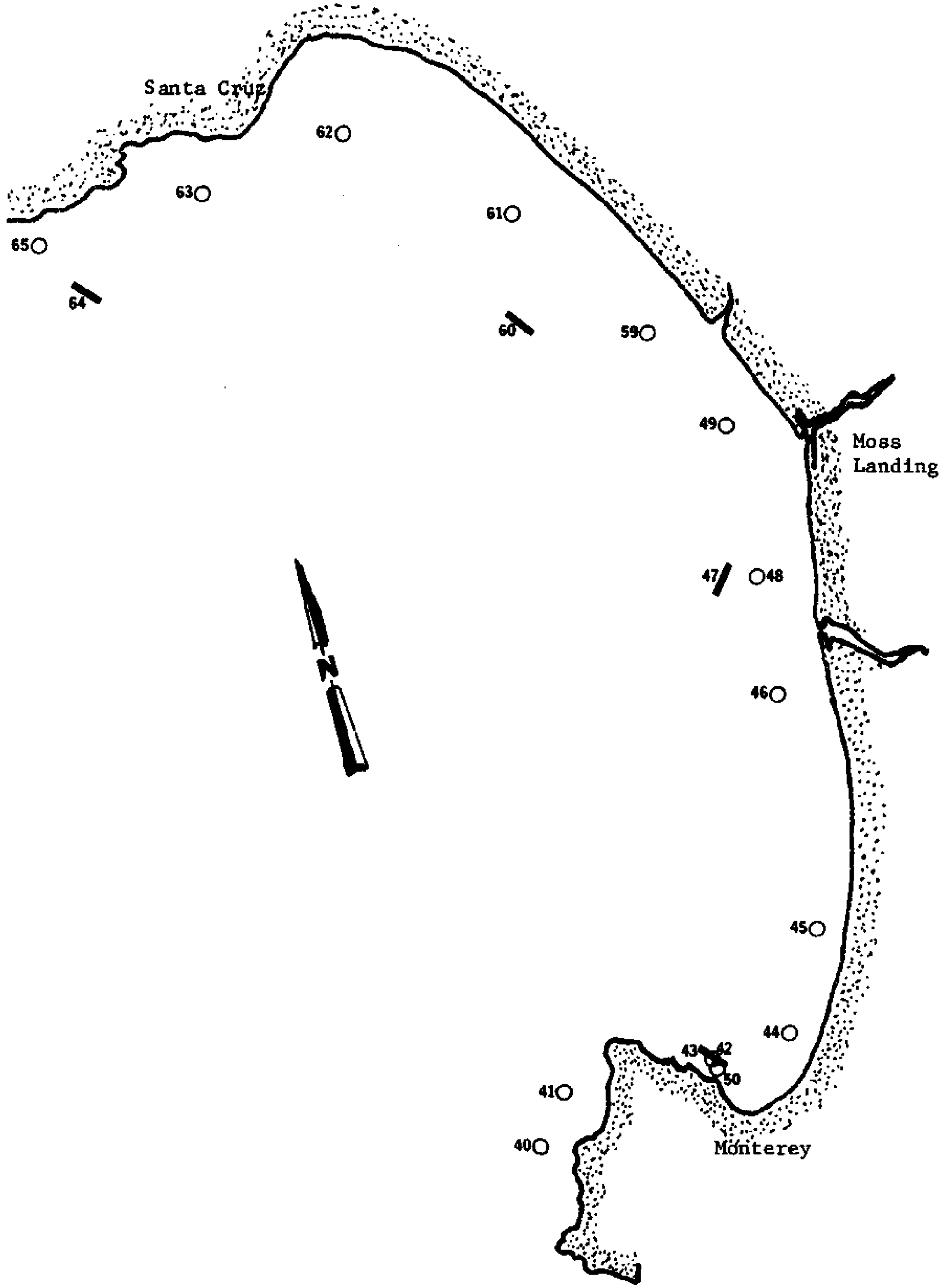

FIGURE 7. Cruise 74-A-5: O = night-light stations; ▬ = midwater trawl stations.

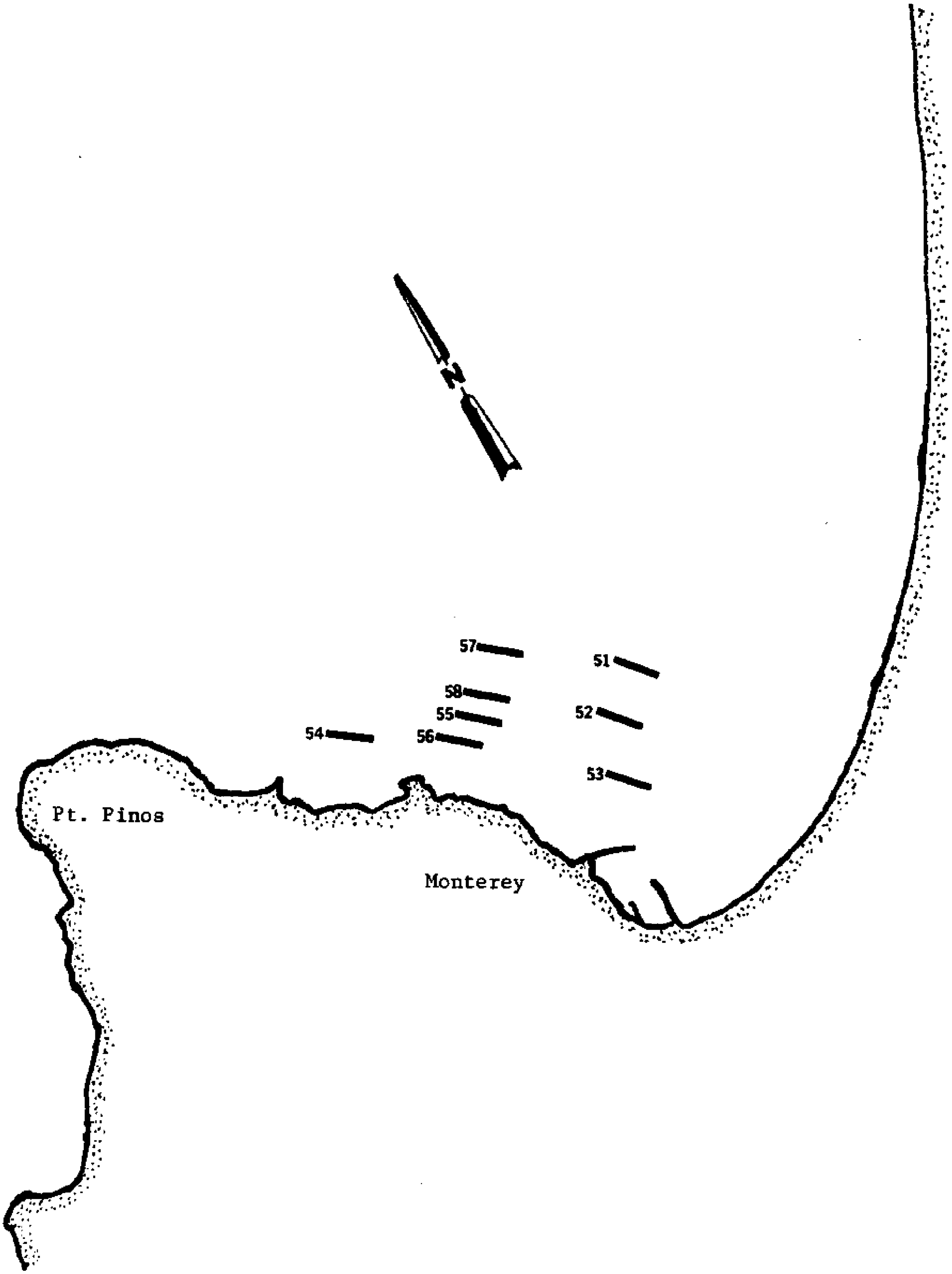

FIGURE 8. Cruise 74-A-5. Bottom Trawl Stations

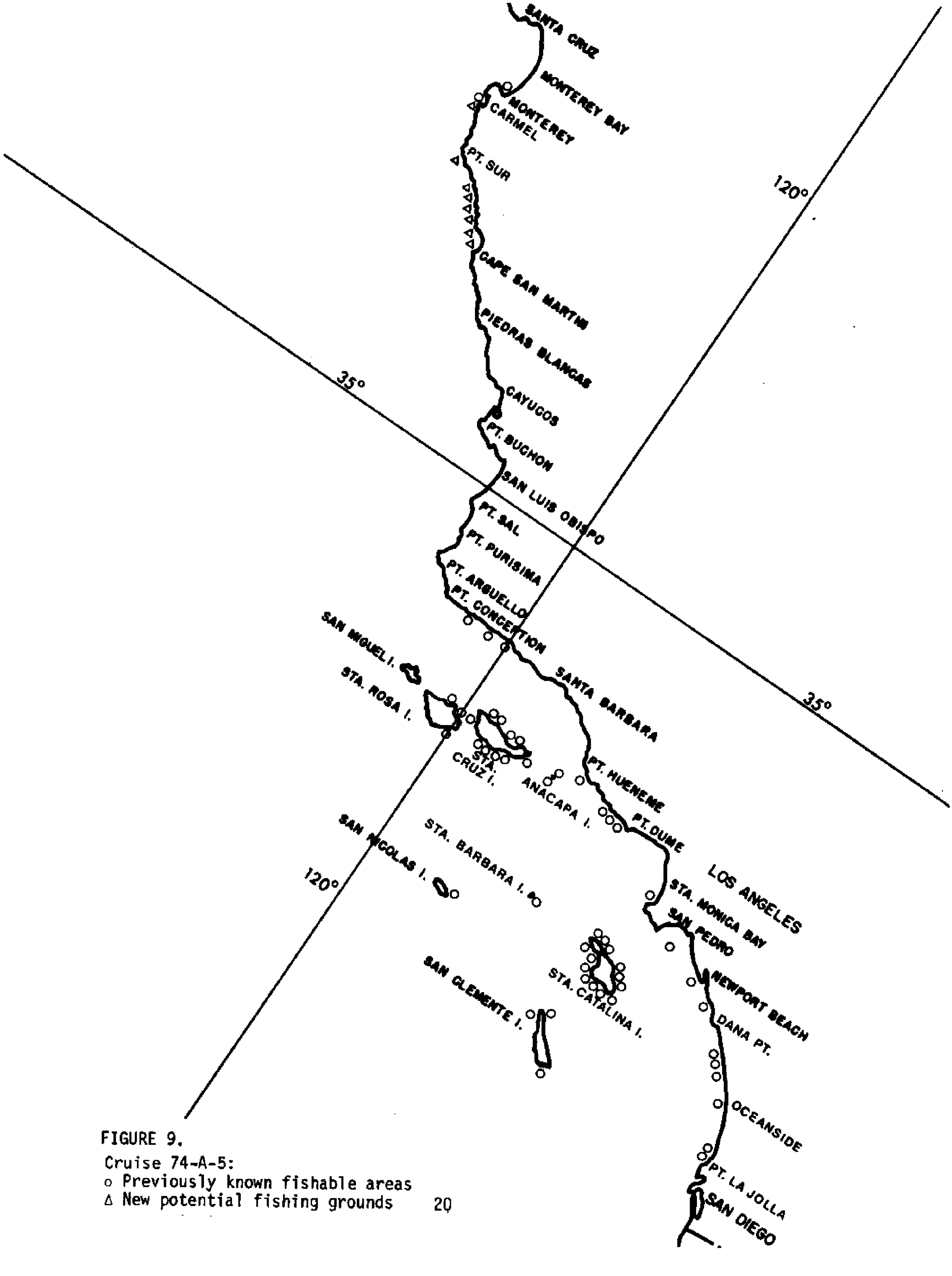

FIGURE 9.
Cruise 74-A-5:
o Previously known fishable areas
Δ New potential fishing grounds

TABLE 1
CRUISE 74A5
SQUID OCCURRENCE
(150-FT. MIDWATER TRAWL)

La Jolla to Santa Cruz	16 of 17 trawls	94.1%
South of Estero Point	7 of 8 trawls	87.5%
North of Estero Point	9 of 9 trawls	100.0%

ORGANISMS CO-OCCURRING WITH *LOLIGO OPALESCENS*

	South of Estero Point		North of Estero Point	
	%	Avg. No./Trawl	%	Avg. No./Trawl
Pelagia	28.6	10	88.8	23
Sebastes juv.	28.6	2800	55.5	2340
Anchovy	85.7	1520	55.5	221
Medusa fish	42.9	1	33.3	3
Cancer	14.3	1	55.5	1
Pompano	57.1	20	55.5	4
Midshipman	57.1	75	55.5	11
Flatfish	42.9	7	77.7	4
Chrysoara	28.6	10	44.4	5
Hake	14.3	1*	55.5	12
Euphausiids	14.3	900*	22.2	17500

*Occurred in only one trawl.

TABLE 2
CRUISE 74A5
SQUID OCCURRENCE
(NIGHT-LIGHT STATIONS)

La Jolla to Santa Cruz	53 of 66 stations	80.3%
South of Estero Point	17 of 21 stations	85.0%
North of Estero Point	36 of 45 stations	80.0%

ORGANISMS CO-OCCURRING WITH LOLIGO OPALESCENS

	South of Estero Point %	North of Estero Point %
Pelagia	35.3	30.5
Sebastes juv.	None observed	30.5
Anchovy	23.5	2.8
Chrysoara	5.9	19.4
Euphausiids	None observed	5.5
Jack mackerel	17.6	2.8
Smelt	11.8	13.9