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Seasonal Variation of Alginic Acid Content in *Sargassum cervicone* Greville from Hikkaduwa

by

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Sargassum cervicone Greville is one of the species of Sargassum occuring in abundance along the South Western Coast of Ceylon. Durairatnam 1966 carried out a survey from Ambalangoda to Hambantota and estimated that approximately 130 tons of dried Sargassum can be harvested annually. The bulk of the Sargassum found in this area was Sargassum cervicone Greville.

This brown seaweed has the appearence of a flowering plant reaching a height of 40 cms. or more with branches arranged in a distichous manner. The branches at the base are longer than above. The leaves are petiolate varying in length from 3–7 cms. Vesicles are borne on dilated foliaceous petioles about the same length of the vesicle which is somewhat elliptical. Receptacles axillary forming pedunculate more or less devided racemes.

Sargassum contains one of the most important seaweed product and its sodium and calcium salts. Sodium alginate is used in forming gels in cosmetics and food, preparing films and coatings, transparent papers and textile sizes and as stabilisers in cosmetics, ice creams and salad creams. Alginic acid and alginates are used in dentistry for dentures and denture surfacings, in dying and water proofing of clothes, in the plastic industry, in paints and varnishes, in the making of gum and linoleum and wall panellings and even in the manufacture of artificial textile fibre called alginate rayon. The use of calcium alginate, berylium alginate for the manufacture of silks, offers enormous potentialities for the raw materials.

Due to the economic importance of alginic acid and its salts it was decided to determine the alginic acid content of Sargassum cervicone Greville monthly for a period of one year and observe the variation of the alginic acid content.

MATERIALS AND METHODS

Sargassum cervicone Greville was collected from a fixed area at Hikkaduwa every month. The plants were thoroughly washed and dried completely for a week. It was then chopped to very small pieces along with the leaves, stipes, vesicles and receptacles. Exactly weighed quantities of the weeds were used for all experiments.

In the first instance the following pretreatment methods were tried out :

(1) Pretreatment with Na_2CO_3 and H_2SO_4, Extraction with Na_2CO_3. Purification with H_2SO_4

(2) Pretreatment with HCl. Extraction with Na_2CO_3, Purification with H_2SO_4

(3) Pretreatment with $CaCl_2$. Extraction with NaCl and Na_2CO_3. Purification with H_2SO_4

(4) No pretreatment. Extraction with Na_2CO_3, Purification with H_2SO_4

From the same batch of S. cervicone Greville collected at Hikkaduwa yields of alginic acid obtained were 25% by method (1) 21% by (2) 31% by (3) and 20% by (4). Since method (3) was the most satisfactory it was adopted for all analysis.

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ANALYSIS

(*a*) Pretreatment. A known quantity of the seaweeds was taken. Boiling water was poured on the weeds and allowed to stand for 30 minutes and then drained. It was then heated with 0.5% $CaCl_2$ at 100° for 30 minutes, then drained and washed.

(*b*) Digestion. Add NaCl (10% weed) and add water 30 times the weight of the weed and heat at 80–100° for 30 minutes. Add Na_2CO_3 (10% weed) and at 90°C for 10–20 minutes. Stand several hours to complete digestion.

(*c*) Extraction of Alginic acid. Dilute with Kiesulguhr and filter them. Add dilute H_2SO_4 to filtrate till all alginic acid is precipitated. Centrifuge and wash with hot water 55°C and 95% alchol and dry at 90°C and weigh.

The result of the analysis of Sargassum cervicone Greville is given below :—

Month	*%Moisture*	*%Alginic acid*	*Alginic acid as % of moisture free seaweed*
July 1963 ..	.. 13.0	.. 28.4	.. 32.6
August ..	.. 16.0	.. 24.5	.. 29.2
September ..	.. 15.0	.. 29.0	.. 34.1
October ..	.. 12.5	.. 28.0	.. 32.0
November ..	.. 13.0	.. 43.0	.. 50.0
December ..	.. 14.0	.. 48.0	.. 57.0
January 1964 ..	.. 16.0	.. 48.0	.. 57.1
February ..	.. 14.0	.. 48.6	.. 56.5
March ..	.. 17.0	.. 46.6	.. 56.1
April ..	.. 13.0	.. 48.7	.. 56.0
May ..	.. 15.0	.. 33.0	.. 38.8
June ..	.. 14.0	.. 31.0	.. 36.0

CONCLUSION

A definite seasonal variation in the alginic acid content has been observed. The period of high alginic acid content coincides with the North East monsoon and the low alginic acid content with the South West monsoon. This is probably due to the tearing action of the heavier South West monsoon where parts of the plant, especially leaves and receptacles are torn off and only the stipe is left with a few leaves or receptacles. The best period for harvesting will be from December to April.

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The Ecology of Spiny Lobsters, *Panulirus spp.*, of Ceylon Waters

By

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INTRODUCTION

Six species of spiny lobsters of the genus *Panulirus* have been recorded in Ceylon waters. Of these, *Panulirus homarus* was reported to be the most abundant species in Ceylon waters and was also the dominant form on the west and south-west coasts. *P. versicolor* was a species common on the east coast and the dominant variety in that region. *P. ornatus* was not as common as *P. versicolor* but was the species dominant in the north. *P. longipes*, *P. penicillatus*, and *P. polyphagus* were found only in small numbers in the waters around Ceylon. Of these, *P. longipes* preferred waters beyond three fathoms in depth, *P. penicillatus* the shallow, surf-swept regions of the reef-front and *P. polyphagus* the mud banks occupied by prawns. (De Bruin, 1962).

It is clear, therefore, that species dominance and ecological separation in the genus *Panulirus* is demonstrable and that the separation is dependent on the particular ecological preferences of the different species.

In order to determine the factors governing the ecological separation, it was decided to make a detailed study of the environments in which the different species were found.

Diving operations constituted the chief method of investigation. However, information was also obtained from commercial skin-divers, trap fishermen, bottom-set net fishermen and trawling operations. The period of investigations extended from 1962–1968.

ENVIRONMENTAL FACTORS GOVERNING ECOLOGICAL SEPARATION

A. Turbidity

George (1968) considered that turbidity of the water might be an important factor governing the ecological separation. Turbidity of Ceylon coastal waters is related to proximity to river mouths and the monsoons. The monsoons are seasonal, extending from September to March on the east coast and from May to September on the west coast, and cause turbidity for a few months of the year. They affect the flow of waters of rivers so that river-mouth turbidity has a seasonal variation in extent and depth. However, there is no known record of migration during any season of any resident species, except for the observation that they leave the crevices they live in during mass movement of sand over reefs. This was observed in the Galle Harbour during the month of September. What is known is that lobsters are available in a given area throughout the year although fishing for them is difficult during the monsoon season. These observations show that turbidity, *per se*, is an unimportant factor since all species tolerate wide ranges in turbidity and clarity of water for quite long periods of time. Turbidity, especially that caused by rivers, might have an indirect effect on the ecological separation through its inhibition of the growth of coral. It is an observed fact that coral grows most profusely away from the action of rivers and the most luxuriant coral reefs are in seas lying adjacent to the arid land-masses of the north-west, north and east coasts of Ceylon. Turbidity may also affect the type of food that is available for the lobsters.

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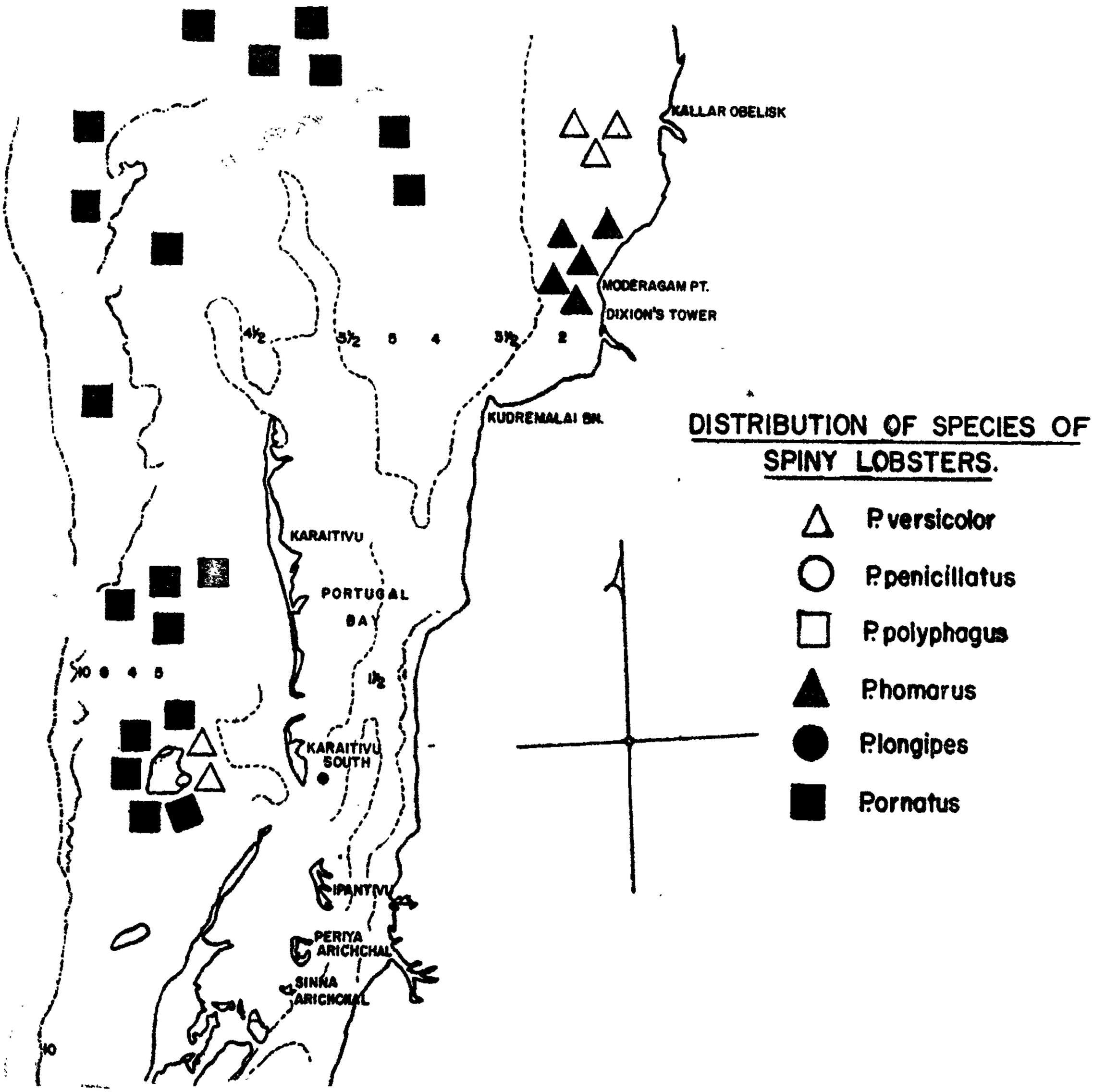

Fig. 1.—North-west coast-Kalpitiya to Kallar Obelisk,

B. The Sub-Strata

The sub-strata found along the coasts of Ceylon are 1. Live coral reefs, 2. Dead coral reefs, 3. Sand-stone reefs, 4. Sand-stone plateaus, 5. Sand-banks of silicate sand, 6. Sand-banks of fine calcium carbonate, 7. Banks of sand and shell, 8. Mud banks, and 9. Granitic rocks.

Extensive live coral formations are found along the north-west and east coasts of Ceylon where they form long barrier reefs skirting the shore-line. Extensive living coral formations are also found in those areas of the sea unaffected by the out-flow of rivers. In relatively calm areas, as in bays, coral formations also flourish as around the Islands of the north of Ceylon in Palk Bay. In the southern and south-western sectors of Ceylon there is comparatively poor coral growth owing to the heavy out-flow of silt and fresh water during the south-west monsoon.

During the monsoons, coral growth is at a minimal and parts of the living coral reefs die. The dead coral fronds are heaped up close by to form extensive dead reefs. This appears to be s seasonal occurrence. Such dead reefs are also most extensive in the north-west and east coasts of Ceylon.

Sand-stone reefs formed of compacted sand are most extensive in the south-west and southern sectors of Ceylon where they form extensive fringing reefs parallel to the coast. Such sand-stone reefs have scattered coral out-growths only.

It is a fact that living coral reefs, dead coral reefs and sand-stone reefs give aboudant shelter to marine organisms. There is ample space for marine animals to hide among the tangled out-growths of living coral, the heaped masses of dead coral and the cracks and crevices of sand-stone formations. Yet, of the two most abundant species of spiny lobsters in Ceylon waters—*P. homarus* and *P. versicolor*—the former is dominant in sand-stone reefs and is seldom if ever seen close to any living or dead coral formations. The latter is rarely found in sand-stone but is abuudant among living coral and is commonly seen in association with dead coral.

Sand-stone plateaus, as designated, are found at greater depths than live coral or sand-stone reefs—generally beyond ten fathoms. These plateaus have only scattered coral out-growths and are periodically covered by sand during monsoon times. The only shelter afforded by these plateaus are the scattered pot-holes of varying diameter. Unlike the sand-stone reefs of shallower waters extensive cracks and crevices are absent. Such plateaus are found opposite the north-west, south, south-west and east coasts but the most extensive one is opposite the north-west coast—the Pearl Banks. Only one species of spiny lobster has been seen in appreciable numbers on such plateaus—*P. ornatus*—but not in commercial quantities.

Sand-banks, whether composed of silica or calcium carbonate, or sand-shell banks do not support spiny lobster populations of any species for they do not afford cover. At night, however, numbers of *P. versicolor* have been seen on fine coral sand close to living coral formations. *P. homarus*, however, has never been seen on such a sub-stratum but has been observed on silicate sandy patches close to sand-stone reefs.

The most extensive mud-banks are found in the north of Ceylon in Palk Bay. Less extensive patches occur opposite the north-west and north-east coasts. On the west, south-west and south coasts, mud-banks of varying extent are found at a depth of 5 to 10 fathoms but they are of a much smaller area than those in the north, north-west or north-east coasts. Spiny lobsters are rarely seen at day time on mud-banks, but at night, small numbers have been captured while trawling for prawns. The species were *P. homarus*, *P. ornatus* and *P. polyphagus*.

Granitic rocks are most common in the south-west and southern sectors of Ceylon and are generally found quite close to the shore. Only two species have been regularly seen within the crevices afforded by these rocks—*P. homarus*, & *P. penicillatus*.

C. Other Factors Governing the Ecological Separation

The other factors that could cause the ecological separation are salinity, temperature, depth and calmness or agitation of waters. The feeding habits may also be of importance.

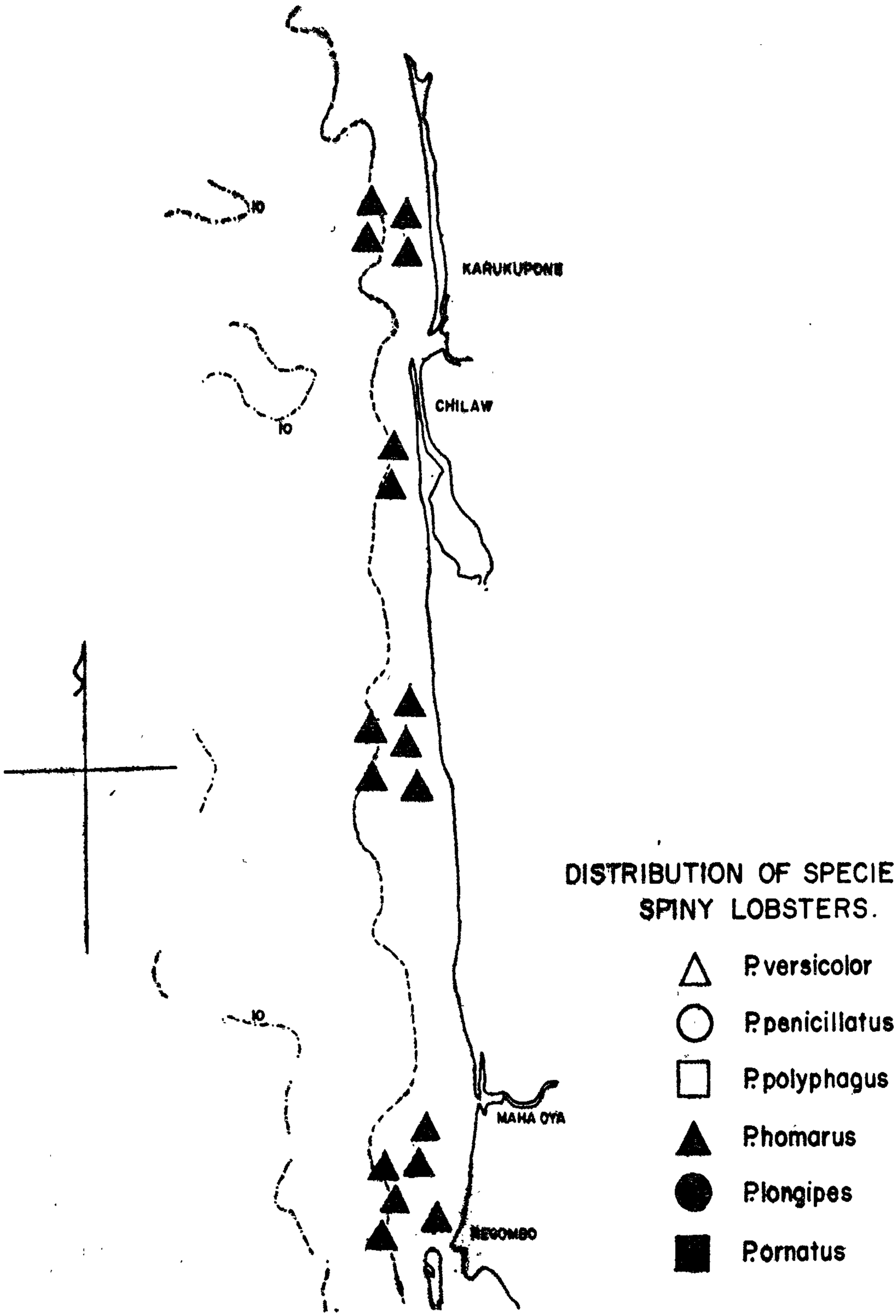

Fig 2.—West coast—Negombo to Chilaw

1. Salinity

All species of spiny lobsters are purely marine organisms for not a single species has been found in lagoons which had a salinity lower than 24 p.p.m. They are also very sensitive to fresh water which kills them in a few minutes. Judging from their distribution in relation to proximity to river mouths, *P. homarus* seems to be the most tolerant to low salinties for this species has been seen quite close to river mouths where the salinity was as low as 24 p.p.m. This faculty it seems to share with *P. penicillatus* but no more can be said about this species for it has never been seen in large numbers. The other species avoid areas close to river mouths.

2. Temperature

The temperature variations in the sea in Ceylon are not great and even when variations do occur the distribution of spiny lobsters bears no relation to such variations. Lowering of the temperature has a similar effect on all species in that it causes them to hide. This is most noticeable in the month of December on the reefs lying between Galle Face and Mount Lavinia at depths of 4–5 fathoms. Fishing for them by skin-diving is difficult during this month as most species are seen to hide deep within the shelter afforded by these reefs.

3. Depth, Calmness and Agitation of Waters

The depth of the sea appears to be a factor causing the ecological separation for *P. penicillatus* has only been found in very shallow water that is subject to surf, *P. homarus* can also tolerate surf but is also in abudnace at depths up to 10 fathoms but not deeper. The four other species have been found in waters greater than 4 fathoms or in protected bays and thus appear to prefer calm seas.

P. ornatus is the only species that has been found in waters greater than 10 fathoms deep—the greatest depth was 25 fathoms. Its ability to survive in deep waters against the attacks of large sharks and groupers appears to be its comparatively large size for, many specimens weighing as much as 10 lbs. each have been taken from depths of 20–25 fathoms.

4. Feeding Habits

The study of the feeding habits of most crustaceans is rendered difficult by the fact that they possess a gastric mill which converts anything eaten into an unidentifiable mass. However, examination of the stomach contents of *P. homarus* has shown the remains of polychaete worms, bivalve shells and echinoderms. Moreover, observation at night has revealed large numbers of *P. homarus* feeding on the tubes of polychaete worms. These polychaete worm tubes form a mat over the shallower parts of the reef between Galle Face and Mount Lavinia at the end of each monsoon. The localization of *P. versicolor* and *P. longipes* among living coral indicates that they may be feeding on living coral.

SPECIES DISTRIBUTION

1. Distribution of *Panulirus homarus* (L.)

North-west of the Mutwal Fisheries Harbour and about a quarter of a mile distant, is a mud-bank lying at depths of 5–7 fathoms. The bank lies on the inner side of Ona Gala—a long sand-stone reef populated by considerable numbers of *P. homarus*. During trawling operations, especially at night, a few specimens of this species are frequently caught. This region is quite turbid for at least half the year and the turbidity is caused by terrigenous particles washed down by the Kelani river which opens into the sea close by.

About a mile away from the Mutwal Fisheries Harbour is the Colombo Port. In the crevices of the break-waters of this harbour are to be found concentrations of spiny lobsters—the most abundant is *P. homarus*. It is also the dominant species in the rocks and sand-stone formations opposite the Galbokka Light House.

Moving farther South, wherever rocks and sand-stone formations are found from a few feet to 10 fathoms, a similar dominance is displayed by this species almost to the exclusion of others. Wherever live coral is present on the south-coast of Ceylon, as for instance, on the inner side of Barberyn

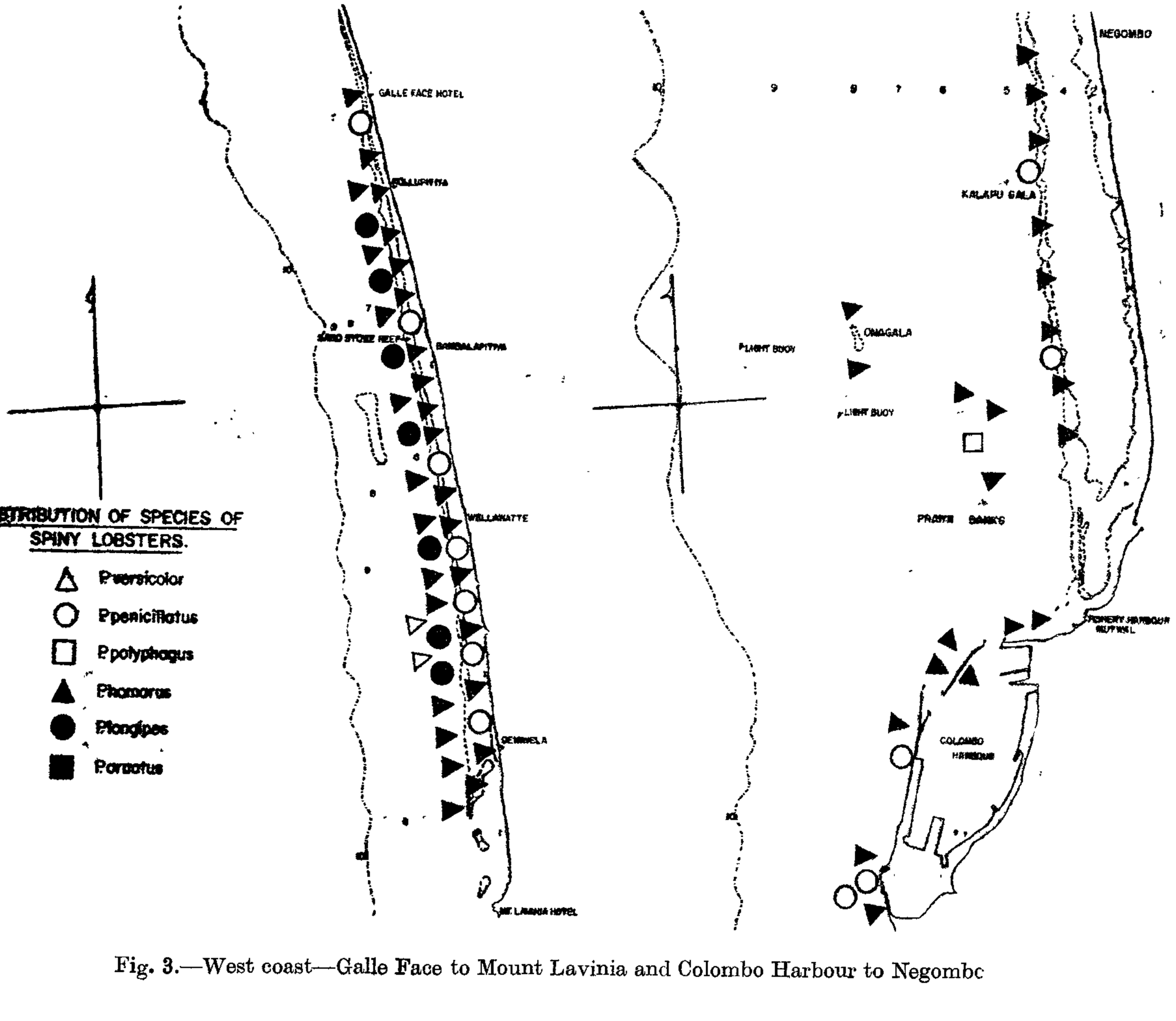

Fig. 3.—West coast—Galle Face to Mount Lavinia and Colombo Harbour to Negombc

Island or off Hikkaduwa Rest House, *P. homarus* is virtually non-existant. The sea between Colombo and Galle is turbid during the south-west monsoon and quite clear during the north-east monsoon. Yet, large concentrations of this species are found throughout the year in the sand-stone reefs and rocky areas.

P. homarus is the dominant form in the Galle Harbour especially in the dynamited rock masses of the Kamba Bandina Gala and the Diyamba Lihini Gala (De Bruin 1960). In other regions of the Galle Harbour, wherever there is granitic rock or sand-stone, this species predominates. In the rich coral formations near Watering Point it is absent. The Galle Harbour becomes seasonally murky and clear, but there was no evidence of any change in the species compositions or catch per unit effort with change of season.

Farther South, close to the Matara Rest House is a sand-stone reef. Here, too, *P. homarus* is the dominant form.

At the foot of Tangalle Rest House are rich coral formations. *P. homarus* was absent among the coral but in the sand-stone near-by considerable numbers of this species were available.

At the foot of the hill on which the Hambantota Rest House stands is a very wide bay. Near the Rest House end of the bay is an old pier and quite close to this pier in the sea are scattered granitic rocks and sand-stone formations. Large numbers of small *P. homarus* were captured from these rocks and sand-stone formations.

Off Tirrukkovil, on the east coast, a fringing reef lies a little more than a hundred yards from the shore. The reef plateau itself is covered by a carpet of soft *Alcyonarian* coral. On the landward side of the reef are prolific growths of *Acropora* coral. Diving operations were conducted here oth during the day and the night but not a single specimen of *P. homarus* was observed.

Off Addalachenai, on the east coast, are parts of old wrecked ships. One is found almost on the shore. Large numbers of *P. homarus* were found to have made this wreck their home.

In the coral reefs between Kalkudah and Passikudah not a single specimen of *P. homarus* was observed among the coral during a month's survey.

In the Trincomalee Harbour, *P. homarus* is quite rare. A single specimen was observed outside the harbour near Elephant Point.

In Back Bay, Trincomalee, a sand-stone-reef extends from the shore from a point near the cemetery which is quite close to the Trincomalee Railway Station. A fair number of specimens of *P. homarus* were observed in this area in the sand-stone formation at day time and in the open at night. No other species were encountered. A little farther away into the sea are scattered coral boulders and coral reefs but no specimens of *P. homarus* were available here. The ecological separation between *P. homarus* and *P. versicolor* was most clearly demonstrable here.

Between Trincomalee and Boulder Point, *P. homarus* was rarely seen as coral formations predominate in this region. However, at Red Rocks a few miles north of Trincomalee, numerous specimens of *P. homarus* were found concentrated in the granitic formations.

Near Pulmoddai, the site of vast deposits of the black sand-Ilmenite, granitic rocks are found quite close to the shore but in the sea farther out are coral reefs, *P. homarus* was found in small numbers among the granitic rocks but not among the coral.

The dominant species in Palk Bay was *P. ornatus* but around Kachchitivu, the most abundant was *P. homarus*, judging from the bottom-set net catches. The sub-stratum around Kachchitivu is predominantly sand-stone with scattered coral heads. Around the other islands, however, coral is more abundant.

On the north-west coast, *P. homarus* was absent among the masses of living coral of the Arippu and Vankalai reefs which consist mainly of *Acropora* coral and the calcareous alga *Halimeda*. Near Moderagam Point, however, sand-stone formations are found quite close to the shore. A number of *P. homarus* were picked up from the sand-stone and just outside the sand-stone area while diving at night.

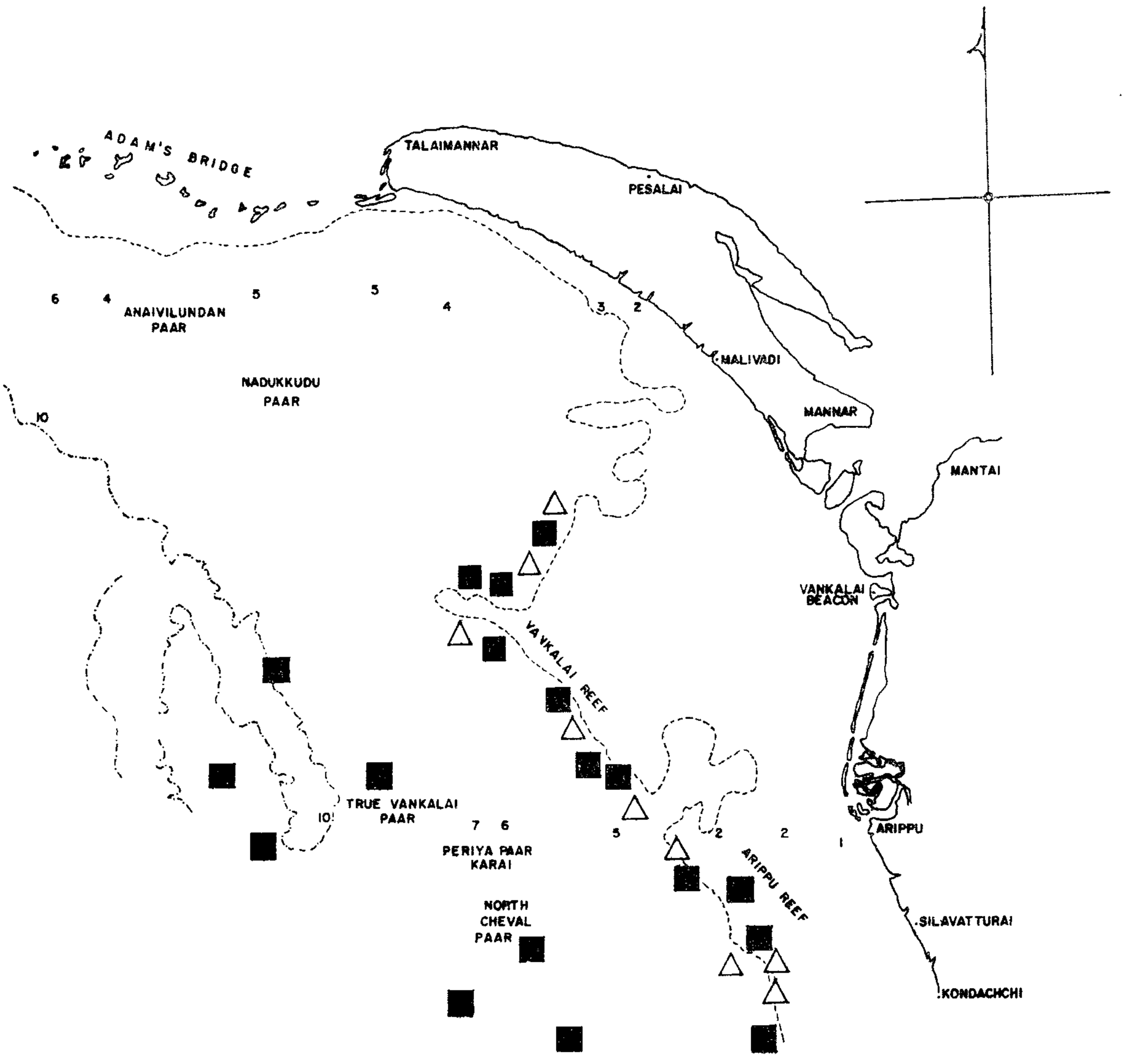

Fig. 4.—North west Coast—Kondachchi to Talaimannar

South of Karativu Island, large numbers of *P. homarus* were captured from the sand-stone areas but not from among the coral. A flourishing fishery for this species has been established west of Chilaw and Negombo.

It is clear, therefore, that *P. homarus* prefers a sub-stratum of sand-stone or granitic rock to coral. It appears to avoid actively coral formations. It tolerates extremes of turbidity and clarity of water. When the water becomes very turbid during monsoon seasons it comes out into the open to feed even at day-time. The fishermen in the Galle Harbour make use of this fact in fishing successfully for this species during day-time. It's preferance for sand-stone reefs appears to be associated with it's feeding habits, for, large concentrations have been observed at night feeding on the polychaete worm tubes that form carpets on the shallow parts of the reef at the end of each monsoon season. Greater numbers of this species have been found on sand-stone than on granitic rock formations. It has also been found in abundance quite close to the mouths of rivers and has a greater tolerance of low salinities than the other species. It has also been taken from a very muddy sub-stratm but avoids coral sandy areas.

The distribution of *P. homarus* is illustrated in Figs. 1, 2, 3, 6, 7, 8 and 9.

2. Distribution of *Panulirus versicolor.* (LATR.)

Panulirus versicolor is rare on the west coast of Ceylon and whenever it was observed on this coast there were always some living coral formations in the vicinity. It has only very rarely been seen on sand-stone reefs or among granitic rocks. These could therefore be regarded as stray specimens. A few specimens were captured from granitic rocks within the Mutwal Fisheries Harbour. Some were obtained at depths of 4–5 fathoms from the sand-stone reefs between Galle Face and Mount Lavinia. These were from areas where living coral was present close-by.

On the land-ward side of Barberyn Island among the luxuriant coral formations *P. versicolor* was the most abundant species.

This species was not present in the Galle Harbour except among the coral formations near Watering Point.

On the east coast between Kalkudah and Passikudah, *P. versicolor* was the most common species among the rich coral formations off this area. Although it was the dominant form on the east coast it was not present in as great abundance as *P. homarus* on the west coast. Unlike *P. homarus* it is unlikely to support a commercial fishery.

P. versicolor even enters the mouth of estuaries, several were captured at the mouth of Salupe Aru on the east coast where the salinity at the time of capture was 28 p.p.m. Since living coral formations were present at the mouth of this estuary, it is unlikely that the salinity is very much lower than 28 p.p.m. at any time of the year.

In Back Bay, Trincomalee. *P. versicolor* was in abundance in 1950—almost every other coral boulder had one or several specimens living within its crevices. Today, however, although it is still the dominat species in this region, its numbers have been reduced considerably no doubt as a result of the fishing activities of skin-divers. On the inner side of Fort Frederick within Back Bay, coral formations are found from the water's edge to a depth of ten fathoms. Many specimens of *P. versicolor* were observed here in 1950 but, today, only a few are available. *P. versicolor* is the most common species between Back Bay and Boulder Point and was present among the very dense coral growths of *Acropora* in Boulder Bay. It was absent, however, in all the granitic rocks present in this region.

Very small specimens of *P. versicolor*, their body-length not more than an inch, were found in their hundreds in the crevices of granitic rocks in Dutch Bay, Trincomalee. The preference for living coral, therefore, is that of the adult.

Small numbers of very large *P. versicolor* were caught in botton-set nets within Trincomalee Harbour near coral formations.

In the north of Ceylon small numbers of this species were found near and under coral formations near Delft Island and Kachchitivu Island.

Fig. 5.—North coast—Vankalai and Palk Bay areas

In the north-west of Ceylon, quite a few specimens were found under the fronds of *Acropora* coral at depths of 3–4 fathoms close to the Arippu and Vankalai reefs. Here, too, this species was seen in association with *P. ornatus*.

P. versicolor, therefore, prefers a coral sub-stratum to sand-stone or granitic rock—especially in its adult stage. It avoids mud-banks but grazes at night on coral sand close to living coral. Its greater abundance on the north-west and east coasts is related to the more prolific coral growths in these regions. It avoids the reef-front and seeks the shelter of protected bays or the less agitated deeper waters. It can also tolerate extremes of turbidity or clarity of water but is very sensitive to low salinities and avoids areas close to river mouths.

The flesh of *P. versicolor*, compared to *P. homarus*, is quite sweet. It is interesting to speculate that this may be due to its feeding on living coral.

Although abundant on the east coast, it avoided entering traps, no matter what design was used. (De Bruin, 1960.) It might be interesting to try the influence of coral and sea-weeds as bait in future experiments.

The distribution of *P. versicolor* is illustrated in Figs. 1, 3, 4, 5, 6, 7, 8 and 9.

3. Distribution of *Panulirus ornatus*. (Fabr.)

P. ornatus is not abundant in Ceylon waters and has most often been seen in association with *P. versicolor*.

Small specimens, about a foot in total length, have been taken from the crevices of the break-water of the Colombo Port. At night this species has been seen grazing on the muddy bottom outside the Port but the larger specimens apparently prefer a hard sub-stratum.

A few have been captured, along with *P. versicolor*, from the coral near Barberyn Island. Years ago, it was possible to capture a few specimens from the coral formations off Hikkaduwa Rest House and near the old Light House on the Galle Fort. Some were available in the coral off Watering Point near the Galle Harbour.

About six miles away from Kudawella is a fishing village called Unakuhuruwa and in the sea off this village is a coral-reef lying at depths of 3–4 fathoms. The reef itself is composed of large fan-shaped corals. A considerable number of very large *P. ornatus* were observed under the coral and the fishermen regularly capture this species while hand-lining for fish.

P. ornatus has frequently been seen on the east coast together with *P. versicolor* but only in small numbers. Generally, a single specimen or pairs have been observed under coral boulders and among large pot-holes in reefs, but this species, like *P. versicolor* avoids the reef-front.

P. ornatus was the dominant species as judged from the bottom-set net catches of fishermen operating in the Palk Bay. It is very likely that these specimens had moved out from the coral formations around Punkudutivu, Irainaitivu and Delft Island. It has also been seen in the coral formations around Kachchitivu Island.

On the north-west coast it has been taken in small numbers from the coral formations of the Arippu and Vankalai reefs. It has also been captured by bottom-set net fishermen operating on the Pearl Banks and has been seen in large pot-holes close to living coral heads on these banks.

P. ornatus is regularly captured by trawl especially at night during operations on the Wadge Bank at depths of 10–25 fathoms. It is the dominant species on this bank.

Very large specimens have been captured while hand-lining for fish on the east coast at depths of 20–30 fathoms and it appears to be the only species available at these depths.

P. ornatus, therefore, prefers a sub-stratum of living coral. On sand-stone reefs, at depths not frequented by other species, it lives in large pot-holes close to coral heads. The juvenile stages graze on a mud-stratum while the larger specimens seem to avoid mud. It can tolerate extremes of turbidity and clarity of water but avoids low salinity areas close to river mouths. Like *P. versicolor*, it is

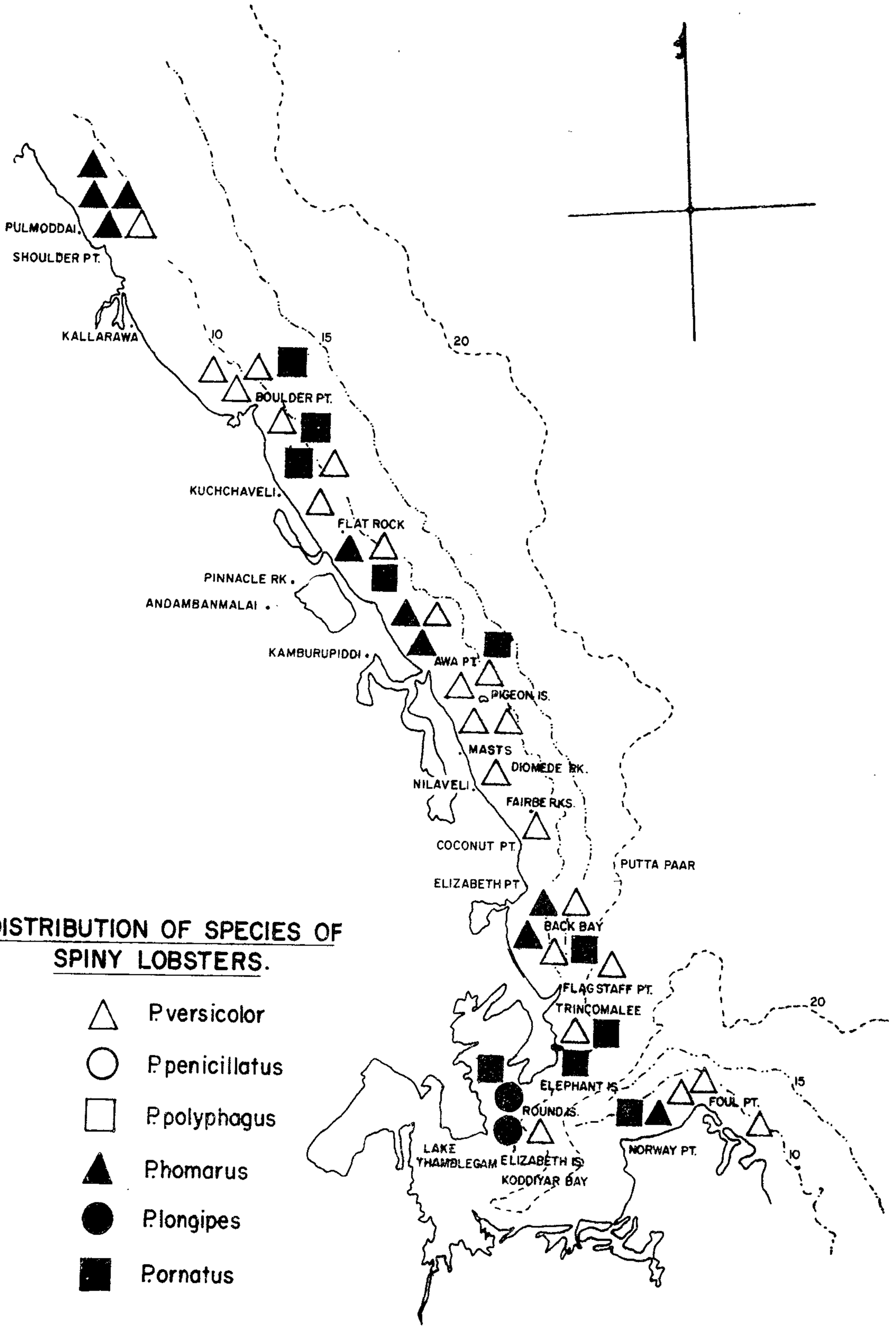

Fig. 6.—East coast—Trincomalee to Pulmoddai

more abundant on the north-west and east coasts than on the west, south and south-west coasts. It is the only species that has been found at depths greater than 10 fathoms. Like *P. versicolor* it did not enter lobster traps (De Bruin, 1960).

The distribution of *P. ornatus* is illustrated in Figs. 1, 4, 5, 6, 8 and 9.

4. Distribution of *Panulirus longipes* (Milne-Edwards)

On the west coast of Ceylon, *P. longipes* has been regularly observed while diving at night, at depths of 3 fathoms and beyond, on the reef lying between Galle Face and Mount Lavinia. It is seldom, if ever, seen in the day-time and appears strictly nocturnal in habits. It has never been observed on the reef-front although the distance between the reef-front and the 3 fathom line is only a few hundred yards. When observed on the sand-stone reef between Galle Face and Mount Lavinia, it was almost always seen close to coral fronds.

In the Galle Harbour a few were seen in close association with living coral.

In Trincomalee, on the east coast, it was observed in small numbers close to living coral near Round Island.

P. longipes has never been seen in the shelter afforded by granitic rocks but on several occasions it has been observed in the company of *P. homarus* within the crevices of sand-stone reefs. However, in the majority of instances, it was observed either alone or in pairs away from aggregations of *P. homarus* and most often close to living coral fronds.

Charbonnier and Crosnier (1961) found *P. longipes* in the company of *P. versicolor* and *P ornatus* among the living coral formations of Madagascar. They also found, like the results of experimental fishing in Ceylon, that *P. longipes* was the only one of these three species which would enter traps. This suggests that although all three species prefer living coral they might be having feeding habits which differ in details.

In the Maldive Islands, *P. longipes* was found in small numbers among the luxuriant coral formations of the islands constituting the Male Atoll. The other species present were *P. versicolor* and *P. penicillatus*. *P. homarus* and *P. ornatus* were curiously absent. This shows that *P. longipes* can find sustenance in the marine environment of a pure coral island.

Like the other species, *P. longipes* can tolerate wide fluctuations in clarity and turbidity of water. Turbidity is, therefore, a negligible factor where its particular distribution is concerned.

P. longipes is the most delicate of the species captured by hand and puts up the least resistance once held. This would account for its inability to find a niche in the turbulent reef-front and its preference for calm-deeper waters.

The distribution of *P. longipes* is illustrated in Figs. 1, 3, 5 and 6.

5. Distribution of *Panulirus penicillatus* (Olivier)

Next to *P. polyphagus*, *P. penicillatus* was observed to be the least abundant species in Ceylon waters. It has most often been captured from a surf-swept coral or sand-stone reef. Very small specimens, weighing a few ounces and very large ones, weighing as much as five pounds, have been taken from the reef-front between Galle Face and Mount Lavinia. Only rarely has it been taken from the four fathom-line known as the deep ledge in this area of the sea.

Many have been captured by bottom-set nets in shallow water opposite the Galbokka Light House. In this region are to be seen coral formations, sand-stone and granitic rocks. The two species *P. penicillatus* and *P. homarus* are present here right throughout the year. *P. penicillatus* is found in all three habitats while *P. homarus* is found only in sand-stone or granitic rock.

P. penicillatus has been caught in lobster traps set in the Galle Harbour where it is the third most abundant species.

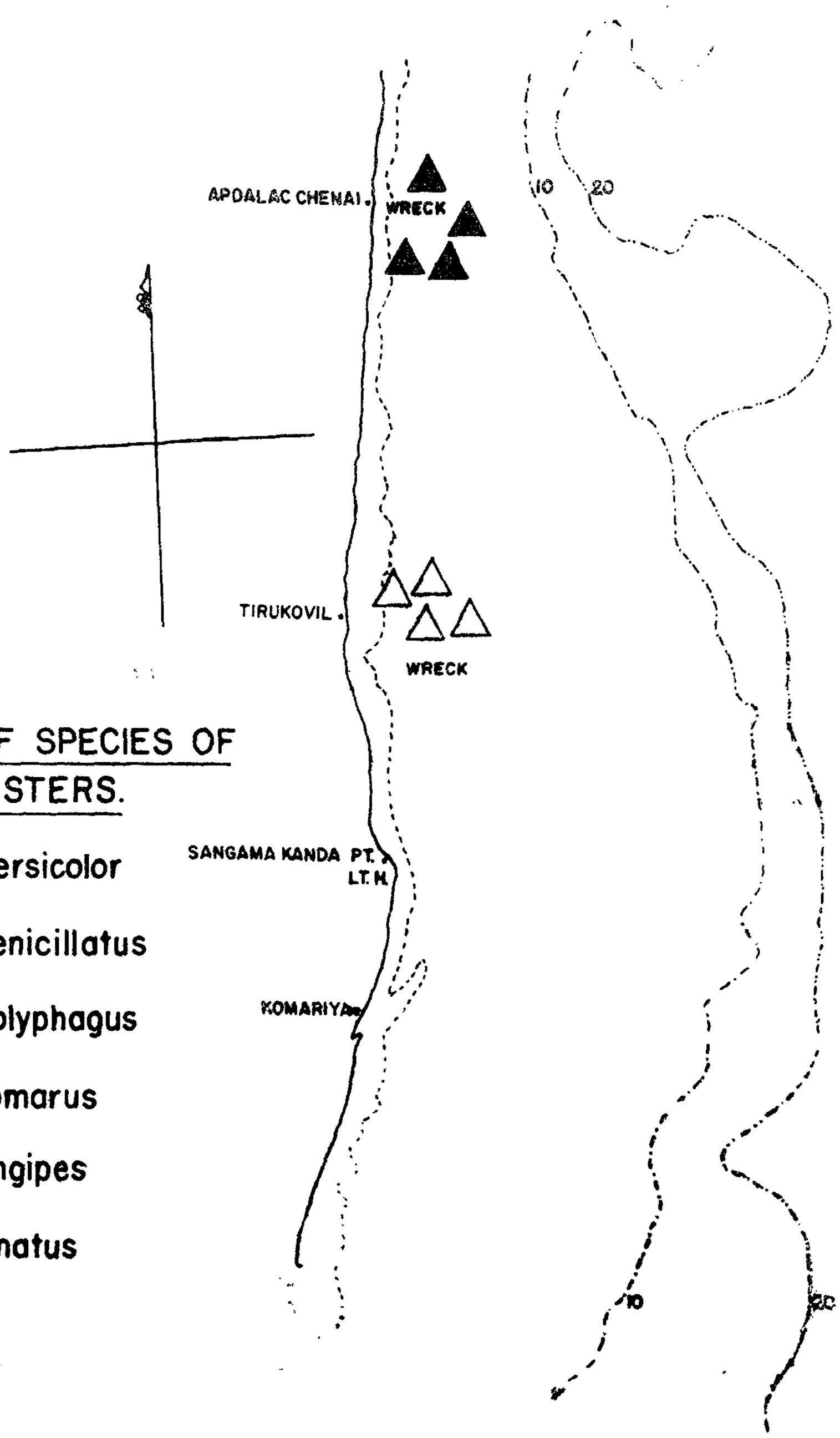

Fig. 7.—East coast—Komariya to Addalaichenai

On the east coast it has been observed in small numbers between Kalkudah and Passikudah in very shallow water among the dense coral growths. Numerous exuviae of this species have been observed cast ashore but the exuviae of other species have been rarely seen in this region.

P. penicillatus, therefore, prefers the very shallow surf-swept regions of the reef-front, regardless of whether the sub-stratum is coral, sand-stone or granitic rock. On the reef-front it is out-numbered by *P. homarus* especially when the sub-stratum is sand-stone.

On a coral reef-front, however, *P. penicillatus* predominates since *P. homarus* avoids coral. The reasons for its scarcity on a sand-stone reef, compared to *P. homarus* requires investigation, especially since it appears to be the best adapted for living in agitated waters. It is known to have the strongest grip of all species captured by hand and it is with the greatest difficulty that it can be removed from the sub-stratum once it has taken hold of it. It can tolerate wide ranges in clarity and turbidity of water and also has the capacity to withstand low salinity. Unlike *P. homarus*, *P. ornatus* and *P. polyphagus* it does not come out to graze at night on a mud sub-stratum.

The distribution of *P. penicillatus* is illustrated in Figs. 1 and 5.

6. Distribution of *Panulirus polyphagus* (Herbst)

This is the least abundant species in Ceylon and has still to be seen among coral, sand-stone or granitic rock masses. It has been encountered only on a mud sub-stratum during trawling operations at night. Several specimens were caught at depths of 6 to 10 fathoms SE of Mullaitivu Light House. A few were caught NW of the Mutwal Fisheries Harbour at depths of 6 to 7 fathoms. It is very likely that it hides during the day in coral, sand-stone or granitic formations in the vicinity. Chapgar and Deshmuk (1961) observed it to be the dominant species on the mud-banks off Bombay and its ecological preference seems to be muddy strata.

TABLE I

Ecological Preferences of Spiny Lobsters of Panulirus spp.

Agitated Water	*Agitated or Calm Water*	*Calm Water*		
Less than two fathoms	Less than two and up to ten fathoms	Over three but less than ten fathoms		Over three and up to twenty-five fathoms
Coral, sand-stone or granite	Only sand-stone and granite	Coral or coral heads on sand-stone	Mud	Coral or coral heads on sand-stone
P. penicillatus	*P. homarus*	*P. longipes* *P. versicolor*	*P. polyphagus*	*P. ornatus*

DISCUSSION

The phenomena of species dominance and ecological separation of species is clearly demonstrated in the genus *Panulirus* and, in the six species of spiny lobsters present in Ceylon waters, appears to be determined by environmental factors such as sub-strata and calmness or agitation of the sea. These phenomena have a particularly important bearing on fisheries development since they lead to scatter or discontinuity in the distribution of fish populations which are basic considerations in estimates of productivity. Scatter or discontinuity in distribution of fish populations, as seen in the genus *Panulirus*, is displayed by a considerable number of demersal species of fish and seem to be determined by the irregular distribution of different sub-strata in the sea.

Observations of the distribution of penaeid prawns in the sea shows that *Panaeus semisulcatus* prefers the very soft green mud found in patches in the sea, *Panaeus indicus*—fine soft silicate sand, *Metapenaeus dobsoni* and *Parapeneopsis coramandelica*—a mixture of mud and sand while *Metapenaeopsis mogiensis* seeks out a sub-stratum of coral and shingle.

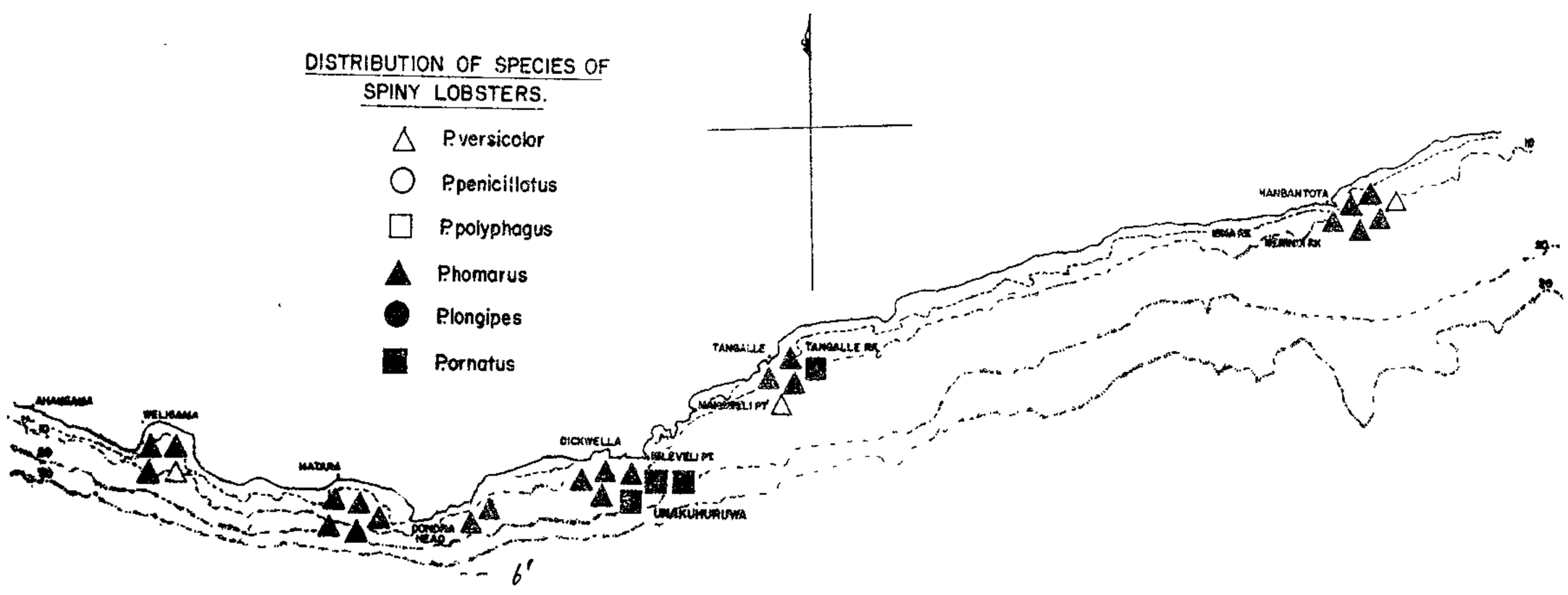

Fig. 8.—South coast—Ahangama to Hambantota

Certain species of carangid fishes prefer grazing grounds of a mixture of mud and sand at certain times of the year as shown by their regular appearance in thousands on such areas of the Wadge Bank lying south of the Indian Peninsula. The distribution of the resident species of demersal fishes of the Wadge Bank such as *Lethrinus*, *Lutianus* and *Epinephelus* also shows discontinuity for they are found in abundance on hard sand-stone or rocky patches but are absent in muddy or sandy stretches.

Some species of the Wadge Bank, such as *Aprion virescens* and *Pristipomoides typus* show a preference for waters beyond twenty-five fathoms in depth for they are seldom, if ever, seen in shallower regions of the Wadge Bank or elsewhere around Ceylon.

Most species of *Leiognathus* or pony fish prefer a sub-stratum of mud and this accounts for their great abundance in the Palk Bay in the north of Ceylon and other muddy areas of the north-west and north-east coasts of Ceylon.

Lack of consideration of this most important phenomenon of scatter or discontinuity in distribution certainly leads to completely erroneous estimates of productivity of the sea whether they relate to spiny lobsters, penaeid prawns or demersal fish.

SUMMARY

The ecological observations made on the six species of spiny lobsters suggest that turbidity, *per se*, might be an unimportant factor in determining the observed species dominance and ecological separation of the different species, since all appear to tolerate wide ranges in turbidity and clarity of water for quite long periods of time. Some species appear to prefer coral formations while others avoid them. Turbidity, might therefore, have an indirect influence on the ecological separation through its inhibition of the growth of coral. This seems particularly true for the species *Panulirus homarus* and *Panulirus versicolor* and could account for their respective dominance on the west and east coasts of Ceylon, since *P. homarus* prefers a sand-stone sub-stratum while *P. versicolor* seeks out living coral formations.

On sand-stone reefs, *P. versicolar*, *P. longipes* and *P. ornatus* keep close to living coral fronds which are found scattered on the reef. They also avoid agitated waters of the reef-front and select depths beyond three fathoms which are comparatively calmer. *P. versicolor* and *P. longipes* have not been found beyond ten fathoms while *P. ornatus* has been seen living in large pot-holes of coral and sand-stone sub-strata beyond ten fathoms. *P. ornatus* has been caught while trawling at night on a sand-stone and coral sub-stratum up to twenty-five fathoms in depth. Very young *P. versicolor*, measuring an inch in total length, have been seen in their hundreds on the east coast of Ceylon among the crevices of granitic rock but all these three species avoid granitic rock masses in their adult stage. Juvenile *P. ornatus*, measuring a foot in total length, have been caught on mud-banks in fair numbers. The dominance of this species in the north of Ceylon might be due to its ability to sustain itself by grazing on a muddy sub-stratum. *P. longipes* and *P. versicolor* seem to avoid mud-banks and are scarce in the north of Ceylon. Not one of these species has been found close to river mouths and thus appear the most sensitive to low salinities.

P. penicillatus thrives in very shallow surf-swept waters but in such regions it is unaccountably out-numbered by *P. homarus* especially in sand-stone reefs. However, on a coral reef, exposed to surf, *P. penicillatus* predominates as *P. homarus* avoids coral. Both *P. homarus* and *P. penicillatus* can tolerate low salinities as both have been seen very close to the mouths of rivers. All species, however, die when exposed to fresh-water.

P. polyphagus has not yet been seen in coral, sand-stone or granitic rocks and has been encountered only on muddy bottom. However, it should be seeking the cover afforded by one of these environments during day-light hours.

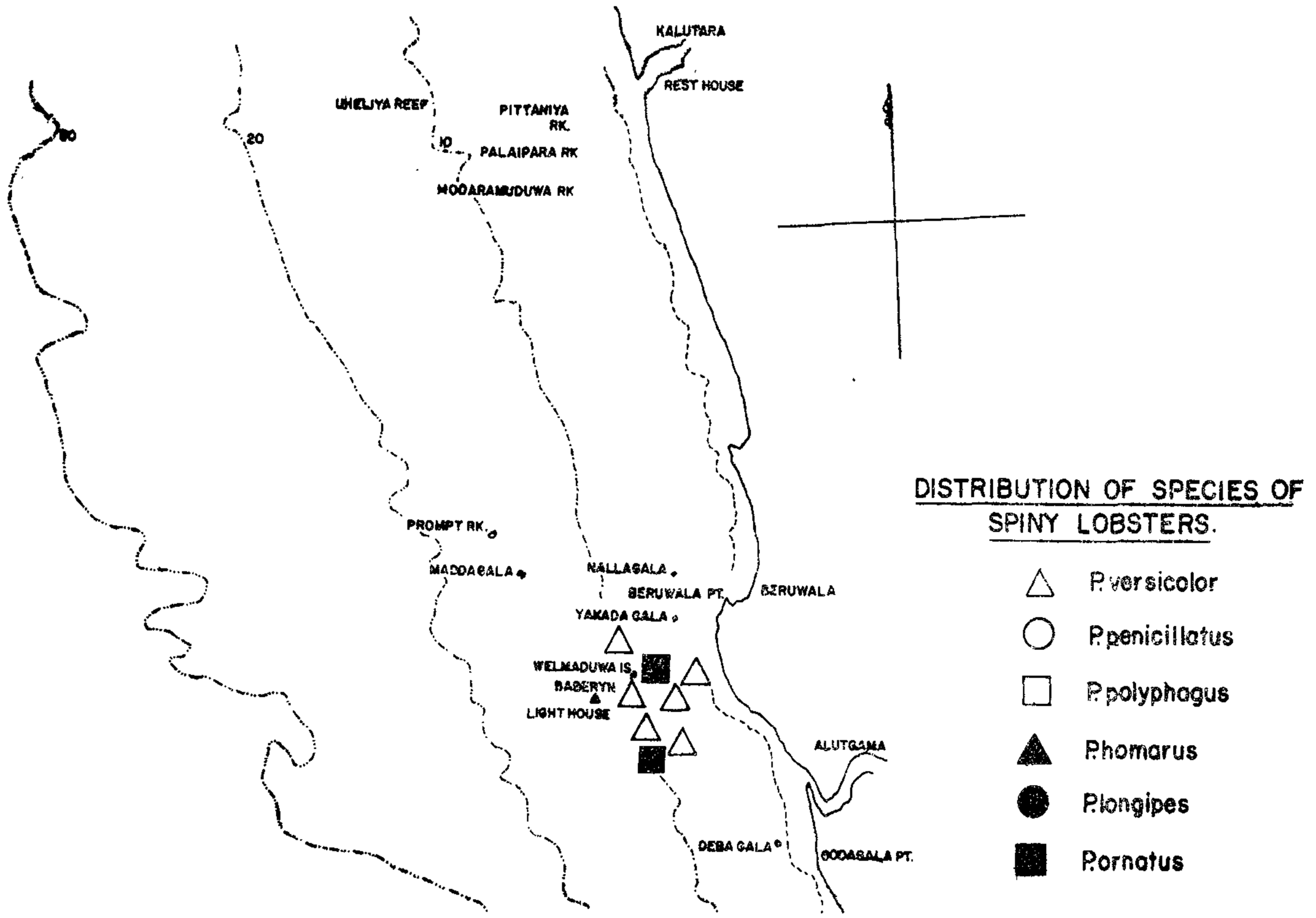

Fig. 9.—South west coast—Alutgama to Kalutara

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