THE SPINY LOBSTER, Panulirus argus, OF SOUTHERN FLORIDA: ITS NATURAL HISTORY AND UTILIZATION.

By

D. R. CRAWFORD, *Assistant, U. S. Bureau of Fisheries,*

and

W. J. J. DE SMIDT, *Formerly Scientific Assistant, U. S. Bureau of Fisheries.*

Contribution from the U. S. Fisheries Biological Station, Key West, Fla.

CONTENTS.

INTRODUCTION.

CLASSIFICATION AND DISTRIBUTION.

The spiny lobsters belong to the family Palinuridæ, which is represented by six genera and numerous species distributed throughout the tropical and subtropical seas. The genus Panulirus, of which the spiny lobster, or crawfish, found around the Florida Keys is a species, is represented by species of economic importance on both the Atlantic and Pacific coasts of America, in the Hawaiian Islands, and in Japan.

The northern limit of *Panulirus argus*, apparently, is Beaufort, N. C., where a few small specimens are caught occasionally by the fishermen seining for shrimps; but the spiny lobster does not often reach a large size there, and it is of little, if any, economic importance in that region.[1] This genus probably does not extend farther south than Rio de Janeiro, Brazil.[2]

Panulirus argus is very abundant on the Florida Reef from Miami to the Dry Tortugas, a distance of over 200 miles. The best fishing grounds are known to be along the southern shores of the reefs and keys. Spiny lobsters are found in less abundance on the northern shores of the keys, and an occasional individual is seen as far north as Cedar Key.

COMMON NAMES.

The spiny lobster is known about Key West as crawfish and langouste, a name borrowed from the French. Other names are rough, thorny, or rock lobster, and sea crawfish. The most common name among the fishermen and dealers is crawfish.

---

[1] Hay, W. P., and C. A. Shore: The Decapod Crustaceans of Beaufort, N. C., and the Surrounding Region, p. 398. Bulletin U. S. Bureau of Fisheries, Vol. XXXV, 1915-16, p. 369-475, Pls. XXV-XXXIX, 20 text figs., Washington, 1918.

[2] Gruvel, A.: Contribution à l'Étude générale systématitique et économique des Palinuridæ. Annales de l'Institut océanographique, Monaco, Tome III, Fasc. IV, p. 5-54, VI Pls., 22 text figs. Paris, 1911.

Part 1.—THE SPINY LOBSTER FISHERY OF SOUTHERN FLORIDA.

THE SPINY LOBSTER FISHERY AT KEY WEST, FLA.

IMPORTANCE OF THE FISHERY.

The importance of the spiny lobster can not be questioned. Besides being of value as food for human consumption, it is the favorite food of many fishes and other marine animals. Were it not used for fish-baiting purposes the catch of fish by hook and line and small traps would be greatly curtailed. According to the United States Bureau of the Census, Fisheries of the United States, 1908, the catch for the State of Florida was 53,000 pounds, having a value of $3,600. The total value of all fishery products for the State at that time was $3,289,000. The spiny lobster industry, therefore, constituted a very small part of the total value. It has been estimated that the present annual catch is 300,000 pounds, valued at $25,000. It is impossible to determine the number of spiny lobsters used for bait, but it is said that fully one-half of all caught are used for this purpose. It can be seen that the lobster industry, although still small, has been developing.

In the local fishing with hook and line, or with traps, or pots, the fishermen depend almost entirely on spiny lobster meat for bait. The tail of this animal consists of solid meat, and it is said to be equal in quality to that of the northern lobster. The spiny lobsters utilized in the fishing industry are caught by the fishermen on the way to the fishing grounds. Spiny lobsters which die before the fishermen can market them are also utilized in this manner. It is said that four or five dozen, with a market value of $1 per dozen, when used for bait usually net the fishermen $40 to $50 worth of fish.

The industry is of greater importance at Key West than elsewhere in southern Florida, though the markets at Miami, Fla., are handling more and more spiny lobsters each year. The demand is sometimes greater than the supply. During the migratory periods, when spiny lobsters are plentiful and easily taken, it is more profitable to catch them than fish. Consequently, a large majority of the fishermen engage in the industry at this time. Only about one dozen boats are engaged in the industry throughout the year, and two men per boat usually constitute the crew.

FISHING GROUNDS.

LOCAL DISTRIBUTION.

The spiny lobsters are found throughout the Florida Reef but are most numerous along the southern shore, where the bottom is rocky and ledges are prominent. The local fishing grounds are about 25 miles in length, extending from Boca Grande Key on the west to Sugar Loaf Keys on the east. The principal and most important fishing grounds are between these extremities off the following Keys: Boca Grande, Mann, Ballast, Mule (Little Mullet Key),[3] Woman, Man of War, Barracouta, Joe Ingams, Mullet (Big Mullet),[3] and King Fish Shoals (Crawfish Bar).[3] The older fishing grounds are off

[3] Local names in parentheses.

the southern coast of Key West and to the eastward off the following: Cow Key, Boca Chica, Geiger's Key, Saddle Bunch Keys, and Sugar Loaf Keys. A few fishermen with power boats sometimes go 6 miles beyond Boca Grande Key to the Marquesas Keys on the west and 26 miles beyond Sugar Loaf Keys to Bahia Honda, on the east. Big Pine Key, which lies between Sugar Loaf Key and Bahia Honda is known to be an excellent fishing ground. Some spiny lobsters are obtained from East Harbor Keys, Middle Keys, and Cayo Agua, about 5 miles northeast of Key West. A few are obtained to the south on the shoals off the Eastern Dry Rocks. When the local supply is limited and the weather is favorable, a few fishermen go to the Dry Tortugas. Since the "Tortugas" are about 65 miles to the westward, it is seldom, and only under the most favorable weather conditions, that fishermen with power boats undertake this trip. Not more than a few thousand spiny lobsters are brought from there annually. Nearly all of these are of large size, much larger, indeed, than any others brought to the local markets.

SEASON OF THE FISHERY.

Spiny lobsters are caught throughout the year, but the best season is from February to July, during which time about 60 per cent of the total annual catch is taken. A majority are caught while feeding in water that varies from 1 to 10 feet in depth. In order to catch them in deeper waters, it is necessary to use traps or pots. In February the spiny lobsters begin to return to the shallower waters, probably for the purpose of spawning. During this period they are very active and can be seen at all times during the day but are more numerous during the early evening and throughout the night. During the day most of them are concealed in hiding places, under rocks, sponges, corals, and other places that protect them.

During the last part of February and the greater part of March it is a common sight to see them in groups by the hundreds, in shallow water in the most favorable places. Because of their great abundance at this time they net the fishermen better returns than any of the other fisheries. The fishermen avail themselves of this opportunity, and it is not unusual for two men, having spent a day and a night "crawfishing," to return with a thousand or more spiny lobsters. This season of the fishery is a short one, and by the early part of April or May many of the fishermen have returned to their vocation, the hook-and-line fishery. The female spiny lobsters, now carrying eggs, have migrated to the deeper waters, but they come to the shallower waters to a limited degree during the night for the purpose of feeding, while the males seem to be regularly present on the flats in normal numbers.

APPARATUS AND METHODS IN GENERAL USE.

The methods of capture employed in the industry have changed materially during the last decade. The greater part of the catch formerly was made with cast nets, gill nets, and haul seines. Since the shellfish were then more abundant and less in demand, very satisfactory catches were made with the cast net, which was particularly effective for taking spiny lobsters that had collected in groups, as during the mating season. These nets were of woven twine, 12 to 16 feet in diameter, with sufficient leads to prevent the spiny lobster from making its escape under the net after it had been thrown over the animal. This method of capture is not now in general use, and few fishermen are able

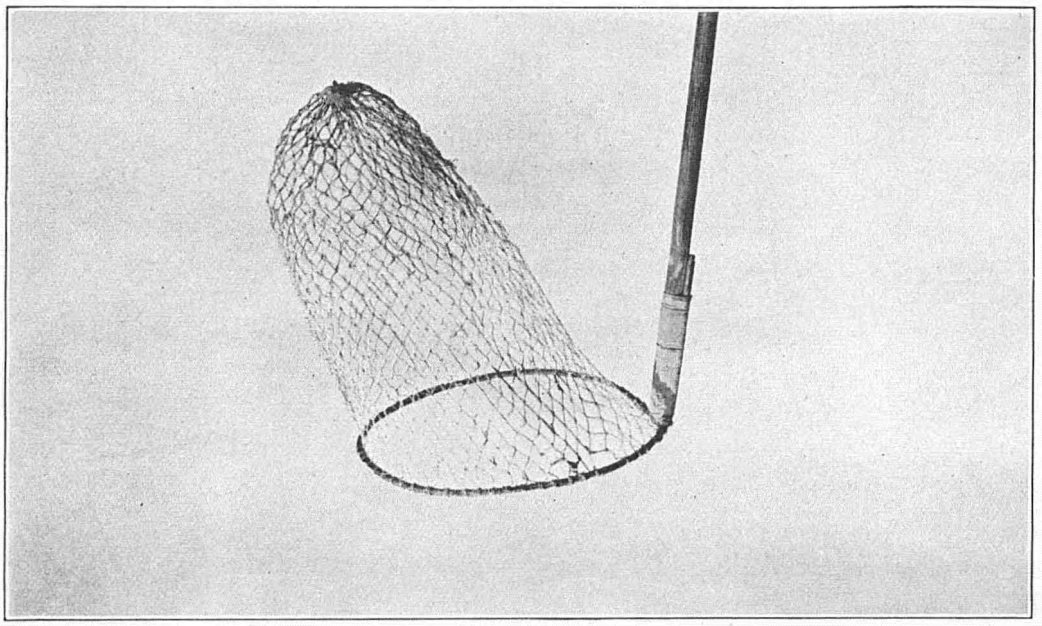

FIG 260.—The bully net.

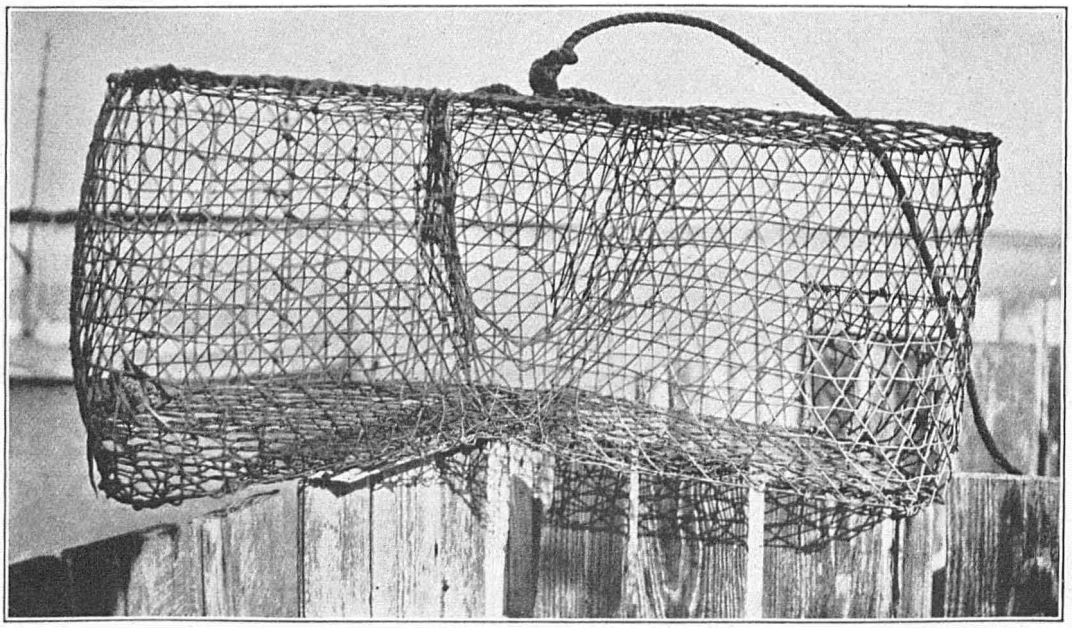

FIG. 261.—Spiny lobster trap.

to handle such a net skillfully. Gill nets and seines were hauled for the purpose of catching spiny lobsters which, while engaged in feeding, were scattered over the flats. Gill nets are no longer being used in this fishery, although a few spiny lobsters are often taken accidentally, when nets are operated in the other fisheries.

The apparatus used today is distinctly different, as the following list and estimates of the percentage of the catch made by each shows:

	Per cent.		Per cent.
Bully	50	Hoop nets	5
Fish traps	20	Seines	5
Grains	15	Hooks, and all other means	5

THE BULLY.

The "bully" (Fig. 260) is used by the fishermen in general throughout the Florida Reef. It is the best-known device employed in catching the spiny lobsters while they are moving about in the waters where they can be seen. The bully is a small hoop net 15 to 18 inches in diameter, 2 feet or more in depth, and with mesh of 1¼-inch bar measure. The hoop is set at right angles to a pole or handle 8 or 12 feet in length.

In using the bully the bag of the net is pulled through the hoop and allowed to hang over one side of it. This allows the net to open upwards when placed over the lobster. The hoop of the net surrounds the lobster, but the bag of the net has been lowered in such a manner that when the lobster tries to escape from the imminent danger by swimming backward it lands in the net. The fisherman then raises the net, causing the bag of the net with the imprisoned animal to hang over the side of the hoop. The lobster is released by pulling the center of the net upward, allowing the animal to fall through the hoop.

In some cases, when using the bully, the fishermen work singly in a small boat which is ballasted in the stern. The fisherman stands in the bow, using the handle of the bully to propel the boat. In this way, upon seeing a spiny lobster, the boat can suddenly be brought to a standstill, the bully inverted, and the spiny lobster captured. A good fisherman seldom misses, unless the depth of the water causes the bully to be deflected from its course, or the bottom is rough so that the hoop does not fit snugly on the bottom, which is often the case when working on a rocky ledge. Occasionally two men work together, one sculling the boat according to directions of the fisherman in the bow.

FISH TRAPS.

The fish traps or pots (Fig. 261) are of galvanized wire construction. They are usually made by the fishermen. The woven wire meshes are about 1½ inches square. These traps vary in size, but on the average are 3 feet wide, 2 feet long, and 20 inches high. The side containing the opening to admit the spiny lobster is the longest, being about 3 feet in length. The two parallel sides of the trap at right angles to the former are each about 1 foot long. The trap is closed behind by two sides which meet at an angle directed outward. The floor and top of the trap are parallel to each other. The shape of the trap is roughly cardiform, the entrance lying in the concave side. The longest side is bent inward at the center, forming a conical funnel-shaped passageway which is inclined slightly upward. The lower side of the entrance to the passageway is placed about 2 inches above the bottom of the trap. This entrance is somewhat

irregular in form, being about 6 inches in diameter at the smaller end which is closed, except for an elliptical opening, about 4 or 5 inches in the passageway through which the lobster falls about 6 inches to the floor of the trap. A wire door, hinged above, is provided in one side to take the catch from the trap.

These traps are used for catching spiny lobsters in deep water. The bottom is usually weighted, so that the trap when lowered will reach the bottom of the water in the desired upright position. This also tends to prevent strong tides from tumbling the pots about. The trap is always set with the pointed end, which the fishermen call the "front," directed against the flow of the tide. A few fishermen fasten buoys to their traps, but most of them know the fishing grounds so well that they are able to locate the traps without the use of attached floats. The traps are raised once or twice a day but usually only once during the morning. A fisherman who depends on this method usually has 15 or more traps. The same traps when baited with spiny lobster meat are used in catching fish.

THE GRAINS.

The "grains" (Fig. 262) is a two-tined spear on a long handle. Every fishing boat includes a "pair of grains" or "grain hook" in its equipment for spearing spiny lobsters and large fish in general. Spiny lobsters speared with this apparatus are usually killed,

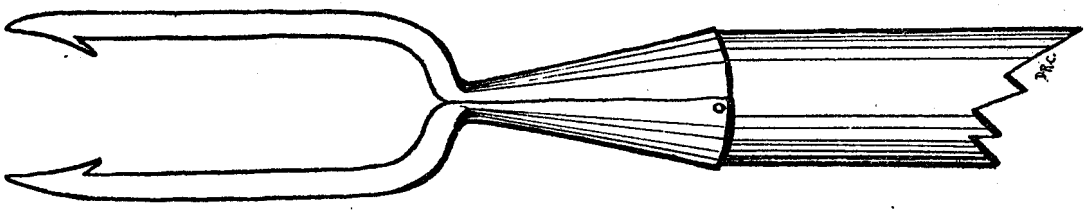

FIG. 262.—The grains.

so the grains are used chiefly in catching them for fish-baiting purposes, though a few caught in this manner are sold where immediate consumption is possible. The spiny lobster hides under rocky ledges, and usually the antennæ are visible. It can be induced to leave its hiding place by scraping and jabbing on the rocks, giving the fisherman an opportunity for spearing it.

HOOP NETS.

The hoop net, or lift net, consists of a metal hoop varying in diameter from 3 to 6 feet, to which fish net is woven in such a manner as to allow it to sag in the center. The net is raised and lowered by means of a single rope, one end of which is tied at the middle and intersection of two short loose ropes, the ends of which are tied to the hoop. At night the nets are lowered to the bottom and inspected frequently by carefully raising the net to the surface. This means of capture is seldom used except by those having no boats. It is employed chiefly around wharves and piling where spiny lobsters are known to be hiding.

SEINES.

Seines are used but little, because the spiny lobsters are not plentiful enough to warrant using them often. They are the same as the beach seines used in capturing fish. The nets are hauled over the shallow flats, keeping the lead line on the bottom. They are then dragged up on shore, and the spiny lobsters and fish are easily taken. Once

out of water the legs of the spiny lobster are not strong enough to enable the animal to walk to any appreciable extent. It is said that the spiny lobsters are caught in seines more frequently off the coast of Cuba than off the coast of Florida.

HOOKS AND ALL OTHER MEANS.

On the southern coast of Florida, in the vicinity of Miami, a common way of catching these lobsters is by "hooking" them. A large fishhook is tied to the end of a pole, and in order to catch the lobster it is necessary to get the hook under it and then give the pole a sudden jerk. Since the shell of the animal is hard, this device is not very successful. A few spiny lobsters are caught by diving for them. It is common to observe fishermen reaching under rocky ledges trying to catch any that may be hidden there.

BOATS AND EQUIPMENT.

The boats (Fig. 263, opp. p. 289) used in the spiny-lobster fishery are identical with those used in the hook-and-line fishery. Cypress and yellow pine are the principal woods used in their construction. All of them are of the sail type, and a few of them have gasoline engines installed. The latter are the more profitable, since there is no delay in waiting for favorable winds. A prolonged delay in getting the crawfish to market often results in the loss of many.

All boats are equipped with wells, located in the middle of the boat. The sides of the well are made of double thickness matched cypress, and the bottom is perforated with many 1-inch holes. The depth of water in the well varies according to the load carried, but it is never less than 1 foot. Spiny lobsters when placed in the well are brought to the market alive. They are also held in these wells at the markets until the fisherman is ready to sell his catch. The wells may be of any convenient size. Those of the smaller boats are usually able to carry a few hundred spiny lobsters, while the wells of the larger boats may hold as many as 1,000.

A boat crew usually consists of two to four men. The sleeping quarters are in the bow of the boat. In the cockpit, immediately back of the well, food, water, oil, lamps, cooking utensils, and other paraphernalia are kept. The cooking is also done in the cockpit. It is necessary to have considerable food on board the sail-type boats, since storms often break without much warning, and it is often safer to anchor on the shoals than to attempt to reach port. It is not practical to fish during stormy weather, and often these fishermen remain anchored for more than a week without catching any spiny lobsters. The power boats have the advantage in being able to make daily trips when the weather is most favorable.

Upon arriving at the fishing grounds the boat is anchored. One or more small boats or skiffs can be seen riding at anchor, having been left by these same fishermen before departing for the market on their previous trip. These skiffs are from 10 to 15 feet in length and are not supplied with wells. Some of the fishermen always tow their skiffs, as there are certain risks involved in leaving them at the fishing grounds. If the men begin their operations during the day, it is often necessary to hold a water glass on the surface of the ripple water, thus enabling the observer to see the bottom. The water glass is merely a glass-bottomed wooden bucket. This is held in one hand and the bully in the other. At night a lamp similar to a street lamp is fastened to the bow of the boat, thus enabling the fisherman to examine the flats.

METHODS OF FISHING.

The men work singly or in pairs from the small skiffs. There is no advantage in working two-men crews except when it is necessary to use the water glass. One man can not manipulate the boat and the water glass and bully. More spiny lobsters can be caught in a few hours during the night than in a whole day. Most of the fishermen plan to arrive on the fishing grounds late in the afternoon, when the spiny lobsters begin to move about. After fishing four or five hours the men rest awhile and again fish a few hours before sunrise. If they fail to catch enough from the flats, they may attempt to get more during the day from the deeper water by means of the water glass. However, most of them prefer to spend another night on the grounds in an attempt to catch the desired number.

The shellfish that are caught are tossed into the skiff. They can be safely kept there several hours, providing there is no bilge water in the boat, as bilge water tends to kill the animals. From the skiff they are transferred to the well of the larger boat. If more are caught than the well will hold, they are put into wet sacks and are kept well watered until they are delivered at the market.

When there is a dew, it is necessary to keep the spiny lobsters covered as soon as they are taken from the water. Some fishermen carry a tub or barrel partly filled with water in which the catch is placed. The same precautions have to be taken in the summer when the sun is very warm; but most of the time the spiny lobsters can be carried in the bottom of the boats without any attention.

The fisherman who depends on spiny lobster pots usually spends a few hours in the morning taking the catch from the traps. Some fish are usually found in the traps, and these may be used in rebaiting. The average catch for a given night from pots is never as good as that of the fisherman who has spent the night using the bully. However, the pots have the advantage of operating regardless of weather conditions. During the summer months, when the spiny lobsters are in deep waters and are scarce, the pot fisherman is almost certain of a steady supply. Spiny lobsters at this time command higher prices, and the men using the bully are able to get but few. On the other hand, the pot fishermen lose many traps, and they require constant mending due to the corrosive action of the sea water on the wire.

VALUE OF APPARATUS.

There is no general uniformity of design in the apparatus used in this industry. Most of the apparatus is made by the fisherman according to his individual ideas. The fishing boats, depending on size, age, and equipment, range in value from $200 to $700 each. Some of these boats have been in service daily for almost 50 years and are still seaworthy. The smaller boats or skiffs range in value from $20 to $40, according to the material used in their construction. Below is a list of some of the apparatus with an estimate of the value of each:

Fish traps or pots	$6.00–$10.00	Grains	$1.00–$1.50
Boat lamps	3.00– 5.00	Water glass	.75– 1.25
Bully	1.25– 1.50	Hoop nets	1.50– 3.00

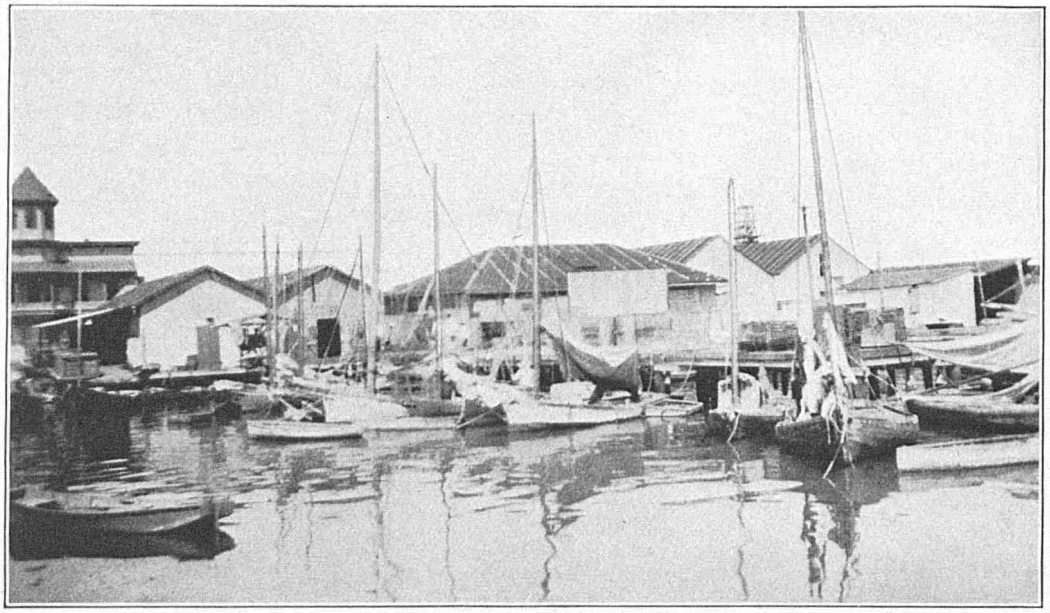

FIG. 263.—Fishing vessels and market for spiny lobsters, Key West, Fla.

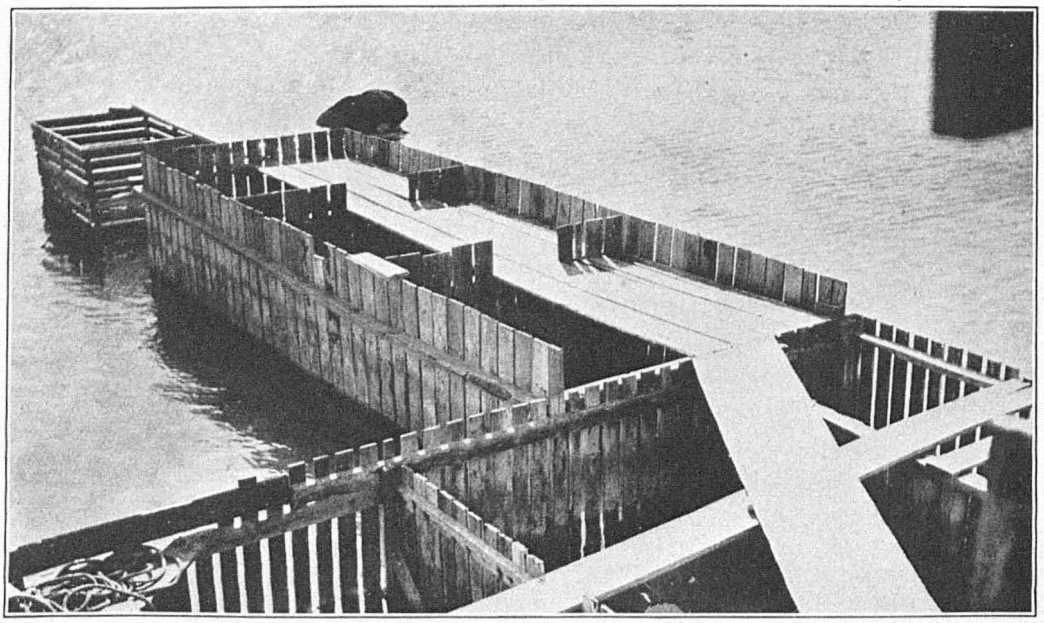

FIG. 264.—Experimental pens for spiny lobsters, Fisheries Biological Station, Key West, Fla.

MARKETING THE CATCH.

The spiny lobsters are taken to the local markets alive, having been kept in the wells where there was a free circulation of water. It sometimes happens when lobsters are plentiful that the well will not hold the entire catch. This surplus is put into bags which are carried on deck. It is necessary to keep the animals cool and wet by frequently pouring water over them.

At the market (Fig. 263) the catch is sorted, counted, and transferred to floating cars or inclosures where it is kept until ready for shipment. Spiny lobsters which have died and those in a dying condition are sold as bait to the hook-and-line fishermen. The market value varies from $0.75 to $2 per dozen according to season and demand and size. The average price obtained by the fishermen is $1 per dozen. The dealers sell by the pound. The average spiny lobster weighs about 1½ pounds or 6 dozen weigh 100 pounds.

During cool weather spiny lobsters shipped to points in southern Florida are simply placed in wet sacks, and under such conditions they will live four or five hours. If properly packed, they will live from two to three days. During the winter and spring months many spiny lobsters are shipped as far north as Philadelphia, New York, and Boston. They are packed in barrels containing alternate layers of ice and shellfish. The method of packing is the same as that employed in preparing fish for shipment, except that a layer of sponge clippings or seaweed separates the shellfish from the ice.[4] The average barrel will hold 10 to 12 dozen spiny lobsters.

Spiny lobsters caught by means of the grains are seldom sold at the market but are disposed of readily at the local hotels and restaurants. This product does not command as high a price as the live shellfish. When caught, the tails are twisted from the back and the latter thrown overboard. In order to dispose of this produce, it must be sold a few hours after capture. When spiny lobsters are plentiful and bring a low price, some of the fishermen salt and dry the meat for their own consumption.

ABUSES IN THE FISHERY.

Since there is always a ready sale for the spiny lobster, it is constantly being sought by the fishermen, both for its food value and value as bait in fishing. The fishermen generally believe that the supply is decreasing to some extent, since each year finds them going farther and farther for their prey. However, the old fishing grounds are known to yield very large catches after intervals of neglect, and it is doubtful whether these grounds have been actually depleted. From observations and data obtained it is known that spiny lobsters have not reached sexual maturity until they have attained a total body length of 8 to 9 inches, and a great many that are sold have not had an opportunity for spawning. The smaller spiny lobsters have a very delicate flavor, and those too small for market are consumed either by the fishermen and their families or are used for bait in fishing.

Formerly, the egg-bearing spiny lobsters sold as well as the others, but within the last few years the fishermen have been unable to sell the berried females. In this stage and until after the eggs have hatched they are said to be unwholesome.

[4] The method of packing spiny lobsters in barrels with ice is not a good one, for heavy losses frequently are sustained in long-distance shipments.

Those methods of capture which tend to injure and kill the spiny lobsters are prohibited by law. Egg-bearing spiny lobsters are protected, but this protection can not be successful as long as spears, grains, hooks, and other injurious devices are used illegally in capture. Many of the spiny lobsters struck with these implements are injured, although not taken, and are left in the water to die sooner or later from their injuries. The pots in use catch all spiny lobsters regardless of size, but it could be required that the mesh be of sufficient size to permit the escape of the smaller animals.

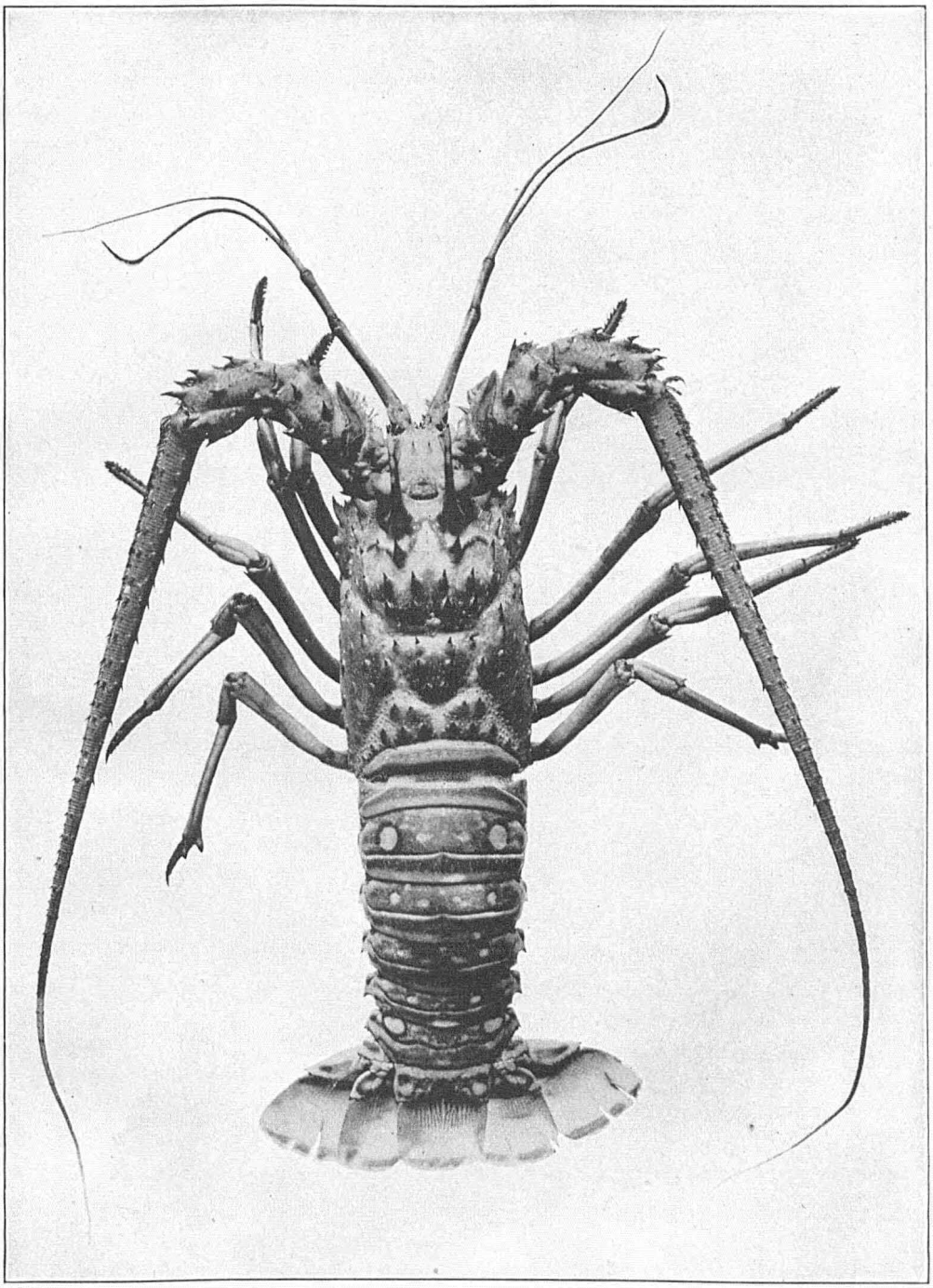

FIG. 265.—Spiny lobster, *Panulirus argus*. Dorsal view of young adult female.

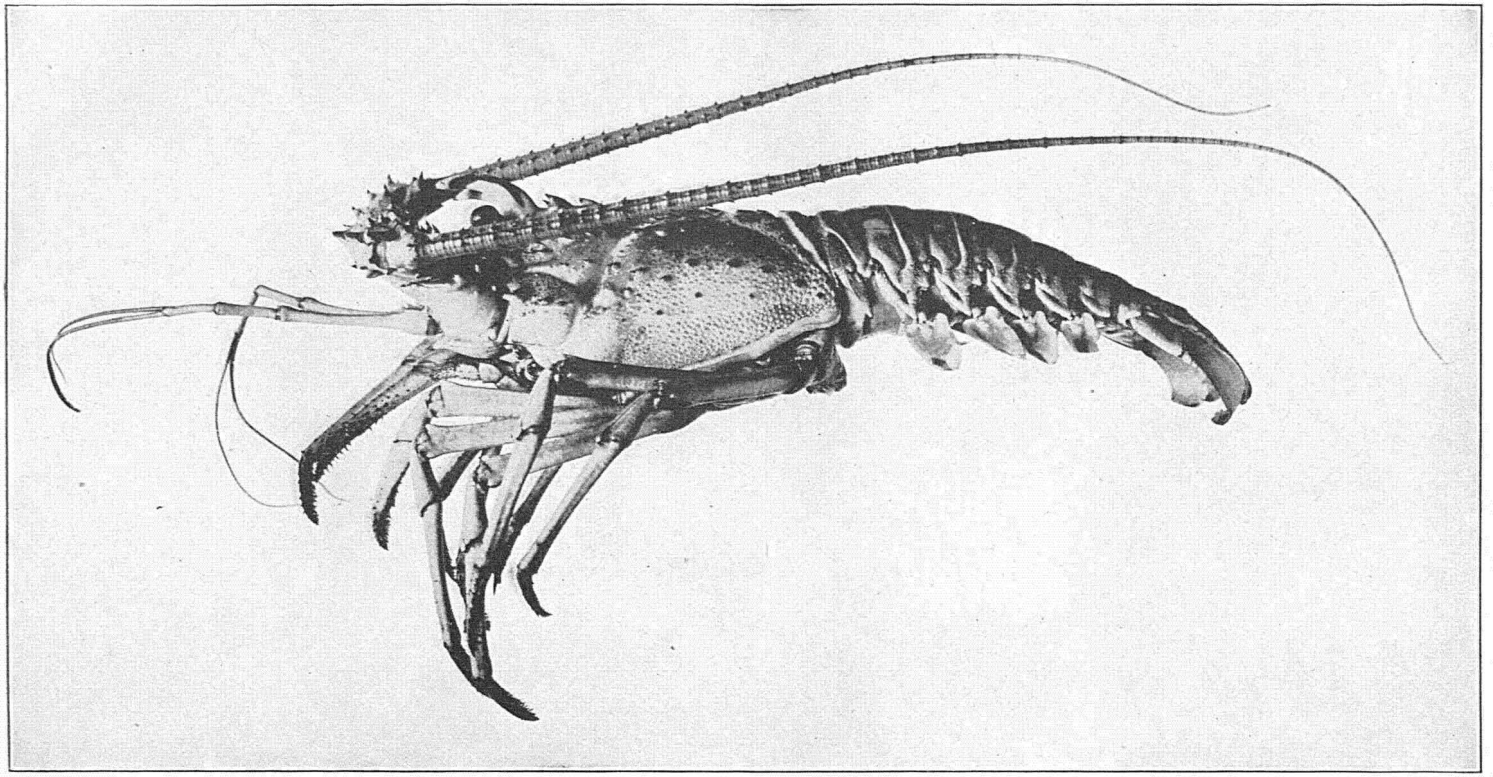

FIG. 266.—Spiny lobster, *Panulirus argus*. Lateral view of adult male.

Part 2.—LIFE HISTORY OF THE SPINY LOBSTER.

DESCRIPTION.

EXTERNAL CHARACTERISTICS.

The spiny lobster, *Panulirus argus* Latreille (Figs. 265 and 266), is compared frequently with the northern lobster, *Homarus americanus*, but even a cursory examination shows that there are many differences between the two crustaceans. The carapace of the spiny lobster, as the name implies, is studded with many sharp, forward-pointing spines which are arranged in more or less regular longitudinal series. The largest spine projects forward and curves above the eyes. The base of each spine is continuous with a low, flattened ridge which passes forward and downward below the eye. The base of the first segment of the antenna is modified into a padlike structure which engages this ridge and produces a strident sound when the antenna is moved.

The spiny lobster does not possess chelate appendages or large claws, like those of the northern lobster, the legs all ending in sharp dactyls which bear tufts of setæ. The three basal segments of the antennæ are very heavy and spinous, and the flagellæ are somewhat longer than the body in perfect specimens. The flagellæ are heavy and stiff, although they taper out to fine ends, and they are encircled with small spines at irregular intervals for almost the entire length. The inner edges of the flagellæ are fringed with short setæ which are probably sensory receptors. The antennules, or inner antennæ, are long and biramose, and the inner branch of each is fringed with cilia.

The pleon, or tail, is smooth and without spines or setæ, and each segment is crossed by a furrow which is more or less continuous, being broken in many small individuals. The furrow across the sixth segment of many adults is broken, but it is continuous in many others. The lower angle of each segment is produced into a strong tooth which is directed backward and deeply notched on the posterior margin.

The first segment of the tail does not bear appendages, but on the next four segments there are paddlelike swimmerets, or pleopods. The inner limb, or endopodite, of these appendages is not developed in the male, but in the female both exopodite and endopodite are developed, and the last three endopodites are developed into biramose structures for carrying the eggs. The tail fan is composed of five parts, the middle one being the telson, or seventh segment of the pleon, and the outer parts, which are the appendages of the sixth segment, known as the uropods, each being composed of exopodite and endopodite. The telson is covered by longitudinal series of small spines directed backward, and the distal parts of the tail fan are roughened by minute spines scattered over the surface.

COLORATION.

The sexes can not be distinguished by their color, although there is well-defined sexual dimorphism, as will be shown presently (p. 293). The coloration varies from very light shades to very dark shades, but the light and dark areas cover the same regions

in all individuals, thus forming a definite color scheme. The tail is spotted with yellowish ocelli, and the posterior margin of each segment is edged with yellow or orange. The lower angles of the segments are marked with dark bluish or greenish tints and sometimes additional colors. The pleopods are usually orange, about half the area being covered by a black blotch. The legs are striped longitudinally with blue. The ventral surfaces of the body are cream colored or light yellow, and the thoracic sternum is marked with irregular, radiating stripes. The tail fan is crossed by bands of orange, yellow, and black and is fringed with white.

The coloration of the young differs from that of the adults in some respects. The colors of the carapace in very small individuals are arranged in transverse bands, usually three, the middle one being dark. The antennæ are frequently ringed with alternate light and dark bands, and the legs are ringed with blue.

Panulirus argus, like other species of the same genus, varies considerably in color. Coloration, apparently, is correlated with habitat, two groups of coloration being distinguished, one consisting of lightly colored individuals and the other of darkly colored individuals. The range in color of the former group is from light gray and tan to shades of green and light brown, while the second group varies from shades of red to deep browns and blues.

Large catches have been observed in the market, and it was noted, when it was possible to learn where they had been caught, that the lightly colored spiny lobsters came from places where the bottom was known to be lightly colored, and the darker individuals came from places where the bottom is covered by growths of sea fans and sponges. Such growths have been raised occasionally with the traps when it was noted that the color is similar to that of the spiny lobsters taken. Large numbers of spiny lobsters which have been caught in a given area have been found to vary only in slight degree in this respect.

Depth of water does not influence the color except indirectly, since the growths of sea fans and sponges are sometimes heavier in deep water and lightly colored bottoms are more generally found in shallow water. A migration, therefore, from one kind of habitat to another is indicated when spiny lobsters of different colors are caught in the same trap.

DIFFERENCES BETWEEN YOUNG AND ADULTS.

The young of both sexes possess antennæ which are longer in proportion to the body than they are in the adults. The spines on the carapace are better developed in the young, and very small individuals have on the carapace numerous setæ which gradually disappear with age. Specimens measuring 2 inches in length of carapace do not possess these setæ. The spines on the carapace of very large spiny lobsters are replaced frequently with tubercles, only those on the anterior parts of the carapace remaining acute.

Adolescent males, while often nearly as large as the adults, differ from them in the development of the second pair of legs and the size and shape of the second dactyl. The dactyl of the adult male is rather slender and curved and provided with a brush of long setæ which is not as well developed in the young or adolescent males. The second dactyl of adolescents is stouter and less curved and the setæ are shorter than those of the dactyl of the adult.

Adolescent females differ from the adults in the development of the fifth claw. The dactyl of the young is more curved and more acute than the dactyl of the adult, and the number and arrangement of the setæ on the dactyl of the young also differ. The cheloid part of the fifth claw is shorter in proportion to the dactyl in the young than it is in the adults.

Small individuals of both sexes are found in shallow water at all times and can be caught by means of traps set there. Large numbers of them are often taken by the fishermen for bait, and they are brought to market during stormy weather when fishing is restricted to sheltered places. The adults are more commonly taken in deeper water, but they are taken in large numbers in shallow water during migrations.

MORPHOLOGICAL DIFFERENCES IN SEX.

Adult spiny lobsters exhibit well-defined sexual dimorphism. The young of both sexes can be distinguished readily, although the differences are not as well marked as they are in the adults. The sexes can be distinguished by the fifth dactyl of the female, the second pair of legs of the male, the pleopods, the difference in the shape of the carapace, and the development of the thoracic sternum.

FIFTH CLAW OF THE FEMALE.

The fifth claw of the female (Fig. 267) furnishes the most ready means of distinguishing the sexes. The most striking difference between the dactyl of the male and that of the female is the development of a small chela on the fifth dactyl of the latter. This chela is composed of spurlike extensions of the propodus and dactyl, both parts being concave on their inner surfaces and provided with tufts of soft setæ, those on the dactyl being longer.

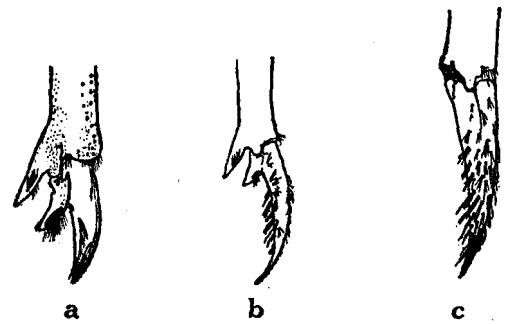

FIG. 267.—Fifth dactyl of spiny lobster, *Panulirus argus*. × 1.5 approximately. *a*, fifth dactyl of mature female; *b*, fifth dactyl of immature female; *c*, fifth dactyl of mature male.

The fifth dactyl of the female is shorter in proportion to the length of the propodus than the fifth dactyl of the male, and the number and arrangement of the setæ differ to a marked degree, since the dactyl of the female is almost naked.

Spawn-bearing females have been observed using the fifth dactyls to manipulate the eggs, and in one instance a female was observed to use the fifth dactyl to scrape off the surface of the seminal vesicle just before the eggs were laid.

SECOND PAIR OF LEGS OF THE MALE.

The second pair of legs of the adult male (Fig. 268) is extraordinarily developed, being so long that these legs are rarely used in walking and are usually extended forward. The dactyl is long and curved and provided with a brush of long setæ which probably aids in clinging to the shell of the female during copulation. (See Copulation, p. 305.)

The second dactyl increases in length with age, becoming more curved, until, in very old individuals, it is almost falcate. The setæ also increase in length with age,

and the brush is more conspicuous in older individuals than in the young. The tufts of setæ which are found on the propodus of the young and adolescent males disappear gradually with successive molts, until their places in large individuals are marked by small pits.

PLEOPODS.

The pleopods of the male differ from those of the female (Fig. 269) in having only the outer limb, or exopodite, developed. Both exopodite and endopodite are developed in the female. The exopodites of the female are somewhat longer and broader than those of the male. The first endopodite is similar in shape to the exopodite, but the remaining three endopodites are bifurcate, and in adult females they are fringed with long setæ upon which the eggs are carried. These bifurcate endopodites are not colored, being composed of white, flexible chitinous material. The edges are reinforced with scutes from the undersides of which the long setæ project in tufts. Some of these setæ are plumose and shorter than the others which are nonplumose.

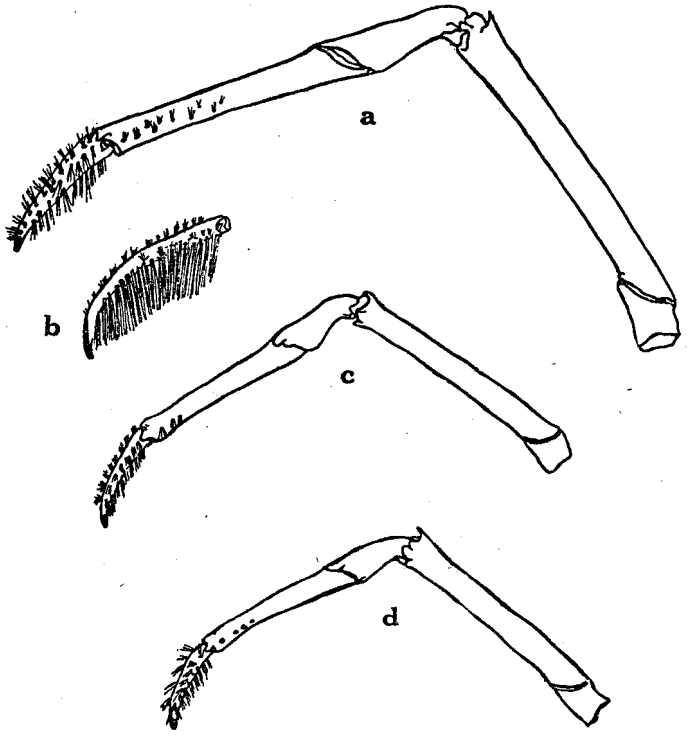

FIG. 268.—Development of second pair of legs of spiny lobster, *Panulirus argus*. Natural size. *a*, second leg of mature male; *b*, second dactyl of old male; *c*, second leg of young male; *d*, second leg of adult female.

The exopodites appear to the naked eye to be finely ribbed. These ribs appear under the microscope as dense, granular masses, along which at intervals are groups of minute setæ. All of these groups of setæ do not appear to be the same, some being composed of two or three comparatively long setæ and one seta which is short. The longer setæ are segmented and plumose, while the shorter seta is segmented and nonplumose. Nerve fibers extend through these setæ, which indicates that they may be sense organs, but whether they receive tactile or chemical stimuli is not apparent. The bases of these setæ are flask shaped, the distal portion of the segment being greatly enlarged.

Other groups of setæ are composed of three or four short setæ, none of which are plumose. They may represent the remains of longer setæ which have been broken off, although their ends are rounded.

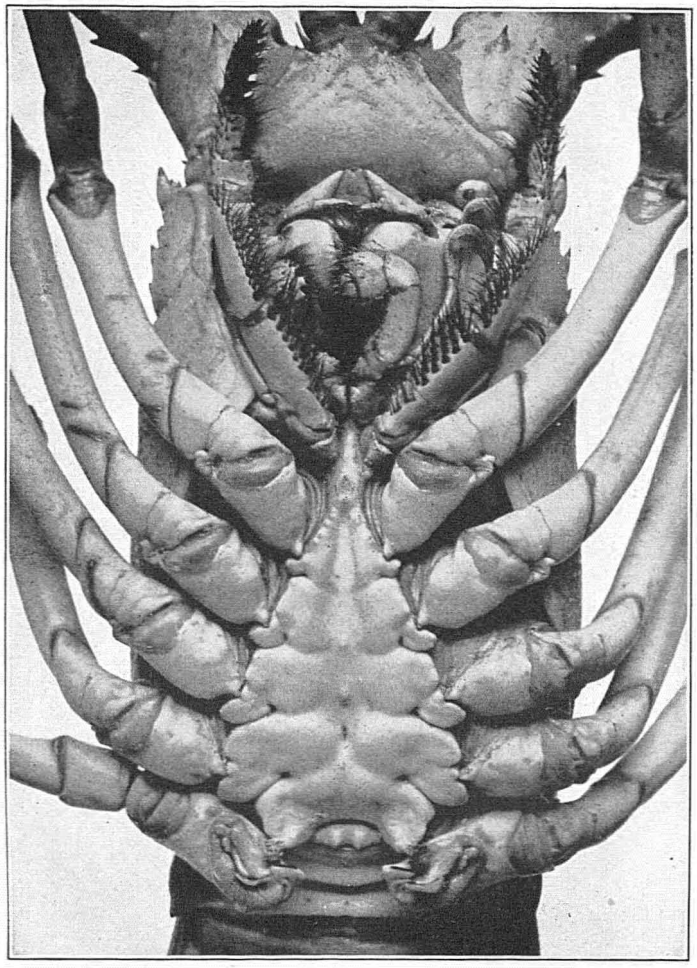

FIG. 270.—Sternum of adult male spiny lobster, *Panulirus argus*.

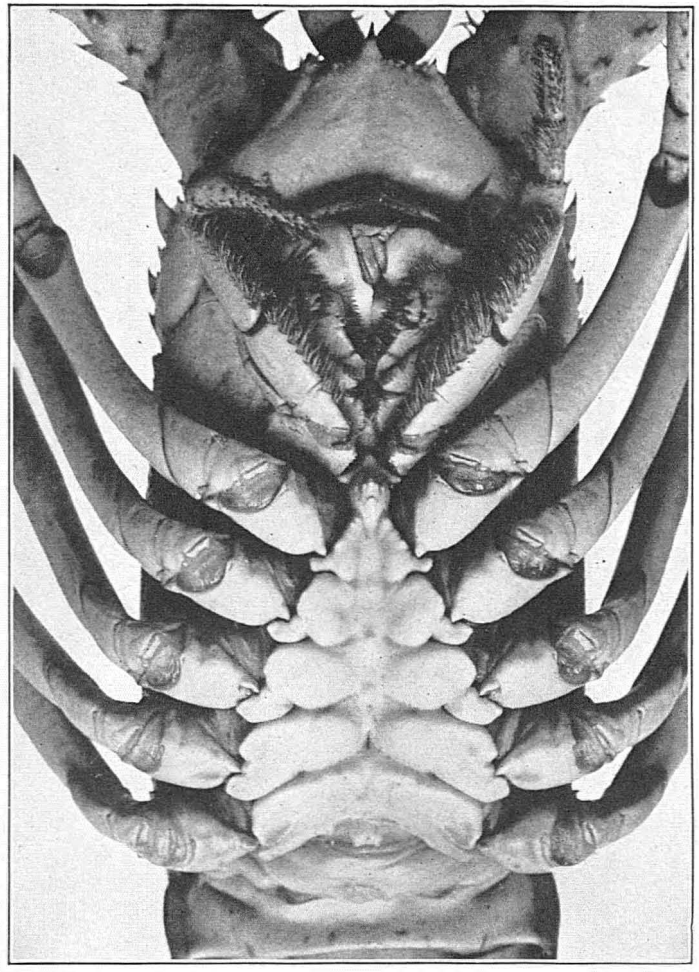

FIG. 271.—Sternum of adult female spiny lobster, *Panulirus argus*.

The margins of the exopodites are finely scalloped and fringed with short, plumose setæ which are provided with nerve fibers, indicating that they are probably sense receptors.

CARAPACE.

The carapace of adult males is of different shape from that of adult females. The branchial lobes are highly developed and give this region an oval appearance in contrast to the more cylindrical appearance of the carapace of the female.

The abdominal somites of the male are progressively narrower posteriorly causing the tail to taper and the uropods to appear proportionately wider than they do in the female, which, however, is merely an optical illusion, since there is no actual difference in width in individuals of the same size.

THORACIC STERNUM.

The posterior margin of the sternum of the male (Fig. 270) is narrower than the posterior margin of the female, the last thoracic segment being constricted posteriorly between the greatly developed coxopodites which extend inward, and is raised into small ridges which extend from the articulations with the fifth pair of legs toward the center. A small, bilobed part of the sternum lies between the bases of these ridges and extends posteriorly. The sternum of the male is longer than the sternum of the female.

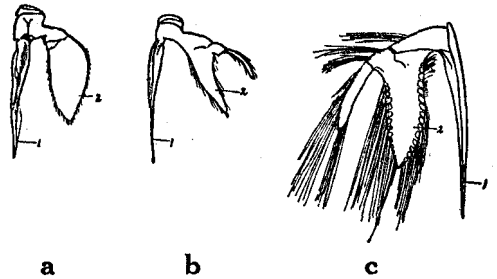

FIG. 269.—Pleopods of female, spiny lobster, *Panulirus argus*. × 0.75 approximately. *a*, first pleopod of adult female; *b*, second pleopod of young female; *c*, second pleopod of mature female; 1, exopodite; 2, endopodite.

The sternum is furrowed by a median groove which extends from between the first pair of legs to between the fourth pair. A narrow pit lies at the termination of this groove, and in the male there are three small tubercles anterior to and in line with the pit. The first of these tubercles is conical and acute and lies somewhat posterior to the bases of the first pair of legs. The second and third tubercles are rounded and but little elevated and lie between the bases of the second and third pairs of legs, respectively. These tubercles seem to form a locking device with those on the sternum of the female.

The median groove in the sternum of the female (Fig. 271) contains two small tubercles, both of which are conical and lie between the bases of the second and third pairs of legs. The seminal vesicle when present covers the sternum of the female from the third to the fifth pair of legs. The surface of the sternum when the vesicle is removed is striated, these small grooves or striæ probably serving to hold the material of the vesicle more firmly in place.

The posterior margin of the sternum of the female forms a rather broad arch. Small ridges extend from the articulations of the fifth pair of legs toward the center. It is seen when a male and female of the same size are placed with their ventral surfaces together that the grooves in the sterna form a mold which is nearly filled by the seminal vesicle. The extensions of the coxopodites of the fifth pair of legs of the male

upon which the external genital organs are located press against the posterior margin of the sternum of the female, and the little brushes which are located on the anterior sides of the external sexual organs of the male are in such a position that the backward flow and escape of the seminal fluid would be prevented. It seems, therefore, that the seminal vesicle is formed between the sterna and that its shape is determined by the depressions.

HABITS AND MOVEMENTS.

HABITS.

The spiny lobster is nocturnal in its habits and remains hidden during the day under shelving rocks, large sponges, or other growths offering protection. Spiny lobsters may be detected in such places by the protruding antennæ or forepart of the body. Feeding evidently occurs at night while they are crawling about, and most of those taken by the fishermen are caught at this time.

Spiny lobsters are observed frequently crawling about in trains, the antennæ of one in contact with the body of the one in front. These trains probably constitute the so-called schools reported at times. Several small individuals are seen usually under the same sponge or rock, and numbers of them often crowd together in a small space. They seem to be gregarious, it being well known among the fishermen that where one spiny lobster is seen there may be several more close at hand.

The spiny lobster in captivity tends to avoid the light, and the character of its natural habitat is indicated by its habits. The best fishing grounds are found where plenty of cover is available, such places being rocky bottoms, coral heads and reefs, places where sponges are growing, or where artificial shelter has been provided accidentally. There is no evidence that the spiny lobster burrows into muddy banks or inhabits muddy bottoms. None was taken with traps set repeatedly in such places, while better success was attained with traps set on rocky bottoms or where sea fans were plentiful.

MOVEMENTS.

It is generally believed that the spiny lobster is rather sluggish in its movements. The usual method of locomotion is crawling slowly but nimbly about on the tips of the claws, but movements can be made to either side or backward with considerable rapidity. The most powerful movements are accomplished by flexures of the pleon or tail, but no great distance is covered in this way between rests. Short distances are covered rapidly sometimes by swimming on the side, or even on the back. Swimming is used principally in escaping from enemies and is not often employed in going from place to place while feeding. There is no reason to believe, however, that the range is restricted to a small area. Considerable distances could be covered by crawling, and it does not seem probable that the spiny lobster actually returns to the same shelter except by accident.

HABITS IN CAPTIVITY.

Spiny lobsters upon being impounded crawl about the inclosure and seek a sheltered place away from the direct rays of the sun. The antennæ are carried above the ground while the spiny lobster is crawling about, and if there is sufficient room they are spread out on either side. They are thrust forward or switched up and down when an enemy approaches. The tail is flexed under the body usually while the animal crawls slowly

about, but at times it is straightened out and the pleopods aid in buoying up the body while more rapid movements are accomplished.

The tail is flexed under the body while the spiny lobster is at rest and the antennæ are spread outward. One or more legs sometimes move back and forth or from the body outward with slow rhythmic movements. The flagellæ of the antennules are drawn frequently through the setæ of the third maxillipeds, probably for the purpose of cleansing the cilia of sediment or growths of red algæ and diatoms which sometimes burden the cilia.

FOOD.

The natural food of the spiny lobster consists of worms, small mollusks, and probably smaller crustaceans. The lobsters are often scavengers, for it has been observed that they eat a great variety of food, such as bits of fish, and fish offal, meat, bits of crushed blue crab, pieces of clams, conchs, and garbage. The fishermen bait their traps with beef ribs or fish, but it has been found that bait is nonessential, since larger catches have been made at times when no bait was used than when the traps were baited.

Bits of seaweed have been found in the stomachs of a few spiny lobsters, but it is supposed that this material was ingested with small crustaceans or other small animals and does not form a part of the regular diet, since it was scarcely acted upon by the strong digestive fluids.

Spiny lobsters in captivity have been fed successfully on fish—either fresh, dried, or salted—clams, conchs, or any kind of meat scraps. Plenty of food should be provided and some regularity in feeding should be observed. The lobsters are not cannibalistic naturally, but when food is scarce they will not hesitate to eat the smaller individuals or those that have recently molted. Cannibalism has been observed more particularly among the larger males, and they should be kept separated from the spawning females and smaller individuals.

ENEMIES.

The spiny lobster at all stages of its existence is the prey of numerous enemies. The greatest losses no doubt occur during the larval development, when great numbers of them are probably eaten by pelagic animals. The black grouper, the mutton fish, and the jew fish are known to devour adult spiny lobsters, since the remains are found frequently in the stomachs of these fish. The stomach of a jew fish weighing about 350 pounds was found to contain 16 spiny lobsters of marketable size.

MODES OF PROTECTION.

The stiff heavy antennæ are used to ward off the attacks of enemies. They are raised upward or backward according to the direction of the attack or thrust directly forward and held rigidly, thus preventing large fishes or other animals from reaching the body. The flagellæ are rather brittle and break off when an attempt is made to draw the spiny lobster along by them. The loss of the flagellæ is the most common mutilation observed.

The heavy armature and sharp forward-pointing spines of the carapace form an effective means of defense, making it almost impossible for a person to escape injury while handling live spiny lobsters for examination. The legs separate readily from the body, especially in large individuals, and escape from capture is often effected in this way.

SENSE ORGANS.

Simple experiments showed that receptors for the sense of smell are located on the flagellæ of the antennæ. No specialized organs have been found, unless the setæ are the receptors, and it is not possible to locate any definite region where the sense of smell is most acute. Pieces of fish suspended in the water near the antennæ will attract the spiny lobster, and the flagellæ are moved so that they come into contact with the fish even though the food may be hidden by seaweeds. Experiment showed that in still water the reaction takes place to a piece of fish suspended a meter away from the antennæ, but the scent of food under natural conditions is probably carried much farther by currents.

Different sense organs are located on the legs. Pieces of fish dropped on the legs cause a definite response The legs are moved, causing the piece of fish to be brought under the body. This takes place even though the spiny lobster is eating other food. The response is different when inorganic materials, such as stones, are dropped in place of food. There seem to be similar receptors at the bases of the antennules and about the mouth parts. These two chemical senses differ from each other only in sensitivity. Particles of food must be dissolved in the water before they can stimulate either kind of receptor, but since one set of receptors receives stimuli from a distance it is more closely allied to the olfactory sense organs of air-breathing animals, while the other set of receptors receives the stimuli of particles of food directly in contact with it and is similar to the sense organs of taste in other animals.

Vision does not seem to be acute, for objects thrust near a spiny lobster do not always cause movement, and in diffused light the lobsters are more readily caught with a dip net than in bright sunlight. The antennæ are raised when a shadow passes over the spiny lobster, which will turn in different directions as the shadow moves. Vision, therefore, appears to be limited to distinguishing the quality of light rather than the qualities of definite images as in higher animals. It has been observed that food is not located by vision, since pieces of fish suspended in a current below the spiny lobster will not attract it although the distance is very short.

It is often thought that animals capable of producing sound are able to hear. If this is the case, the spiny lobster should respond to various noises, but experiments do not show that the auditory sense is present. The strident sound produced seems to be made only when an enemy has driven the spiny lobster into close quarters and hearing may not accompany it. This noise may be a means of defense.

HABITAT AND MIGRATIONS.

No direct observations have been made to determine the depth and distance from shore at which spiny lobsters may be found, but the following has been inferred from observations of catches brought into the market.

Traps are often set in deep water by the fishermen while they are fishing for large fish along the reefs 5 miles off Key West. Spiny lobsters are caught frequently on the outside of these reefs in 70 feet of water, and several fishermen claim to have taken a few with hook and line from somewhat deeper water. It is not probable that spiny lobsters in deep water inhabit different kinds of places from those found in shallow water; that is, they are restricted to rocky places or places where the growths of sponges

and other forms offer protection. It is known from a limited local knowledge of the bottom near these reefs and also from the charts that the character of the bottom outside these reefs is less rocky and apparently does not afford good protection for spiny lobsters. The inference, therefore, is that the limit of distribution is bounded by these reefs, or it may extend a short distance beyond to detached coral reefs farther out.

Fishing operations are thus practically limited to shallow water and to an area not over 7 miles in width, including all places where all sorts of gear could be used. The region actually covered by the regular fishermen is not more than half this width and is confined to shallow banks not far from shore. The remaining strip is now, in reality, a natural reservation where protection is enforced by the limitations of the fishermen. This reservation, however, may be destroyed easily when the demand for spiny lobsters will make it profitable to invest in more elaborate gear, and it may be necessary then to establish definite reservations protected by law. The situation now prevents the concentration of large numbers of fishermen on a limited area, and extermination of the spiny lobster is not imminent. The dangers of overfishing, however, are obvious, and the present laws should be enforced.

The causes for migrations are numerous and rather obscure, but the three which seem to be the most important are molting, mating, and changes in temperature which probably affect both molting and mating. Local movements of relatively small numbers of spiny lobsters take place, which are probably caused by varying conditions of the water and food supply. A migration, as here considered, is a movement of a large number of spiny lobsters over a wide area, the movement being marked by more or less definite conditions.

The approach of the maximum molting season is marked by an increasing number of spiny lobsters in shallow water which differ in color from those usually found there, and many of which are about to molt. This condition does not exist merely locally but is found to be general over an extensive area. Catches of spiny lobsters brought into the market at Key West from widely separated places, such as Sugar Loaf Key and Marquesas Keys, show that the spiny lobsters about to molt migrate into shallow water at both places within the same month. Fewer spiny lobsters are taken at the height of the molting season than at other times, probably because the animal is less active at this time, and few spiny lobsters with soft shells are taken by the fishermen. This has led to the belief that, although the old shell is cast in shallow water, the spiny lobster soon retires to greater depths. Spiny lobsters with soft shells have been caught in quite shallow water near Key West, and it may be that there is no extensive movement of newly molted ones into deeper water unless the changes in temperature of the shallow water become unfavorable to the animal in its delicate condition.

The maximum breeding season varies somewhat in time from year to year and in different places. The number of spiny lobsters is known to increase in certain places during this time and also during the spawning season. Migrations of large numbers of spiny lobsters must then occur, for large catches of spawn-bearing females are made in certain places and not in others, and after the spawning season is over the catches of females decrease in places where they were formerly plentiful.

The following table (1) is a summary of the catches of spiny lobsters taken by means of a group of three traps set in about the same location from March to August, 1919, inclusive, the purpose of which is to demonstrate the decrease in the number of large

females in shallow water during the maximum spawning season (March, April, and May) and the increase in the number of large females in shallow water after the hatching season is over and the molting period of the females has begun (June, July, and August).

TABLE 1.—SUMMARY OF CATCHES OF SPINY LOBSTER TAKEN IN THREE TRAPS, MARCH TO AUGUST, 1919.

Month.	Males.	Females.	Ratio of females to males.	Month.	Males.	Females.	Ratio of females to males.
March	30	14	0.45	June	65	32	0.49
April	38	10	.26	July	39	53	1.35
May	28	5	.17	August	42	73	1.73

The numbers of individuals involved in these data are small, but the catches brought into the markets at Key West were observed and the relative numbers of females to males were approximately the same as given in the table.

It is not evident that there are migrations parallel to the coast. Traps set offshore at various depths always take spiny lobsters regardless of the directions of the openings. Places known to be depleted from overfishing are not repopulated in a short time, which it seems reasonable to suppose would be the case if migrations occurred parallel to the coast. Migrations occur from deep to shallow water and back again to deep water.

Large numbers of spiny lobsters come into shallow water at times, apparently for the purpose of feeding. These constitute a type not usually found in such places, and they can be distinguished by their size and color, since they are larger and darker than those usually found in shallow water. The causes for this migration are obscure, but the changes in the temperature of the water probably are a determining factor.

INFLUENCE OF CHANGES IN TEMPERATURE.

Changes in temperature of the shallow water about Key West are often great and occur abruptly. The direction of the wind and condition of the weather account for these changes, and their influence upon the sizes of the catches of spiny lobsters is marked.

It is well known among the fishermen that the spiny lobsters are more abundant in shallow water after gales than during long continued calm spells. Closer observation has shown that when the wind blows from the sea more of them are taken in traps set off a lee shore, or the shore upon which the wind is blowing, than in traps set in the shelter of small islands or banks. It has also been observed that the catches are smaller when the wind blows from the shore.

The fluctuations in the abundance of spiny lobsters in shallow water at various times can be explained as follows. Sea winds cause the water to move shoreward, and as this water is generally cooler than that over the shallow banks it causes a temporary fall in the temperature of the shallow water. Conditions in shallow water then approach the conditions found in deeper water and spiny lobsters come into shallow water while feeding. Continued offshore winds tend to drive the water from the shallow banks, and thus prevent the cooling of the shallow water offshore. The spiny lobsters do not come into shallow water, because the temperature is excessive. The temperature of the shallow water rises rapidly during calm weather, and few spiny lobsters are caught.

INFLUENCE OF TIDES.

The influence of tides is not noticeable except where there are definite currents, such as occur between the keys and reefs. Traps set in such places have shown repeatedly that more spiny lobsters are taken when the tide is flowing out during the night and early morning, or when the moon is in perigee, than when the tide rises during the night and early morning, or when the moon is in apogee. It is thus possible to predict the relative sizes of catches in a given place with considerable accuracy. This is the reason, no doubt, for the belief among the fishermen that the moon influences the movements and abundance of spiny lobsters.

Traps set on the sides of a channel usually take more spiny lobsters than traps set in the middle, which indicates that the lobsters avoid strong currents.

MOLTING AND REGENERATION.

No sharply defined season during which spiny lobsters molt could be determined, since individuals of all sizes showing signs of molting can be found throughout the year. From observation of a small number held in captivity the young are known to molt more frequently than the adults, and it is supposed that females molt more regularly than the males because they carry spawn. The males, however, attain a larger size than the females, which probably indicates that their rate of growth is more rapid and perhaps that they molt more frequently than the females. The time of the molting season apparently varies somewhat from year to year, the variation being due probably to the temperature of the water and to the abundance of food, both of which seem to affect the rate of growth.

Numerous males of medium size which were caught during February, 1919, had recently molted or were in the process of molting. Larger males and females of small and medium size molt during April, May, and June. Females which have carried spawn molted in the summer from June to September or after the eggs had hatched. Several large females caught in 1918 were observed to molt as late as October, but several large males molted in the pounds as late as December. Several large females were observed to molt three or four days after the eggs had hatched.

PREPARATIONS FOR MOLTING.

Spiny lobsters preparing to molt can be distinguished from the others by the dull appearance of the shell, which is usually covered with fine silt and growths of seaweeds and stalked diatoms. It has been observed among spiny lobsters in captivity that such individuals seek sheltered places and remain inactive unless disturbed. Very little, if any, food is taken by them. The second pair of legs is used to rub the eyes and anterior parts of the carapace, and the fifth pair of legs frequently is used to rub the posterior parts of the body.

Hairlike lines appear about 80 hours before the shell is cast, one extending along the branchial region of the carapace and another downward between the first and second pairs of legs. These lines mark the places where the carapace will break and are apparent only when molting is about to occur, although their places are marked after molting by the regular arrangement of the tubercles. The lime salts of the shell are gradually dissolved away along these lines until the shell is broken, and molting usually occurs three or four hours afterward.

A period of activity immediately precedes molting, during which the spiny lobster crawls about with intermittent intervals of rest. During this time the anterior legs are used more frequently to rub the eyes and surface of the carapace and mouth parts. The fourth and fifth pairs of legs are brought over the other legs and held there momentarily at irregular intervals, and sometimes in a pushing position, while the other legs are placed forward as though pulling. Crawling ceases when the carapace becomes disarticulated at the pleon.

CASTING OF THE SHELL.

The spiny lobster while molting remains in an upright position, with the three anterior pairs of legs extended forward and the fourth and fifth pairs of legs extended some what backward, the dactyls apparently gripping the ground. This position was observed in at least seven instances while molting took place (Fig. 272).

FIG. 272.—Newly molted shell of spiny lobster, *Panulirus argus*, showing position at instant of molting. × 0.5 approximately.

The posterior rim of the carapace begins to rise as soon as it is separated from the pleon and crawling has stopped. No violent movements are made at this time, and the old carapace slowly rises as the cephalothorax is withdrawn from the old shell. The cephalothorax is elevated until the eyes and bases of the antennæ are on a level with the posterior rim of the old carapace, which is at an angle of about 75° with the ground. The critical time has now arrived, and the antennæ are moved upward, downward, and to both sides as the flagellæ are withdrawn. The cephalothorax and legs are freed by a lunge backward, and the shell is cast from the tail by a few movements.

THE NEWLY MOLTED SPINY LOBSTER.

The appearance of the newly molted spiny lobster is much the same as the old shell in details, but the colors are fresher and brighter, and the appendages which were

lost before molting have been regenerated. The new shell is soft to the touch, and all of the spines can be bent.

The spiny lobster remains near the cast-off shell for a short time unless disturbed and then seeks shelter. The belief among the fishermen that the newly molted spiny lobster eats part of the old shell has been verified by observation, but also spiny lobsters which have hard shells have been observed eating such material when other food was scarce.

HARDENING OF THE NEW SHELL.

The time required for hardening of the new shell varies considerably with individuals. The shell does not harden appreciably for 24 hours after molting, but by the end of the second or third day the mandibles, legs, claws, spines, and branchial regions of the carapace have hardened sufficiently to have rigidity, and in four or five days the shell has a papery firmness. The shell can not be dented easily after 14 days. One spiny lobster was impounded without other sources of lime than the cast-off shell, and it was observed that the new shell hardened after 18 days to the extent that it could not be easily dented.

AUTOTOMY.

Autotomy has been observed to take place among spiny lobsters lying in the bottom of a boat, the third pair of maxillipeds and first pair of legs being lost more frequently than the other appendages. Autotomy, or reflex amputation, occurs along definite lines where the tissues are probably prepared to check bleeding. This provision of nature undoubtedly saves the life of the spiny lobster, for it has been observed that when a leg is broken off at any other place than that where autotomy occurs bleeding is usually unchecked, and such an injury often proves fatal. The plane of fracture when autotomy occurs is between the coxa and basis, and if a leg is broken off at any other place the remaining part is cast off at this plane. The legs of very large males often drop off while the body is temporarily suspended, and it has been observed that autotomy occurs when a spiny lobster comes into contact with certain objects, such as a sun-heated plank or tin bucket. The flagellæ of the antennæ break off at their bases when an attempt is made to pick up the spiny lobster by the antennæ.

REGENERATION.

The completeness of regeneration of lost appendages depends upon how long before the next molt they were broken off. It has been observed that legs lost six months or more before molting are regenerated to about two-thirds their normal length, but if a leg is lost a month or less before molting regeneration is very incomplete and the appendage is represented by a small papilla. One female was observed which had lost the dactyl of the fifth leg two months before molting. This segment was replaced at the next molt by a budlike papilla.

It has been observed that the flagellum of a broken antenna is regenerated sometimes before the next molt by the outgrowth from the stump of a small, soft flagellum. This form of regeneration of the antenna has been observed infrequently. Regenerated appendages are always smaller than the originals and are usually malformed, but they gradually approach perfection of size and shape in succeeding molts. Broken places in the shell, if they have not proved fatal, are poorly mended after molting, and holes

which were punched in the uropods of large individuals under observation remained open after the shell was cast. Such holes, however, were observed to close in a few young individuals.

RATE OF GROWTH AND SIZE.

The rate of growth depends upon the frequency of molting, and consequently varies with age, abundance of food, and temperature of the water. The young increase in length more rapidly than the adults because they molt more frequently. The actual increase at each molt was found, however, to be small. This increase was not noticeable immediately after molting, but when measurements were made three or four days later it was observed that the percentage of increase in the length of the carapace of females averaged 3.32 and of males 2.75. The ratio of the increase in length of the young at each molt is about the same as that of the adult. The actual increase in length of the adult at each molt is, of course, greater than that of the young, because the percentage of increment at each molt is based upon the length of a larger individual. For example, the actual increase at molting in the case of a male spiny lobster 2 inches long would be 0.055 inch, while that of one 5 inches in length would be 0.1275 inch.

The most rapid increase in weight at each molt occurs in the young, the percentage of increase in weight at each successive molt becoming smaller. Table 2 shows the general relationship between the length and weight of spiny lobsters of various sizes.

Persistent fishing apparently has reduced the size of spiny lobsters near Key West, but very large individuals are found around the Dry Tortugas and parts of Florida Reefs unfrequented by the fishermen. Measurements of a few of the largest spiny lobsters brought into the Key West market indicate that the maximum size of those caught near Key West is 14 inches total length, excluding the antennæ, with a weight of about 5 pounds. Several very large males brought from the Dry Tortugas measured 18 inches in total length, excluding the antennæ, and weighed from 6 to 8 pounds. No females of this size have been observed, the largest measured being not over 13 inches in total length.

The weight increases rapidly with increase in length, but individuals vary greatly in weight because of the loss of appendages and differences in the proportions of the body. The pleon of the female is wider than the pleon of the male, and females weigh more than males of the same length.

Table 2 is compiled from the measurements and weights of over 150 individuals. It is a comparison of the lengths and weights of the sizes of spiny lobsters usually brought into the market at Key West.

TABLE 2.—COMPARISON OF LENGTHS AND WEIGHTS OF SIZES OF SPINY LOBSTERS BROUGHT TO KEY WEST (FLA.) MARKET.

Length carapace (inches).	Average total length (inches).	Average weight.		Length carapace (inches).	Average total length (inches).	Average weight.	
		Pounds.	Grams.			Pounds.	Grams.
2.0–2.4	5.5	0.26	120	4.0–4.4	10.50	1.85	840
2.5–2.9	6.875	.54	245	4.5–4.9	11.50	2.51	1,140
3.0–3.4	8.25	.87	395	4.9–5.0	12.50	3.42	1,550
3.5–3.9	9.375	1.29	588				

GENITAL OPENINGS AND COPULATION.

GENITAL OPENINGS OF THE MALE.

The external sexual organs of the male (Fig. 270, opp. p. 295) are located on the greatly enlarged coxopodites of the fifth pair of legs. The coxopodites extend inward, the inner ends nearly meeting on a median line, and curve anteriorly and outward, the anterior part being compressed into a sharp ridge which is flatly concave on the anterior side. The ventral surfaces of the coxopodites are concave, forming a cup in which the external sexual organs of the male lie. These organs are somewhat pear-shaped and appear in life as suckerlike pads. Each of these pads is provided with a small brush of short setæ which project from the anterior side next to the sharp ridges and which are set obliquely to the axis of the coxopodite. The external openings are curved slits protected by thin lips of chitinous material, which are usually kept tightly closed in life.

GENITAL OPENINGS OF THE FEMALE.

The external openings of the oviducts (Fig. 271, opp. p. 295) are located on the coxæ of the third pair of legs at the articulation of the coxopodites with the sternum. These openings are roughly ovoid in outline, measuring 3.5 mm. on the major axis and 2.0 mm. on the minor axis. The oviducts do not open directly downward, since the anterior margin is somewhat higher than the posterior margin. The opening of the oviduct is protected by a flap of thin chitin which narrows the opening itself to a small pore.

COPULATION.

The manner in which copulation is effected has been deduced from observations of spiny lobsters in captivity. The male crawls nimbly about, approaching females approximately his own size. The legs are used to fence in the female, and an attempt is then made to turn her over. Sometimes the female is met head on and forced upward and backward, the second pair of legs being used to hold the female. The female successfully repulsed the male each time during these observations, and coitus did not actually take place, but there seems little doubt that the female is turned over upon its back during copulation.

One female was observed carrying a seminal vesicle while the shell was still quite soft, showing that copulation evidently had taken place soon after molting. This spiny lobster died, and it was not learned how long the seminal vesicle is carried before spawning takes place. Later observations indicated that the sperm is probably carried over winter.

Observations during two seasons (1918, 1919) were made upon large numbers of spiny lobsters brought into the Key West market during August, September, and October. It was noted that over half of the females which evidently had recently molted were bearing fresh seminal vesicles, which seems to support the belief that mating takes place soon after the female molts. The mating season, judging from these observations, occurs from August to November.

THE SEMINAL VESICLE.

The seminal vesicle is deposited on the sternum of the female between the last three pairs of legs and is composed of a dark gray or black material which has the consistency of whalebone. Males taken in July and August contain a dark gray, waxy material in a coiled tube under the carapace. This seems to be the material of which the seminal vesicle is composed.

The interior of the seminal vesicle is porous and has much the appearance of a piece of coarse, dry bread, which suggests that the material contained in the testes and vas deferens of the male during the mating season is composed of two different substances. One substance, which hardens soon after being deposited upon the sternum of the female, forms the bulk and body of the vesicle, while the other substance remains liquid. This liquid does not harden, since it can be expressed when the surface of the vesicle is scraped away. These two substances, however, form a homogeneous waxy fluid before the vesicle is deposited, and they are probably separated from each other by the process of hardening of the waxy material around the liquid, the pores being formed in a way analogous to the air bubbles in thick glue, or molten glass. A large part of the old vesicle is picked off by the females with the fifth dactyls soon after the eggs hatch. In three instances it was observed that molting took place from three to five days after the eggs had hatched. The end of the spawning season and the beginning of the molting season of the female are indicated by the condition of the seminal vesicle.

SPAWNING.

AGE OF FEMALE AT SEXUAL MATURITY.

The age at which the female reaches sexual maturity is not definitely known, but, judging by the development of the secondary sexual characteristics, the female reaches sexual maturity at a smaller size than the male. The smallest females observed carrying spawn measured 3 inches on the carapace, or about 9 inches in total length, exclusive of the antennæ. The size of spawn-bearing females varies considerably, the variation probably indicating differences in age.

THE SPAWNING ACT.

One spiny lobster was observed closely while spawning was taking place. The position of the female was that which is normally assumed while at rest and not upon its back. The abdomen was flexed, and the uropods formed a pocket with the exopodites of the pleopods. The fifth legs moved rapidly from the seminal vesicle to the pleopods during short intervals and then remained at rest. The vesicle was scraped frequently with the fifth and sometimes with the fourth pair of dactyls. The exopodites of the pleopods beat slowly and rhythmically at times, the movement being from side to side. The pleopods remained inactive and extended while the vesicle was being scraped, and they moved rapidly while the fifth pair of legs moved backward to them.

DEPOSITION OF EGGS.

The eggs were not seen as they left the oviduct and passed to the pleopods, nor was the method by which they are attached to the setæ observed. The eggs are fastened to the setæ in bunches of different sizes, which indicates that they were laid either in bunches

or issued from the oviducts in a steady stream and were driven backward against the pleopods by the beating of the exopodites. Examination under the microscope shows each egg to be stalked, and the stalks of a bunch of eggs are tangled together to form a common stem whose distal end is flattened where it comes into contact with the seta, to which it is fastened. All of the eggs were laid from four to six hours after spawning commenced.

DEVELOPMENT OF THE EGG.

The earliest stage in the development of the egg which was seen was that of eight cells. Subsequent stages were observed to the blastula, but the exact time between consecutive stages is not known, because the eggs died quickly in water under the microscope. Eggs of 16 cells were found in the same lot with eggs of 8 cells, and the inference is that they do not all develop at an equal rate. Some were found which segmented abnormally, the yolk remaining in a solid mass at one pole, while it was segmented at the other pole. The 8-cell stage was not found on the pleopods after 12 hours, and the 16-cell stage was not found after 24 hours. The morula was observed 30 hours after the eggs were known to have been laid and the blastula after 48 hours. These later stages may have been reached at an earlier period in other eggs than those observed. The yolk material of the eggs is dense and opaque, and further study of the embryo was impossible without resorting to sectioning. The eyes of the embryo can be seen after seven days, and examination under the microscope shows that at least five pairs of appendages are developed. Much yolk is present at this time and but little detail can be seen. It is known from observation of three females carrying spawn that the eggs were all hatched in 18 days from the time they were laid. The time probably varies as it does in the development of other eggs, but the maximum time evidently does not exceed three weeks.

Recently laid eggs are of a bright orange-red color, but as the embryo develops the color changes to clear, light brown, and just before hatching the eggs are almost colorless. This change in color is due to the absorption of the yolk material. It is not difficult, therefore, to judge the approximate age of the eggs by their color and general appearance.

SIZE AND NUMBER OF EGGS.

The eggs are quite uniform in size and shape. Eggs which have been recently laid are slightly oval or spheroidal in shape, the major axis measuring 0.5 mm. and the minor axis 0.45 mm., but they become more spherical as the embryo develops. The eggs increase slightly in size and the diameter is about 0.55 mm. just before the larva hatches.

Several estimates of the number of eggs carried by the female have been made. The number for a female measuring 3½ inches, length of carapace, is about 500,000. A larger individual, measuring 4 inches, length of carapace, carried about 700,000 eggs, which seems to be about the maximum number. The eggs measure about 7,500 to the cubic centimeter.

Practically all of the eggs hatched on females observed, only a small number of dead eggs remaining. The dead eggs were opaque and dull in appearance, and it is possible that they were never fertilized. It is known that mud covering the eggs will cause their death. It therefore is important that the fifth dactyls of the female remain intact, for it has been shown that these appendages are utilized in keeping the eggs free of sediment.

CHARACTER OF OVARIAN EGGS.

The ovaries are greatly distended just before spawning and appear as a bright red, bilobed organ extending from the head beyond the cephalothorax, the posterior end lying between the muscles of the first segment of the abdomen. The ovary has a mealy appearance when the eggs are fully developed, and it is very fragile. The eggs under the microscope appear to be without a shell or other protecting covering, and they soon coagulate in water, becoming white and opaque. The eggs are not round, but of various shapes, due to being packed closely together in the ovary. Their greatest diameter, however, is not more than 0.5 mm. The yolk material is very dense and granular, and the nucleus of the cell is rather difficult to find.

HABITS OF THE FEMALE DURING SPAWN BEARING.

Spawn-bearing females in captivity seek sheltered places in the pens and are less active than those not bearing spawn. It was observed that females bearing eggs about to hatch were less active than those whose eggs were newly laid, and this was of considerable aid in selecting individuals with ripe eggs for experiments in hatching.

The female while carrying spawn normally assumes a resting position; that is, it rests on the bottom on the tips of the dactyls with the tail somewhat extended and the uropods curved downward. The exopodites of the pleopods beat slowly and rhythmically, evidently for the purpose of keeping the water about the eggs in circulation. There are two movements of the pleopods which alternate at frequent but irregular intervals. One movement is backward and forward at the rate of 55 or 60 times per minute. The tail is slightly raised and the pleopods extended before the other movement, which is more rapid, the pleopods beating obliquely 65 to 70 times per minute, begins. The fifth legs are used frequently to manipulate the eggs and no doubt clean away any sediment or débris that might settle on them.

Small fishes sometimes attack spawn-bearing females, but they are often repulsed with the antennæ. There is little tendency for the female to move, and usually but little food is taken when the eggs are about to hatch.

TIME OF SPAWNING.

There is no sharply defined spawning season, since spiny lobsters bearing spawn have been found throughout all the year except during the winter. The maximum number spawn in the spring and early summer, the first being females of large size. Small females measuring 2¾ to 3 inches, length of carapace, have been observed bearing eggs late in the fall, but no spiny lobsters have been seen with spawn in November, December, or January. It is known that spawn-bearing females are brought to market later in the season from places west of Key West than from banks near Key West, and that the earliest spiny lobsters observed with spawn come from places considerably east of Key West.

The time between successive spawning periods of individuals is not known, but it is certain that spawning does not occur more than once a year. Females kept in pounds did not spawn the second year of captivity, and but one out of over a hundred was observed bearing a new seminal vesicle after molting during the second season.

EXPERIMENTS IN HATCHING.

Preliminary experiments were made by the junior author in 1917, which showed that the eggs would hatch while attached to females placed in floating boxes. The young, however, could not be reared in such apparatus and died within a day or two after hatching.

Another attempt was made to hatch the larvæ in 1918. The eggs were stripped from a number of females and placed in MacDonald hatching jars, which were supplied with

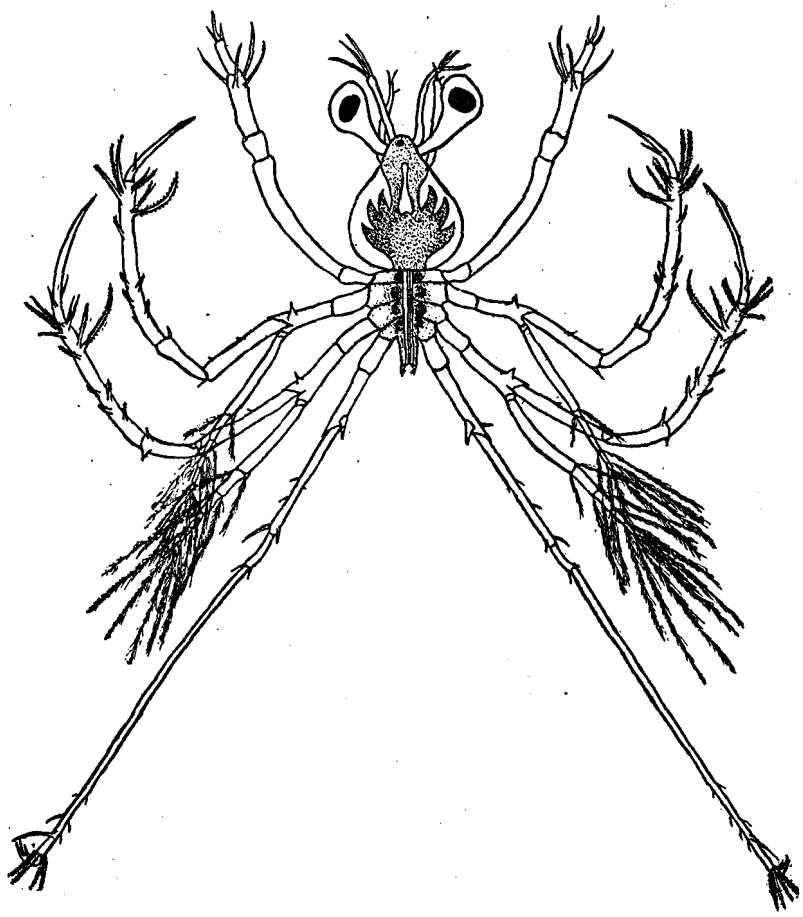

FIG. 273 —Newly hatched larva of spiny lobster, *Panulirus argus*, hatched at Key West (Fla.) Biological Station, June, 1918. × 33⅓, approximately

running salt water. This method proved to be more convenient than floating boxes for observation, but as a practical method it can not be recommended, since a very small per cent of the eggs hatched normally. It was found that the eggs hatch much better when left on the pleopods of the female. Newly laid eggs were observed to be slightly heavier than water, but as the embryo develops the specific gravity of the eggs decreases, and when the eye of the embryo is visible the eggs are more buoyant. The newly laid

eggs did not hatch in the jars, since they could not be prevented from adhering to each other in masses, and they soon died.

The effects of changes in temperature of the water on hatching were observed. The highest temperature at which the larvæ were observed to hatch normally was 78° F. The temperature of the water fluctuated considerably during the day, the range being from 76 to 98° F. The changes often occurred abruptly and marked the death of many larvæ. Many of the eggs did not hatch at 98° F., and the larvæ which did emerge at the higher temperatures usually died before becoming entirely free of the egg membrane.

It was observed that the temperature of the water fluctuated less during the night, especially when the tide was rising, and it remained not far from 76° F. It was inferred from this that the temperature offshore was not far from 76° F. It, therefore, does not seem probable that hatching takes place in shallow water where the temperature conditions apparently either inhibit the hatching of the eggs or cause the larvæ to emerge in a weakened condition. It is known that the phyllasomes of closely related species have been taken in 75 fathoms of water far offshore.

The embryo about to hatch is much compressed within the egg membrane, and it is colorless and transparent except for the black eyes and bright yellowish red dot of unabsorbed yolk, which are opaque. It was found necessary to reduce the flow of water in the jars at this stage, because the embryos are buoyant and hatch as they float upward. The larva emerges much doubled up, like a fleck of cotton waste, but quickly straightens out into the normal position and at once begins to move about actively.

The first-stage larva (Fig. 273) is a phyllasome which is a modification of the mysis or schizopod larva of other Macrura, such as the northern lobster, but the subsequent development is by no means the same. The short embryonic development predicts a long larval development which may render artificial propagation a very difficult problem.

No cannibalistic tendencies were noted among the larvæ, but plenty of space should be provided, to prevent their appendages which are long and provided with numerous spines and setæ, from becoming closely entangled with those of other larvæ. This danger is especially great unless the light is diffused, since the larvæ are decidedly heliotropic. They become massed together and must be separated by means of some stirring device. Silt suspended in the water becomes lodged on the setæ and spines of the larvæ and weights them down to their death. Feeding was attempted, but the results were negative. The food of the larvæ is probably other plankton, and any method that can be devised to increase the growth of these organisms will greatly aid the solution of a difficult problem.