CARIBBEAN FISHERIES SESSION

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Chairman – James A. Prunty, *Marine Regulations Advisor, Mobil Oil Corporation, New Orleans, Louisiana*

A Study of the Spiny Lobster Fishery of Antigua and Barbuda

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INTRODUCTION

There has been a decline in the landings of spiny lobsters (*Panulirus argus*) in Antigua and Barbuda over the last 4 years, at a rate of possibly 15% per annum. This problem caused particular concern in Barbuda where the lobster fishery is one of the most important activities and led the British Overseas Development Administration to undertake a project to study the industry, and to appoint a marine biologist to work in the Fisheries Division of Antigua and Barbuda. This paper is an outcome of that project.

A large or long term project would have been unrealistic in view of the relatively small scale of the fishery, thus the project has been aimed at the best coverage of relevant aspects of lobster biology possible within 16 months. There is a lack of detailed statistics outlining the history of the fishery, thus the conclusions have had to be based on field experiments and data collected during the project period. Sophisticated yield estimates leading to precise regulations governing minimum size and quotas could not be attempted within this time frame. However, these small island fisheries have not developed to a point where such refined regulation can be applied, and qualitative advice is more useful than quantitative detail. Information to redirect the fishery was required, with future refinements to be based on subsequent collection of statistical data.

ANTIGUA AND BARBUDA

Antigua and Barbuda, two islands of the Lesser Antilles, have respective areas of 108 and 80 square miles, and respective populations of 69,000 and 1,200 (Fig. 1). These islands share a bank of approximately 1360 square miles of which 74% is less than 120 feet deep. A pattern of shallow reefs forms a rough semicircle around the windward side of each island. Reef protected areas of shallow turbid water have a larger temperature range (25.5 – 30.5°C) than the offshore water (26.0 – 29.0°C). The reefs and inshore shallows account for less than 10% of the bank.

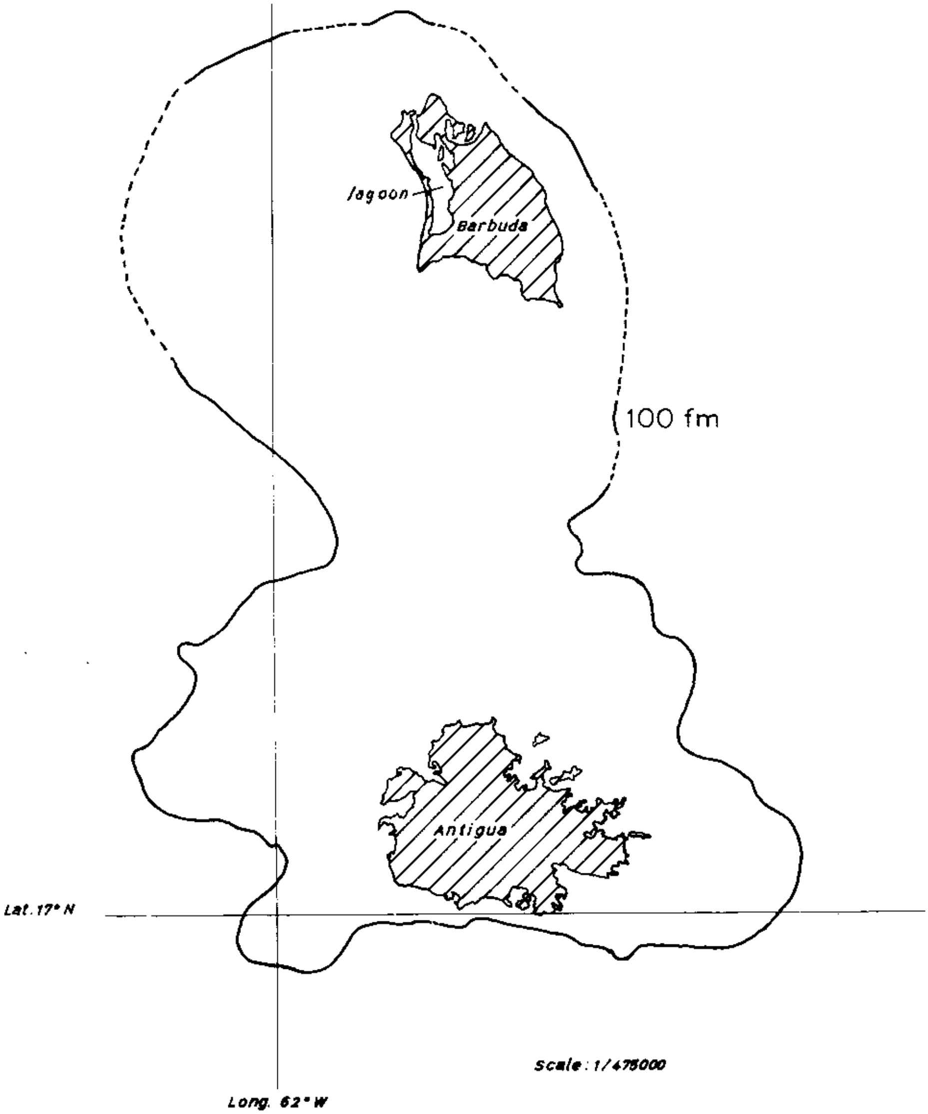

Fig. 1. Antigua and Barbuda Bank.

Three gross ecological divisions can be made: (1) THE OFFSHORE BANK has an average depth of 80 feet and areas of low coral growth. (2) THE REEF COMPLEX is mainly offshore and fringes the islands. (3) THE LAGOONAL AREAS lie between the reef complex and coastline (and are termed lagoonal after an area studied in Barbuda). They are characterized by a lack of extensive reef development, together with fine bottom sediments and abundant growths of marine algae and Thalassia. Habitats 2 and 3 tend to become mixed on the leeside of the islands.

THE FISHERY

The fishery employs both Antillean fishtraps and free divers using wire lassoes. The traps are rectangles of 1.5 inch wire mesh on wooden frames with two 6-inch width funnel entrances and overall dimensions of 5 x 4 x 1.5 feet.

Legal regulations apply only to exported animals, setting a minimum size of 9 inches total length and restricting export of berried females.

The great bulk of the catch is *Panulirus argus*, with *P. guttatus*, *P. laevicauda* very occasionally caught although the former is locally abundant. The fishery can be divided into three sectors.

The Inshore Fishery is casual and diffuse around the coast of each island. The catch is taken from lagoonal areas and the reef complex by both traps and diving. It is locally consumed, and is a small proportion of the total catch in Antigua but more important in Barbuda.

The Diving Fishery is the main Barbudan fishery employing 10 to 15 full-time divers working from open motor boats. The divers fish mainly on the reef complex but probably exploit offshore lagoonal areas as well. Lobsters from this fishery, and to a smaller extent from the inshore fishery, are exported live to Puerto Rico. Present exports are in the region of 25,000 lbs. per annum.

The Trap Fishery is the most important fishery and is based in St. Johns, Antigua. There is a fleet of 38 locally built 25- to 40-foot diesel powered sloops. They exploit the offshore bank at depths from 50 to 150 feet, fishing mostly to the west of each island and between the islands. Each boat fishes between 40 and 60 unbaited traps which are set in 2 ranges and pulled alternately allowing each trap a 7-day soak. The traps catch both reef fish and lobster, and in many cases the former is the more important economically. The lobster landings have declined from approximately 1.5 lb. per trap to 1.0 lb. per trap (0.4 lobster per trap) over the last 4 years, and attempts to increase production by using Florida slat traps and hide-baited traps have been unencouraging. Exploratory fishing with Nicaraguan wire traps also gave very poor results (UNDP/FAO Project 1971). This is then perforce an unintensive lobster fishery, but as an ancillary to the fin-fishery is valuable. Approximately 110,000 pounds are exported annually.

PROJECT PROCEDURES

As there were no statistical data sufficiently detailed to be biologically useful, project effort was partly directed towards collecting these data for the year August 1972 to August 1973 and partly based on field experiments. These activities were: (1) The landings of each sector of the fishery were sampled regularly. (2) A tagging experiment was conducted in the lagoon of Barbuda. (3) The rates of settlement of larval lobsters were monitored through the year. (4)

Temperatures and salinities were recorded at 6 stations located between the shallow lagoonal environment and the open sea. (5) Lobsters were observed in their various environments in the course of 67 daytime and 6 nighttime free and SCUBA dives. (6) Lobsters were reared in cages to observe the effects of tagging, and to gain further information on growth. In this paper, the first three objectives of the project are discussed in detail, and the results and observations from the latter three included where relevant.

RESULTS

Landings Samples

I examined 3800 lobsters on a monthly basis, of which at least 1000 came from each sector of the fishery. Size was always measured in terms of carapace length (cape) from between the ocular horns to the posterior edge. It is related to total length according to the formula:–

Total length = 2.61 cape (males)

Total length = 2.91 cape (females)

Because of the difference in the growth characteristics between the sexes only one sex (male) is depicted in the size-frequency diagrams 2b and c. Moulting lobsters are not caught by trap, and the incidence of moulting was estimated from diver caught samples. Sexual state was established by the presence of eggs or spermatophores on the female.

The Inshore Fishery

The inshore fishery was studied only in the lagoon at Barbuda. This virtually land-locked body of water has an area of 7.48 square miles and connects to the sea through a narrow mangrove-lined channel. It typifies the "lagoonal" habitat, being shallow (nowhere deeper than 10 feet), and having a fine sediment bottom with scattered patches of Thalassia and various marine algae. There are no reefs, and only isolated coral colonies of *Porites furcata* and *Mancina areolate* were observed. However, it is atypical in having high salinities particularly at the south end range from 42 to 50 parts per thousand.

Most samples were taken by unbaited Antillian fish trap. Samples taken by free diving on artificial habitats had an almost identical size distribution as those caught by the Antillian traps, except that there were some smaller lobster present which were not caught by the traps. The size-frequency distribution is shown in Figure 2a. The mean is 6.3 cm; the mode is in the 6- to 7-cm size class and the range is from 4 to 9 cm.

Lobsters with cape lengths from 1 to 4 cm were readily collected by diving in the lagoon, especially in autumn and winter months, and their absence from the traps probably indicates uncatchability. Lobsters over 10 cm were never collected by diving and are apparently absent from the lagoon, and as this cannot be all due to mortality it must be the result of emigration. No lobster was recorded with external evidence of sexual maturity in a sample of more than 500 females. Local fishermen report that berried females have never been caught in the lagoon. Thus the lobster population of the lagoon is (a) entirely immature and (b) emigrates before the lobsters reach a cape length of 10 cm. Lagoonal

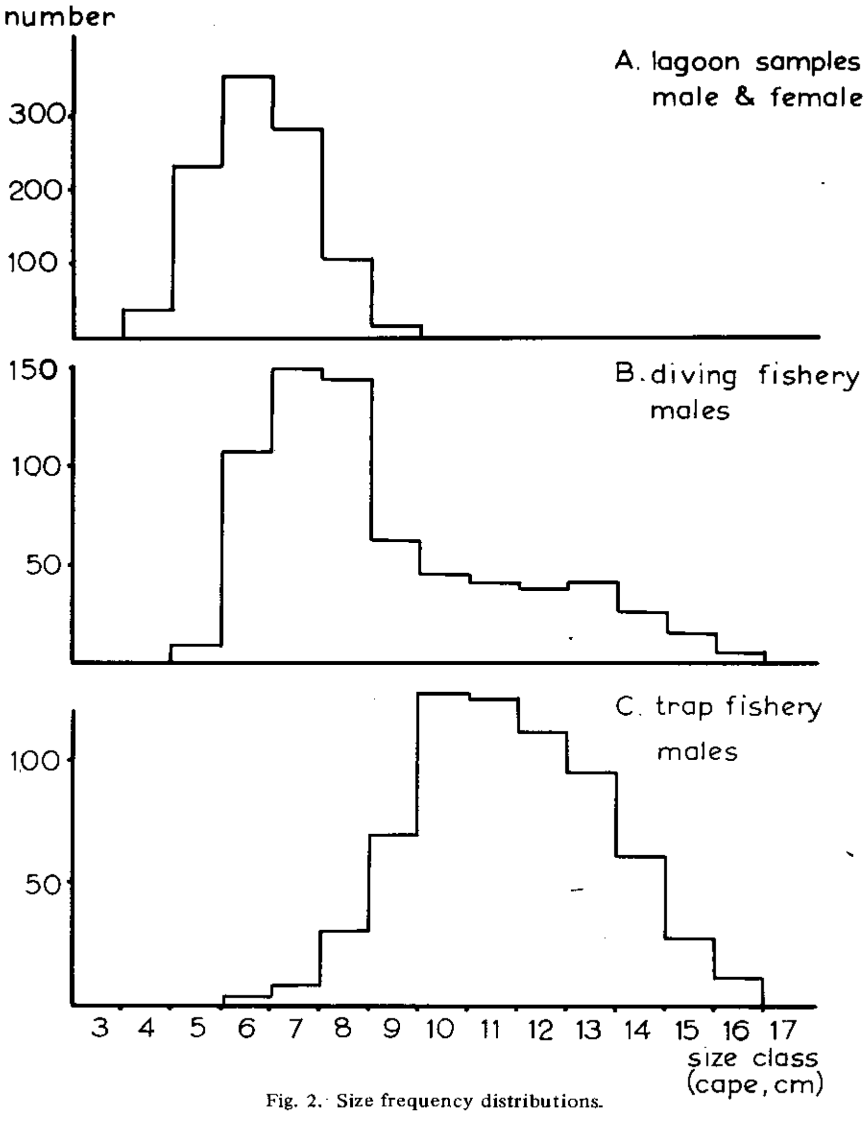

Fig. 2. Size frequency distributions.

environments were sampled in other areas off the Barbuda coast and contained very similar lobster populations with modes between 5 and 7 cm and range from 4 to 8 cm.

The Diving Fishery

The size distribution in Figure 2b describes the catch taken from the Barbudan reef complex and offshore "lagoonal" areas. It is complicated with a mode in the 7-to 8-cm size class, a mean of 8.86 cm and a wide asymetrical range from 5 to 17 cm.

The large proportion of the sample with a size of less than 10 cm and a mode of 7 to 8 cm can be interpreted as the result of exploitation of lagoonal areas. This overlies a distribution from at least 8 to 17 cm which would then be the catch from the reef complex. My diving on the reef complex tended to confirm this hypothesis as lobsters of sizes from 3 cm to 13 cm were observed. The smaller lobsters were found on very shallow inshore reefs, whereas animals over 11 cm were not caught in depths less than 20 feet. Thus, lobsters can be collected from the shallow reefs over most of the life span. The very old animals (17-cm males and 16-cm females) were collected only from the reef complex.

The Trap Fishery

This sample is taken from the offshore bank and is shown in Figure 2c. The great majority of lobsters are larger than 9 cm, with a mean at 11.36 cm and a mode in the 10- to 11-cm size class. The range is from 6 to 16 cm. Lobsters are recruited to this fishery over the range of 7 to 9 cm either by migrating into the fishing area, or by already being present and becoming catchable. It is known that lobsters of 4 cm are readily caught in traps identical to those used in the Barbuda lagoon, and over the range of 6 to 9 cm the samples appear to represent the population well. Thus the inference is that lobsters are recruited to the offshore bank fishery by immigration.

Migration

These three sets of samples indicate a pattern of migration from the lagoonal areas to the offshore bank. If the average size of the migrants is estimated as the respective inflexion of the distribution curve, the emigrants from the lagoon average 8 cm, and the immigrants to the offshore bank average 9.25 cm. This suggests that the migration is not direct, but involves a period of time which may be spent on the reef complex.

The monthly samples from the lagoon and offshore bank were studied for indications of seasonal migration. (The reef complex sample is unreliable because changes in the proportion of the "lagoonal" lobsters cannot be assessed.) These distributions suggest that migration occurs throughout the year with two peak activities. (1) The mode of the lagoon sample drops from the average annual value of 6 to 7 cm to 5 to 6 cm during the months from April to June. This is unlikely to be the result of growth of smaller lobsters recruited to the catchable size as a preceding peak in the 4-cm size class was not apparent. This may indicate a lowering of the mode by emigration of larger animals. (2) The offshore bank sample showed a recruitment of lobsters in the 7- to 9-cm range during the months from September to February. Table I shows the proportion of the lobsters under 10 cm as a percentage of the whole sample for quarterly periods. This indicates a winter peak in recruitment during December, January, and February.

Table 1. Percentage of Offshore Bank Lobsters with Cape Lengths Less than 10 Cm

Month	%
9 - 11	22.4*
12 - 2	30.3
3 - 5	26.8
6 - 8	15.5
Annual average	23.5

* Small sample of 74

Breeding and Moulting

First sexual activity in terms of external characteristics occurs in 8- to 9-cm lobsters, and is at a maximum in lobsters from 10 to 13 cm. Females larger than 13 cm have a lower incidence of egg bearing and a high incidence of fresh spermatophores that have not been used for fertilizing eggs. This may indicate a degree of senility. Breeding occurred throughout the year, with most activity during the months from May to August. In no sector of the fishery was there a significant difference in the sex ratio (P = .05) either during the year, or for the whole year.

Moulting animals were characterized by external signs of either premoult lateral-carapace fissures or post-moult softness. This would include 8 to 10 days of the moult cycle. (Travis, 1955). There was no defined moulting period, 10% ± 5% moulted in any month of the year.

Tagging

1100 lobsters ranging from 5- to 9-cm cape length were tagged in the Barbuda Lagoon from December 1972 to August 1973 in monthly groups of approximately 120 animals. They were alternately tagged with flat dart tags under the first abdominal tergite or with sub carapace FT6 sphyrion tags. These tags were numbered, and implanted in the muscle so that most are retained on moulting. All lobsters were additionally marked by punching a hole in the telson. After tagging the animals were immediately placed in a sea water crawl, and held for at least 2 hours to eliminate initial mortalities. Healthy animals were released over a Thalassia bed in the lagoon where there was ample protection. 74 animals were recovered, of which 13 had illegible tags. Of the 61 useful returns, 51% had moulted. A further 7 tags without lobsters were returned by divers fishing the reef complex at distances up to 7.3 miles from the release point.

Growth

Size increases ranged randomly from 4 to 15% with no clearly defined moult classes. This was equally true of lobsters reared in captivity when single moult increases of 0 to 13% were recorded for similar sized animals. As the growth caused by one moult could not be separated from that caused by several, the average increase per moult was calculated for each size class. The inter-moult period was estimated from the average period non-moulters were free. When this is known, the growth per moult of the moulters can be calculated from the size increase and period free of the moulters (Table 2).

Table 2. Growth of Returned Tagged Lobsters

Size Class (cm)	Moulters (returned)	Non-moulters (returned)	Intermoult Period (days)	Growth per molt (cm)
5-6	4	0	60*	0.85
6-7	14	4	70	0.58
7-8	10	16	80	0.56
8-9	2	8	74	0.75
9-10	2	1	85*	0.56

*extrapolated

The growth rate was alternately estimated from average growth per time free in each size class. These values agreed closely with those calculated above with the exception of the 8- to 9-cm class, and the estimate for this class was averaged. The growth rate is shown in Table 3.

Table 3. Growth Rate

Cape Length (cm)	Time from Settlement (yrs.)
5	x
6	x + .3
7	x + .6
8	x + 1
9	x + 1.45
10	x + 2

The value x was tentatively estimated from a Ford-Walford plot of length at t against length at t + 1. If growth of the early juveniles follows the same pattern as subsequent growth, x is approximately 1 year.

Stock Density

The results from the tagging experiment were also used to make a mark-release-recapture estimate of the stock size of catchable lobsters (5- to 9-cm cape length) in the lagoon. This was calculated by Bailey's (1951) lincoln index, where

$$N = \frac{M(n) + 1)}{(m + 1)} \quad \text{and} \quad Var(N) = \frac{M^2(n + m)(n - m)}{(m + 1)^2(m + 2)}$$

N = total population
M = total number of tags
n = number of animals in a subsequent sample
m = number of tags in that sample

The samples (n) were taken monthly by supervised fishing (and in part comprised the subsequent batch of tagged lobsters). The estimate was made over the months from April to July 1973, after the experiment had already run for 4 months, and so the bulk of the marked population had been free for more than one month at time of sampling. During this period n was 802, and contained (m) 35 tags.

The number of tags free during this period was subject to continual change in two directions. There are both instantaneous increases at the end of each month as the tags are released and an overlying continual decrease due to mortality and migration. The former values are obviously known, but the latter has to be estimated. The tagged population was in essence the sample which is believed to represent the catchable population of the lagoon. The tagged population was assumed to behave similarly to the wild population, and so the decrease in numbers is expressed by the right-hand side of the distribution in Figure 2a for animals of over 6-cm cape length. The mean time taken for each size class to recruit to the subsequent class is known from the growth data, and so the summed decrease per size class, per month, can be calculated as follows,

$$\sum_{n=9/10}^{n=6/7} \frac{\text{number in class } n - \text{number in class } (n+1)}{\text{Time taken for class } n \text{ to recruit to class } (n+1)}$$

Size classes 4 to 5 and 5 to 6 cannot be treated in this manner and so an estimate was made of natural mortality by extrapolation. The estimate for decrease in M was 8.5% per month and this was applied to all batches released to give a monthly value for M.

The mark-recapture method requires a number of assumptions to be made. Three of these were avoided in the nature of the experiment. (1) Tag loss, which did occur, was not a problem because all animals also had a hole punched in the telson which lasts for at least 2 moults. (2) Incomplete reporting of returned tags was avoided by basing estimates on samples taken by supervised fishing. (3) Samples were taken by two methods – trap fishing and diving, and estimates of population based on either samples were similar. It is very unlikely that a similar bias for, or against, tagged lobster would exist in two so dissimilar methods of capture.

However, two assumptions had to be made. (1) That complete mixing ensured random distribution of tags amongst the wild population. The greatest distance animals can move from the release point within the lagoon was 3.4 miles, and most of the lagoon area was within 2 miles of the release point. Dawson and Idyll (1951) showed that lobster on average move 4 miles per month, and Little (1972) obtained a value of 2.3 miles, and so complete monthly mixing is probable. Incomplete mixing should decrease with time as the proportion of lobsters which have been free for more than 1 month increases. This would show in the results as an initial overestimate of the population with subsequent decreasing values, and as this was not observed over 8 months, complete mixing was assumed. (2) That tagged animals are subject to similar mortality as wild animals. Original experiments with captive lobsters showed that although initial mortality could be high, subsequent survivors apparently fared as well as untagged animals. Thus, as was mentioned above, all animals were held prior to release to remove the initial mortalities. Field observation of released animals showed that provided they were active on release (measured by regular scaphognathite beating) recovery was rapid and subsequent mortality minimal.

Stock size estimates are given in Table 4.

Table 4. Stock Size in Barbuda Lagoon

Values	April (TS)*	May (TS)	June (TS)	July (DS)*
M	364	430	542	605 (mean 485)
n	329	185	95	193 (total 802)
m	16	5	4	10 (total 35)
N	7100	13000	10400	10700
±	3000	10000	8000	5500

*TS = Trap sample
*DS = Diver sample

A mean value from the summed results was 10800 ± 3360. This is a density of from 1000 to 1900 catchable lobster per square mile. (This gave a catch rate of 5.25 lobster per trap-week (2.5 lbs) with a standard Antillian trap).

Larval Settlement

Witham et al (1968) describe a floating habitat for collecting settling puerulus lobsters after they had completed their planktonic larval stages. Similar habitats constructed from non-woven nylon sheets or teased lengths of rope mounted on a 1-foot square section of board were placed in Parham Harbor, Antigua, and the Barbuda Lagoon. No puerulus were collected within the lagoon, but were collected from the roots of mangrove lining the narrow entrance. Local fishermen report large concentrations being seen here in late summer. The two habitats at Parham Harbor collected 86 puerula during the year at a rate of 0.2

larvae per inspection, (the habitats being inspected 6 to 11 times per month). During the months from May to October settling rates were much higher with monthly values up to 2.75 larvae collected per inspection, as shown in Figure 3. The bulk of the summer settlement occurred in two periods, each of less than one week, when 64% of the total was collected. During the second peak settlement period, larval lobsters were collected from similar locations at the opposite end of the island. In the light of the work by Ingle et al (1963) the settling puerula, which are the final stage of a long planktonic larval life, probably are carried by currents from distant breeding populations to the southward. The peak settlement can be seen as the result of water masses rich in late-stage larvae occasionally passing Antigua. This appears to be an important part of the initial recruitment, overlying the sporadic year round settlement.

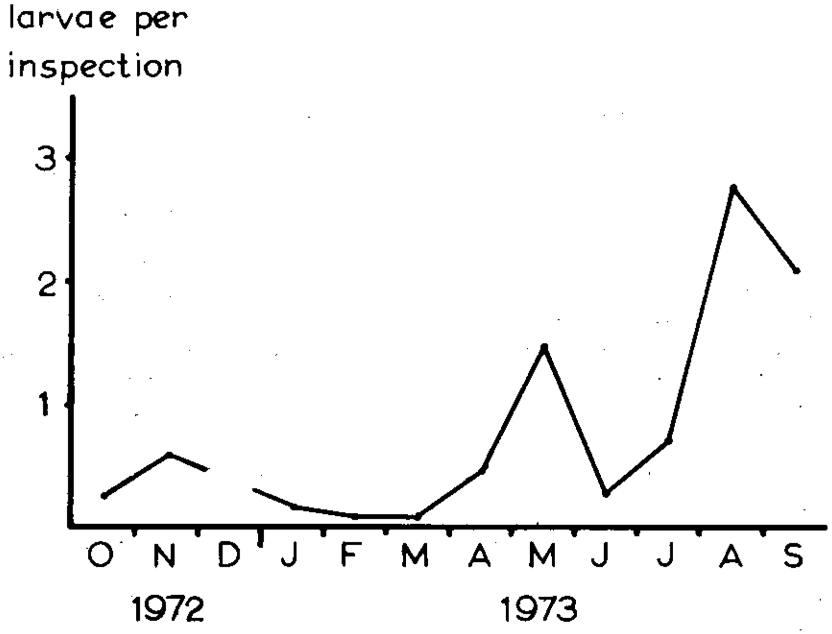

Fig. 3. Larval lobster settlement habitat at Parham Harbor.

Feeding

The mandibles of *P. argus* are massive, and the working surface has two components. There is a pair of grinding molar surfaces, and a combination of peg and friction pad diagrammed in Figure 4. The peg does not occlude with the friction pad and appears to act analogously to a nut cracker. Wear on the peg during the course of an intermoult period can reduce its height by 50%. Thus, the mouthparts are adapted to crushing hard shelled animals or plants.

The food taken by the lobsters was studied in two ways. (a) The collected frass of 10 lobsters inhabiting a car tire placed in the lagoon was retained within

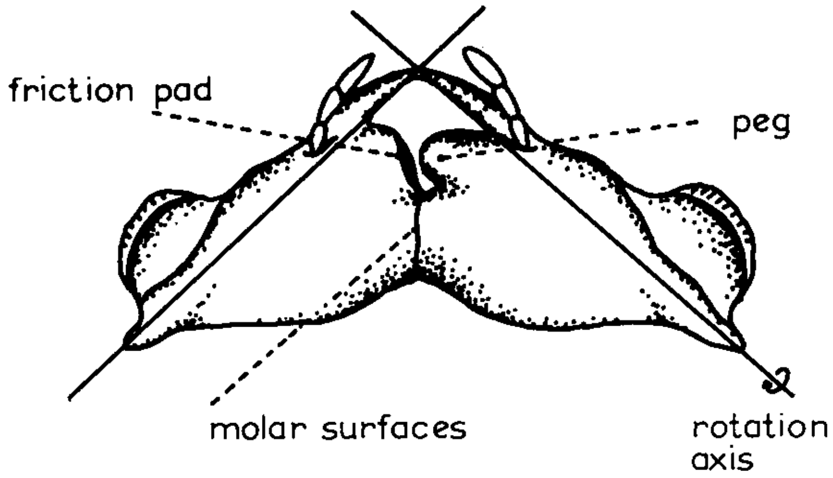

Fig. 4. Mandibles of *P. argus* (ventral view).

the tire and could be sampled. (b) Lobsters were observed by night on a shallow reef and eight were collected after midnight to insure the gut was full. Lobsters caught by day invariably had empty guts.

Reef lobsters became active after dusk, feeding on the reef and over adjacent sandy areas. Gut contents included algae, foraminifera, sponge spicules, polychaetes, and sand, but the principle contents were fragments of crustaceans, gastropods and bivalves. Lagoon lobsters' frass contained only mollusc fragments. *P. argus* appears to be an opportunistic carnivore with feeding behavior adaptable to the variety of foods of the reef or the mollusc-rich lagoon.

CONCLUSION AND RECOMMENDATIONS

The findings of the various sections of the project show a pattern of environmental preferences with the development for the immature and recently mature lobsters, and a tentative model for their growth and movement can be formulated. The initial recruitment from the plankton occurs throughout the year but reaches a maximum during summer. A proportion of this occurs within the sheltered lagoonal areas, probably along their mangrove flanked edges. The new recruits develop to prematurity in these areas, where the limiting factor is more likely to be protective cover than food. They are gregarious, often found in concentrations under available cover. With oncoming maturity (cape length 6 to 9 cm, age 1.5 to 2 years), they begin to migrate into offshore deeper water, the peak movement possibly occurs during early summer. This is not so much a discrete event but a sporadic migration through the shallow reefs lasting several months. The maturing animals (cape length 8 to 9 + cm, age 2 to 2.5 years) move onto the offshore bank during autumn and winter in a more clearly defined migration which becomes apparent as winter recruitment to the trap fishery.

This is not the only pattern of habitat preference shown by *P. argus*, because it is also evident that they can initially recruit almost directly to the shallow reefs and develop to maturity there. There is also probably a continual inter-change of juveniles from lagoonal habitats with those on the shallow reef, and a further inter-change between shallow and deeper reef populations. However, this complex situation can be simplified by regarding the lagoonal and offshore bank environments as the extremes of environmental preferences by juveniles and mature sectors, with each sector being found almost exclusively in the respective environment. The onshore reefs, being both shallow and often adjacent to lagoonal environments, is a compromise and thus caters to both sectors. It is possible that the oldest and possibly senile lobsters (cape 15 to 17 cm) move back into shallower water as described by Sutcliffe (1953) for the Bermuda *P. argus* population.

The stock density in the lagoon was found to be high. Similar Antillian traps had a much higher catch rate there than on the offshore bank. (The lagoon catch in terms of numbers per trap week was more than 10 times higher than the banks, and 2.5 times greater in terms of total weight). It is then probably that these areas are very important and that shallow areas in general are critical to eventual recruitment to the offshore bank.

Thus the lagoonal areas contain high densities of juvenile lobsters, which in view of the shallow depths and lack of protective cover are particularly vulner-able to divers. This means that conservation measures in terms of actually changing the location of the fishery are most realistic, and the following recom-mendations are made: (1) That fishing effort in lagoonal areas should be reduced as much as possible. (2) That this should be balanced by redirecting the fishery from diving in these areas to the use of traps on the offshore bank adjacent to Barbuda. (3) The minimum size limit regulations should be particularly directed at the diving fishery on tne reef complex to shift the emphasis away from smaller animals caught in offshore lagoonal areas, and on to the larger size sector of the coral reef population. The offshore bank landings are mostly above the legal size and so there is a natural enforcement of the regulation tied in with the location of the fishery.

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