SPINY LOBSTER PANULIRUS ARGUS AND PANULIRUS LAEVICAUDA (LATREILLE) ON THE CARIBBEAN COAST OF COLOMBIA WITH PARTICULAR REFERENCES TO THEIR BIOLOGY AND THE FISHERIES FOR BOTH SPECIES ON THE COAST OF THE GUAJIRA PENINSULA

GERMAN RIVEROS CELIS

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OF THE GUAJIRA PENINSULA

by

German Riveros Celis

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Department of Biology
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ABSTRACT

The Colombian Government and its FAO Project for Marine Fisheries Development included in its plans for research the biology of spiny lobsters to determine among other things the minimum legal size at which they could be fished. This study was done on the Guajira coast where statistics of catched showed them to be the most abundant in Colombia.

The objective of the study was to know more about the biology of the species in this area, and to establish a minimum legal size limit as a safeguard until at least first maturity was reached.

The hydrographic data considered were temperature, current systems (especially near Cabo de la Vela), because in this area there was good fishing for lobster and apparently a nursery for lobsters. The temperature and salinities remained constant throughout the year. The length weight relationships for males and females showed that males became larger than females, and that the weight increase was 3.47 times, but in the females weight did not quite reach the cube of the tail length. On the other hand, from moulting data it is possible to say they reached a 32% increase in weight in one moult.

Maturity studies showed that embryogenesis was approximately equal to oogenesis and there were apparently three main spawning peaks in a year (August, September, and January; Fig. 7).

According to the data gathered during the sampling period, 65 mm was the carapace length for first maturity, and between 80 to 90 mm the largest size group.

It was found that the rate of growth was more accelerated in males than in females, there being a difference of 27 mm (approximately) between males and females.

In some specimens the stomach was examined, but unfortunately was found empty in almost all cases, perhaps due to the method of transport used, but in general the main fragments found were fish bones, crustaceans, and filamentous algae among the most important.

Of the different places considered as lobster grounds in Colombia, the Guajira area seems to be best, because this place offers at least two nursery areas and because the bottom conditions are favourable in "turtle" grass, sea weeds, rocks, and coral formations.

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TABLE OF CONTENTS

INTRODUCTION

The main fishery resource exploited in Colombia is shrimp, which has reached 80% of the total fishery products exported. However, in the last few years the fishery for lobster has increased and in 1969 a total of 70,490 lbs of frozen tails were landed. In 1970 the production amounted to 106,474 lbs, that is a 51% increase over the previous year (Anuario Estadistico INDERENA, 1970).

The species presently exploited are *Panulirus argus* (Latreille) and *P. laevicauda* (Latreille).

The main objectives of this paper are:

a. to show in a brief way the present state of exploitation,

b. to give some notes on taxonomy,

c. to show world distribution and ecology in Colombian waters,

d. to advise on minimum size for exploitation, and

e. to analyze the main morphometric relationships found for this specieson the Caribbean coast of Colombia.

Limits of Distribution

World Distribution

Chace and Dumont (1949) reported the distribution of the spiny lobster in tropical and subtropical seas and in some temperate regions, noting its occurrence from North Carolina (U.S.A.) to the southern part of Brazil and in the West Indies (Smith, 1958). Large quantities were landed in Cuba and Brazil, amounting to 74.8% of the 92 million lbs of world landings of P. argus from 1961 to 1966 (Buesa and Paiva, 1969). The largest catches are from Cuban grounds which are continuous with the grounds off Miami exploited by the U.S. with a landed volume of 3.5 million lbs in 1957. This is perhaps one of the world's richest grounds for this species.

It seems that an inter-mixing of species occurs on the continental shelf off Brazil more than in Cuba (Buesa and Paiva, 1969).

The second important species in Colombia is Panulirus laevicauda which occurs, according to Chace and Dumont (1949), from Cuba to Brazil. However, Moore (1961) reported the occurrence of P. laevicauda in Palm Beach, Florida, where it was caught but never equalling the landings of P. argus. Where they occur together, a lower proportion of P. laevicauda is reported in all the references consulted on these species.

General Distribution with Respect to Depth, Habitat (Temperature, Salinity) and Substratum

The spiny lobster shows a distribution mainly in the tropical and subtropical zones of the Caribbean Sea where, according to Chace and Dumont (1949) it had originated. These species occur on coral rock bottoms and live in shelters; the young lobsters are generally caught on bottoms covered by grass, while the adults in areas with rock shelters and sandy bottoms (Allsopp, 1968).

The distribution of the lobster is greatly affected by temperature and salinity. Witham, et al., (1968), working with larvae in the puerulus stage in the laboratory under controlled conditions of temperature and salinity found that they had a tolerance to gradually changing salinities from 35 $^{o}/oo$ to about 19 $^{o}/oo$.

Allsopp (1968) mentions some changes in distribution due to changes of temperature, and some migrations because of weather conditions, moon phases and others of undetermined origin. On the Caribbean coast of Colombia, and especially in the Guajira Peninsula, the temperature was found to be 27^{o}C between 1 and 10 m deep and 24^{o}C from 10 to 20 meters, according to readings taken on shore and on board the R/V CHOCO (Table I).

SYSTEMATICS AND TAXONOMY OF BOTH SPECIES

Nomenclature

Valid Names

a. Panulirus argus (Latreille 1804)

b. Panulirus laevicauda (Latreille 1817)

Taxonomy

Order: Decapoda

Supersection: Reptantia

Section: Macrura

Family: Palinuridae

Genus: Panulirus

Species: P. argus

P. laevicauda

Key for Identification of Tails*

A couple of large yellow spots surrounded by a dark color occurring on the second and sixth segment, with similar but smaller spots on the third and fifth segments .... Panulirus argus (Ltr.)

Upper surface covered with many small yellow or whitish spots (rarely plain colored or marbled with yellow or white as in P. japonicus) .... Panulirus guttatus (Ltr.)

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*Adapted from Chace and Dumont, 1949.

The first three segments greenish on the forward part, dirty red on the hind part, and provided with a line of yellow dots very near the hind margin; hellow spots on sides of segments and the last three segments dull green with a broad, deep, red band on the hind part, also with yellow dots.....<u>Panulirus</u> <u>laevicauda</u> (Ltr.)

<u>Common Names</u>

Colombia:

<u>P. argus</u>	-	Langosta roja, langosta
<u>P. laevicauda</u>	-	Langosta verde, langosta cotorra, langosta
U.S.A.:	-	Spiny lobster
Brazil:	-	Langusta
Cuba:	-	Langosta
Vulgar Name:	-	In the area where these observations have been collected, the Guajiro native does not make any difference between the two species, calling them Italzu (?).

<u>External Morphology</u>

The external morphology, including color, is important since the two species can be distinguished by this. The following are the main characteristics:

a) In <u>P. argus</u> the carapace shows well-defined scutes (Fig. 1) with a small number of spines. The color is thought to be due to the type of bottom on which the animal lives; in general, pinkish yellow or reddish; in the spiny lobster these colors vanish towards the edges of the cephalothorax. The abdomen shows dark, rounded spots. The posterior edge of each segment is yellow or orange in color; the more posterior angles show a greenish or bluish color. The telson is crossed with yellow-orange dots or stripes with white fringes. In general, half of the surface of the pleopods is yellow, the rest is covered with dark spots. The legs have longitudinal stripes, blue in color. The ventral surface of the body is yellowish; the sternum is marked with irregular radial bands (Williams, 1965).

b) In P. laevicauda the carapace does not show well-defined scutes or whields but a large number of spines all over the cephalothorax (Fig. 2). The color is dark; fresh specimens show a dark green color vanishing towards the fringes where it is almost white with a series of dots or green spots surrounded by a white band. Holthuis (1959) describes the carapace as a yellowish color with pink appearance becoming purple in the middle region; in the enterior region the color is dark red. Around the large spines the red is more accentuated. On the sides of the carapace the color is white with spots of various sizes. In the middle of the anterior fringes of the first somite the white spots are more visible, these spots are present on the abdominal pleura and near the articulations where they are more conspicuous. The dorsal surface of the abdominal somite is splashed with small dots in the middle region, these dots are less conspicuous usually fading when dead; the posterior fringe is dark red or purple in color. On the sixth somite the dots are more conspicuous than on the others. The calcified portion of the telson shows a great quantity of white dots similar to those on the abdominal pleura. The legs show alternate stripes, whitish and purplish on the dorsal surface of the merus, carpus and propodus.

Difference between *Panulirus* and *Palinurus*

There is often some confusion between the genus *Panulirus* and *Palinurus*; unfortunately, the relevant bibliography is rather scanty. The key for the genera of Palinuridae from South Africa, according to P. F. Berry (1971) is included here:

A. No stridulating organ (Silentes)

1. Carapace with rounded sides and covered with many subequal spines; abdomen smooth or squamiform .... *Jasus* (1 sp)

- Carapace with angular sides and with longitudinal, spiny ridges; abdomen with median carina .... *Projasus* (1 sp)

B. Stridulating organ present (Stridentes)

1. Carapace angular with elevated median keel 2

- Carapace cylindrical or subcylindrical with no elevated median ridge 3

2. Supraorbital processes small, fused and close to midline. Cornea ventral, not wider than eyestalk. Antennae thick, shorter than total body length .... Linupurus (1 sp)

- Supraorbital processes well-developed; spaced wide apart. Cornea much wider than eyestalk. Antennae slender, up to 12 x total body length .... Puerulus (2 spp)

3. Antennular plate broad, spinose ..... Panulirus (5 spp)

- Antennular plate narrow, unarmed 4

4. Major supraorbital processes terminating in an acute point. First peduncular joint of antennae not extending to the end of peduncles of antennules .... Palinurus (2 spp)*

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*Separation of Palinurus and Palinustus is based on a key produced by Barnard (1950).

- Major supraorbital processes terminating in a blunt crenulated margin. Two spines on anterior straight margin of carapace between the supra-orbital processes. First peduncular joint of antennae extending beyond end peduncle of antennule .... Palinustus (1 sp)

Key devised by George and Grindley (1964).

Summary of difference between Panulirus and Palinurus

The description of the genus Palinurus by Filho and Costa (1969) says that the carapace of this genus is flattened and convex, covered by granules which are rather different on the side and anterior parts. The cervical groove is not very pronounced. The rostrum is short and triangular and without large spines as in the genus Panulirus.

It has been inferred that the spiny lobster genus Panulirus shows the highest evolutionary position in the Palinuridae. However, because of the few references to Palinurus available and the fact that this genus is not present in South America, the differences between Palinurus and Panulirus could not be investigated in this study.

FISHERY FOR LOBSTER IN COLOMBIA

Historical Aspects

Unfortunately, few data on this fishery are known. Until very recently landings were not significant, mainly because:

a) the lobster grounds are located in a rather isolated region though it is a strategic one. The people in this region have faced a hard way of living because of primitive conditions. The majority of the inhabitants are Indians with very low income.

b) The fishing methods are very primitive; the lobster is caught by diving by a few fishermen. The weather conditions, as well as the fear of sharks during one season of the year, prevents fishing. However, there is a growing interest in this fishery and there has been an expansion of the industry since 1968. At that time there was only one freezing plant. In 1972 the total storage capacity installed amounted to 36,000 (approx.) lbs. of frozen tails.

Distribution and extension of the fishery for both species in Colombia

The distribution of the lobster *P. argus* and *P. laevicauda* is not continuous on the Caribbean coast of Colombia, but only because there are some places where favorable conditions, such as the kind of bottom, depth, salinity, or temperature are not found.

There are three main grounds, Southwest of Cartegena, the Guajira, and the San Andres and Providence Islands. The latter areas have increased in importance in the last few years but the most important are the grounds off the Guajira.

Description of the different fisheries on the various grounds off the mainland and off the islands

Three main catching methods are being used on the various grounds:

a) Diving: This is perhaps the most popular fishing method. The majority of the fishermen (Indians) use only a mask, being able to dive to between 4 and 11 m deep. When they go fishing, they go in small groups of three or four divers in a dug-out canoe called a "cayuco". They dive in couples being able to catch five lobsters per fisherman per dive. The Indians catch all sizes of lobsters, including those carrying eggs.

b) Diving and Harpoon: This is the second method, diving sometimes being complemented by an underwater gun. This method is mainly used in San Andres and Providencia Islands. As we can see, the fishery is subject to certain restrictions as to the number of optimum working days, and the depth, because of limitations on diving.

c) Traps: This is a relatively new fishing method in Colombia.

The traps were first used in 1968 in the San Andres Islands with hardly any success, perhaps because of the lack of experience of the fishermen.

In 1970 the fishery enterprise "Crustaceos de la Guajira" began setting Florida type traps off Riohacha. The traps are made of wood available locally.

Several kinds of bait have been used from artificial ones to fish heads, raw cow skin and/or a piece of clothing soaked in gasoline. The most efficient baits have proven to be a small lobster in a trap and/or a piece of cow skin in the mouth of the trap, according to reports from fishermen.

d) Gill Net: This is a gear not very much used, except by some fishermen southwest of Cartagena.

Established Regulations

Few regulations for the protection of the lobster have been established in Colombia. The existing ones are considered not adequate. This is one of the reasons why we undertook this study. The established closed season coincided with the best season for catching, from the last of February to the 30th of June. This regulation did not take into account that the temperature regime, among other variables, is almost the same throughout the year and that there is no climatic "season" for the lobster.

When the closed season was in effect, most fishermen only partially accepted it and interpreted it according to their own judgement.

The Government of Colombia is now considering the establishment of a regulation based on minimum size and weight in order to guarantee that the lobsters reach their first maturity before they are caught.

It has not been considered reasonable to protect large females carrying eggs, although according to Herrick's law (1891) for *P. interruptus*, the number of eggs varies with the cube of the length of the specimen (Lindberg, 1955). However, even the minimum size of females suggested (with an average total length of 215 mm - 65 mm carapace length) has already reached first maturity and produced a large number of eggs (Herazo, 1973). Besides, because of the high rate of reproduction, females not carrying eggs are usually ready to lay eggs in this area and according to Allsopp (1968) there is no argument with a good biological basis for protecting the female carrying eggs.

Perhaps the most important regulation is that for a minimum size because ambiguities with regard to egglaying, etc., could occur.

Based on what has been said, a regulation will be established for a minimum size (a carapace length of 65 mm, tail length 122 mm and tail weight of 3.4 oz (95 g)) with the necessary exceptions, because although general principles on the conservation of the stocks are important, socio-economic considerations must apply as well. For example, the Guajiros will not sell to buyers who refuse to accept small lobsters, but in time they will realize the importance of protecting small lobsters.

Some restrictions on management and marketing may be taken into account as suggested by Walton Smith (1958).

Notes on the Catch

The catch statistics available were few because the fishery was new and the geographic location of the grounds made statistics collection difficult. However, statistical data collections has been improving but in the results presented in this paper, some data have been collected at a time different from when the biological sampling was done.

It has been impossible to obtain details of yield from the traps. From the data gathered we can only present the production from diving and traps according to the daily records kept in the processing plants.

In order to facilitate this study, the fishing area was divided into two zones:

a. the south zone, between Camarones and Riohacha, and

b. the northern zone from Riohacha to Cabo de la Vela (Fig. 3).

In Fig. 4 we can observe that catches by diving were more abundant than by traps in November, 1971; a peak was reached in October with 16,615 kilos of whole lobster, and a minimum was in August with 818 kilos.

With the use of traps a maximum production was obtained in September with 5,500 kilos of tails (18,600 kilogrames of whole lobster) and a minimum in December as with diving. From January to July, 1972, the catch showed a decreasing trend with traps, but just the opposite occurred with diving (Fig. 4).

According to the division made in the two areas of commercial catches, and according to Fig. 5, we can notice that in a whole cycle of one year the maximum yield in the northern zone was obtained in August to December, and the minimum yield in December to March. Later on, however, a cycle occurred in which we could notice a constant increment in the yield.

Regarding the southern zone, there were present three cycles but with less production than in the north.

As the animals grow, reproductive behavior becomes apparent and they start looking for rocky or grassy bottoms with clear and warm waters. They show night feeding habits and migrations. During these movements, territorial behavior has been observed which is used by fishermen and scientists to catch them (Dees, 1961).

Witham, et al., (1968) found a strong correlation between the level of salinity in the St. Lucia estuary and the amounts of rain produced by Hurricane Alma in South Florida in June 1966. Decreases in salinity stopped the entrance of larvae into the estuary during recruitment at the puerulus stage. On the Guajira coast of Colombia the Peninsula provides a sheltered area just west of Cabo de la Vela, and with a semidesert climate salinities are high over long, well-defined periods giving good possibilities for settling and survival of larvae and young.

Unfortunately, records of rainfall could not be obtained yet to make a comparison with lobster production. It was observed during the infrequent rainy periods that lobsters living in shallow water near the shore showed in the joint of the carapace with the abdomen a dark red color due perhaps to the low salinity. These periods would be inimical to young lobster survival.

BIOLOGY OF THE LOBSTER *PANULIRUS ARGUS* ON THE GUAJIRA COAST OF COLOMBIA

Notes on the Species in Other Areas

Lobsters in general have slow growth (Allsopp, 1968). Growth rate determined by tagging shows that it is subject to differences in habitat. Growth is by a change of shell or ecdysis, generally after a period of abundance of food. It is also affected by the water temperature (Dees, 1961).

Physical Conditions on the Colombian Lobster Grounds

The area of the Guajira, due to its geographical position, possesses several factors which differentiates it from the rest of the Caribbean Colombian coast. The prevailing winds are those from the northeast during almost nine months of the year, having an average of 11-16 knots. During the remaining three months the wind changes its direction, blowing from the north during one month and from the east during two months, with an average intensity of 6-8 knots (Consorcio de Ingenieria).

According to Eng. E. Gutierrez (personal communication), the position of the peninsula makes one believe that it is a sheltered zone; however, the line of the coast is straight and does not give any shelter, and the waves produced by the wind reach the shores with all their intensity. These conditions make the coast unprotected and rather dangerous for navigation (Fig. 3).

On the other hand, 20 miles offshore there is a westward current with an intensity of 0.6 - 1.2 knots, while a countercurrent close to shore has 0.9 knots. This tends to produce an anticyclonal gyre west of Cabo de la Vela which could act as a trap for planktonic larvae of the spiny lobsters. This is borne out by the large numbers of small lobsters found in this area which would only result from considerable settling and survival of larvae.

Climatology

According to L. Currie (1950) the area of the Guajira can be divided into:

a) Tropical semidesert: In the northern part of the Peninsula there are high temperatures, low to nil precipitation, and relatively low humidity. The air temperature varies considerably between day and night.

b) Tropical steppe: The area of the middle Guajira which comprises the center of the Peninsula with low precipitation, low humidity, high temperature and luminosity which contribute to rapid evaporation.

A third sector is that between the tropical steppe and the tropical humid with sporadic heavy rains, which is dominant and characteristic of the rest of the Caribbean coast of Colombia. This area begins just west of the Sierra Nevada de Santa Marta and is subject to seasonal heavy rains, some of which extend completely over the Guajira during rainstorm conditions.

Salinities

Witham, et al., (1964) when studying the tolerance of puerulus larvae of P. argus noted that the optimum salinity was that of 35 $^{o}/oo$ with a minimum of 25 $^{o}/oo$.

From the data gathered during several exploratory cruises of the R/V CHOCO, we considered, as most suitable for larval settling of both species of lobsters, the area off Carrizal, north of Riohacha, and the area off Dibulla, south of Riohacha. According to the table, these two areas showed the best conditions of salinity, temperature and shelter (Table I).

Though the data in Table I are rather scanty, they show very clearly the maximum variations in salinity and temperature, being values very close to the optima for this species.

METHODS USED IN THE BIOLOGICAL STUDY OF THE LOBSTER *P. ARGUS* ON THE GUAJIRA COAST OF COLOMBIA

Sampling

Samples were collected monthly at the processing plant of "Crustaceos de la Guajira" in Riohacha. The lobsters sampled had been bought from the divers (Guajiro Indians) who fished them between Cabo de la Vela and Camarones lagoon. Some lobsters (rather few) had been fished by traps set off Riohacha.

The sampling programme started in November, 1968, and lasted until May, 1970. However, some months could not be sampled because of weather conditions, which prevented fishing.

A total of 1,070 specimens were sampled belonging to both sexes and both species of *P. argus* and *P. laevicauda* (Latreille). Specimens of *P. laevicauda* were very few (only 77 specimens of both sexes).

Sampling was at random, but in some cases because of the small number of specimens collected, all of them had to be considered.

Measurements

The length of the carapace was measured with stainless steel calipers of 70 cm to the nearest mm. The measurement was taken from the groove anterior to the most prominent spines in front (supraorbital "horns") to the posterior edge of the carapace between parallels.

The total length was measured putting the specimen dorsally on a measuring board (Fig. 6) having the supraorbital horns against the fixed end of the board which was cut low to permit the large antennae to extend forward.

The reading was at the end of the telson to the nearest mm. The tail length was measured in a similar way, putting the end that had been separated from the cephalothorax against the fixed end of the board and then reading the length at the end of the telson to the nearest mm. In the females, the width of the abdomen was measured at the second segment having the second pleural spines as reference points.

The total weight was obtained with a dial, Toledo type balance with a 20 gram accuracy and a total capacity of 8 kilos.

Total weights were taken with the animals alive. Once the tail was separated from the cephalothorax it was weighed; with the females, tails were first weighed carrying eggs then the pleopods were removed with the eggs and the tail weighed again; the weight of the eggs and pleopods was then obtained by the difference.

Sex

The sex was determined by observing the external characteristics which are very distinctive allowing even the stage of maturity to be defined.

In the males, the degree of dilation of the openings in the fifth pair of legs and in the females the presence of eggs or spermatophores were noted.

Maturity

In the males, besides the observation of the external characteristics, the degree of maturity was determined by removing the cephalothorax and observing the size and color of the vas deferens and noting the presence of sperm and the color of the testis.

In the females, the maturity was determined by the color of the ovary in the various stages by using a scale of colors from transparent to dark red.

The ovaries were removed and some were preserved in Bouin-Dubosc for later histological analysis. Histology was done by using Mallory's triple stain and checking the scale of colors against the stage of maturity of the ovaries.

The eggs were carefully removed and preserved in 10% formalin. They were examined in order to establish the degree of embryogenesis noting color, diameter and the most visible characteristics: eyes, yolk proportion, etc.

Most of the ovaries were preserved in formalin and the diameters of the ova were measured at the laboratory with a stereoscope X 12.5 and a stage micrometer reference of 10 mm.

The diameters of the eggs were measured in a similar way. The carapace was examined to note its nearness to moulting, using a hardness scale from soft, semisoft and hard in order to determine ecdysis periods in relation to time of the year.

Feeding

From the specimens sampled, some stomachs were preserved in 10% formalin to examine contents. The stomach was emptied in a petri dish, the walls scratched and washed carefully with water. The observations were made with the aid of a stereoscope.

Data Recording

The data were recorded in the field - filling out forms, noting length of cephalothorax, total length, abdomen width and tail length in mm. The total and tail weight were recorded in grams. Sex, maturity, spermatophores, carapace condition and epifaunal growths were also recorded.

The diameters of the ova and of the eggs and the maturity were recorded later in the laboratory, but ovary colors were recorded in the field.

Fecundity

Two methods of counting the eggs were used: volumetric and gravimetric with some modifications:

a) In the volumetric method the pleopods with eggs were carefully washed to eliminate material such as sand, cement, etc. The eggs were separated and washed again with the aid of a sieve of fine mesh. In a graduated cylinder of 5 cm^3 an aliquot of 1 cm^3 was taken using distilled water. One thousand eggs were dropped in the cylinder noting water displacement.

Then, the rest of the eggs were dropped in 10 ml of distilled water in a cylinder of 25 ml, noting the total displacement.

The result of the two displacements was then related proportionately estimating the number of eggs.

b) The gravimetric method was used following the technique of Mota, Alvarez & Becerra (1968) considering the following four steps:

i. weight of the pleopods with eggs,

ii. weight of a raceme of eggs,

iii. weight of the pleopods without eggs, and

iv. number of eggs in the raceme weighed.

All the weights were determined with Sartorius analytical balance with an accuracy of 0.01 mg and a maximum load of 100 grams.

The pleopods with the eggs were preserved in 96% alcohol solution. They were then washed to clean and to hydrate them; the excess water was eliminated by putting them on a filter paper up to two hours, depending on the quantity of eggs, The moment for weighing was determined in each case by observing the amount of water absorbed by the paper and the changes in color, as well as the average between repeated weights which should be constant.

A raceme of eggs was weighed in the same balance and the eggs separated and counted. The difference between the first and the third weights gave the weight of the eggs which was then related to the weight of the raceme and the number of eggs counted by a simple rule of three, giving the total number of eggs.

BIOLOGY OF THE SPECIES IN OTHER AREAS

Although this species is one of the most valuable from the economic point of view, its biology has not been studied in detail. Smith (1958) stated that some of the knowledge has been referred to research done in South Africa, Australia, Japan and France with similar species.

Northern End of its Distribution

Hay and Shore (1918) reported the occurrence of *P. argus* as far north as North Carolina. However, this does not mean that it can be exploited on a commercial scale in that area (Williams, 1964). The abundance in this region is rather low because this is not its proper habitat, and occurrence is perhaps due to the existing correlation between the currents and the recruitment of larvae (Ingle, et al., 1963).

On the Coast of Florida

According to its zoogeography, the spiny lobster is found mostly in Florida and adjacent areas as well as the West Indies and South America to Brazil where the greatest quantities are produced, and the only differences between lobsters from these areas are in the growth rates and spawning periods (Williams, 1964).

Otherwise, the biological account of this species for all the areas could be basically the same.

Feeding

The species is mainly omnivorous and they eat any kind of small animals that they catch. The normal diet includes sea worms, molluscs, small crustaceans and all kinds of dead organisms. They are also scavengers (Chace and Dumont, 1949).

Reproduction

Generally speaking for P. argus, and based on a division into three steps as stated by Chapa Saldana (1949), during copulation the male attaches to the female a spermatic sac on the lower region of the cephalothorax between the soxae of the III, IV and V legs in step one. The spermatic sac has male gametes and a cement which keeps it attached to the female for several weeks. Further studies have indicated that no relationship exists between this impregnation and the sexual maturity of the females (Wilson, 1948).

The second step is that of expulsion and fertilization of the eggs which are attached in racemes to the exopods of the pleopods. (Spermatozoa are released from the spermatophore through scratches made by the spines of the dactyl and propodus of the fifth legs of the female - Fig. 8). Fertilization occurs when the eggs are expelled, and when hatching takes place the first larval stage appears, known as a phyllosoma.

In the third step, the phyllosoma larva reaches the puerulus stage which is very similar to an adult lobster and settles on the lobster grounds.

Growth

As previously stated, the lobster grows slowly and according to Lindberg (1955) for P. interruptus in California, when sexually mature it moults twice a year with an increase in total length of 2 cm. However, this figure may be different for P. argus in this area because growth is dependent on species and the prevailing habitat conditions of salinity, temperature and abundance of food. All these factors are essential for the lobster to reach its maturity and large size, which implies moulting many times.

However, Marshall (1948) reported two cases of moulting with no increase in length of the carapace. This was also observed by Witham, et al., (1968) when working on the physiology and ecology of P. argus in the estuary of St. Lucia, showing that the feeding rate and the abundance of food are key factors in the growth by ecdysis of this species.

According to Squires (1972, in press) there are evidences of four spawnings a year of the lobster in this tropical habitat. This hypothesis is supported by Fig. 7 in which three peaks of spawning are shown.

Besides, the occurrence of repeated spawning is shown by the fact that females carrying eggs ready to be hatched also have ova in the ovaries ready to be laid. (See also Berry, 1971, for similar conditions in P. homarus). This gives grounds for the statement that lobsters in the tropics and with optimum habitat conditions, have a high rate of reproduction and recruitment to their populations.

LIFE HISTORY OF THE LOBSTER *P. ARGUS* ON THE GUAJIRA COAST OF COLOMBIA

Life History of the Species

The life history of the spiny lobster *P. argus* has been well described in several publications (Allsopp, 1968) with variations due only to the animal accomodating itself to the physical conditions of a particular region. The spiny lobster of the family Palinuridae resembles to some extent the Homaridae, although they lack the pair of large claws. The spiny lobsters, however, have very large antennae and stridulating organs (Dees, 1961).

These antennae have both equilibrium and sensorial functions. The tail or abdomen tends to be narrower in males than in females and the four pairs of pleopods are larger in the females than in the males (Dees, 1961).

The tail fan and telson are much less robust in the Palinuridae than in the Homaridae and probably could not be marked to observe growth (Wilder, 1953). The color of the body appears to vary depending on the kind of bottom and the moulting season.

The sex ratio in some areas has been noted to vary with the season (Dees, 1961; Paiva, 1962).

Males and females of the Palinuridae mate the year round with higher occurrences during certain months according to the region.

Mating in the lobsters occurs in the same way as in the majority of crustaceans. However, in the Palinuridae, the male deposits the spermatophore on the sternum of the female between the fourth and fifth pair of walking legs. The spermatophore soon becomes hard and darkened (Buesa, 1969), and is scratched and broken with the barbs of the dactyl and propodus of the fifth pair of walking legs (Fig. 8) when the eggs are being extruded, and they are then fertilized by the large numbers of spermatozoa released.

The eggs become attached to setae along the pleopods. The time the eggs remain attached to the tail of the female varies according to the species and the temperature of the water (Allsopp, 1968; Berry, 1971). Embryogenesis in P. homarus has been shown to require 29-59 days at temperatures of 20-24°C (Berry, 1971).

Sex

The sex in spiny lobsters is easily distinguished by the shape of the fifth pair of walking legs. In the males this pair of legs ends simply and is very similar to the other legs (Fig. 8-A); but in the females, this pair of legs or pereiopods ends in a small claw (Fig. 8-B) formed by the dactyl and propodus which are used to open the spermatophore when the eggs are laid (Chace and Dumont, 1949). The male in this pair of legs has a kind of bristle-like brush which may be used in copulation. There is also a difference in the pleopods which in the male are smaller and more simple than in the female.

Besides the characteristics already mentioned, the biometric record kept showed a morphometric difference for sex. Having the length of the tail as reference, the relationship total length-tail length gave the following linear equations:

a. For males: $TL = -8.3 + 1.75\ tl$

$r = 0.996$

b. For females: $TL = 13 + 1.54\ tl$

$r = 0.998$

Thus, the increase in total length is at a greater rate in the males than in the females for sizes between 90 and 240 mm. In this relationship the total length increased by 1.75 for each mm of increment of the length of the tail. For the same interval of tail length in the females the total length increases by 1.54 times the tail length, giving a linear divergence which indicates sexual dimorphism (Fig. 9).

The growth of males, therefore, is faster than in the females. A positive correlation similar in both sexes was found with values of 0.996 and 0.998 for males and females, respectively.

The percentages of tail length in relation to the total length (Fig. 10) in the great majority was superior in the females than in the males.

The proportion of the tail length to total length shows a great variation being more pronounced at 175 mm in total length as a minimum value and a maximum in the males at 155 mm, where however there were few specimens.

In the females this variation at each total length was greatest at 315 mm (its maximum value) and 345 mm at its lowest.

On the average, the proportion of the tail length to the total length was about 60.5% in the females and 58% in the males.

Sex Ratio

The total samples were 1,012 specimens, 492 males and 520 females; for some samples only data on carapace was collected. This indicated that the representative numbers of males and females could be considered equal because the larger value for females was not statistically significant.

Observations made in more detail (Fig. 11) showed that the sex proportions theoretically were within the limits of normal variation so that there was no predominance in the sex ratio by month.

Reproduction

This species, as was referred to before, shows a high rate of reproduction due to the favourable conditions of salinity and temperature, and mature females have been found throughout the year.

This fact supports Squires' hypothesis on the rate of reproduction which says that the number of spawnings per year can be estimated from the number of months required for 100% of the females to spawn. This can be related to the monthly percentage of mature females taken in samples.

During the present survey, females carrying eggs were found with patches or remains of spermatophores and were classified as in the reproductive process. Also, the percentage of females ready to spawn each month were shown in Fig. 13.

Although there are gaps in the data, it can be stated that according to Squires' hypothesis the females spawned every 3.3 months or 3.5 times per year (not including the juvenile females). Plotting the percentages of mature females (Fig. 12), the possibility of four periods of major spawning incidence can be seen. Berry (1971) showed conclusively that the South African lobster, P. homarus also spawned four times in the course of a summer of 9 months at temperatures of 20-24^{o}C.

Monthly Percentage of Females Carrying Eggs

As was referred to in the preceding paragraph, lobsters carrying eggs are found in tropical waters all the year round. A clear indication of this incidence can be obtained from the monthly percentages of mature females in samples.

Table II gives the variations of the number of females carrying eggs per month and the percentage of the total of mature females per month (Fig. 13) found during the time of sampling. However, with the gaps in the data it is difficult to predict all the times of major spawnings. From Fig. 12 the occurrence of three peak periods per year is seen in April-June, August-October and January, and this probably constituted at least three periods of spawning synchronization during these periods in 1969 and 1970. Synchronized spawning periods would also indicate similar periods of recruitment (Squires, in press).

State of Maturity of the Ova in the Ovary

Morphology of the Reproductive System

The bibliography on detailed descriptions of the reproductive systems of *P. argus* and *P. laevicauda* is rather scanty. In the present paper the description made by Mota Tone (1966) will be used and can be applied to both species because the main variation is only that of size. The reproductive system of the female has a pair of ovaries located lengthwise in the body cavity, joined together in the anterior part by means of a transverse ligament which also serves as a protective cover.

Each ovary consists of an elongated body of variable thickness. Both are located next to the digestive tube subject to displacements from the inner to the outer part of the cephalothorax according to the status of development of the ovary. The ovary undergoes a series of evolutionary steps in the development of its sexual cells which go from proliferation of oocytes to yolky ova in oogenesis after it reaches maturity. The literature on this subject is very extensive.

In order to distinguish the different stages in maturity of the ovary a scale of colors was established in the sampling programme (Table IV) which allowed the stage of maturity to be determined. These colors and stages were checked with histological sections. These histological sections agreed with the five stages as described by Mota and Tome (1966).

STAGE I: Only oogonia are found evenly distributed in the conjunctive tissue. In this stage the ovaries are whitish in color with a smooth surface.

STAGE II: Besides the oogonia, numerous oocytes are also found. This stage is rather hard to distinguish, the ovary becomes yellowish with an uneven surface.

STAGE III: The ovary presents a complex structure with large elemental components of oogenesis. The first ovules appeared associated with the less developed forms, the oocytes being the dominant elements. The surface of the ovary is rugose and orange in color.

STAGE IV: The ovary looks more uniform with mature ova almost equal in size which appear as polyhedrons with rounded borders. Some germinal immature cells are found dispersed in small quantities, the ovaries become rather large with a rough surface. The membrane is more thin and transparent and some small orange spheres are seen in the interior attached to the walls. The rest is bright red in color.

STAGE V: In this last stage, some empty spaces which correspond to the ova prior to spawning are seen. Germinal immature cells and mature ovules are observed within the conjunctive stroma. Most of these elements are in a degenerative process.

This stage is rather difficult to distinguish macroscopically and it can be confused with Stage II because spawning has occurred. The ovaries are flaccid but not whitish.

During stages III and IV, measurements of ova were taken in 150 ovaries. Comparing the increasing diameter of the ova with the stage of development of embryos in the eggs (Table III), it was observed that as the stage of development of the embryo advanced, the ova were getting large and ready to be hatched (Fig. 14).

With the observations and measurements made in the ovaries it was possible to prepare Table III in which the color of the ovaries, the diameter of the ova in mm, and the approximate corresponding stage of the embryo were related.

Stage of Development of the Embryo in the Eggs

The eggs are fertilized by the spermatozoa and then are carried on the pleopods of the females. As the egg develops the color changes from yellow to brown, dark brown and finally loses color and the embryo is ready for the first larval phase (Dees, 1961). When the color is bright yellow, the egg diameter is around 0.5 to 0.7 mm, spherically shaped and enclosed in a hyaline smooth and homogenous membrane.

This stage called full yolk was found in the majority of the samples taken (Table IV).

In the second stage, the dots of the eyes are distinguishable, being the first recognizable structure of the embryo. The color is less intense but rather dark.

The third stage shows the eyes and some appendages and the color is dark; this stage is known as the prenaupliosoma.

Stages of Maturity in the Males

In the study of the maturity of the males of *P. argus* and *P. laevicauda* the same situation exists as with the females regarding the sameness of the gonads of one species or the other.

Because of the way this study was designed, no special attention was paid to the different stages of sexual development of the males of the lobster. No histological study was made and only a scale of color of the testis was established (Table VI).

This scale was found to be in agreement with the description of Mota and Tome (1966). The three stages considered are:

STAGE I: The gonads appear uniform and elongated in aspect. There are numerous spermatogonia in the peripheral seminiferous canals in contact with the basal membrane. Most of these spermatogonia are in the process of division.

STAGE II: The number of spermatogonia being divided are clearly seen. Numerous spermatocytes, most of them in the process of division, are also seen. The great majority of the seminiferous canals are occupied by these elements with the spermatocytes in considerable quantities. The outer color of the gonads is yellow and the size rather large.

STAGE III: Great quantities of spermatids and spermatozoa are present in the seminiferous tubules. The spermatogonia and the spermatozoa are found stratified, showing a compact aspect. The vasa deferentia are very long and bluish purple in color. The pair of capsules or spermatophore organs of the fifth pair of legs are also very large. After stage III was reached, males continued to be fully mature, independent of season (Fig. 16).

In order to observe the stage of maturity according to sex, the specimens were grouped in total percentages, for males and females separately, and for each stage (Fig. 15 A and B) according to the carapace length. (The carapace length was selected for being easy to work with and because it is widely accepted as a basic biometric characteristic.)

STAGE I: In females shows a bimodal distribution with a concentration of specimens around 70 mm which represents 20% of the females within this stage.

STAGE II: The females within this stage show a wide variation in carapace length from 50 to 100 mm. The great number of specimens are found grouped in two modes of equal proportion; the first from 75 to 80 mm, and the second at 95 mm.

STAGE III: The frequency distribution showed trimodality in this stage. The first mode (with the greatest number of females) was at 80 mm,the second at 100 mm, and the third at 115 mm.

STAGE IV: This frequency distribution had possibly four modes.

The greater number of females was found between 70 and 95 mm and formed the first group with a mode at 80 mm. Other modes were at 100, 110 and 120 mm. In this stage occurs the largest dispersion in carapace length as shown in Fig. 15, varying from 55 to 130 mm. Although the data were scanty at the large sizes, the modes may indicate occurrences of maturity (spawning) in the life span of individual females.

Males

STAGE I: Showed an extensive mode with respect to the carapace length. Specimens were found mostly between 45 and 85 mm and sporadically at the extremes of 35 and 110 mm.

STAGE II: With the largest number of specimens concentrated at 65 mm, these were more than 25% of the total. The distribution showed two modes, one at 80 mm and the second at 105 mm, this last with less than 10%.

STAGE III: The distribution showed three modes of carapace length. The first at 65 mm, the second at 95 mm and the third at 115 mm. The first one comprised 10%, the second approximately 20% and the third 27%. The rest of 1% varied between 110 mm and 150 mm. Considering that the percentages in length frequency distributions did not show clear limits regarding maturity, they were plotted according to accumulative percentages (Fig. 16). (See also Table VII A and B).

Moult Effects on Reproduction

The effect of the moult or ecdysis on the life of crustaceans is well known because from time to time they lose the entire exoskeleton and it is replaced by a new one (Smith, 1958). The new shell very soon becomes calcified and hardened and the animal gains in size and weight; this phenomenon is especially important in females because after several moults they reach sexual maturity and thereafter increase in size by smaller increments.

When the animal is mature, each moult is probably associated with a period of sexual maturity (Berry, 1971) and a first maturity size is very important for regulating the minimum size for the fishery. The rate of growth depends on the frequency of moulting or on the availability of food (Smith, 1958). The changes of food and of type of food as well as changes in temperature could affect the frequency of moulting, as was demonstrated by Knowlton (1965) when working on the shrimp Palemonetes vulgaris.

Marshall (1948) reported ecdysis in P. argus without any change in size. This fact was confirmed by Witham, et al., (1968) when they found that the quality of food was closely related to growth.

In the case of males, this fact seems to be less important, because periods of moulting are associated with conditions of the habitat and not with sexual activity. The males appear sometimes to assist the females when they moult but this is a prelude to copulation.

The conditions of the carapace were recorded (Table VIII), and the major percentages of soft carapaces occurred in May, followed by September, though mature females were found in all months of the year.

Average Size at First Maturity

This was a very important question in this study because it was to give a basis for the regulation of the fishery. The females sampled were divided into immatures, matures and maturing, according to sexual development. The percentage of these three stages (Table IX) was recorded.

It can be seen that the size at first maturity was found between 65 and 70 mm carapace length corresponding to a total length of about 218 mm and a tail length of 122 mm. This was confirmed by observations on the ova of females of 65-70 mm in carapace length. According to Table X, we can notice the difference in total length in which the spiny lobster *P. argus* reaches first maturity given by various authors in different areas.

Abdomen Width and Maturity

Templeman (1944) when working on the lobster *Homarus americanus*, proposed that abdomen width as a percentage of the total length in the females could be a criteria of maturity. He stated that the increase in the relative width of the abdomen started at a total length of 180-190 mm suggesting that the females with an abdomen width 21.5% of the total length would probably be ovigerous.

Squires (1970) working on the same species, gave the size at first maturity in Port au Port Bay as 72 mm in length of carapace, corresponding to an abdomen width of 22% of the total length, or 64% of carapace length and said that this could vary with area and prevailing temperature.

Taking into account these criteria, measurements were taken in the females and plotted against the carapace length (Fig. 17). The percentage of width with respect to the length of the carapace was plotted (Fig. 18). In the same graphs were plotted the juvenile females and smaller than 70 mm in carapace length.

In a female of 64 mm carapace length and 194 mm total length, which was found in ovigerous condition, the percentage of width with respect to the carapace was 78.12 and in the immatures, 72.65. The percentages referred to the total length were 25.77 and 23.96 respectively.

Other specimens with carapaces of 67 mm also showed differences with respect to the percentage referred to,being 74.72 for lobsters carrying eggs and 68.95 for immature females. The percentages referred to the total length were 24.03 for females with eggs and 23.70 for immatures. However, at a certain carapace length, the difference started to disappear for both stages, the width being 71.42% of carapace length and 22.93 of total length.

The differences found could be due to the low number of individuals found at these sizes when they were in ovigerous condition, considering that females carrying eggs smaller than 218 mm total length were precocious.

The differences found between the widths of the abdomen of the females carrying eggs at sizes 64-67 mm in carapace length allows us to suppose that when they matured, that is before another moult, that the abdomen width would be similar. This was confirmed in individuals of 70 mm in carapace length when the difference disappeared. It is logical that the major increase of the abdomen takes place in a moult before the first sexual maturity due to the hormones which are released by developing ovaries.

With the data gathered during the sampling programme, the following regression equation by the least squares method were obtained for the females in ovigerous condition (Y = abdomen width and X = carapace length):

$$Y = 0.28 - 0.72\ X$$

For the juvenile females below 70 mm in carapace length, the following equation was obtained:

$$Y = 0.71 - 0.69\ X$$

<u>Number of Eggs per Female</u>

Lindberg (1965) when studying the lobster *P. interruptus* noted that the number of eggs varied with the cube of the length of the individual, according to Herrick's Law. Later on this was confirmed by Mota, Alvarez and Bezerra (1968) for *P. argus*.

The eggs collected were counted at the laboratory and the resulting figures plotted against the carapace length (Fig. 19), noting that the results fitted the equation $Y = nl^c$ when Y = number of eggs,

l = carapace length

n = a constant

c = an exponent

The constant (n) and the exponent (c) were estimated by the least squares method with transformation of variables and the following result was obtained:

$$Y = 2.032\ L^{2.97}$$

which expressed in logarithmic form is:

$$\text{Log } Y = 0.01317 - 2.97 \text{ Log } L$$

The average number of eggs found by specimens between 65 and 125 mm of carapace length was 630,000 with the lowest 324,736 and the highest 1,140,000 eggs (Table XI; Herazo, 1971).

The average figure can be considered as acceptable when compared with the number of 260,000 found in British Honduras for specimens of 69 mm in carapace length of *P. interruptus* (Allsopp, 1968). Allen (1916) in Dees (1961) reported for a female of 14 inches 500,000 eggs which indicates that the characteristics of species of *Panulirus* are similar regarding the number of eggs produced, but this might vary with area (see also Squires, 1970, 1971, for studies of fecundity of *Homarus*).

Hypothetical Weight Gain per Moult

From the samples collected in the Guajira, carapace length was obtained from 500 males and 493 females, and using this length-weight relationship for both sexes an estimated increase in weight per moult was obtained (See also Squires, 1970).

Carapace length moult increment for this species was estimated to be 8 mm on the average at precommercial and commercial sizes (57 to 81 mm). (See also Berry, 1971; Ingle, et al., 1972).

Moult increment of 8 mm from 57-65 mm, 65-73 mm, and 73-81 mm were used for these estimations in both males and females.

The minimum carapace length recommended was 65 mm (giving a tail weight of 3 oz (74 g) in males and 3.6 oz (100 g) in females. Based on the initial weight (185 g in males and females) the weight after each moult selected gave a hypothetical gain in weight (Table XII). The hypothetical gain in weight was higher for the females, the difference increasing until in the third moult when the gain was 160% for the females and 130% for the males. At the first moult the gain was 32% in males and 46% in females and at the second moult 83% and 103%.

Carapace Length - Total Weight Relationship

Squires, et al., (1971) mentions several authors that had used the length relationships in the lobster H. americanus for conversions of total length to carapace length and in order to distinguish different populations of lobster. Templeman (1944) used them also to indicate sizes at first sexual maturity in females.

The same author stated the importance of the use of these biometric equations in lobster, not only to indicate the difference between populations, but also to convert length to weight and in estimating:

a. hypothetical weight gain after moulting,

b. identification of incidence of regeneration in chelae and periopods,

c. weight from length when lobsters are only measured alive or after tagging,

d. size at first maturity by noting the length when the increase in weight of the chelae (in males) or abdomen width (in females) takes place.

The length-weight relationship of the lobster P. argus of the Guajira coast of Colombia was obtained from specimens whose carapace lengths varied from 46-130 mm in females and 46-150 mm in males. The equation $W = KL^h$ was used and transformed as follows:

a. for males:

$$\text{Log } Y = 2.2873 - 2.578 \text{ Log } X$$

$$Y = 0.005159X^{2.578}$$

$$r = 0.90$$

b. for females:

$$\text{Log } Y = 2.65552 - 2.7921 \text{ Log } X$$

$$Y = 0.002211\ X^{2.7921}$$

$$r = 0.996$$

The carapace length was plotted against the total weight (Fig. 20) and we can observe that for each mm of increase of the carapace length, the total weight of the specimens increased logarithmically 2.578 times in males and 2.792 in females.

Tail Length - Total Weight Relationship

Using the same logarithmic equation for the tail length - total weight relationship, the following results were obtained:

a. for males:

$$\text{Log } Y = 4.8524 - 3.472 \text{ Log } X$$

$$Y = 0.000014\ X^{3.472}$$

$$r = 0.989$$

b. for females:

$$\text{Log } Y = -3.6529 - 2.9004 \text{ Log } X$$

$$Y = 0.000222X^{2.9}$$

$$r = 0.988$$

From the figures we can infer that for the tail length range of 90-280 mm (Fig. 21) the growth is more pronounced in the males than in the females, but in the males a lower weight than in the females occurs at smaller sizes. We can notice that between 130 and 150 mm in tail length the increase in weight is uniform for both sexes. It is also seen in the graph that the correlation between the total weight having as a base the tail length is very similar for both sexes, as we noticed before, reaching 98.9% confidence limits.

Total Weight - Tail Weight Relationship

The linear equation $Y = a + b x$ was used in estimating the relationship for both sexes obtaining the following results (where TW = total weight and tw = tail weight:

a. for males: $TW = -79.5 + 3.68\ tw$

$r = 0.99$

b. for females: $TW = -100 + 3.4\ tw$

$r = 0.99$

As shown in the two equations, the growth of the total weight with respect to the tail weight is somewhat different for both sexes because the slope is not quite equal.

The total weight increased 3.5 times for each gram of tail weight in both sexes (Fig. 22). The relationship shows a 0.99 positive correlation.

Carapace Length - Tail Weight Relationship

In this relationship, the tail weight increased faster in males than in females for a carapace length varying between 45 and 160 mm, and a weight between 37 and 700 gms. This meant that the tail weight in the males increased logarithmically by 2.5146 times on the average as each specimen grew in carapace length (Fig. 23).

In the females, the tail weight increases by 2,331 times on the average.

Carapace Length - Total Length Relationship

Homogeneity in this relationship is found in both sexes because in the average total length for each interval of carapace length the variations in the curve are very small.

In the females (Fig. 24) for each mm of the carapace length, the total length increases 2.4 times.

In the males (Fig. 25) this increment is slightly smaller because the total length increases 2.34 times with respect to the independent variable.

For both sexes, specimens with a carapace length of 48.5 mm were found and at larger sizes males reached 152 mm in carapace length but females were not larger than 130 mm.

OTHER ASPECTS OF THE LIFE HISTORY OF THE LOBSTER *P. ARGUS*

Migrations

According to the literature consulted, the spiny lobster is said to be sedentary in behaviour. However, Smith (1958) found that some tagged lobsters had migrated more than 100 miles with a daily average of a mile per day. This may be a unique example because the same author states that the movements of these lobsters do not exceed one mile per day.

Smith also found that the majority of the migrations were parallel to the coast from shallow to deep waters and down to 100 meters. Some of the movements are associated with changes in the water, especially in its physical and chemical condition. Besides these factors there are two considered as the main causes of movements in the lobsters. One is searching for food, and the other for mating.

Perhaps due to these factors it may be easy to find an abundance of lobsters in areas near shore during certain seasons of the year. Migrations, probably as a response to high density, have been reported for this species. They have been reported to migrate in single file and in large numbers (Herrnkind, 1969).

Larvae

As stated before, the lobster has slow larval growth passing through several stages varying from six to eight months or less on some occasions. During this period they moult up to 11 times. According to John B. Lewis (personal communication to Squires) the larval period is not as long as formerly supposed.

The first larva is flat and transparent, not resembling the adult animal, and it is known as a phyllosome larvae.

During the 11 larval stages, the behaviour seems to be similar to that described by Squires (1972) (in press) which says that the larvae may remain close to shore but without reaching the beaches. They seem to have a defense mechanism which allows them to detect the vibrations of the waves on the shore, making them migrate downward as do other surface plankton and to be carried outward by compensatory currents. However, the larvae again reach the surface when the intensity of the vibrations has decreased and thus they tend to concentrate in a zone not far from shore.

The eleven larval stages are followed by a metamorphosis in which the larva takes the form of an adult lobster, transparent in color, however; and because of its weight sinks to the bottom looking for the most suitable substratum to survive (Chapa, 1964).

The large number of small lobsters found near Carrizal is evidence of larval settlement in the sheltered area west of Cabo de la Vela (5.2).

The current system acts as a trap for larval lobsters and other organisms and the substratum in this area has extensive beds of seaweeds which would be perfect sheltering areas for post-larval lobsters.

Buesa (1968) considers that from the time the egg hatches until the animal reaches its first maturity, it has gone through 35 moults within a four-year period.

Stomach Contents

Ninety-three specimens from the Guajira coast of Colombia were subsampled for stomach content studies. Many were empty, perhaps due to the fact that the animals were transported some distance alive or to the habitat conditions where they were caught. Some intestines were also sampled for undigested materials.

Of the analysis, 40% of the contents were remains of fish and fish bones, 30% crustaceans, and 20% remains of mollusc shells, and in lower quantities, ostracods, foraminiferans, diatoms such as coscinodiscus, and filamentous algae.

Growth

Bimonthly grouping of the carapace length frequencies of samples by sex were examined for occurrence of modes. These modes were plotted at each bimonthly interval (Figs. 26 and 27). Curves were drawn to connect modes that were presumed to have shifted with time. The presumed modal shift represented an increment in carapace length between one mode and the other in the two-month period.

The slope was used to estimate a growth factor = K, and this was entered in the Von-Bertalanffy equation. (See Dos Santos and Da Costa, 1964).

In Fig. 28 and Fig. 29 the point of interception of the curve of zero growth and the curve of growth rate K (t) the asymptotic length can be estimated as follows:

$$Lt = L \; 1-e^{-k\,(t-to)}$$

where Lt = maximum size towards which the length of the specimen is tending,

k = a measure of the rate at which the length approaches L,

to = zero hypothetical age at zero carapace length.

From Figs. 28 and 29 the constant ($L\infty$) could be estimated because the slope of the adjusted curve is (e^{-k}) according to Beverton and Holt (1957), giving K = 0.1625 for females and 0.1310 for males.

These parameters were obtained and applied in Figs. 30 and 31 for males and females:

a. for males: $L_t = 157.95\ (1-e^{-0.131\ (t\ +\ 2.762)}$

b. for females: $L_t = 133.33\ (1-e^{-0.1625\ (t\ +\ 2.0161)}$

So the growth rate is more accelerated in males than in females, the females actually reaching sexual maturity at smaller sizes than males.

DISCUSSION AND CONCLUSIONS

Habitat

The Guajira Peninsula, because of its geographical location and the characteristics of spiny lobsters, habitat presents favourable conditions for the development of a lobster fishery.

In the area of Cabo de la Vela, the effect of the wind and the line of the coast produces anticyclonic currents which make this place a sheltered area and nursery ground for lobsters. Apparently lobsters migrate away from this area and populate grounds from Cabo de la Vela to Punta Caricari. A programme of tagging will be undertaken to prove this.

Sociological Considerations

Generally speaking, the educational level of the Guajiros is rather low. The Guajiros diver is limited not only by the weather conditions, but by capital available to renew his equipment or improve his catching techniques.

With all these limitations the system of diving still provides fairly good commercial catches, compared with traps which are only recently in use in the area. It is important to have regulations to safeguard the lobster resource which the Indians are exploiting.

These could be a minimum size limit and protection of the grounds by forbidding shrimp trawlers to fish in less than 40 m deep in the area, monitored for a period of about five years and kept under review.

The minimum size limit is suggested because the Guajiros catch small lobsters (the smallest about 3 oz in tail weight) and refuse to co-operate with industry if they cannot sell them. It is possible that the taking of the present amount of small lobsters is not endangering the lobster population at the present level of exploitation.

Comparison Between the Two Species

a) Biology: *P. argus* reaches larger sizes than *P. laevicauda* (Paiva, 1963) as shown in samples and in the *P. laevicauda* that are landed at the plants in the Guajira.

b) With respect to Maturity: The difference in size at the time that *P. argus* reaches its first maturity compared to *P. laevicauda* is considerable; the former matures between 65-70 mm in carapace length, the latter at 54-59 mm. These data agree with those found by Paiva and Da Costa (1965) for the same species in Brazil. A low minimum size limit of 65 mm will probably favour *P. laevicauda* if the fishing intensity becomes high off the Guajira.

Comparison Between Several Areas Where a Fishery for the Spiny Lobster is Beginning

According to the statistics gathered, it seems that on the nearby banks of the Islands of San Andres and Providence where a stock of 190 tons was estimated in 1969 (Ben-Tuvia and Rios, 1970), is a rich ground for Panulirus. A third area could be that near Cartagena, with major catches of P. argus. However, no data on the biology of the species are known from these areas.

Application of the Results to the Fisheries

a) The rate of growth is more accelerated in males than in females. The maximum carapace length found was that of 158 mm for a male while in the females it was no more than 130 mm. Although this might make females more vulnerable than males to divers, catches did not show a higher proportion of females than males.

b) Hypothetical weight gain: According to the estimate and the graph (Figs. 30 and 31) the hypothetical weight gain for the first moult was 32% in males and 46% in females, 83 and 103% for the second moult. A moult increment of 30 mm in total length was reported for P. argus (Witham, et al., 1968). This would be about 8 mm in carapace length.

Regulations and Rationalization

a) By size: With the growth of individuals a sexual dimorphism is noticed; the biometric observations showed growth of the females and tail length in relation to carapace length to be greater than in males. A regulation was recommended to the Government for the protection of specimens of less than 220 mm in total length (65 mm carapace length; 22 mm in tail length and 3.4 oz (95 g) in tail weight) in order to permit one spawning, at least, of all females.

This size also gives a 32% yield in weight over a size one moult smaller.

b) By weight: According to the previous statement and to hypothetical weight gain, it is considered important not to fish for specimens with a tail weight lower than 3.6 to 4 ounces. However, socioeconomic factors mediate against this and a lower limit of 3 oz. could be enforced on an experimental basis for several years while the fishery and biology of the species continue to be studied. As an alternative to the marketing of small sizes and immature specimens, it is recommended that the Government assist in the institution of lobster farming since as shown in this study, the weight gain is large enough to justify culture of the small sizes which have to be bought from the Guajiro divers.

Sex Ratio

It can be concluded that for *P. argus* the sex ratio in landings of males and females are 1:1.

Biometric Relationships

a) Tail length - total weight: The total weight to the tail length is to the 3.47 power in males; in females the total weight does not reach cube of the tail length.

b) Carapace length - total weight: According to Fig. 20, the growth of males in total weight with respect to carapace length is less pronounced than in the females. However, the interval of variation is larger in carapace length and in total weight as well.

c) Total weight - tail weight: Based on the equations of growth in total weight with respect to the tail weight, it is concluded that growth is uniform for both sexes because the slope in Fig. 22 is the same. This means that the total weight increases 3.6 times for each gram of tail weight in both sexes. The multiple of 3.6 can therefore be used to convert tail weight to total weight.

d) Total length - tail length: The growth in total length is more accelerated in the males than in the females.

Reproduction

a) During the period the study was made, females carrying eggs were observed in every month and the ovary also showed advanced stages of development in those that had eggs ready to hatch. Comparison of the stage of development of the ovary with respect to that of the embryo in the egg indicated that the period of oogenesis must be approximately equal to embryogenesis.

b) The fecundity is very high with an average of 630,483 eggs per lobster. Herrick's Law (1895) was also confirmed since the number of eggs was related to the size of the lobster and was about the cube of the length.

c) The data obtained tended to confirm Squires' hypothesis about this lobster having four spawnings a year (see also Berry, 1971).

d) The sexual maturity could be estimated from the ova sizes and could be correlated with the scale of colors proposed during the sampling programs.

e) The difference found between the abdomen width of females carrying eggs and those not carrying eggs of 64-67 mm carapace length allowed us to suppose that if they were to mature soon or before another moult, the abdomen width should be similar. This is not shown in individuals of 70 mm carapace length where differences disappear.

It is obvious that the larger increment of abdomen width should occur in the moult after the first sexual maturity due to the mechanisms of growth in lobsters. However, the abdomen width as an index of sexual maturity could be reviewed in further work and with a larger amount of data.

f) Egg color: The color of the eggs varied notably from an intense red to dark brown according to the stage of development of the embryo, from the time the egg is full of yolk until the time the prenaupliosoma is formed in the egg.

g) Egg diameter: The diameter of the eggs appeared to have a straight line relationship to the diameter of the ova as this increased with the increase in diameter of the eggs.

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II TABLES

Table I. Average salinities and temperatures of the Guajira Peninsula in 1969-71, observed on board of R/V "Choco" (depths between 1-10 m)

Area	Temperatures (Celsius)		Salinities $^{o}/oo$	
	Maximum	Minimum	Maximum	Minimum
Carrizal	28.9	25.2	36.89	35.88
Dibulla	29.0	25.5	35.90	34.13

TABLE II. TOTAL PERCENT OF MATURE FEMALE SPINY LOBSTER, *Panulirus argus* IN EACH MONTH DURING MAY - DECEMBER,1969 AND JANUARY - MAY, 1970 OF THE GUAJIRA COAST OF COLOMBIA.

MONTH	OVIGEROUS FEMALES	PORCENTAGE MATURE FEMALES.
APRIL	19	65.51
MAY	17	48.57
JUNE	5	62.5
JULY	—	—
AUGUST	32	72.72
SEPTEMBER	24	55.81
OCTOBER	29	72.50
NOVEMBER	—	—
DECEMBER	14	40.00
JANUARY	2	18.18
FEBRUARY	17	62.96
MARCH	3	27.27
APRIL	—	—
MAY	15	23.43

TABLE III. DEVELOPMENT STAGES OF THE OVARY WITH RESPECT TO THE EMBRYO DEVELOPMENT IN THE SPINY LOBSTER *P. ARGUS* OFF THE GUAJIRA COAST OF COLOMBIA (150 OBSERVATIONS).

EGG DIAMETERS (mm)	OVA DIAMETERS (Average mm.)
0.5	0.15
0.6	0.25
0.7	0.31
0.8	0.38

TABLE IV. Ova diameter with respect to the development stage and color present in ovaries of females of *Panulirus argus* from the Guajira Coast of Colombia.

Color	Stage	Diameter (mm)
Translucent	Juvenile	Indistinguishable
White	Immature	0.1 - 0.2
Cream - Pink	Maturing	0.3 - 0.4
Red - Orange	Mature	0.4 - 0.5
Whitish - Flaccid	Spawned	

TABLE V. EMBRYO DEVELOPMENT STAGES OBSERVED IN SAMPLES FROM AUGUST, 1969 to MAY, 1970, ON THE COAST OF THE GUAJIRA OF COLOMBIA.

MONTH	STAGE I YOLK (FULL)	%	STAGE II EYE POINT	%	STAGE III PRENAUPLIOSOMA	%
AUGUST	18	62.1	6	20.6	4	13.8
SEPTEMBER	9	64.2	2	14.8	3	21.5
OCTOBER	9	60.0	6	40.0	-	—
DECEMBER	7	50.0	5	35.6	2	14.2
JANUARY	-	—	-	—	-	—
FEBRUARY	3	100.0	-	—	-	—
MARCH	-	—	-	—	1	100.0
MAY	2	66.50	-	—	1	33.50

TABLE VI. MATURITY STAGES ACCORDING TO TESTIS COLORS OBSERVED IN MALES OF *Panulirus argus* OF THE GUAJIRA COAST OF COLOMBIA.

TRANSLUCENT	JUVENILE
WHITE (SMALL)	INMATURE
CREAM	MATURING
CREAM - BLUISH (LARGE)	MATURE

TABLE VII A. RANGES OF CARAPACE LENGTH ACCORDING TO MATURITY STAGES IN FEMALES OF <u>Panulirus argus</u> FROM THE GUAJIRA COAST OF COLOMBIA.

STAGE	RANGE OF CARAPACE LENGTHS
I	40 - 90
II	50 - 110
III	50 - 120
IV	65 - 125

TABLE VII B. RANGES CARAPACE LENGTH ACCORDING TO STAGES OF THE MATURITY IN MALES OF <u>Panulirus argus</u> FROM THE GUAJIRA COAST OF COLOMBIA.

STAGE	CARAPACE LENGTH RANGE (mm.)
I	45 - 110
II	65 - 115
III	65 - 150

TABLE VIII. CARAPACE CONDITION FOR BOTH SEXES OF Panulirus argus FROM THE GUAJIRA COAST OF COLOMBIA.

YEAR	MONTH	CARAPACE CONDITION IN PERCENT HARD		SOFT	
1968	SEPTEMBER	(10)	100%	(-)	—
1969	APRIL	(50)	100%	(-)	—
1969	MAY	(134)	82%	(30)	18%
1969	JUNE	(10)	100%	(-)	—
1969	JULY	(64)	94%	(4)	6%
1969	AUGUST	(88)	97%	(3)	3%
1969	SEPTEMBER	(128)	90%	(15)	10%
1969	OCTOBER	(68)	94%	(4)	6%
1969	DECEMBER	(68)	99%	(1)	1%
1970	JANUARY	(21)	100%	(-)	—
1970	FEBRUARY	(72)	99%	(1)	1%
1970	MARCH	(21)	100%	(-)	—
1970	MAY	(179)	92%	(16)	8%

NOTE ; (987) : TOTAL NUMBER OF SPECIMENS.

TABLE IX. NUMBER AT EACH MATURITY STAGE BY CARAPACE LENGTH IN FEMALE <u>P. argus</u> FROM THE GUAJIRA COAST OF COLOMBIA. (MINIMUN SIZE AT MATURITY).

SIZES	IMMATURE		MATURING		MATURE	
i = 5	No.	%	No.	%	No.	%
40	2	0.82	4	-	-	-
45	8	3.29	-	-	-	-
50	9	3.70	-	-	-	-
55	12	4.93	-	-	-	-
60	24	9.87	-	-	-	-
65	37	15.22	4	1.64	2	0.82
70	3	1.23	13	5.34	7	2.88
75	3	1.23	15	6.17	7	2.88
80	7	2.88	9	3.70	12	4.93
85	2	0.82	8	3.29	9	3.70
90	5	2.05	4	1.64	12	4.93
95	1	0.41	7	2.88	5	2.05
100	-	—	3	1.23	1	0.41
105	-	—	3	1.23	2	0.82
110	1	0.41	1	0.41	1	0.41
115	-	—	1	0.41	1	0.41
120	-	—	-	—	-	—
125	-	—	-	—	1	0.41

TABLE X. TOTAL LENGTH IN WHICH THE SPINY LOBSTER *P. argus* REACHES FIRST SEXUAL-MATURITY IN DIFFERENT AREAS ACCORDING TO AUTHORS SHOWN.

AUTHOR	DATE	TOTAL LENGTH (mm.)	CARAPACE LENGTH (mm.)	COUNTRY
BUESA	1961	190	72.7	CUBA
PAIVA & DA COSTA	1963	200 - 260	66.9 - 91.9	BRAZIL
WALTON - SMITH	1958	254	89.4	U.S.A.
PAIVA & DA SILVA	1962	180 - 270	58.6 - 96.1	BRAZIL
DEES	1968	203	203	U.S.A.
ALLSOPP	1968	100 - 250	25.2 - 87.7	BRITISH HONDURAS
DE BARRABY, EWALD AND CADIMA	1972	125.4	65 mm c.l.	VENEZUELA

TABLE XI. NUMBER OF EGGS COUNTED OR CALCULATED IN OVIGEROUS LOBSTERS *Panulirus argus* FROM THE GUAJIRA COAST OF COLOMBIA.

CARAPACE LENGTH	AVERAGE NUMBER COUNTED	NUMBER OF EGGS CALCULATED
65	375,731	250,100
70	-	-
75	324,736	382,500
80	393,741	463,300
85	537,760	554,700
90	621,085	679,280
95	693,419	770,250
100	827,918	898,920
105	855,144	1, 039,000
110	812,452	1, 193,000
120	1,115,089	1, 351,000
125	-	-
130	1,140,734	1,744,0000

TABLE XII. LENGTH-WEIGHT RELATIONSHIP, FOR THE HYPOTHETICAL PER CENT WEIGHT GAINED PER MOULT IN THE SPINY LOBSTER *Panulirus argus* (FIG. 20)

CARAPACE LENGTH MOULT INTERVALS (mm)	PERCENTAGE WEIGHT GAINED MALES	FEMALES	AVERAGE % BOTH SEXES
57	-	-	-
65	40.4	45.7	43.1
73	89.0	101.7	95.4
81	147.8	169.7	158.8

12. FIGURES

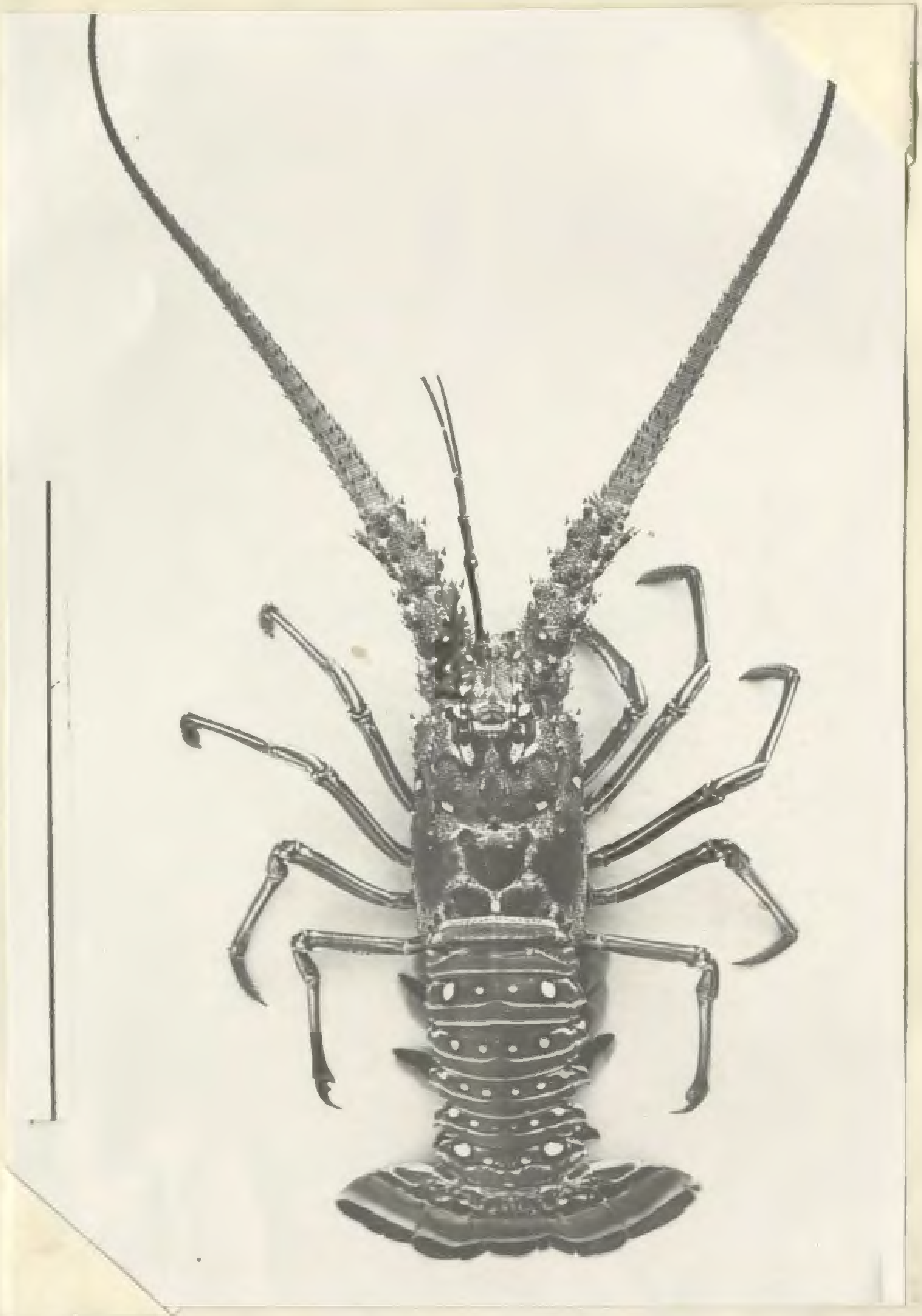


FIGURE 1. GUAJIRA SPINY LOBSTER Panulirus argus SHOWING THE SCUTES ON THE CARAPACE; AND SPOTS ON THE TAIL.

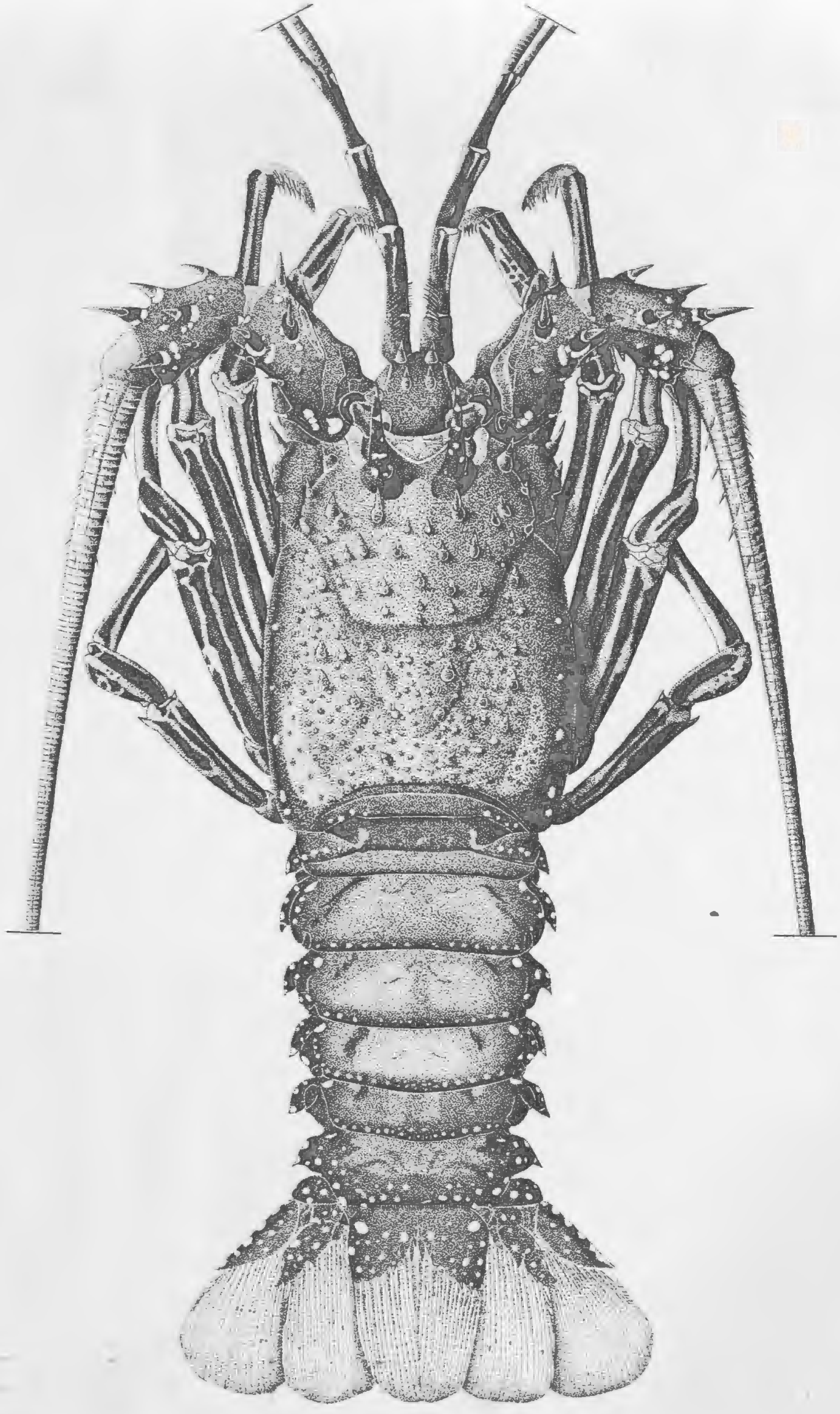


FIGURE 2. GUAJIRA SPINY LOBSTER Panulirus laevicauda SHOWING THE LARGE NUMBER OF SPINES ALL OVER CEPHALOTHORAX AND THE DOTS ON THE TELSUM (DRAWN BY O. BERNAL).

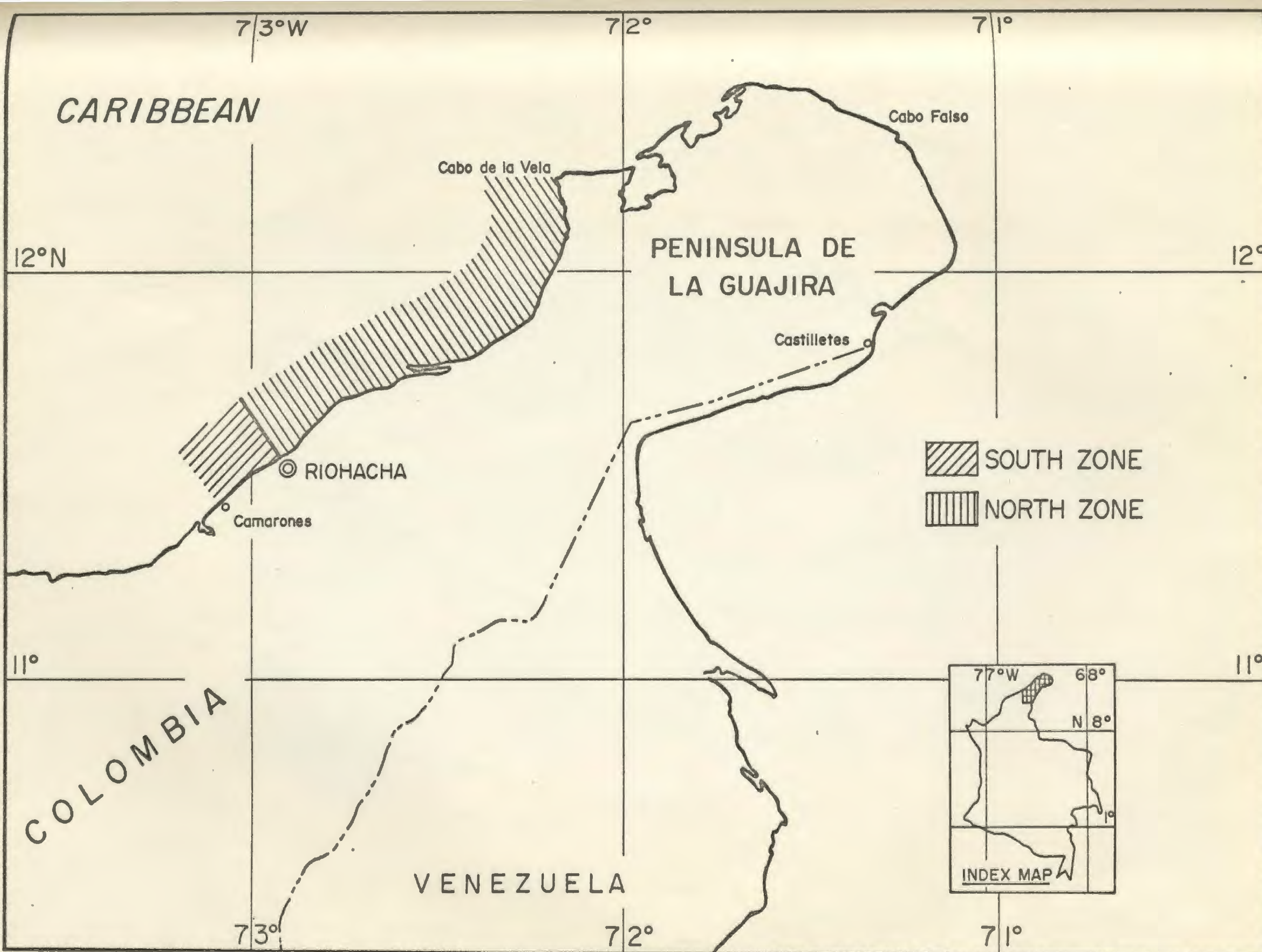


FIGURE 3. CHART OF THE GUAJIRA PENINSULA SHOWING THE MAIN AREAS OF COMMERCIAL CATCHES.

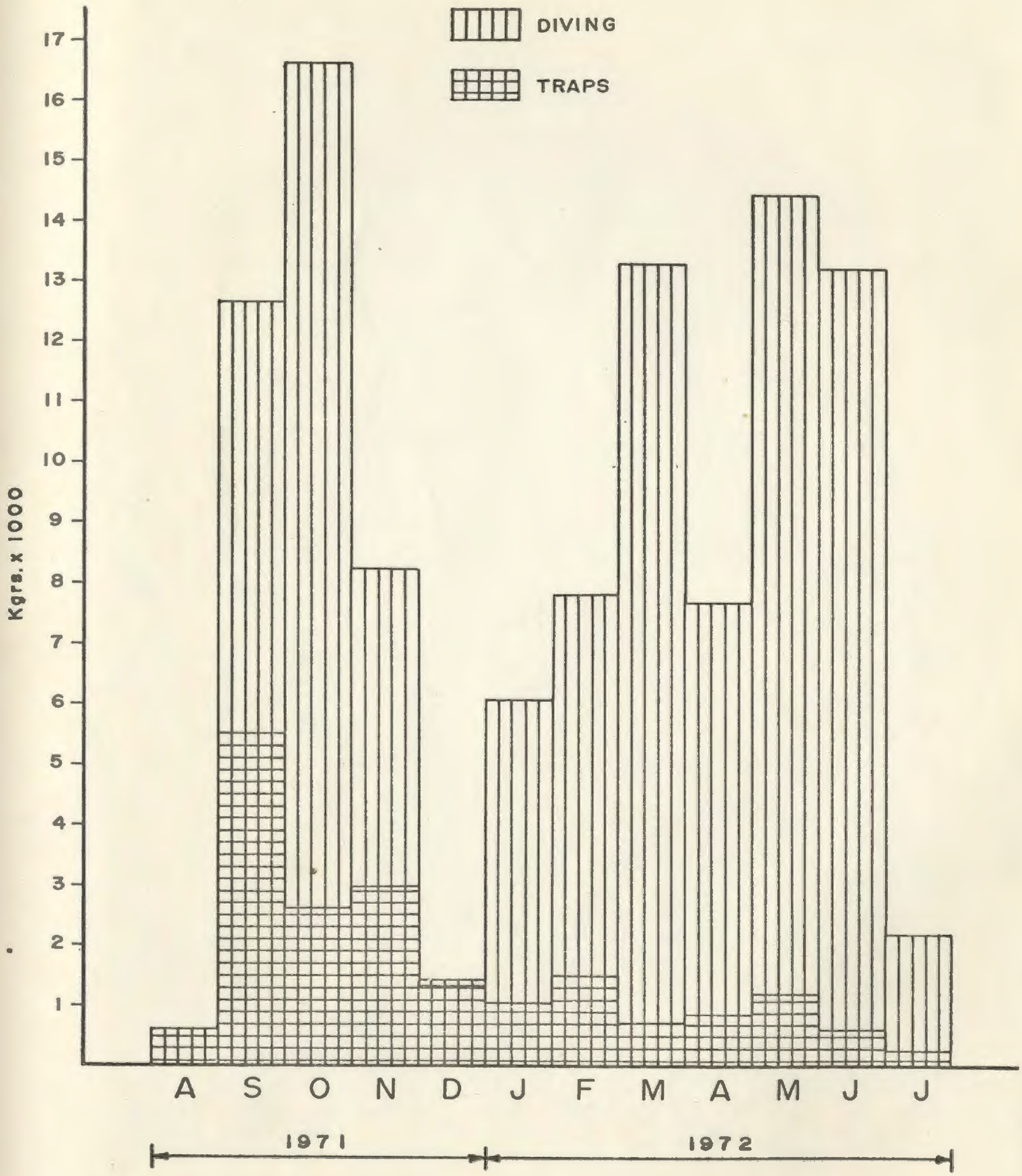


FIGURE 4. HISTOGRAM SHOWING THE TOTAL YIELD IN A YEAR ACCORDING TO THE METHOD OF CATCHING.

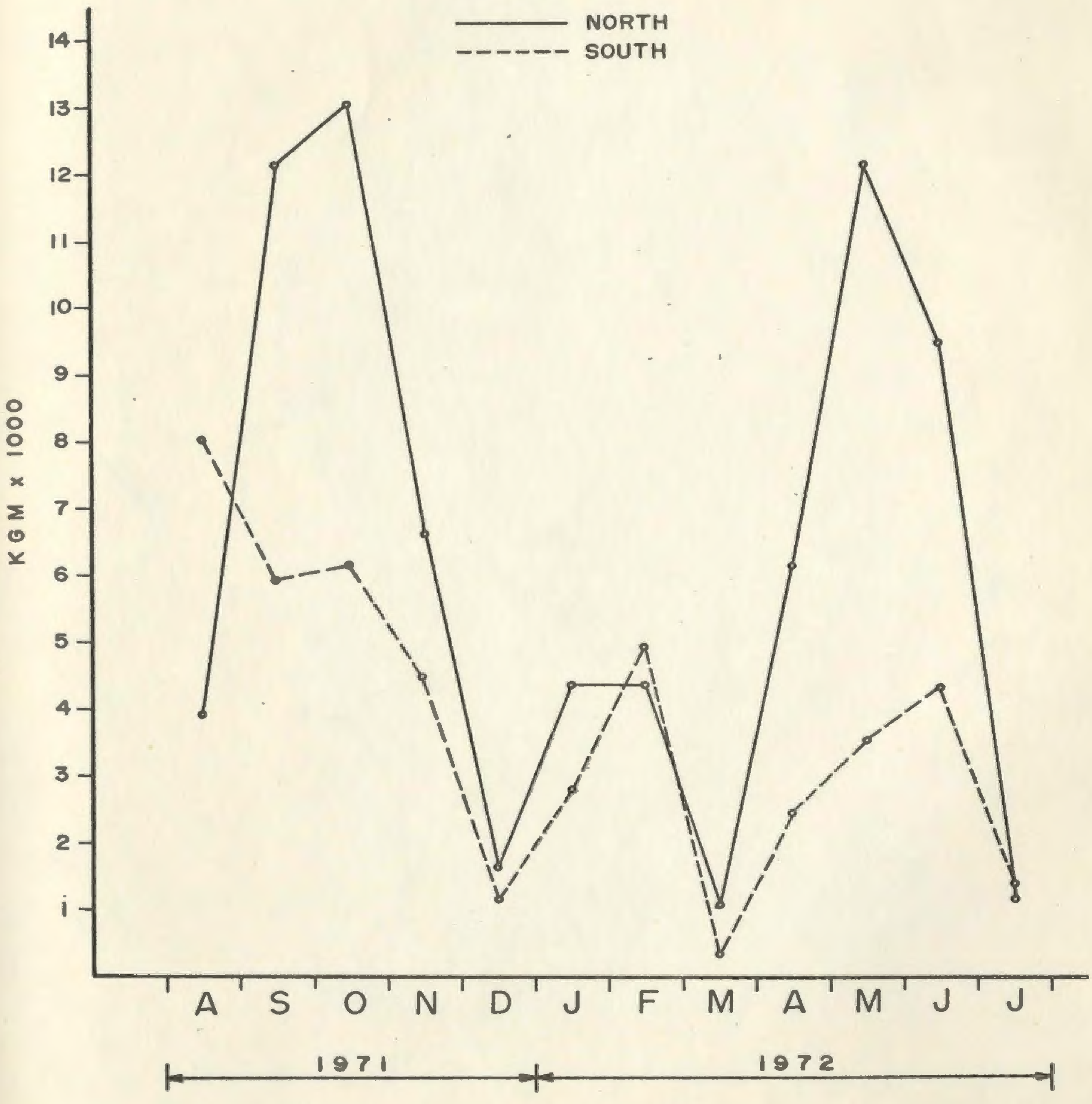


FIGURE 5. TOTAL YIELD IN A YEAR ACCORDING TO THE FISHING ZONE.

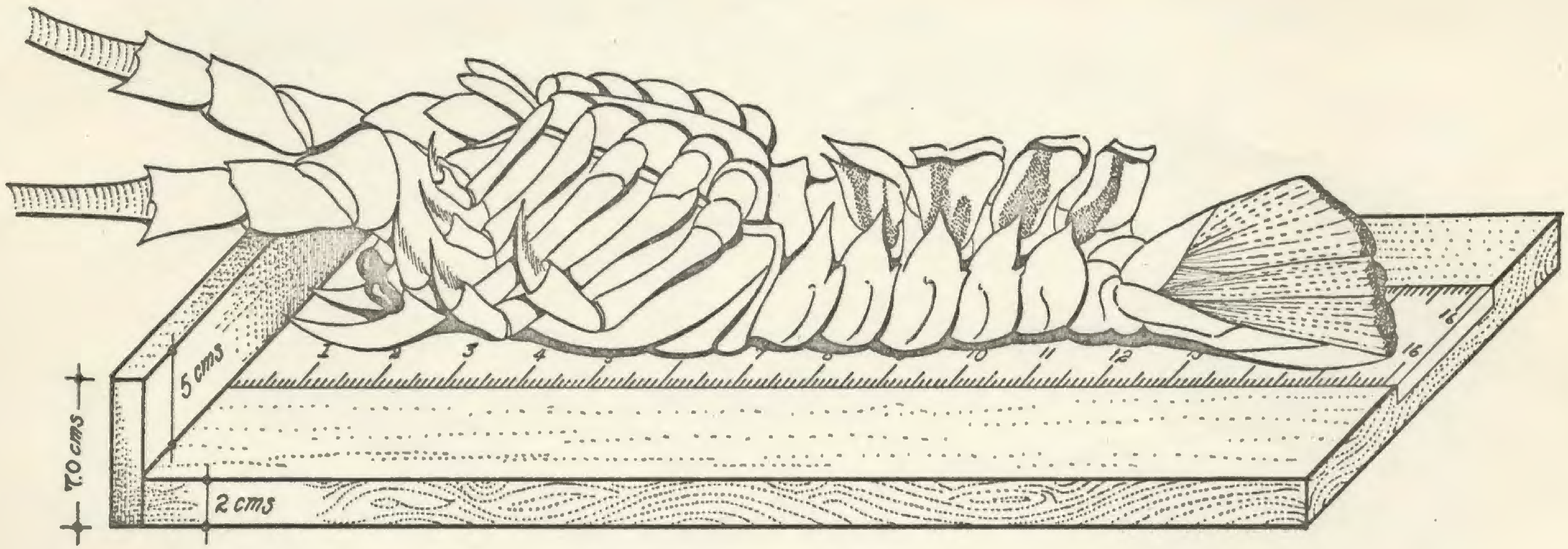


FIGURE 6. METHOD OF PLACING A SPINY LOBSTER ON A MEASURING BOARD TO DETERMINE TOTAL LENGTH.

FIGURE 7. ~~FOUR~~ MAIN SPAWNING PEAKS IN A YEAR FROM THE PERCENT OVIGEROUS EACH MONTH IN _P. argus_ ..

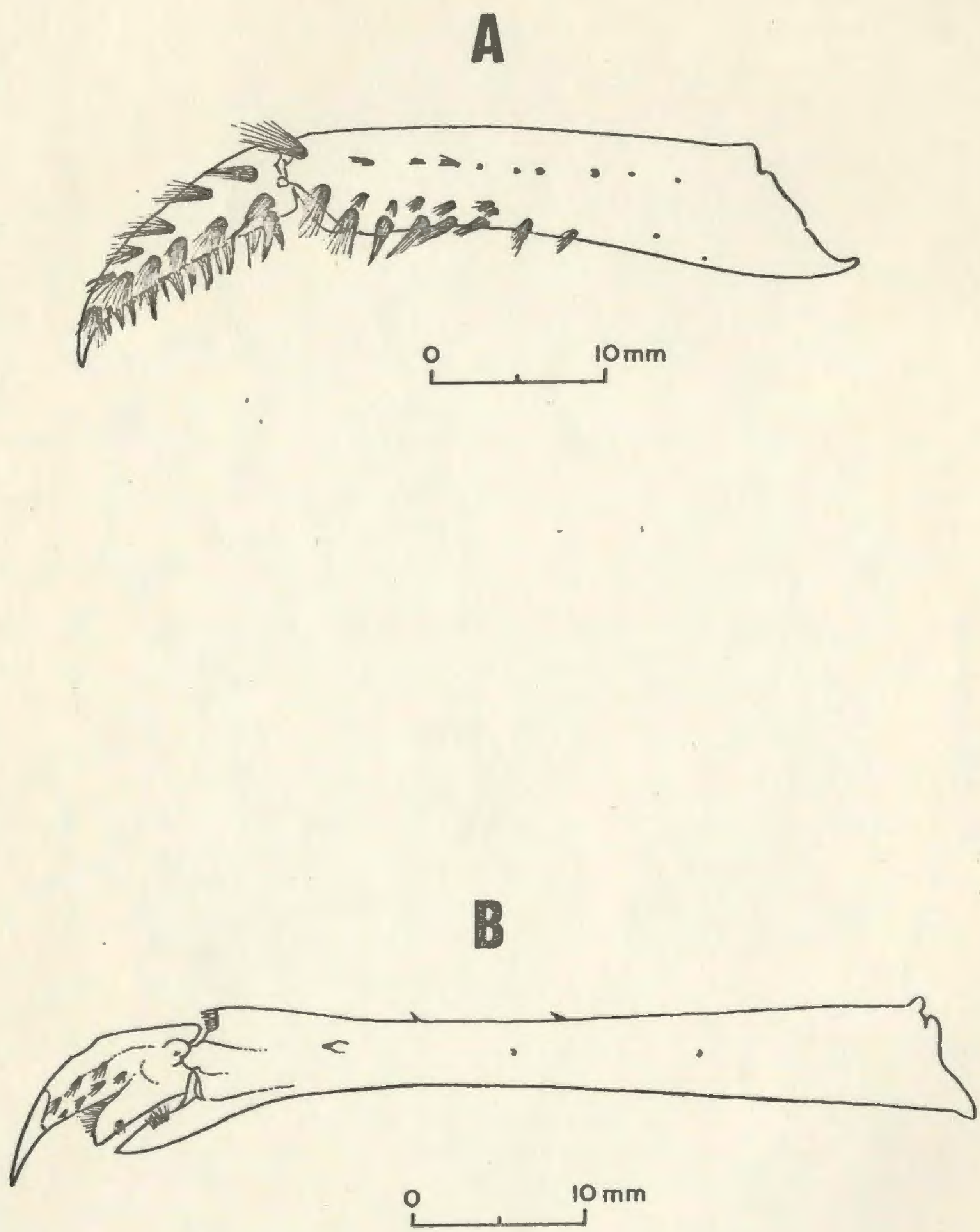


FIGURE 8. DACTYL AND PROPODUS OF :
A. THE FIFTH PAIR OF LEGS IN THE MALE SPINY LOBSTER P. argus
B. THE FIFTH PAIR OF LEGS IN THE FEMALE SPINY LOBSTER P. argus.

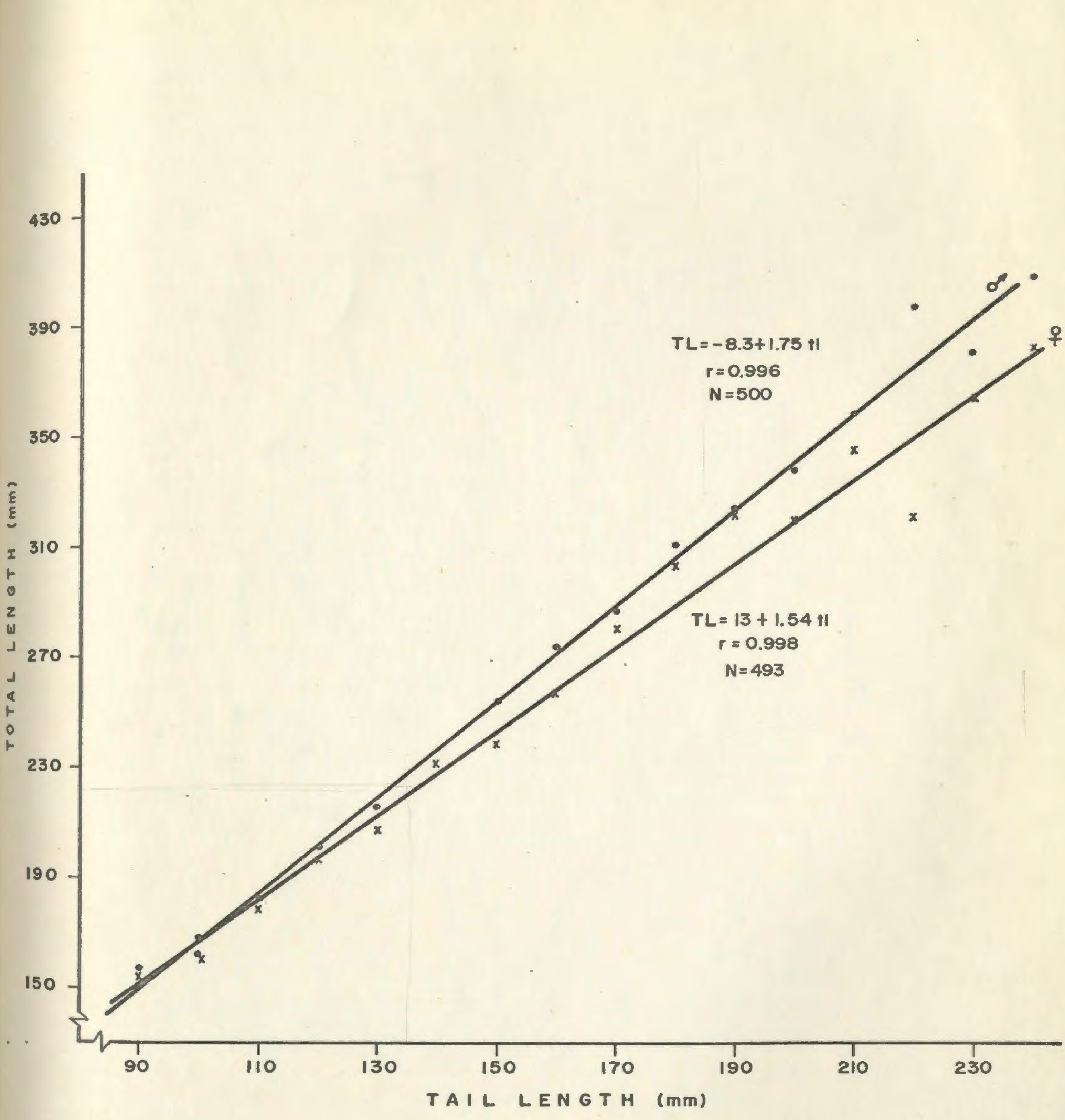


FIGURE 9. SEXUAL DIMORPHISM IN P. argus SHOWN BY TOTAL RELATED TO TAIL LENGTH IN MALES AND FEMALES.

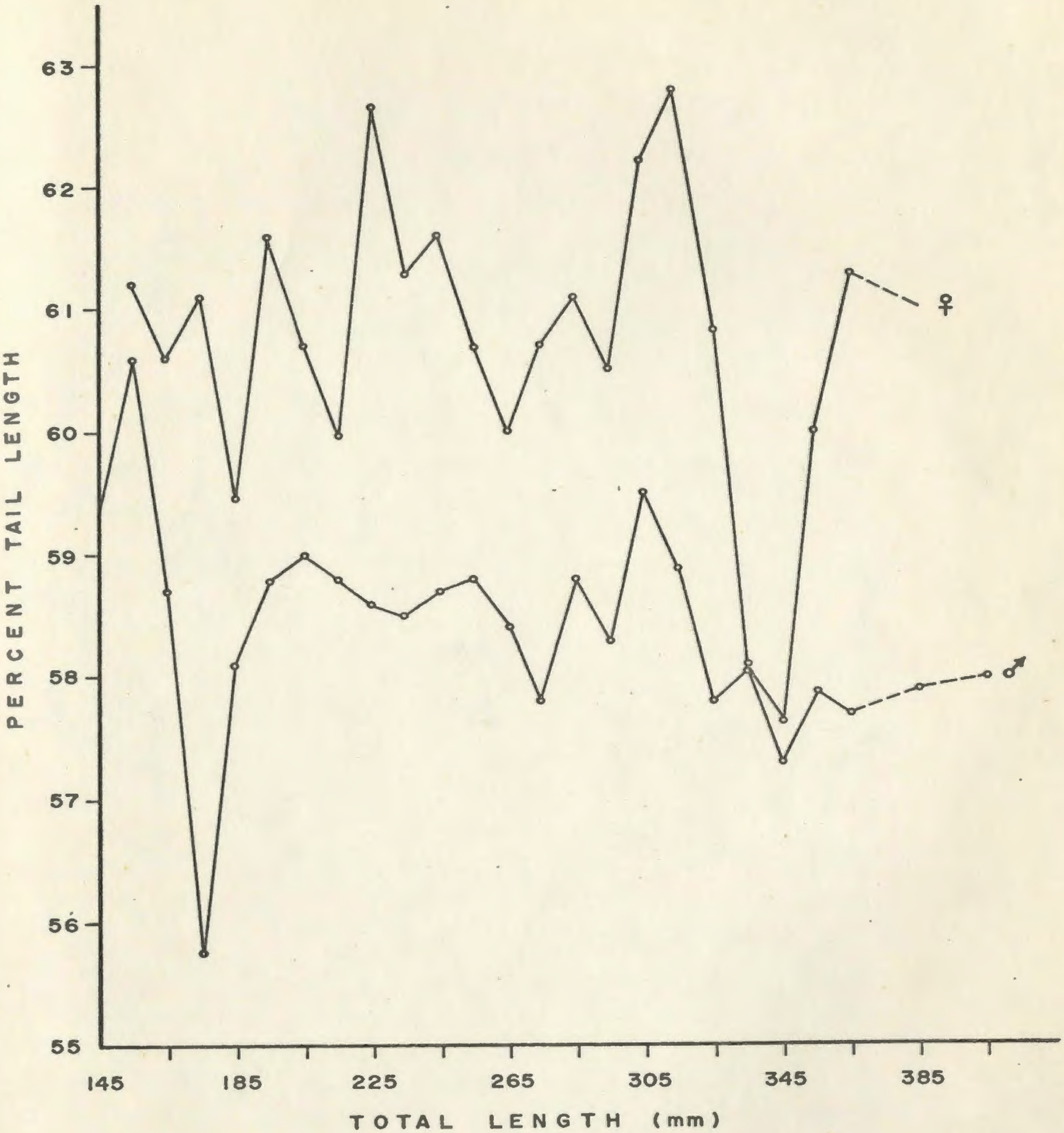


FIGURE 10. PERCENT TAIL LENGTH IS OF TOTAL LENGTH AT EACH TOTAL LENGTH IN MALES AND FEMALES OF P. argus.

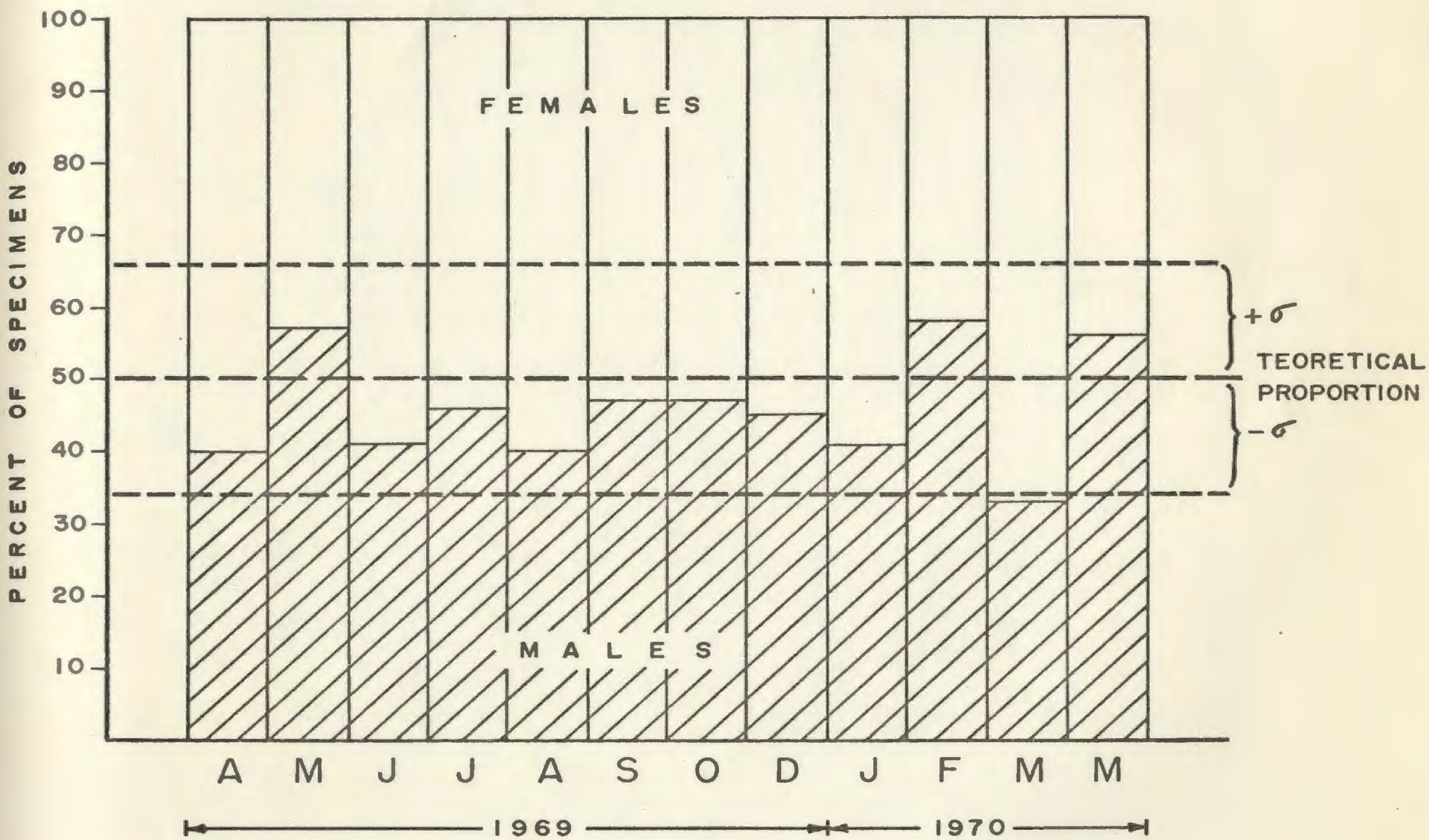


FIGURE 11. SEX PROPORTION IN SAMPLES TAKEN MONTHLY IN 1969 AND 1970 OFF THE GUAJIRA COAST. P. argus

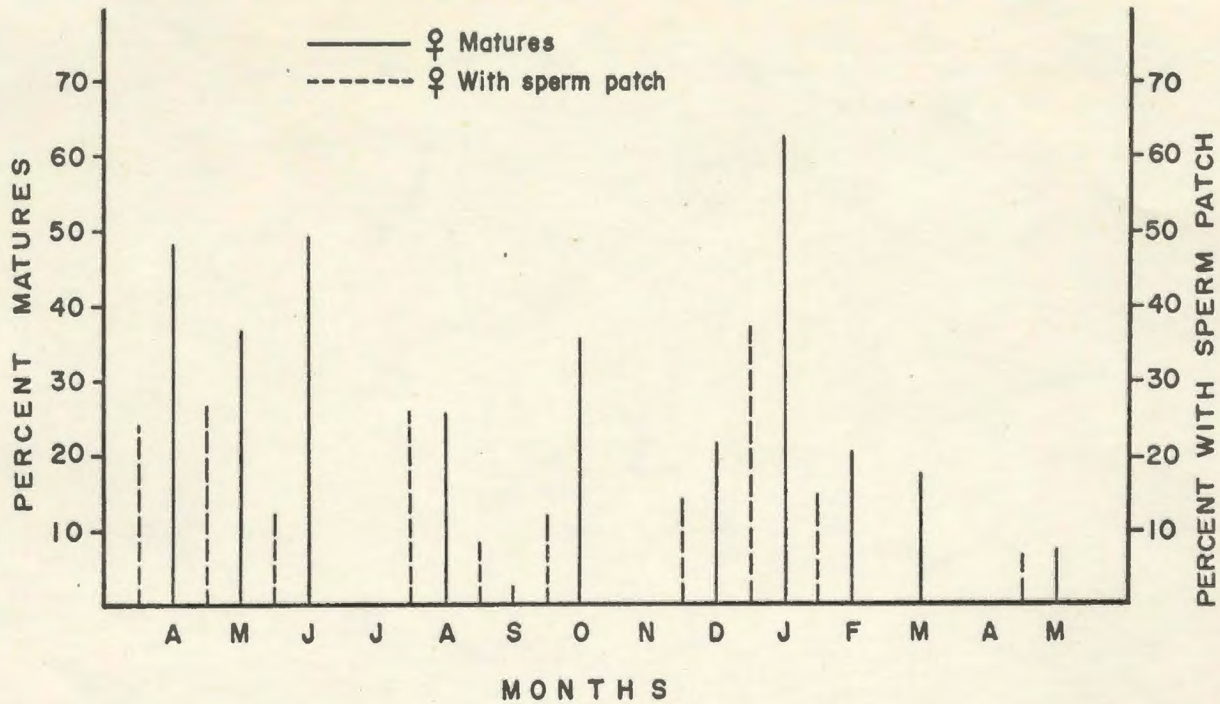


FIGURE 12. PERCENTS OF MATURE FEMALES AND FEMALES WITH SPERMATOPHORE (SPERM PATCH) IN MONTHLY SAMPLES IN <u>P. argus</u>.

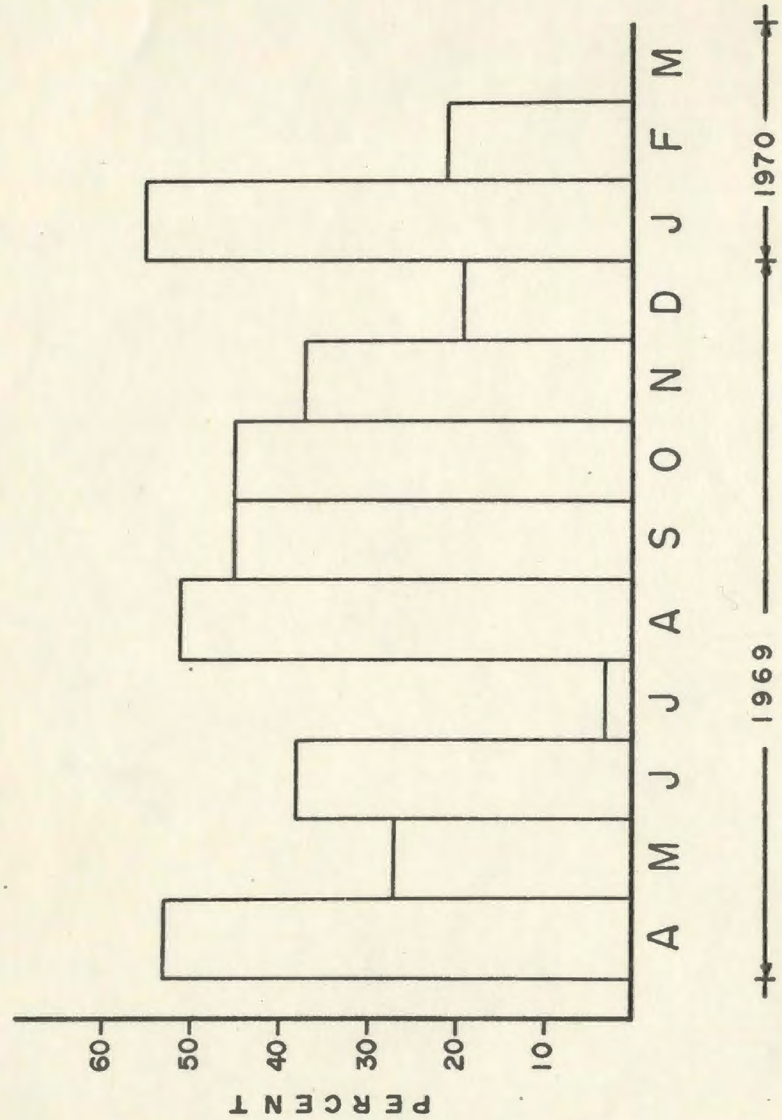


FIGURE 13. PERCENT OF TOTAL MATURE FEMALES CARRYING EGGS PER MONTH.

FIGURE 14. COMPARISON OF THE STAGE OF DEVELOPMENT OF THE EMBRYO IN THE EGG WITH THE OVARY COLOUR IN THE GUAJIRA SPINY LOBSTER.

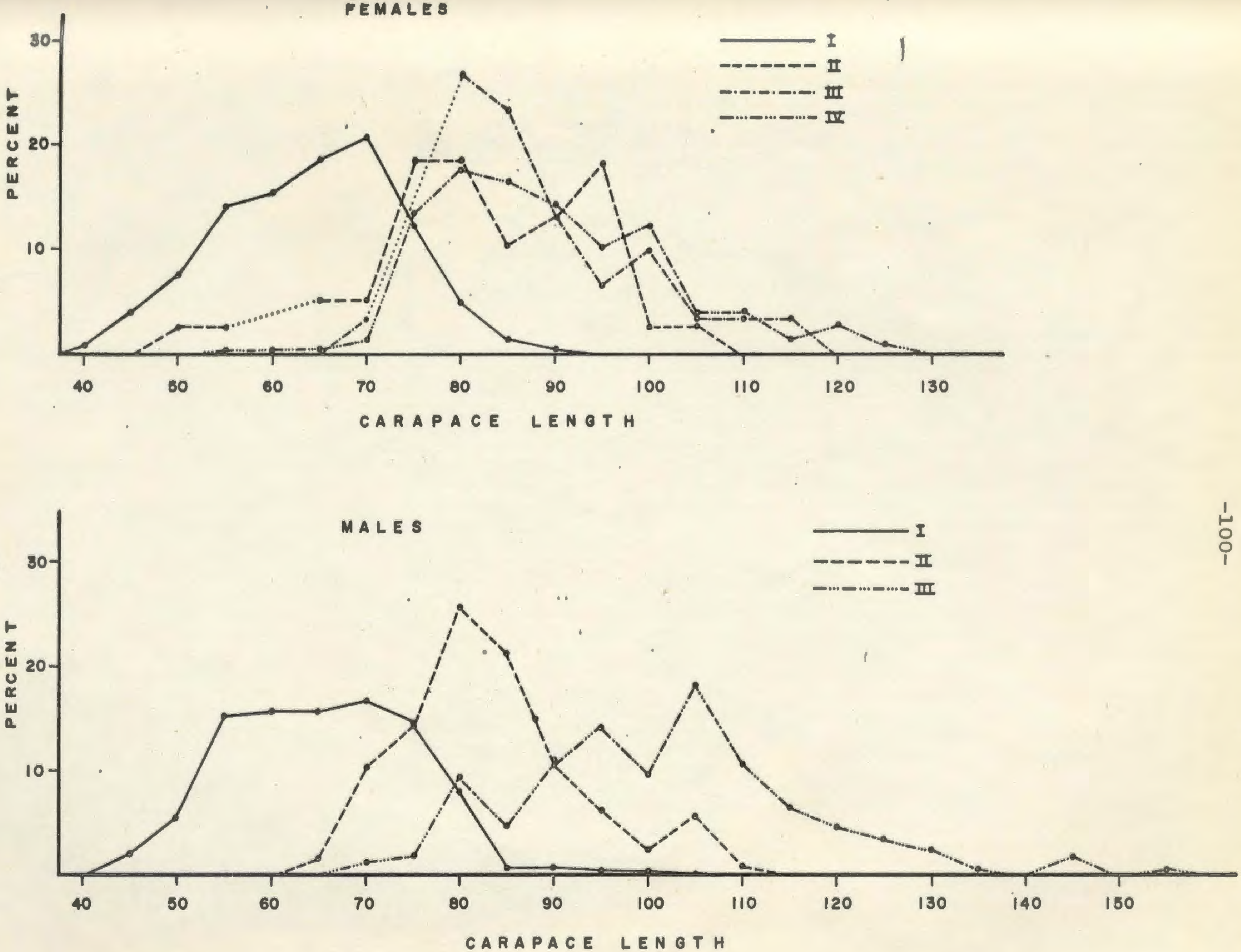
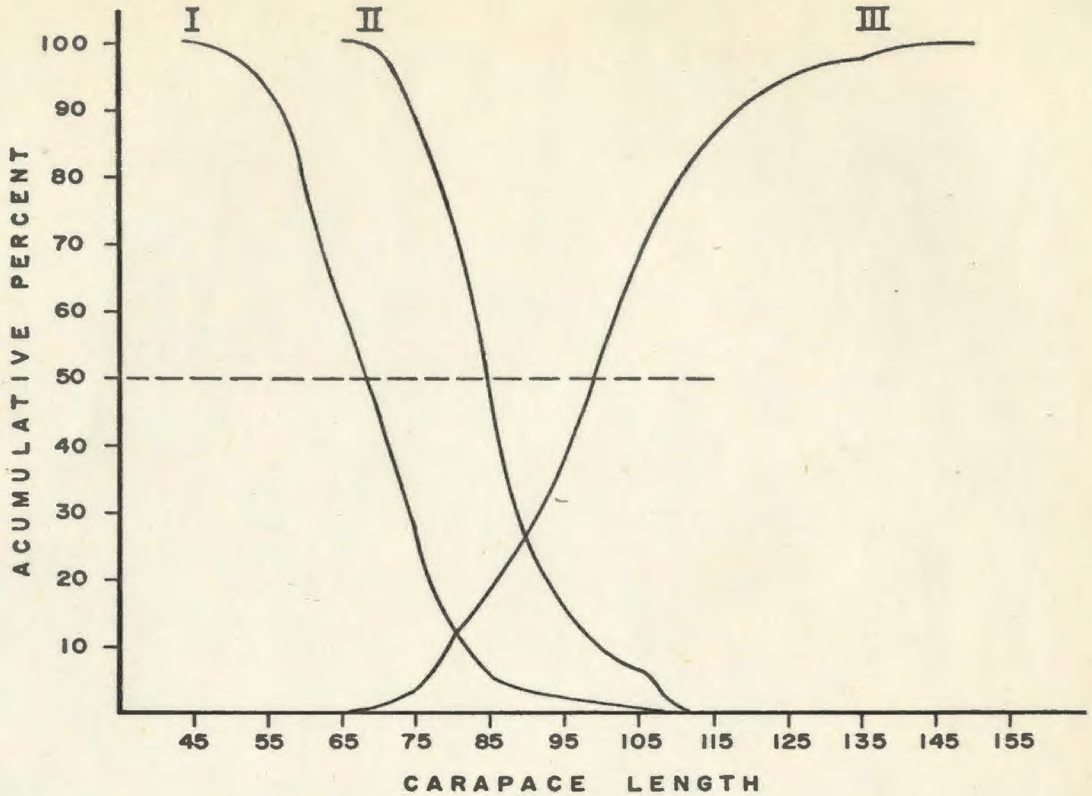


FIGURE 15. STAGES OF MATURITY AT EACH CARAPACE LENGTH IN THE SPINY LOBSTER <u>P. argus</u> .



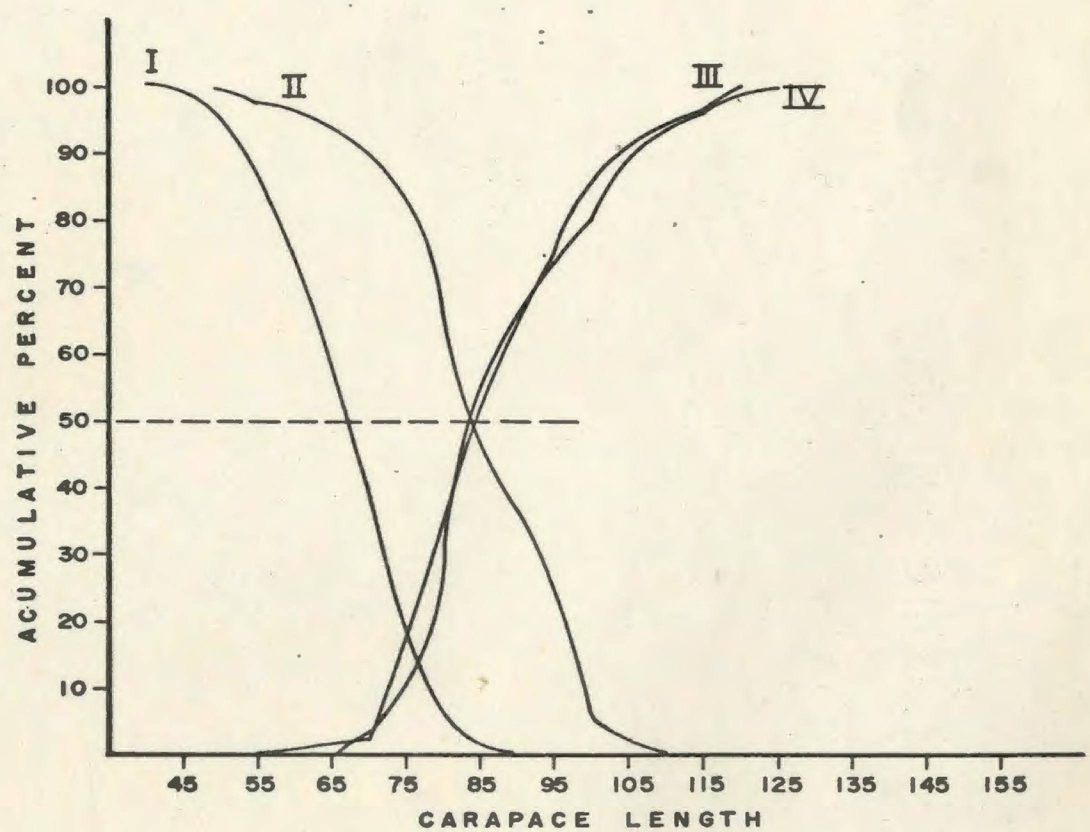


FIGURE 16. CUMULATIVE PERCENTS OF MALES AND FEMALES IN DIFFERENT STAGES OF MATURITY OF P. argus .

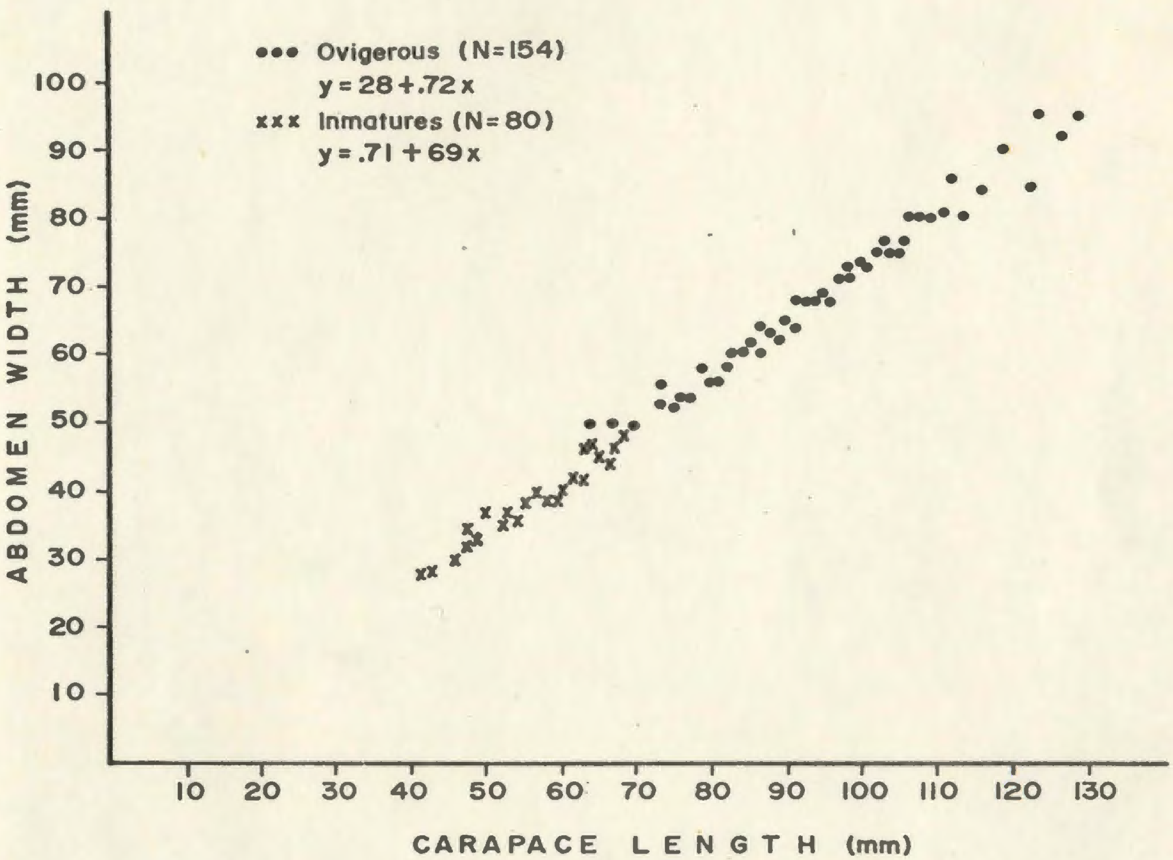


FIGURE 17. RELATION IN P. argus BETWEEN THE CARAPACE LENGTH AND ABDOMEN WIDTH.

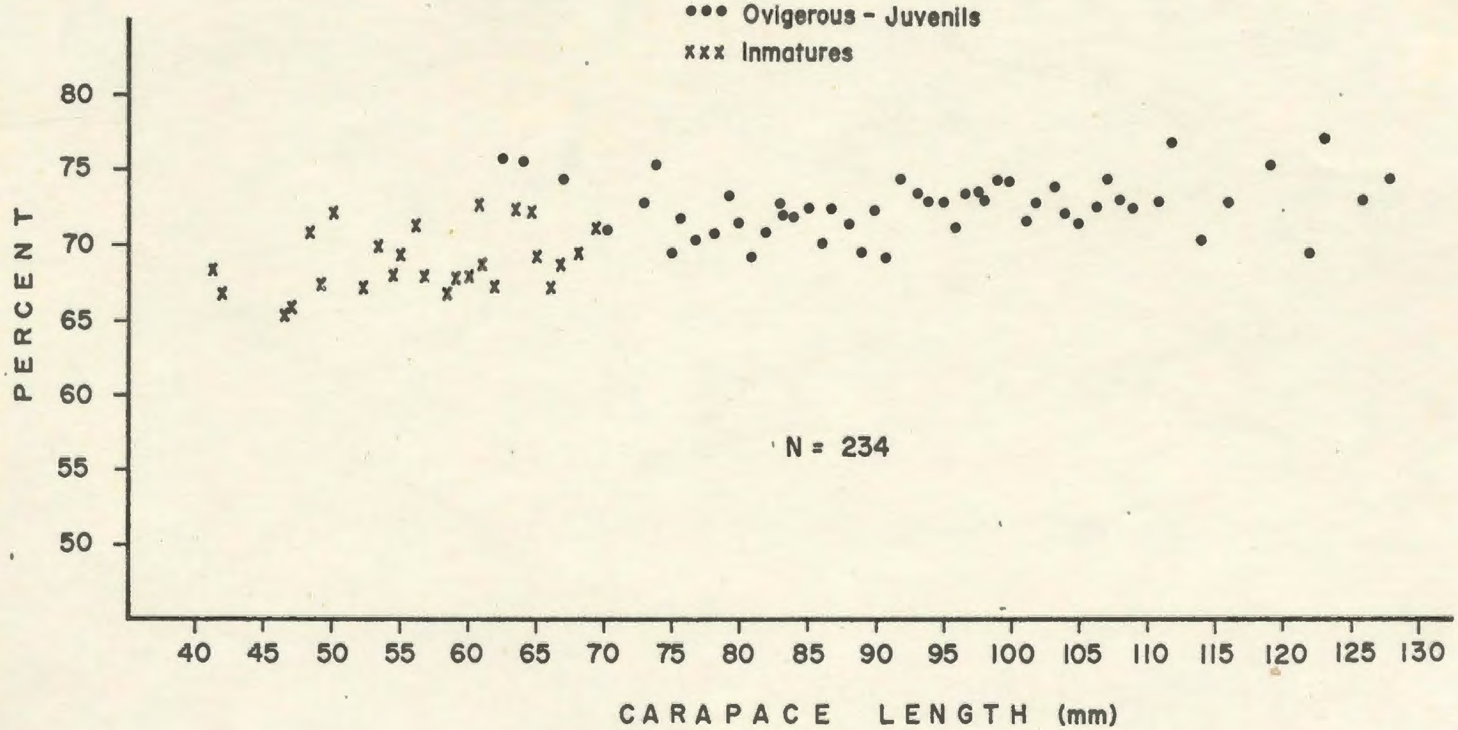


FIGURE 18. RELATION BETWEEN THE CARAPACE LENGTH AND PERCENT OF THE ABDOMEN WIDTH IN THE SPINY LOBSTER _P. argus_ .

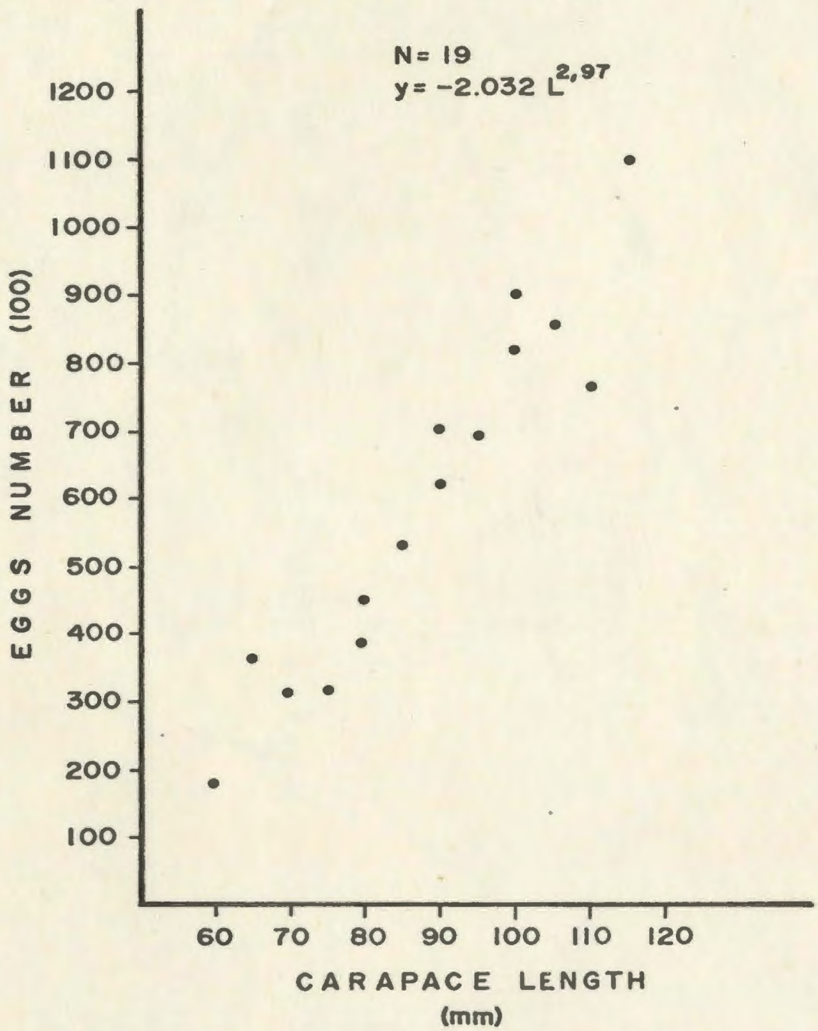


FIGURE 19. RELATION BETWEEN EGG NUMBER AT EACH CARAPACE LENGTH IN P. argus

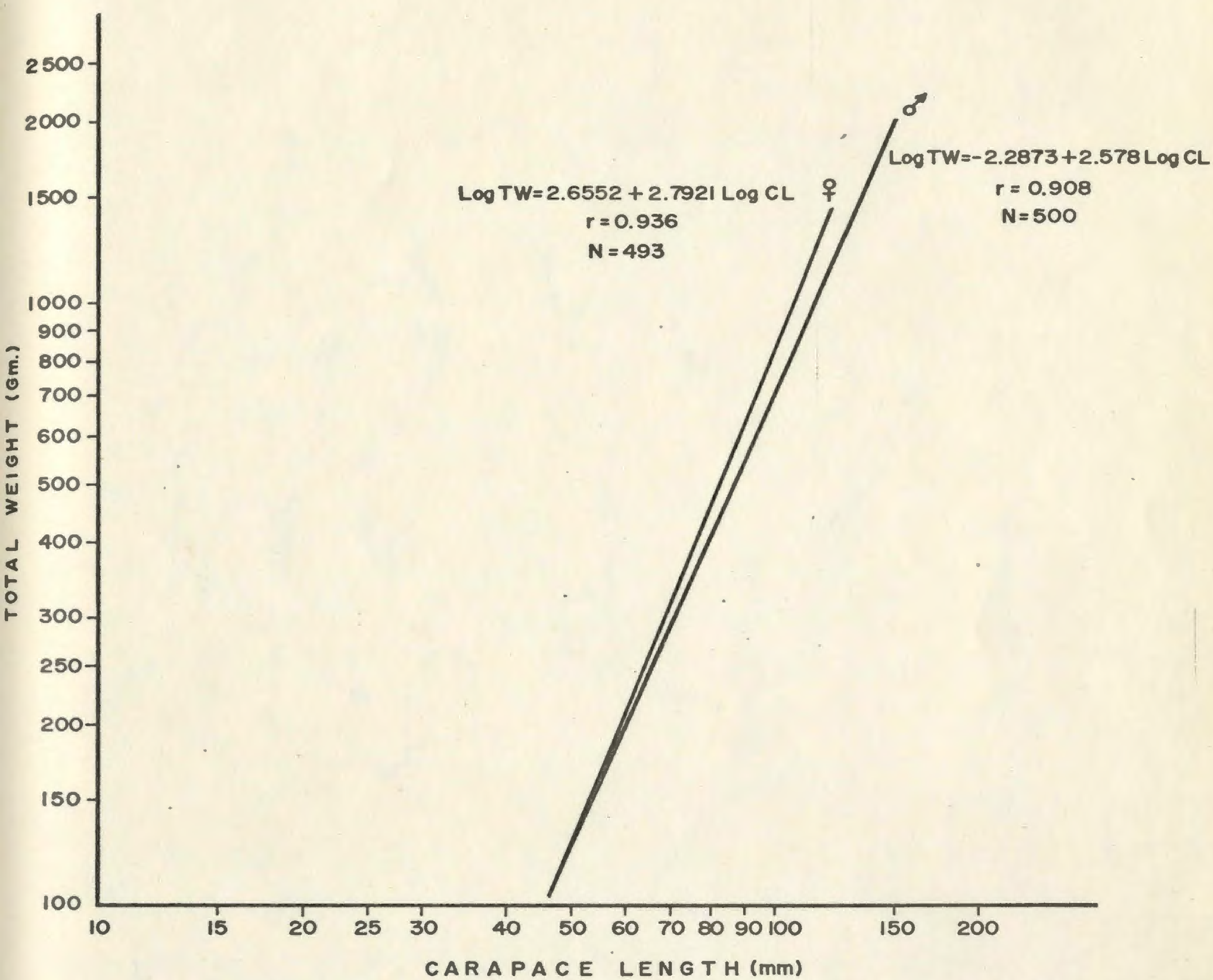


FIGURE 20. RELATION BETWEEN CARAPACE LENGTH AND TOTAL WEIGHT IN MALE AND FEMALE P. argus .

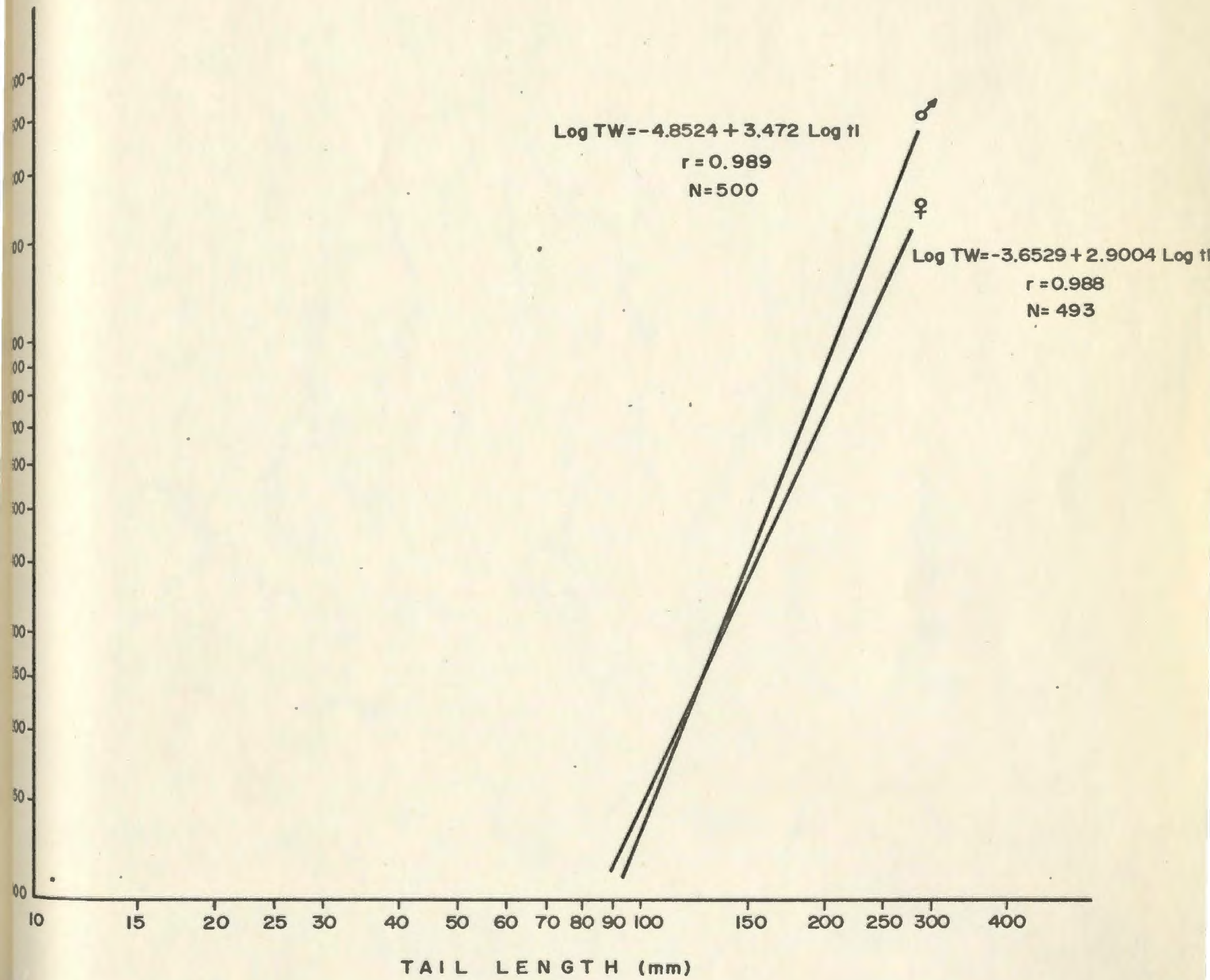


FIGURE 21 . REGRESSION LINES OF TAIL LENGTH AND TOTAL WEIGHT FOR BOTH SEXES IN P. argus .

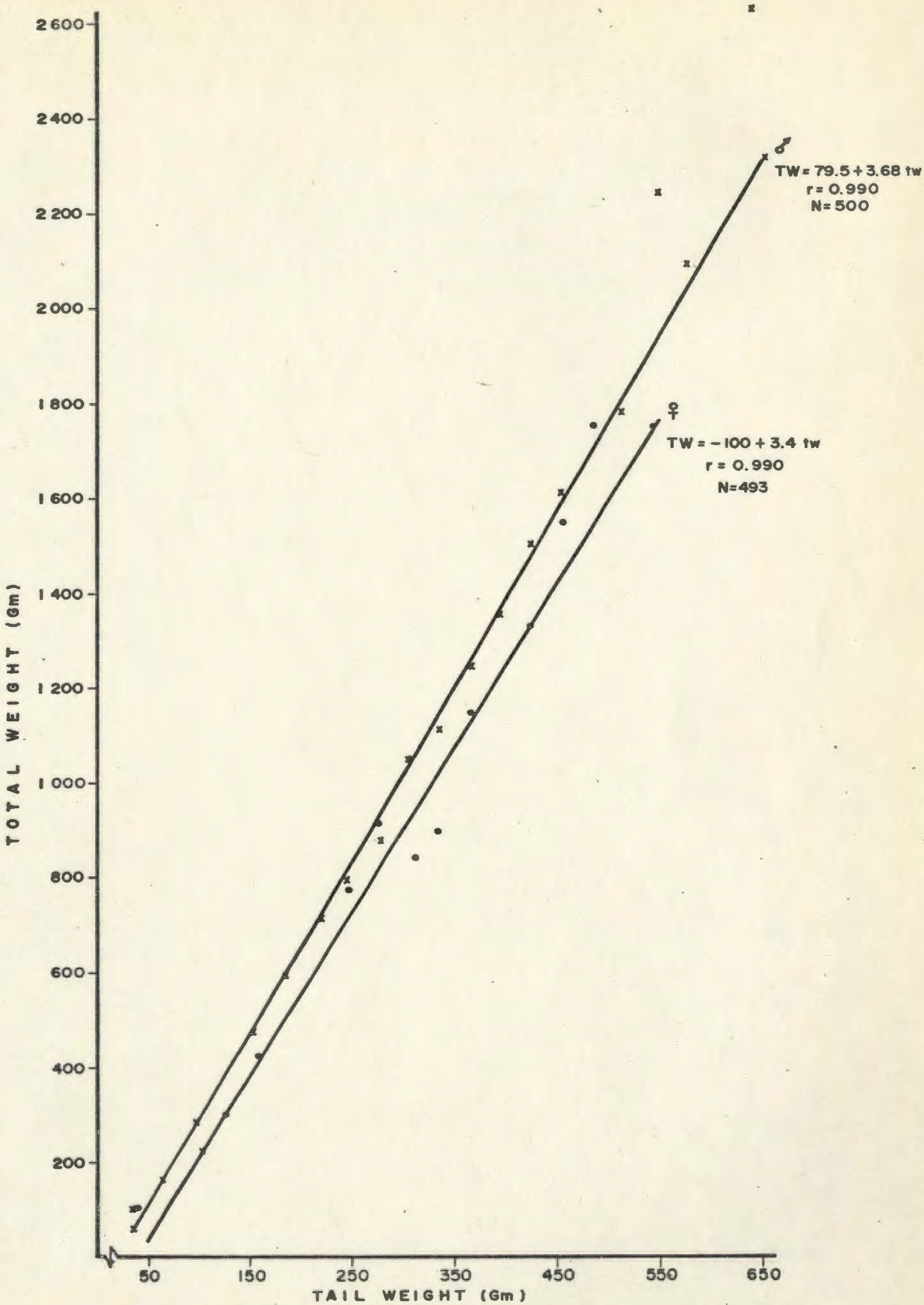


FIGURE 22. RELATION OF TAIL WEIGHT TO TOTAL WEIGHT FOR BOTH SEXES IN P. argus.

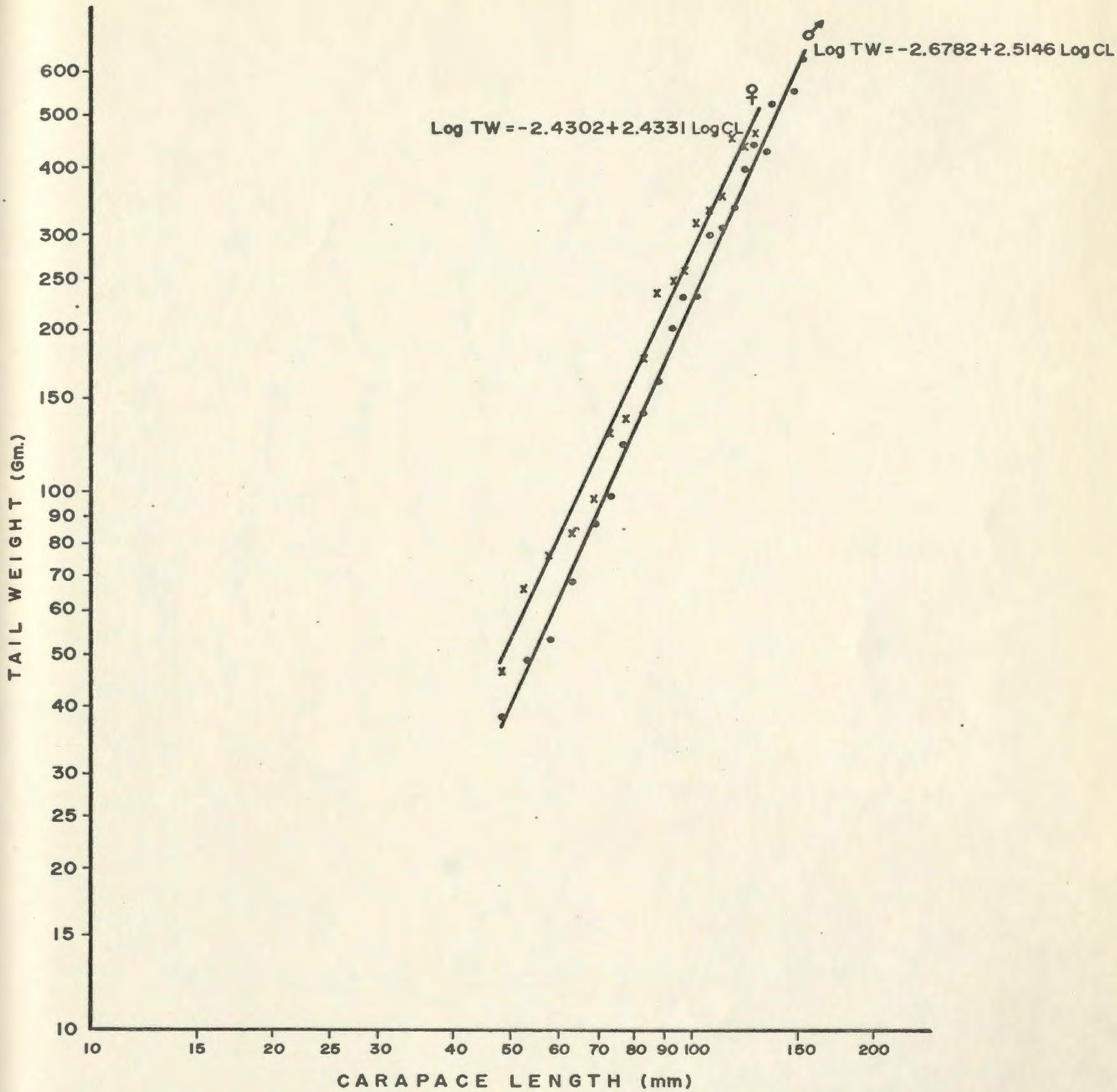


FIGURE 23. REGRESSION LINES OF CARAPACE LENGTH AND TAIL WEIGHT FOR BOTH SEXES IN P. argus.

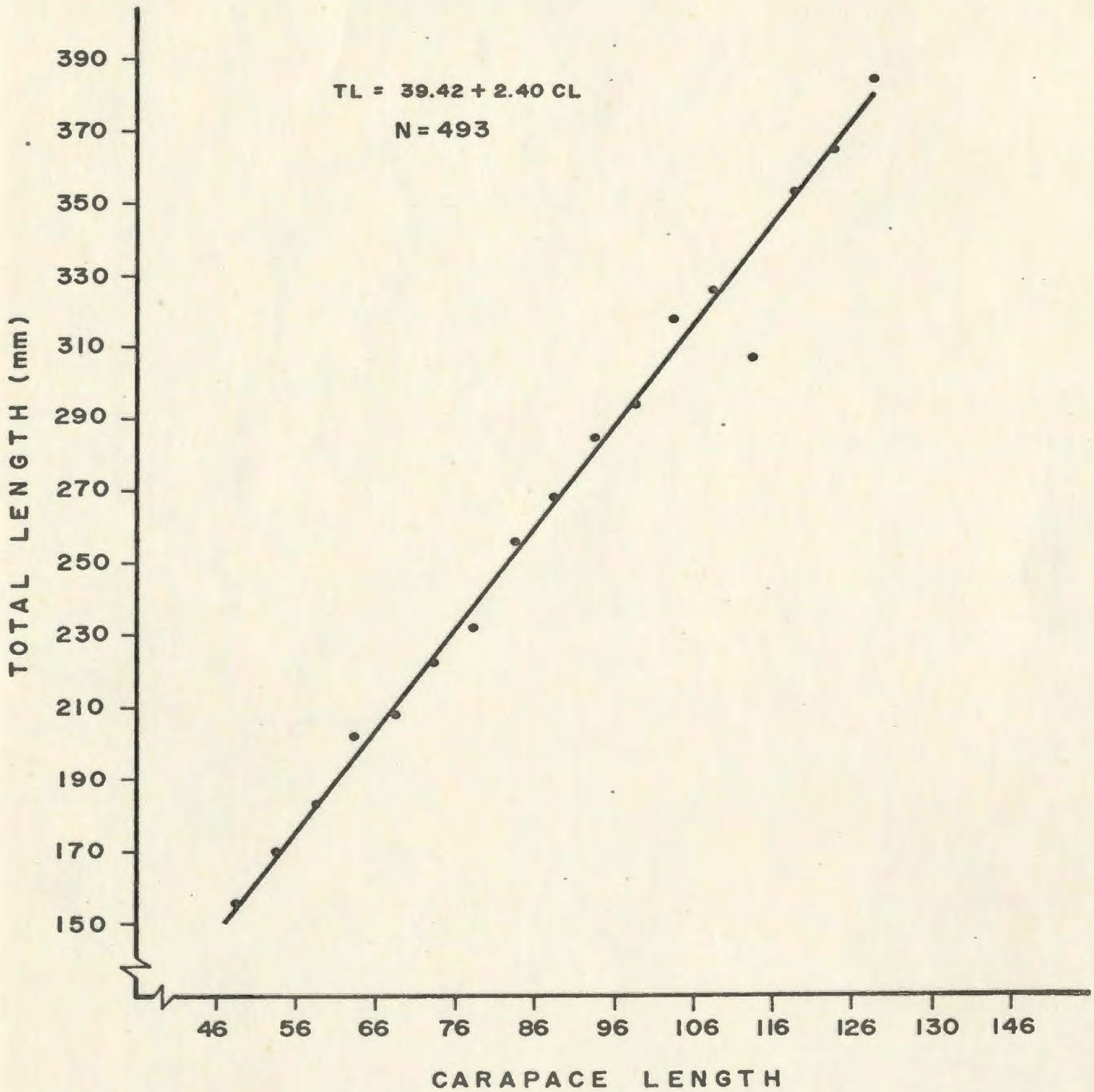


FIGURE 24. CARAPACE LENGTH - TOTAL LENGTH RELATIONSHIP FOR FEMALE P. argus.

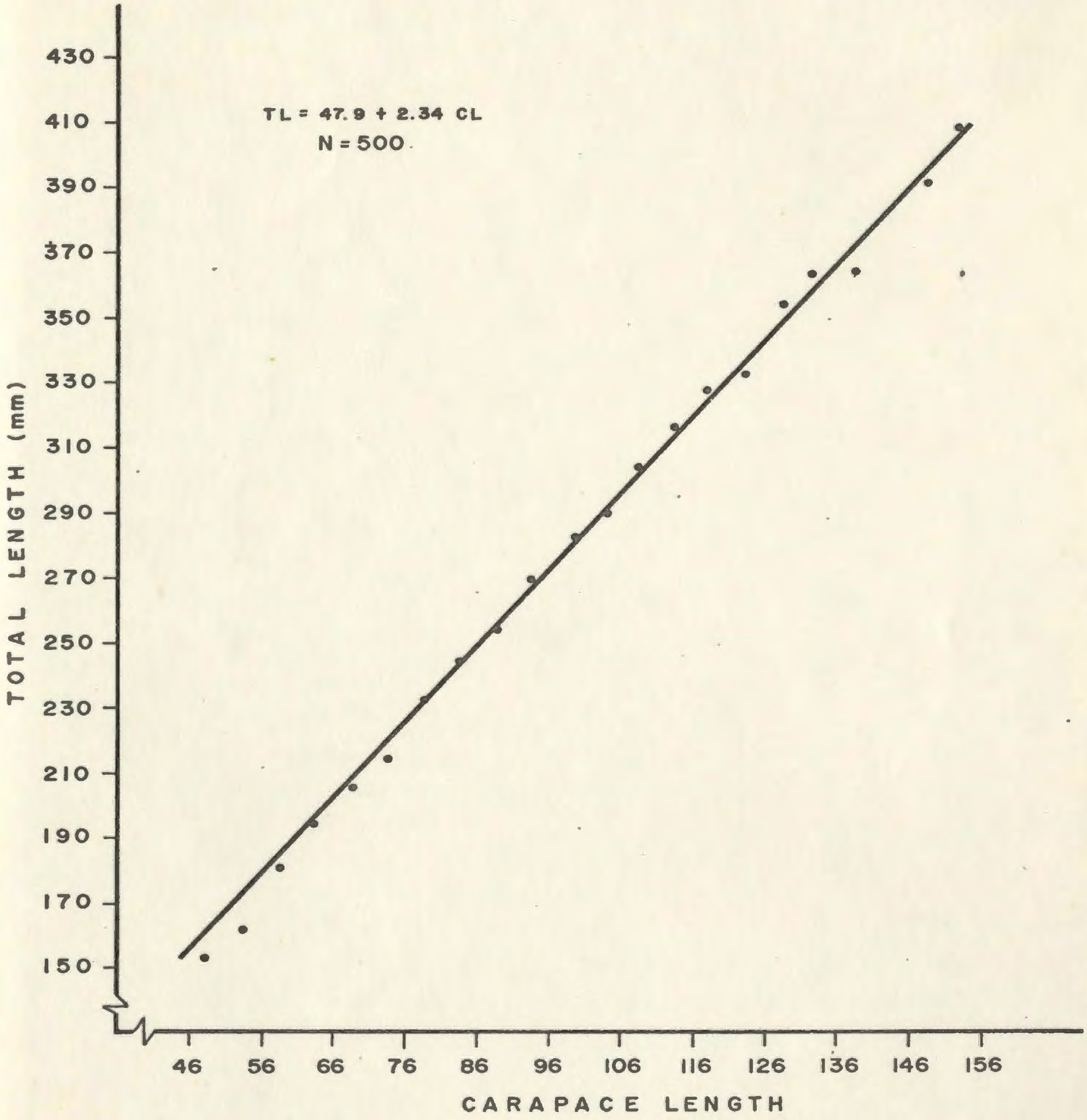


FIGURE 25. CARAPACE LENGTH - TOTAL LENGTH RELATIONSHIP FOR MALE *P. argus* .

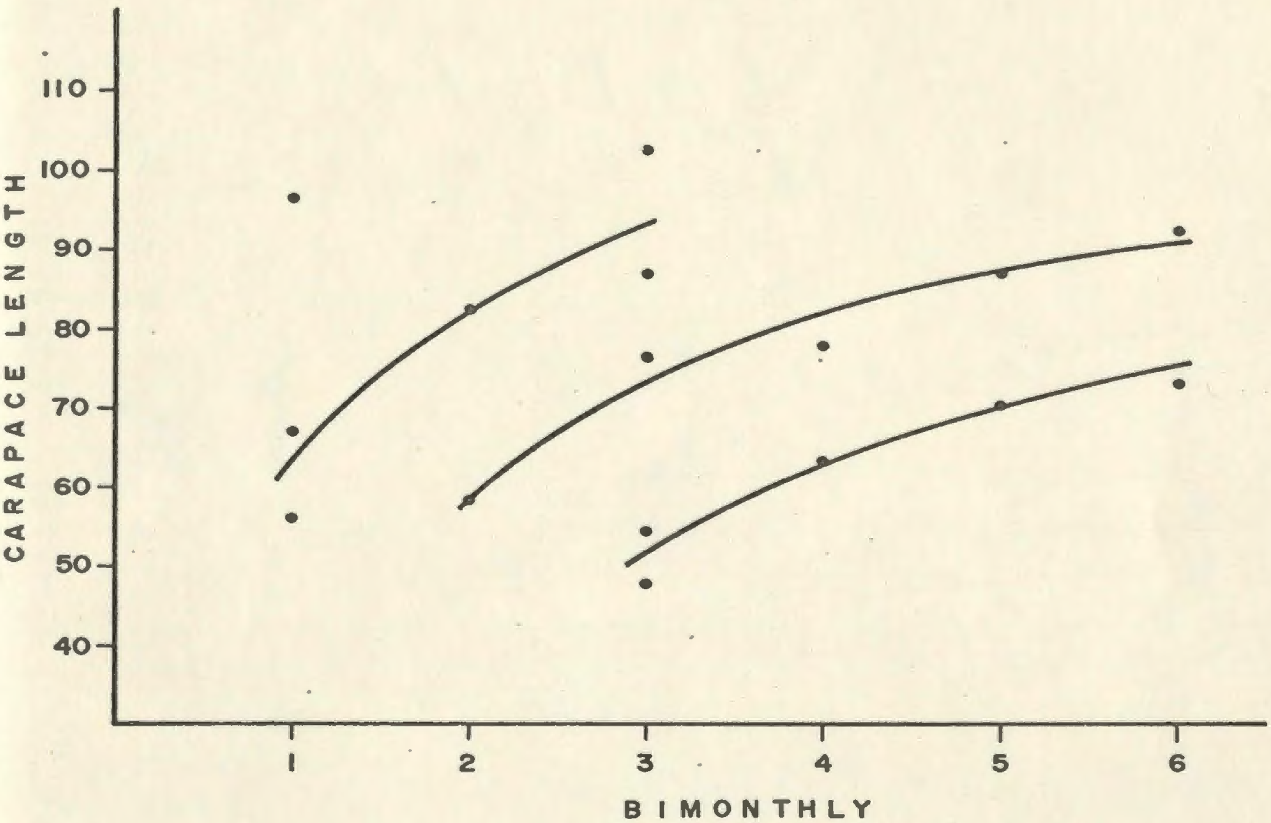


FIGURE 26. MODAL CARAPACE LENGTHS IN SAMPLES GROUPED BY TWO MONTHS PERIODS FOR MALE P. argus IN 1969 OFF THE GUAJIRA COAST.

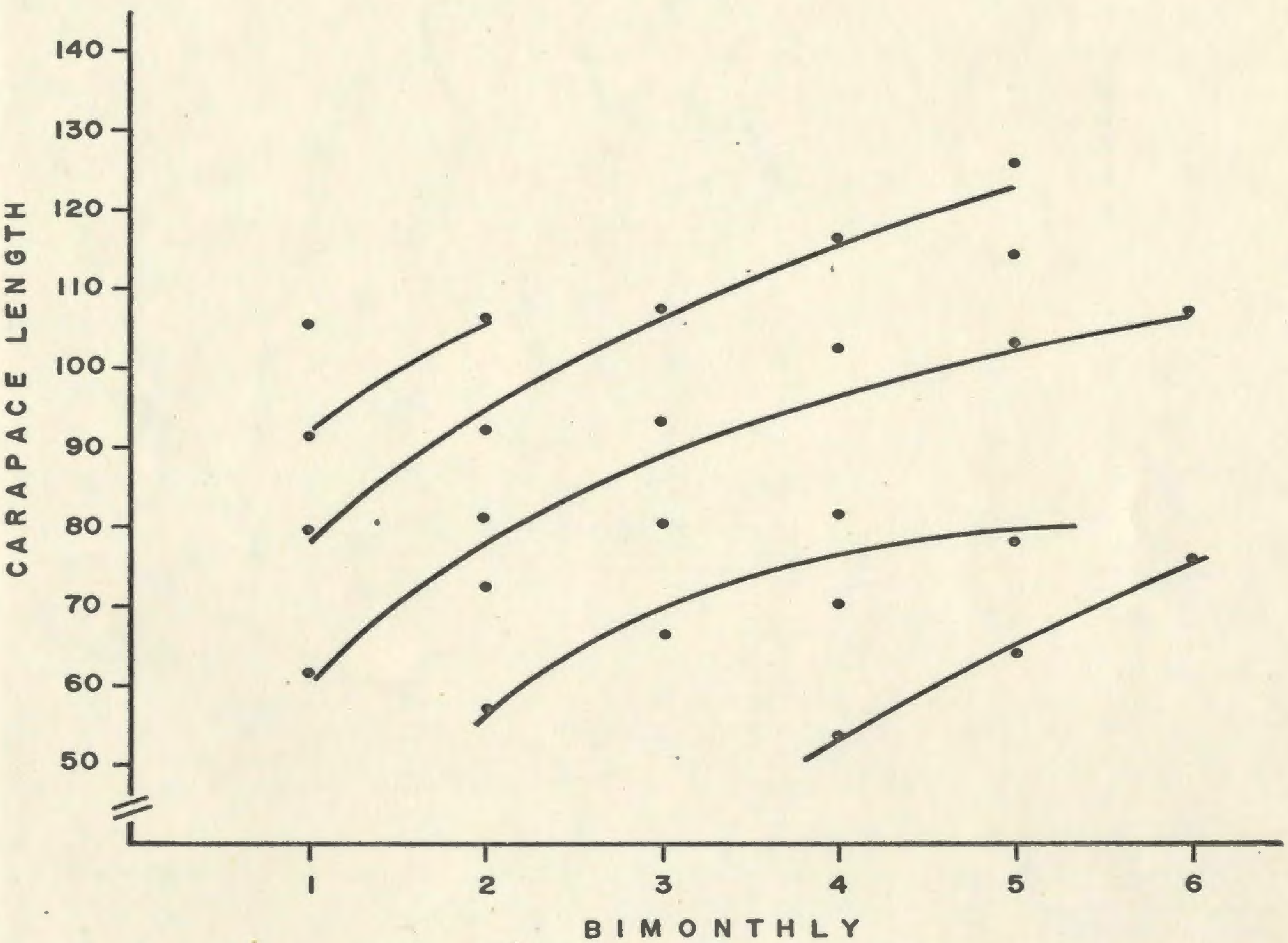


FIGURE 27. MODAL LENGTHS IN SAMPLES GROUPED BY TWO MONTH PERIODS FOR FEMALES IN 1969 OFF THE GUAJIRA COAST.

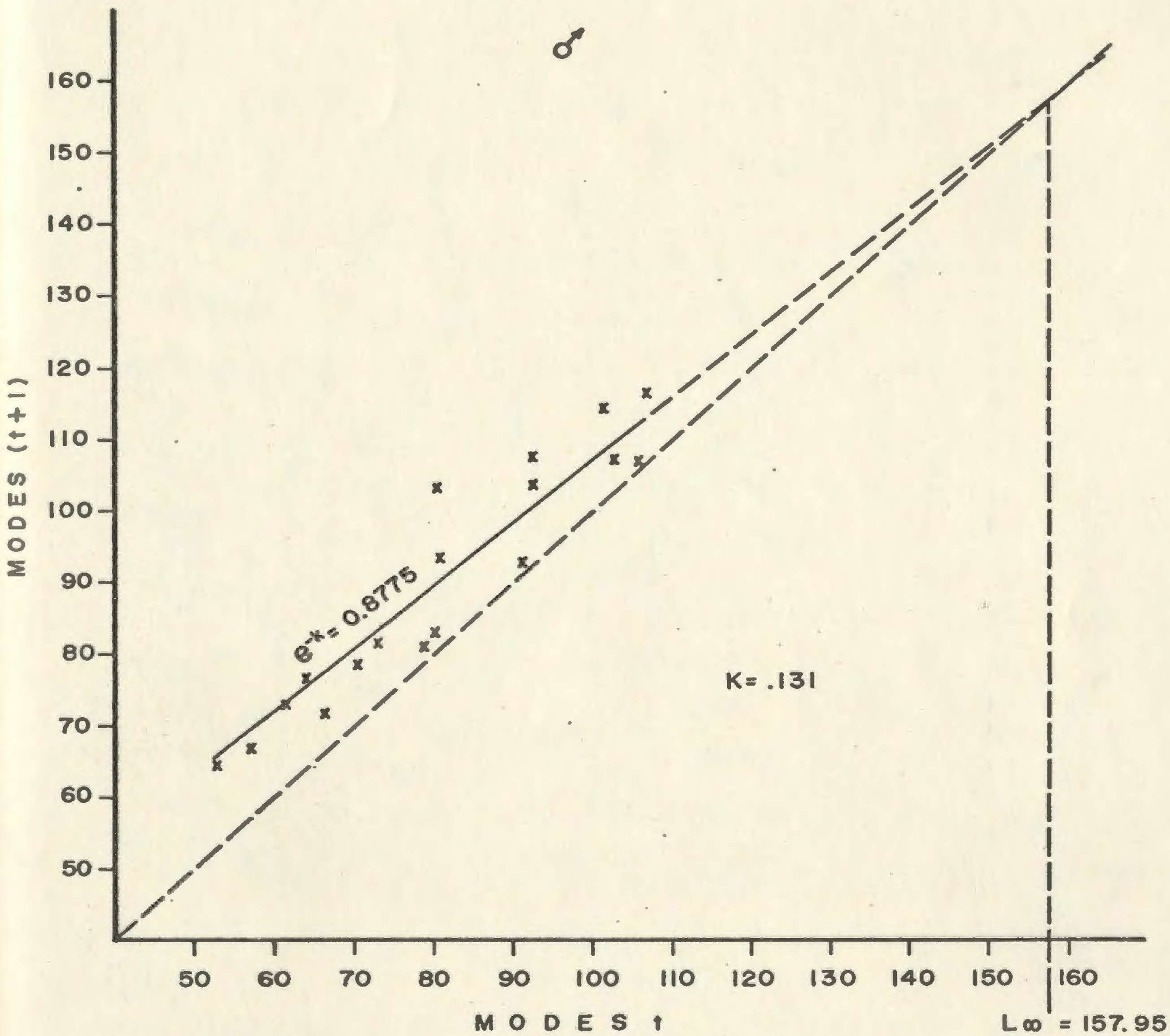


FIGURE 28. MODES AT GIVEN AGES t and t + 1 IN CARAPACE LENGTH FOR MALE *P. argus* .

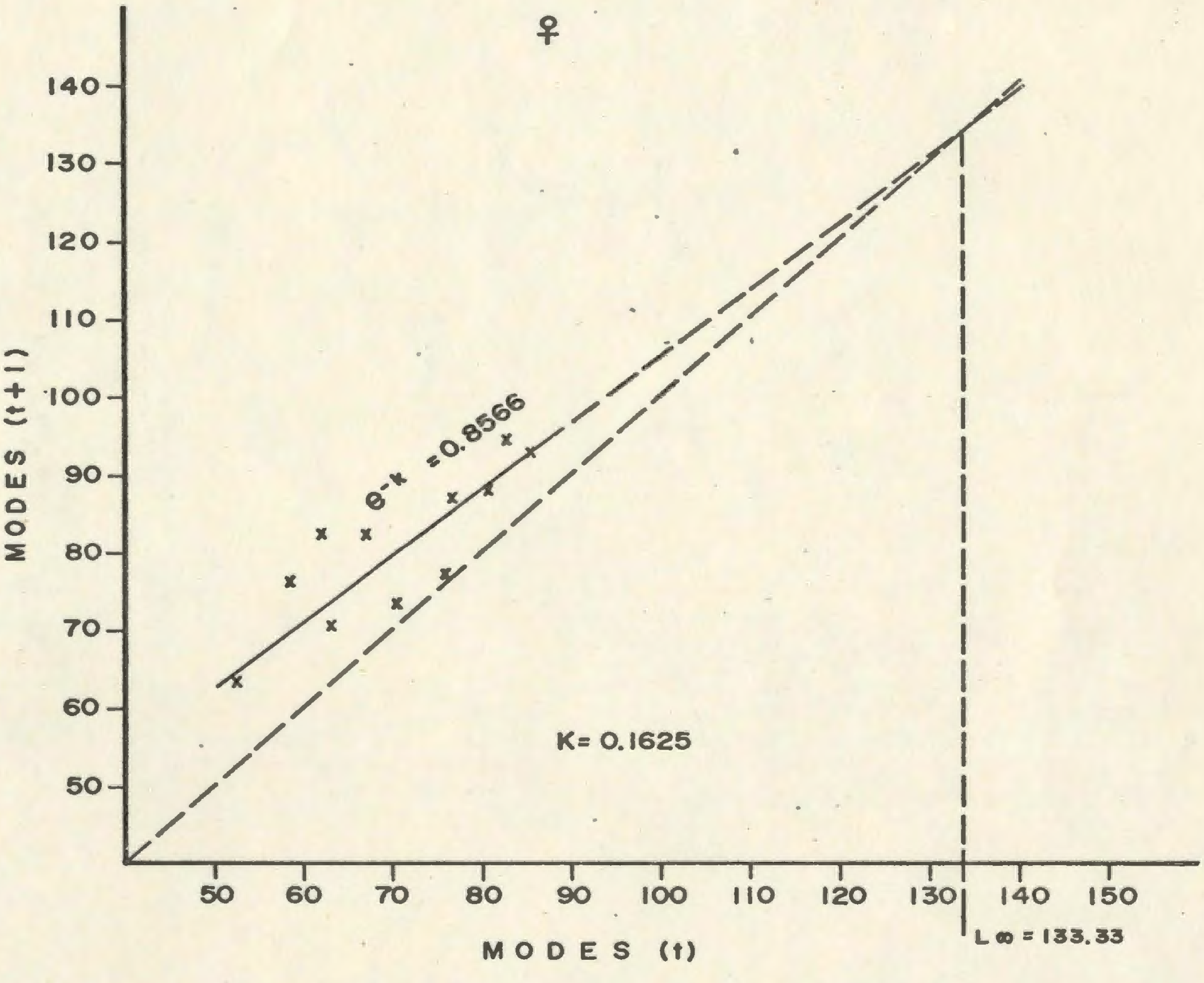


FIGURE 29. MODES AT GIVEN AGES <u>t</u> and <u>t + 1</u> IN CARAPACE LENGTH FOR FEMALE <u>P</u>. <u>argus</u>

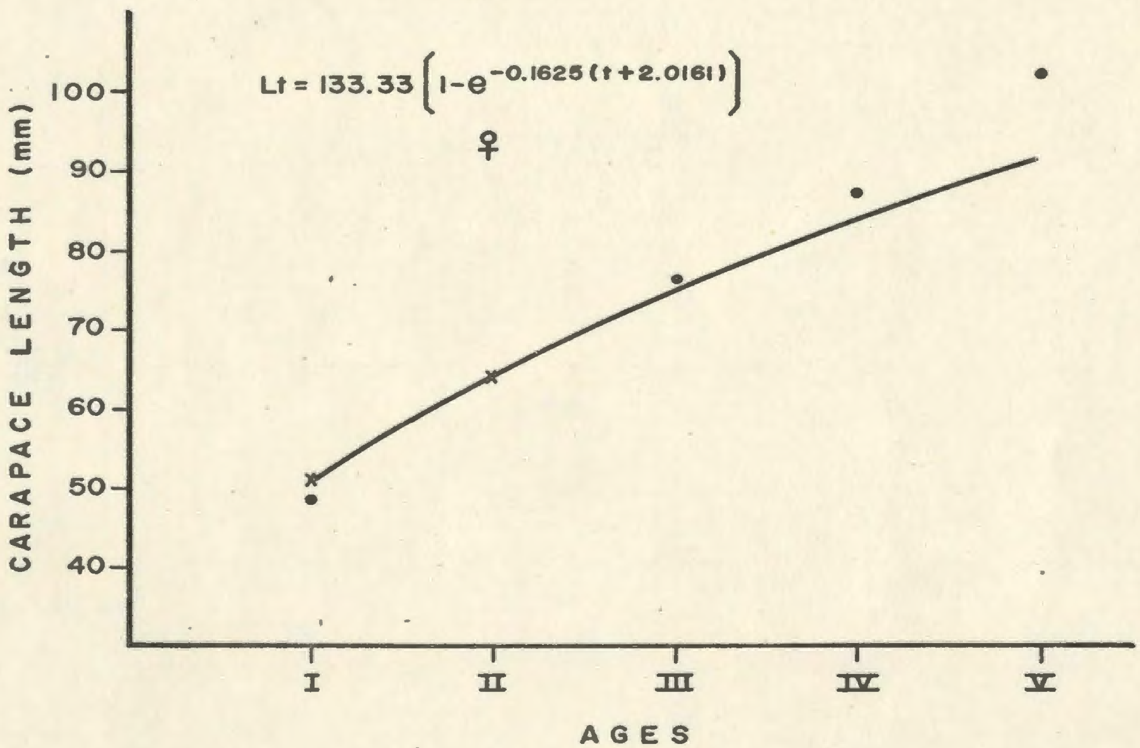


FIGURE 30. GROWTH FACTOR FOR FEMALE SPINY LOBSTER P. argus FROM THE GUAJIRA COAST IN 1969.

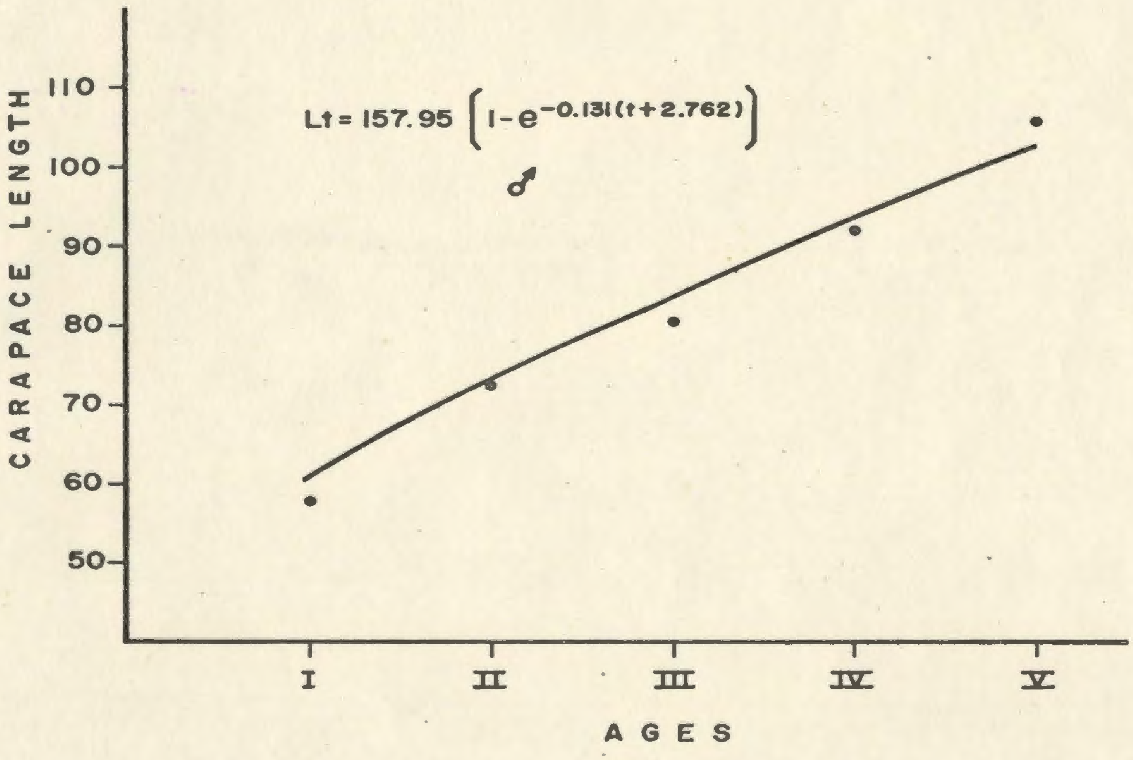


FIGURE 31. GROWTH FACTOR FOR MALE SPINY LOBSTER P. *argus* IN 1969.