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SPINY LOBSTER RESEARCH REVIEW
PROCEEDINGS OF A CONFERENCE HELD DECEMBER 16, 1976
IN KEY WEST, FLORIDA

Compiled and Edited by
Dr. Richard E. Warner, former Marine Agent and County Extension Director, Monroe County, Key West, and Principal Investigator on the project covering the Biological Studies of The Florida Spiny Lobster.

Sponsored by
Monroe County Marine Advisory Program

The information contained in this paper was developed under the auspices of the Florida Sea Grant College Program, with support from the NOAA Office of Sea Grant, U.S. Department of Commerce, grant number 04-7-158-44046. This document is a Technical Paper of the State University System of Florida Sea Grant College Program, 2001 McCarty Hall, University of Florida, Gainesville, FL 32611. Technical Papers are duplicated in limited quantities for specialized audiences requiring rapid access to information, which may be unedited.

Technical Paper No. 4
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INTRODUCTION

The large populations of the spiny lobster (Panulirus argus; family Palinuridae) in South Florida waters form the basis of the state's second most valuable commercial fishery, after shrimp. They also support a large and rapidly growing marine recreational activity. Steadily increasing fishing efforts have been accompanied by a reduced catch per unit of effort that for many is unsatisfactorily low. Associated increases in capital outlay, maintenance, and fuel costs have reduced profits. Questions concerning 1) a further reduction in minimum size for commercial and sport harvest, 2) age and size for onset of reproductive activity, 3) optimum age and size for harvesting, and 4) the effects of limited entry and/or other management practices on the economics and biology of the resource are asked by user groups with increasing frequency.

Over a period of three years beginning about 1974 there had developed a significant group of biological and economic research programs on the spiny lobster populations of South Florida. This included a research project sponsored by the Florida Sea Grant College Program in an attempt to answer the biological aspects of the above questions and to promote and facilitate ancillary studies so that wise management decisions could ultimately be made jointly by user groups and the relevant management agencies. Economic analysis of effort and yield in the Florida spiny lobster industry was also funded by Florida Sea Grant.

By the end of 1976 some of these studies had advanced to the point where important and interesting data had been produced and were available for dissemination. It was felt that other programs in earlier stages of activity would materially benefit from greater public awareness of their goals and procedures.

At the same time both the commercial and recreational spiny lobster fisheries had been reviewing their own needs and plans for the future and in some cases were drafting legislative proposals. Similarly the Florida Department of Natural Resources had been engaged in an ongoing review of management practices for the resource in order to keep abreast of changing use patterns and resource needs. The various activities were at a point where a thorough and careful assessment of progress and needs appeared to be fruitful, especially for the research interests where a comparison of recently obtained field data would facilitate planning of future research and integration of new findings.

To address these questions the Monroe County Marine Advisory Program sponsored a conference in December 1976 in Key West. The intensive one-day meeting devoted itself to a review of recent advances in spiny lobster research and problems and needs of the spiny lobster fisheries. This report, containing papers presented at that conference, is published to inform interested persons of the many aspects of this important Florida marine resource.

ECONOMIC MODELS FOR MANAGEMENT OF FLORIDA'S SPINY LOBSTER INDUSTRY*

Fred J. Prochaska and James C. Cato[1]

Increasing conflicts among spiny lobster fishermen and declining catch rates and size of lobsters are principal incentives for the research reported in this paper. The objectives were to provide a means for determining: 1) the maximum economic yield from the fishery; 2) the most efficient allocation of resources within fishery firms; and 3) the consequences of alternative management programs on production, costs, and profits. Accomplishment of these objectives required estimation of three econometric models. Each model and its use is summarized in the following discussion.

The industry production model in reciprocal form was estimated with multiple regression techniques. Data pertaining to the spiny lobster industry in Monroe County, Florida, for the years 1963 through 1973 provided the basis for estimation. Industry landings were shown to be significantly related to the number of traps fished per firm, the number of firms in the industry, and water temperature. These effort variables explained 80 percent of the variation in industry landings. Increases in the two effort variables, traps per firm and number of firms, both produce additional landings in the industry. However, the marginal increases in landings are declining with additional units of effort.

The decline in catch per additional unit of effort is due to ordinary diminishing returns expected in most production processes and possibly due to negative effects of fishing effort on the biological stock over time, since the data represent observations over time and no stock variables are included in the model.

A cost model, which expressed total firm cost as a function of the number of traps fished per firm and a fixed cost component, was estimated to be incorporated with the industry production model to determine maximum economic yield and optimum resource allocation. The statistical cost model explained 74 percent of the variation in costs of lobster fishing. A stratified sample of 25 Monroe County lobster fishermen was taken to determine production, costs and revenues in the industry for the 1974 season. These data provided the basis for estimating the firm cost function. The industry cost model was estimated as the product of the firm cost function and the number of firms in the industry.

The industry production model, lobster prices and the industry cost model together formed the industry revenue function. Maximization of the net revenue function with respect to units of effort resulted in a maximum economic yield estimate of 5.8 million pounds annually which is consistent with landings in recent seasons. However, an optimum allocation of resources would require 213 firms in the industry each fishing an average of 795 traps. Industry data in 1973 show 399 firms fishing an average of 429 traps each in Monroe County.

Management of the individual fishing firm's operations by the captain and/or owner of the firm is also a necessity for industry efficiency for any given level of total industry effort and/or output selected by management

*Abstract of talk presented at the Spiny Lobster Research Conference, Key West, Florida, December 16, 1976.

1. Food and Resource Economics Dept., University of Florida, Gainesville, Fl.

agencies. To provide guidance for efficient firm management a Cobb-Douglas firm harvest model and cost and returns were estimated from the data collected in a 1974 survey. Since the data in this model represent one production season the stock is considered to be fixed. Ninety-three percent of the variation in landings by individual firms was explained by the number of traps fished per firm, number of weeks fished, trap pulls per week and craft size. Each of these factors had positive effects on landings. Optimal levels of each of these factors depends on associated costs. The optimum level of traps fished per firm is highly sensitive to increases in lobster prices. This explains at least a part of the recent expansion in traps fished per firm.

These three models may be used to analyze numerous alternative fishery management programs, for example, setting a quote on total landings and then determining an optimum number of traps and firms. Complete discussions of the models and their usees are found in the following publications:

Williams, Joel S. and Fred J. Prochaska, 1976. The Florida Spiny Lobster Fishery: Landings, Prices and Resource Productivity. State University System of Florida Sea Grant Report No. 12, Gainesville, Florida.

Prochaska, Fred J. and Joel S. Williams, 1976. Economic Analysis of Cost and Returns in the Spiny Lobster Fishery By Boat and Vessel Size. Florida Sea Grant Marine Advisory Bulletin, SUSF-SG-76-004.

Prochaska, Fred J., 1976. "An Economic Analysis of Effort and Yield in the Florida Spiny Lobster Industry with Management Considerations", in Proceedings: 1st Annual Tropical and Subtropical Fisheries Conference, Corpus Christi, Texas, Texas A&M University, March 1976

Prochaska, Fred J. and Joel S. Williams, 1977. "Maximum Economic Yield and Resource Allocation in the Spiny Lobster Industry". Southern Journal of Agricultural Economics, Vol. 9, No. 1, July 1977.

Williams, Joel S. "An Economic Analysis of Alternative Management Strategies for the Spiny Lobster Industry", Ph.D. dissertation, University of Florida, Gainesville, Florida, December 1976.

SELECTED STATISTICAL ANALYSES OF KEY WEST SPINY LOBSTER DATA

Mark C. K. Yang and Bill Obert[1]

This report is based on data gathered in Key West, Florida, during the years 1974-1976.

The capability of lobster traps to retain small lobsters used as bait was analyzed. For one week soak periods, it was found that 933 out of 988 short lobsters used as bait remained in the same trap. Of nine short lobsters not used as bait, four returned during a one week soak period to the traps from which they were originally released. The probability that a short lobster used as bait would remain in its trap during a one week soak period was shown to be statistically significantly greater than the probability that a short lobster not used as bait would return during a one week soak period to the trap from which it was released.

An analysis of variance (ANOVA) was performed to determine the effect of using baits (short lobsters) on the catch per trap. Two statistical tests were performed, one using the total number of lobsters caught per trap as the dependent variable, and another using the number of legal-size lobsters caught per trap as the dependent variable. A four way classification ANOVA model was used in both cases. The classifications were: (i) area (four classes), (ii) month (seven classes), (iii) soak period (four classes - - one through four weeks), and (iv) number of baits used (two classes - - zero, and one or more). The results of this analysis showed that both the total catch per trap, and the legal catch per trap did significantly improve when one or more short lobsters were used as bait.

Length frequency curves from the beginning of the season and the end of the season indicated that the total mortality rates of juvenile lobsters and legal-size lobsters were almost the same (Figure 1). This result suggested that either there was an illegal juvenile lobster market which was similar (in numbers of lobsters) to the legal lobster market, or that juvenile lobsters have a very high mortality rate when put back into the water after capture, or that both phenomena combined to produce this result.

Data on changes in carapace length between recaptures were used to estimate growth rate. Assuming that the growth of lobsters follows von Bertalanffy's model:

$$\ell_t = L_\infty(1-e^{-K(t-t_o)}),$$

where ℓ_t is the carapace length of the animal at age t, and L_∞, t_o and K are three unknown parameters. We have estimated that L_∞=175 mm. and K=0.111. The comparison of this result with other lobster studies is given in Figure 2. This estimation is now subject to modification because we originally thought that negative growth was not possible, and discarded all the negative growth data. We have since been informed that a negative growth due to injuries is

1. Department of Statistics, University of Florida, Gainesville, Fl., 32611

possible in lobsters and should be considered in building the growth curve. With the two estimated parameters L_∞=175 mm. and K=0.111, and the estimated relationship between weight (W) and length (L),

$$W = 0.0026L^{2.7},$$

we found that relative weight increases were greatest for lobsters with carapace lengths between 70 and 90 mm.

Fishing pressure on the Lower Keys lobster population was also estimated. The beginning of the season capture rate (no. lobsters/trap day) and the end of the season capture rate for the 1975-1976 commercial season were used for this estimation. It was found that the yearly survival rate, (including natural survival and fishing survival) was 19%, which was larger than Maine's 10% survival rate, but comparable to New Jersey's 20% survival rate (Figure 3).

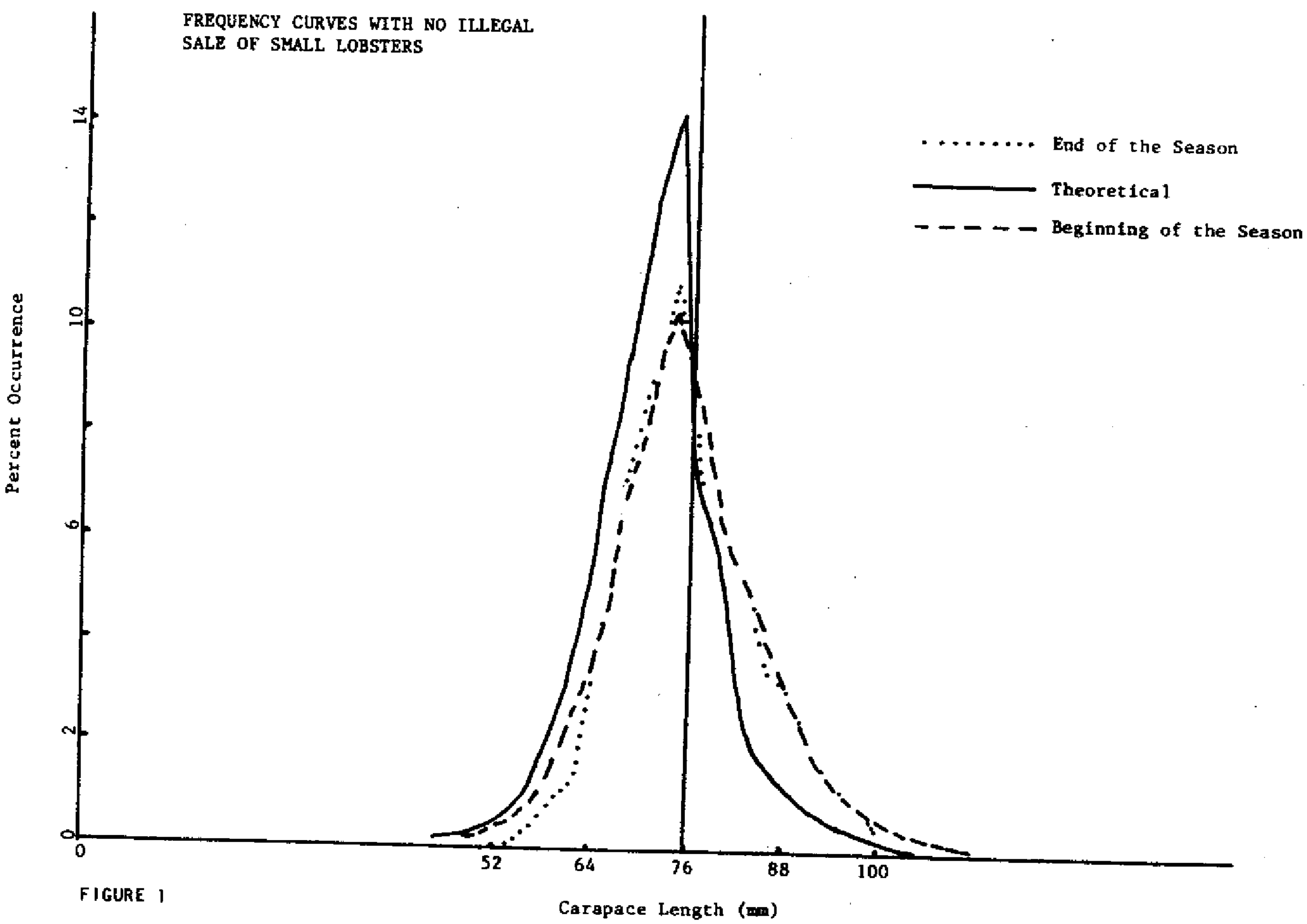


FIGURE 1

GROWTH CURVES

Parameters

	N.J.	Maine	Key West
K	0.127	0.043	0.111
L_∞	190	267	175

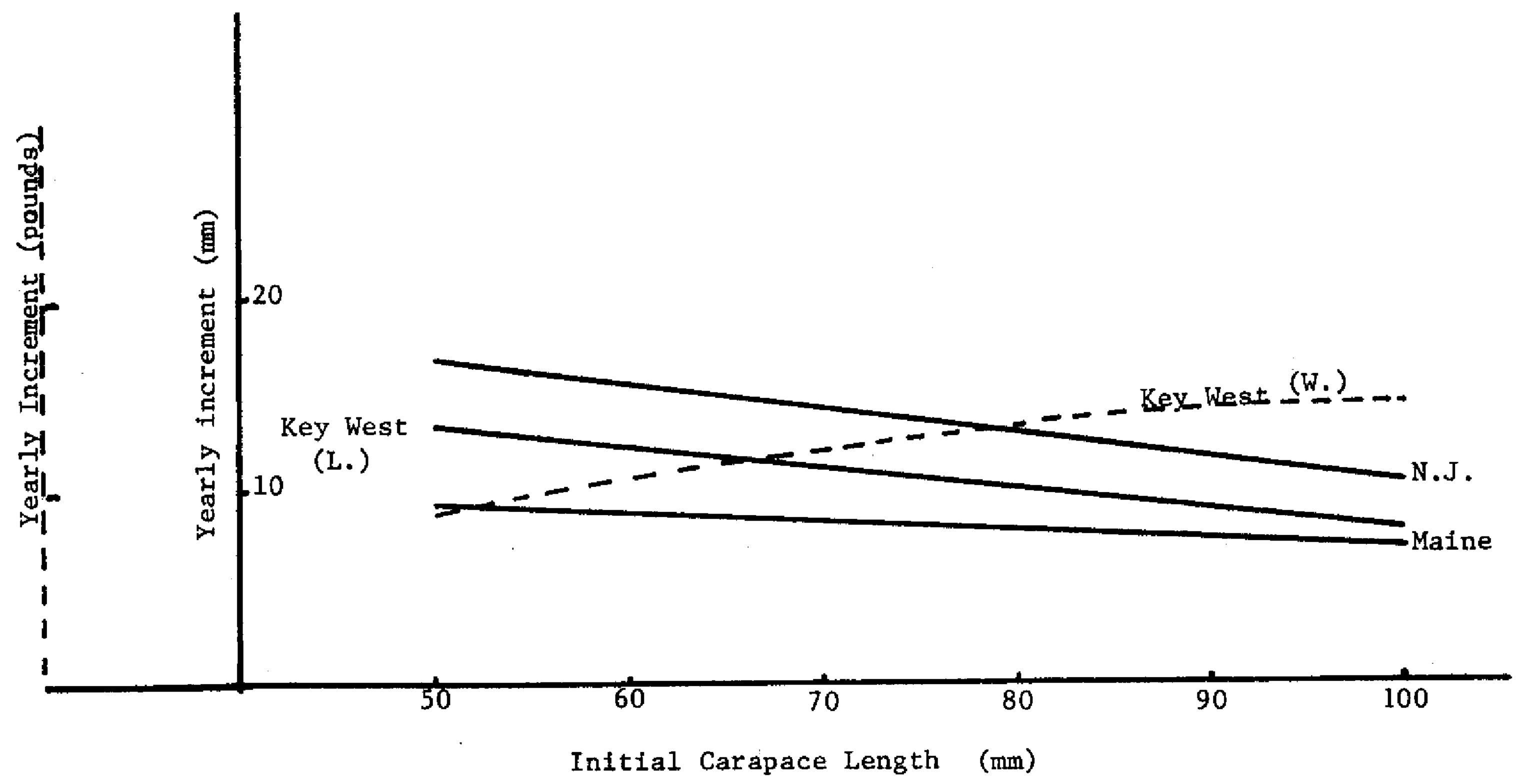
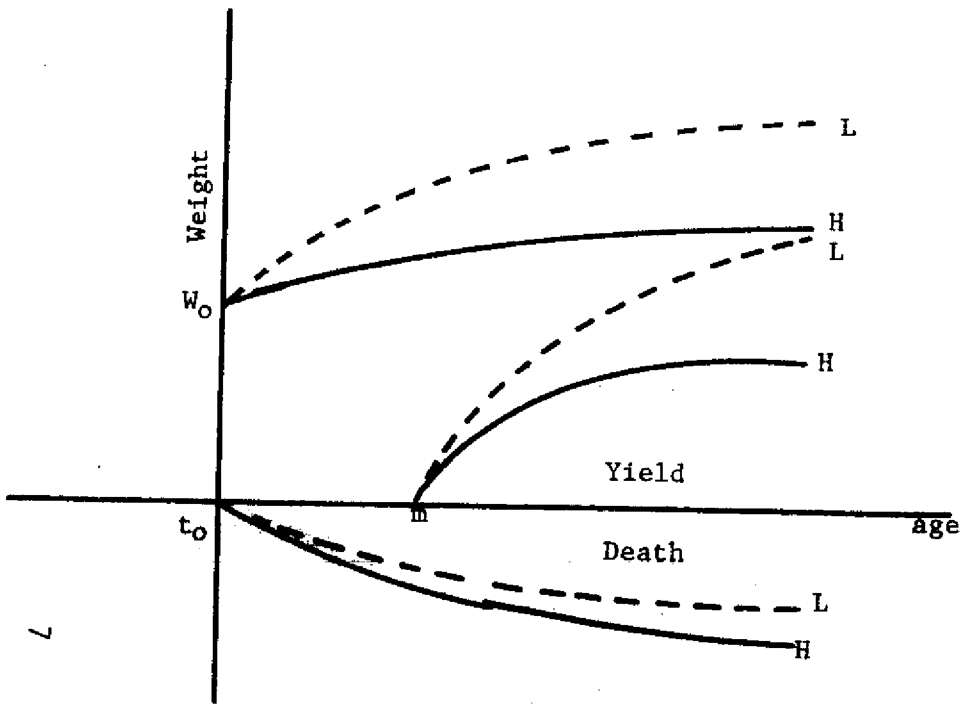
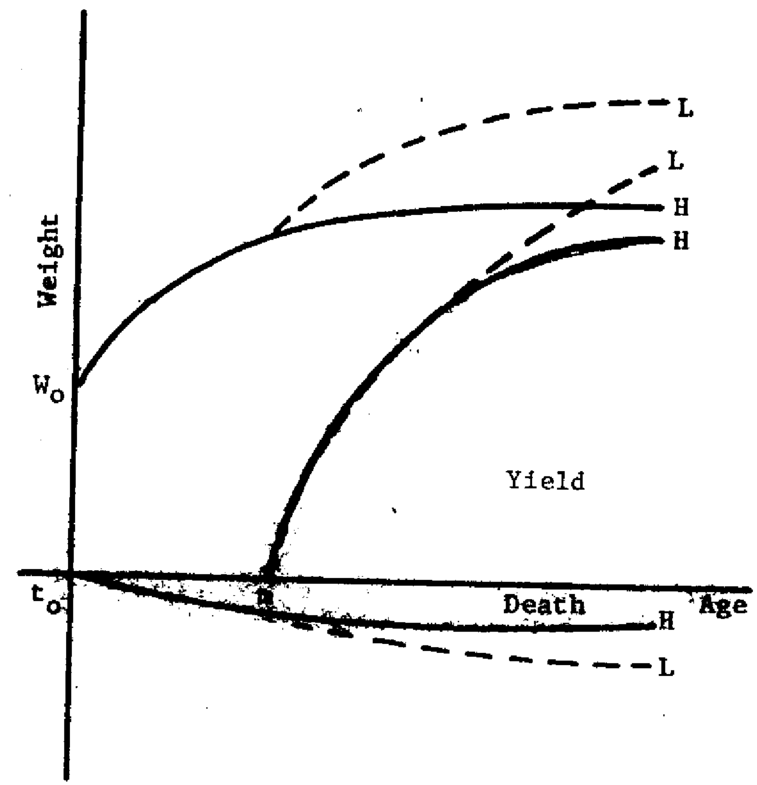


FIGURE 2

EFFECT OF NATURAL MORTALITY



EFFECT OF FISHING PRESSURE



Parameter of Fishing Pressure

	ME	NJ	Key West	VA
Z	2.30	1.63	1.68	1.205
S	10%	20%	19%	30%

FIGURE 3

NATIONAL PARK SERVICE SPINY LOBSTER FISHERY RESEARCH IN FLORIDA

A PROGRESS REPORT

Gary E. Davis[1]

SUMMARY

A 1974 Florida Sea Grant meeting identified 13 major problems and research needs for the Florida spiny lobster fishery. Results and observations from six years of National Park Service spiny lobster research which address several of these topics are presented.

Recreational harvest alone effectively reduced a previously unfished lobster population by 50% in a single season. The average minimum size of maturity of female spiny lobsters at Dry Tortugas was found to be 80-85 mm carapace length (CL), significantly larger than previously reported for Florida, which showed that the current minimum harvest size of 76mm (CL) does not protect a reproductive stock from exploitation. The natural average annual mortality of adult lobsters at Dry Tortugas was 23%, and the total average annual mortality rate was 40%. Tagged juvenile lobsters from Biscayne Bay migrated into the Keys fishery, all the way to Key West. Adult lobsters at Dry Tortugas showed virtually no long distance movement over a three year period. Spaghetti tags (Floy FD-68B) were shed at the rate of 10% per molt by juveniles (35 - 85 mm CL) in Biscayne Bay. Juvenile lobsters occupied concrete block shelters in high densities (mean 2.4/block), but creation of substantially more shelter did not increase the lobster population in the study area, suggesting that shelter is not the limiting factor on the juvenile population in Biscayne Bay.

Creation of a nursery sanctuary in Biscayne National Monument was proposed to increase fishery production. Fishery related injuries caused a 40% reduction in growth rate in an area where over 95% of the lobsters were smaller than the minimum harvest size. The reduced growth rate could delay recruitment into the fishery by a year or more, increasing mortality prior to reaching legal harvest size. A nursery sanctuary would significantly decrease injuries to juveniles and hence increase recruitment of young adults into the fishery. Evaluation of the nursery sanctuary concept would require cooperation of management agencies (both state and federal) and user groups (both sport and commercial), and should begin soon.

PROGRESS REPORT

Nearly three years ago Florida Sea Grant convened a meeting of scientists and fishermen at which 13 major problems and/or needs of the Florida spiny lobster fishery were defined and discussed. At that time declining catch per unit of fishing effort, maximum sustained yield estimates, limited entry to the fishery, minimum harvest size of individual lobsters, fishery recruitment, lobster migratory behavior and patterns, larvae identification, water pollution, oceanographic conditions affecting larvae dispersal, law enforcement, and in-

1. Everglades National Park, P.O. Box 279, Homestead, Fl., 33030.

adequate fishery statistics were all identified as major problem areas contributing to economic and biologic stress on the fishery. (Seaman and Aska, 1974). These are still the problems, but I think we are beginning to get some answers from our research that allow us to address these problems and suggest testable management programs to improve the fishery.

The following topics represent a potpourri of results and observations from the National Park Service lobster research projects which are directly applicable to fishery management problems: 1) the effects of recreational harvest on a lobster population; 2) the size of maturity of Florida lobsters; 3) mortality rates of fished and unfished lobster populations; 4) growth rates and the effects of injuries on growth rates; 5) migratory patterns; 6) effectiveness of spaghetti tags for marking spiny lobsters; and 7) the use of artificial habitats to increase lobster populations.

The National Park Service manages about one third of the juvenile spiny lobster habitat in Florida and nearly 100,000 acres of coral reef inhabited by adult spiny lobsters. Therefore, in addition to the problems identified in the 1974 Sea Grant meeting, the National Park Service needed to identify and address the impacts of fishery activities on the natural ecosystems of the park areas in south Florida.

Three years prior to the 1974 Sea Grant meeting I began an investigation of the impact of recreational harvest on the lobster population in Fort Jefferson National Monument at Dry Tortugas, Florida. Briefly, we found a large, resident population of juvenile and adult lobsters at Dry Tortugas was reduced by 50% during a single eight month long open season for recreational fishermen only (Davis, 1977). There was a harvest limit of two lobsters per person per day enforced. About 22,500 lobsters were caught. The pre-harvest standing crop was 58.3 kg/ha. As a result of these findings, the central core of the Monument (60% of the area) was closed as a sanctuary, and the remaining area was made available to harvest, subject to State law, for both recreational and commercial fishermen.

This study also provided considerable biological and fishery data about fished and unfished spiny lobster populations. For instance, we found that the average minimum size of mature female Florida lobsters was about 80-85mm carapace length (CL) at Dry Tortugas. That was nearly 40mm larger than previously reported for Florida. This may have significant impact on fishery management strategies since it has been shown that the current minimum size for legal harvest (76mm) does not protect a reproductive stock (Davis, 1975; and Kanciruk and Herrnkind, this conference, and 1976). This was one of the problems specifically identified in the 1974 Sea Grant meeting.

Another major problem partially addressed by data from the Dry Tortugas study is mortality rate. This is an important factor in determining optimum yields and harvest size for individual lobsters. We found mean annual mortality rates of 23% for unharvested, 29% for recreational harvested, and 40% for combined recreational and commercial harvested populations of adult lobsters (ages V to X) at Dry Tortugas.

Growth rate is another critical parameter needed to formulate fishery management strategy. We found an average annual growth rate (carapace length) of 50% for tagged juvenile lobsters in Biscayne Bay. This growth rate estimate was based on growth measured on 326 lobsters ranging from 35 to 85mm (CL) during periods of 4 to 60 weeks.

We were also interested in the effects of fishing activity on the lobsters, so we measured the occurrence and extent of injuries on lobsters in fished and unfished areas. We found that less than 24% of the 35 to 85mm (CL) lobsters were missing legs or antennae in an unfished area at Dry Tortugas, whereas in heavily diver-fished Biscayne Bay about 50% of the similar sized lobsters had sustained such injuries. Furthermore, we found significant differences between the growth rates of injured and uninjured lobsters in Biscayne Bay. The growth rate of injured lobsters was 40% lower than uninjured lobsters. At the growth rates observed for 326 lobsters, uninjured lobsters would require two years to grow from 35mm to 85mm (CL), while injured lobsters would take three years. Less than 5% of the lobsters caught in the Bay during this study were of legal larvest size, and even fewer were of reproductive size. If not injured by fishing activity, these juveniles would grow faster and enter the fishery a year sooner, thereby reducing their mortality prior to recruitment into the fishery.

The information we collected from tagged lobsters on migration showed that Biscayne Bay is a nursery of the Keys fishery. Lobsters tagged at the Elliott Key Marina, in southeastern Biscayne Bay, were recaptured moving through Caesar's Creek, on patch reefs east of Old Rhodes Key, on the outer reef to depths of 180 feet off of Islamorada, and as far south as Woman Key near Key West. Many of these movements took place in less than six months. This is in stark contrast to the lack of movement we observed at Dry Tortugas. I think this was just a reflection of the migratory nature of juveniles and the residential nature of adults.

We recently addressed a subject that is crucial to estimates of population dynamics based on tag returns. That is the rate of tag loss. We double marked 1,250 lobsters with holes punched in their tails and spaghetti tags (Floy FD-68B). Then we recaptured a portion of the marked lobsters every month for nine months. Monthly tag losses ranged from 1.9% to 11.1%, but were generally about 4%. Total tag loss after nine months was 30%. Most tag losses were apparently associated with molting, so molting frequency was important for understanding tag loss. Growth data showed that 30% of the lobsters molted during each of the first three months of the study, so that after three months 90% of the lobsters had molted. This molting frequency was apparently maintained throughout the study period as well. There were 117 lobsters recaptured at regular intervals over an extended time and they averaged 13.4 weeks between molts. Additionally, the ratio of long term growth (8-9 months) to single molt growth was about three to one, supporting an intermolt period of thirteen weeks. It was clear that juvenile lobsters in Biscayne Bay from 35 to 85 mm (CL) molted four times a year with tag losses of 10% per molt.

One last topic merits review here. At various times the idea of increasing fishery production by enhancing some possible limiting factor, such as shelter, has been suggested for lobsters (Felik, 1974). At the Elliott Key

Marina we tested this idea by creating a lobster "ghetto" with concrete block shelters adjacent to an established population center. Over the past seven months there was regular movement of lobsters through the area. Young lobsters, (35mm CL) entered the area, and older lobsters (75 - 85 mm CL) left to enter the fishery offshore so there was ample opportunity for an increased population to be established. Lobsters occupied the new shelters at high densities, but the population in the adjacent marine declined at nearly the same rate as the "ghetto" population increased, so there was no net increase in the lobster population of the area. This suggested that while juvenile lobsters may be found to occupy nearly every available shelter in the Bay in high densities (when protected from fishing activity), shelter may not be the limiting factor on juvenile Spiny Lobsters in south Florida.

In conclusion, I would like to suggest a testable management experiment that could significantly improve the lobster fishery's production. Our preliminary studies showed that 95% of the lobsters we caught in Biscayne Bay were under legal size - immature juveniles - and that half of these juveniles had sustained injuries, many from fishing activity, that reduced their growth rate by 40%. This may cause injured lobsters to stay in the Bay an additional year or more, thereby increasing their mortality prior to entering the fishery offshore and to the south in the Keys. If the southern half of the Bay were closed to all lobster fishing, these injuries would be significantly reduced. The 5% legal sized lobsters in the Bay would soon migrate into the fished area and would not be lost from the fishery. The subsequent increase in growth rate and decrease in mortality rate in the Bay should produce a measurable increase in lobster fishery production within two seasons. By closing the southern portion of the Bay that is within the boundaries of Biscayne National Monument, an existing management unit is utilized which is already designated on navigational charts and recognized by the public and commercial fishermen. There is also an established data base for the lobster population in the Monument and an ongoing research program to evaluate changes. Additionally, supplemental law enforcement protection from park rangers is available in the Monument to ensure an effective sanctuary.

To evaluate the effectiveness of the nursery sanctuary, some accurate and precise measure of fishery production must be developed and implemented to measure production before and after closure of the proposed sanctuary. The National Park Service is developing a fishery monitoring program in Biscayne National Monument. It will be compatible with the commercial log book system being developed by the National Marine Fisheries Service for the entire lobster fishery. A similar recreational fishery monitoring program is needed outside the Monument to supplement the commercial log book system. Implementation of these programs already has high priority in the development of alternative fishery management strategies. I suggest that evaluation of a nursery sanctuary would be an excellent demonstration of the value of the good fishery statistics these programs could provide with the cooperation of the fishermen. This fishery needs improvement. A nursery sanctuary could help it. It is time to get the management agencies and the user groups together and test the concept.

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EVALUATION OF METHODS TO MONITOR RECRUITMENT OF POSTLARVAL FLORIDA SPINY LOBSTER

Edward J. Little and Gary R. Milano[1]

Despite the considerable importance of the Florida fishery for Spiny Lobsters, Panulirus argus, comparatively little is known of the manner by which populations are replenished. The larvae are thought to drift up from the Caribbean before metamorphosing into transparent postlarvae. The latter swim or are transported to nursery grounds, suspected to exist primarily in nearshore shallows, where they enter benthic juvenile lobster populations. Management of the fishery resource requires more information than presently available on times and places of recruitment, factors influencing the process, and relationships between recruitment success and subsequent fishery productivity.

The Florida Department of Natural Resources Marine Research Laboratory, funded through a research grant from Public Law 88-309 administered through National Marine Fisheries Service, is studying methods to measure fluctuations in postlarval lobster recruitment. Recruitment is assessed by counting postlarvae that have sought shelter in Witham habitats, artificial substrates that mimic natural fouling communities frequented by newly recruited postlarvae. Each habitat consists of a series of eight to sixteen rectangular thin sheets of a soft material composed of thousands of intertwined vinyl filaments, the sheets being suspended vertically beneath a two foot square plywood and polyurethane foam raft. Virtues of the device are simplicity, low cost, durability, ability to operate while unattended, and, as shown in several years of preliminary studies, proven attractiveness to postlarval lobsters. A unique feature of this recruitment quantification tool is also the ease by which even an untrained observer can count and remove postlarvae.

In our study, begun in February, 1976, we measure daily settlement of postlarval lobsters and associated organisms to groups of nine Witham habitats 1.0 - 2.0 m apart in waters 1.0 m deep at each of three sites 100 - 200 m off the south shore of Boca Chica Key, Florida Keys. Similar sampling off Sugarloaf Beach, approximately 15 km east of Boca Chica, was begun in June, 1976. Through such efforts we hope to obtain data on temporal and geographic variations in postlarval lobster abundance and to see what techniques produce catches most indicative of natural recruitment intensity.

Although the study has been underway for less than a year, a few trends are already evident. Recruitment may occur throughout each month, but only catches during the new moon through first quarter period are large enough to be useful in recruitment analysis. Habitats must have at least two months continuous service before becoming reliable collectors of postlarvae; those with shorter exposure periods catch few postlarvae, presumably because fouling assemblages attractive to postlarvae have not developed sufficiently. Furthermore, not all sites are equally conducive to postlarvae settlement. Sites located over rocky bottoms with good water exchange have been so much more consistently productive than other sites that we intend to study this phenomenon more fully in the future.

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1. Florida Department of Natural Resources, Key West Field Laboratory

In the two remaining years of our project, we plan to continue monitoring recruitment patterns, develop more effective habitats, and identify types of localities where habitats can be deployed for maximum productivity. Our work will hopefully provide techniques for assessing recruitment to lobster nurseries, enhance understanding of reasons for cycles in lobster abundance, and possibly provide a mechanism for predicting future fishery yields.

BEHAVIOR OF THE SPINY LOBSTER, *Panulirus argus*, TO BAITED FLORIDA AND PROTOTYPE TRAPS [1]

By

George C. Miller and David L. Sutherland

INTRODUCTION

An objective of the Resource Assessment of Invertebrate Program, NOAA, NMFS, Miami Laboratory, is to assist commercial small-boat fishermen of Florida. The development of a more efficient lobster trap is one way to help these fishermen.

The Florida wood-slat spiny lobster trap with a top entrance is inefficient because it allows legal-size lobsters to escape. The design of the trap incorporates few features relevant to lobster behavior, ecology, or habitat. The top entrance of the Florida trap forces lobsters to expose themselves to predators, lengthens the time necessary for lobsters to find the entrance, and allows possible escape by orientation toward light coming in through the top of the trap.

A prototype trap was developed with a low, broad entrance near the bottom of the trap, hinged wires across the entrance that swung into the trap but could not swing outward, and a solid top. The wide entrance near the bottom of the trap was accessible to animals seeking food or shelter. Hinged wires were evenly spaced across the entrance to keep legal-size lobsters in the trap while allowing illegal-size lobsters ("shorts") to escape. The solid top was incorporated into the design so lobsters could use the trap as a niche, similar to the overhanging reef ledges beneath which they normally congregate and hide.

A study was conducted to determine: (1) the behavior of lobsters to Florida and prototype traps; (2) the behavior of lobsters outside the Florida trap when bait was in different locations in the trap; (3) methods of entering; (4) methods of escaping; and (5) their behavior to movable, hinged wires in the prototype entrance. This paper presents the results of this study.

MATERIALS AND METHODS

The spiny lobsters were collected at the Elliot Key Marina, Biscayne National Monument, January 23, 1976. Divers randomly captured 7 male and 3 female lobsters from the undercut marine seawall by hand or loop snares. The animals ranged from 52.9 to 68.8-mm carapace length (average 61.1-mm) and from 140 to 305 g (average 221.8 g) in weight. Two lobsters moulted near the end of the study. All lobsters were released at Elliot Key after completion of our study.

1 Contribution Number 479. Southeast Fisheries Center, Miami Laboratory, National Marine Fisheries Service, NOAA, Miami, Fl., 33149.

Traps used were the standard Florida trap (Cope, 1959; Noetzel and Wojnowski, 1975) and a prototype trap. The Florida trap measured 0.8 x 0.6 x 0.4 m (33 x 22 x 16 inches). It was constructed of cypress laths nailed at 25 - 38-mm intervals on a rectangular frame of 25 x 51-mm cypress strips. A funnel in the center of the roof was the trap entrance. The funnel entrance measured 178 x 203-mm (7 x 8 inches) and was constructed of standard width, 152-mm (6 inch) long laths, which extended down into the trap. The trap was weighted at each end with concrete poured into bottom partitions.

The prototype trap, except for the roof and entrance, was similar to the Florida trap in size and construction. The roof was a solid sheet of marine plywood, 10-mm (3/8 inch) thick. The trap entrance, 127 x 508-mm (5 x 20 inches), was 127-mm (5 inches) above the trap floor and extended across the width of one end of the trap. The entrance margin was 25-mm (1 inch) thick pine boards which extended 203-mm (8 inches) into the trap. Nine vertical hinged wires were spaced at 51-mm (2 inch) intervals across the inside edge of the entrance. The light-gauge, steel wires, approximately 2-mm (1/16 inch) in diameter, were hinged at the top of the entrance to a 10-mm diameter steel rod. The free end of the wires fitted into slots notched in the lower inside edge of the entrance. The entrance design permitted lobsters to push the wires inward upon entry but not outward to escape from the trap. This prototype is called the "Bar-room" trap.

Both traps were modified for the study by replacing the horizontal wood laths along one side of the trap with a 6-mm (¼ inch) thick pane of plate glass.

The traps were baited with a piece of cowhide and mackerel or mullet. During the initial observations of the Florida trap, a rectangular, wire mesh container baited with cowhide and mackerel was placed on the trap floor, directly under the entrance. During subsequent observations, cowhide and mullet were placed in separate, perforated, plastic, pint containers and fastened to the trap ceiling next to the entrance. When observations were made of the Bar-room trap, the wire mesh bait container with cowhide and mullet was placed on the center of the trap floor. Fresh fish bait was placed in the containers every second day; one piece of cowhide was used during the entire study.

Lobster behavior to baited traps was observed with closed-circuit underwater television cameras in a saltwater settling tank at the Miami Laboratory. The settling tank measured 14.6 x 24.4 x 0.7 m (48 x 80 x 2.3 feet), and the lobsters were confined to a 5.5 x 7.0 m (18 x 23 feet) area containing the traps and television cameras. One baited trap was observed with two cameras each day.

A Hydro Products[2] Model TC-110 underwater television camera was placed approximately 0.5 m (1.5 feet) from the right-front corner of the Florida trap to view the entrance. The camera was placed at the left-front corner to view the Bar-room trap entrance. To view the entire trap and the immediate surrounding area, a Hydro Products model TC-125 camera was positioned approximately 2 m (6.5 feet) from the center of the glass side of

2 Reference to trade names does not imply endorsement of the product by NOAA, NMFS.

the trap. Two 500-watt Hydro Products LQ-10 quartz iodide lights on each side of the trap provided night time illumination.

The cameras and lights were operated, monitored, and video tape recorded from a nearby room in the Miami Laboratory. Pictures from each camera were viewed on separate television monitors and were recorded on Sanyo model VTR-1200 video recorders. Video tape recorders were run 6-24 hr/day during the study, or an average of 15.5 hr/day. The video tape recorders were run at a tape speed of 7½ inches/sec when personnel were present to view the closed-circuit picture. At night, or whenever personnel were not present, the recorders were run at a speed of 1-1/16 inches/sec. Every hour or 7½ hr, respectively, the video tapes were rewound and reviewed for lobster observations. Video tapes showing lobsters entering or exiting the traps were saved for further analysis while other tapes were reused.

BEHAVIOR OF THE SPINY LOBSTER TO THE FLORIDA TRAP

Behavior Outside the Trap

The behavior of spiny lobsters to a Florida trap depended on the location of the bait container in the trap. Lobsters continually tried to enter at or near the trap's base when the bait was placed on the trap floor. They generally circled the trap once and tried to enter by pushing against the glass or by pushing head-first through the gaps between the bottom three laths of the trap's walls. Further efforts to enter the trap were concentrated near the bottom gaps in the wall opposite the glass. When lobsters were unable to enter the trap through the bottom gaps head-first, it was not unusual for them to try to enter sideways or tail-first. Lobsters seldom crawled onto the roof and rarely entered the trap when the bait was on the floor.

When bait containers were attached to the trap ceiling near the entrance, lobsters frequently climbed up the outside walls and tried to enter the trap through gaps near the top of the trap. Lobsters were persistent climbers, moving slowly up and down and back and forth on the walls. During these movements, they repeatedly tested the same gaps trying to gain entrance. Most lobsters tried to enter the trap through gaps in the trap wall, opposite the glass; little time was spent by the lobster searching along the ends or the glass wall. Lobsters frequently climbed on top of the trap then turned and climbed down the wall, probing for an entrance.

Lobsters reaching the top of the trap often walked directly from the edge of the trap roof to a point directly above the bait container. When the animals were given a choice of two bait containers, one containing mullet and the other cowhide, they always moved directly to a point above the mullet. The lobsters then assumed a head-down, tail-up position, with the first pair of walking legs extended downward between the laths toward the bait container. After about 2 minutes of "pawing" at the top of the bait container, lobsters would find the entrance and enter the trap. Although the animals were not individually marked, we estimated it took from 1 to 3 hours for a lobster to enter a Florida trap.

Lobsters generally entered the trap head-first. At the entrance, they folded their antennae to their sides and crawled down the funnel, gripping the laths with their dactyls. At or near the lower end of the funnel, the lobsters released their grip and settled to the trap floor. When the bait was attached to the roof, some lobsters crawled down and around the lower end of the funnel and directly onto the container. One animal entered the trap tail-first and backed down and around the funnel onto the container.

Behavior Inside the Trap

The lobsters inside the Florida trap were inactive, fed, or made apparent efforts to escape. They successfully extracted bait from the bait containers. After feeding, the animals became inactive. This, in turn, was followed by more feeding or escape efforts.

Lobsters trying to escape from the trap behaved similarly to animals trying to enter the trap. Persistent climbing, probing, and efforts to squeeze between the laths were observed. One exceptionally active lobster, during a 1-2/3 hr period of time, frequently pushed against the glass, climbed every lath wall to the ceiling one or more times, and repeatedly tried to squeeze through every gap between laths.

Lobsters escaped from the trap only when bait containers were suspended from the ceiling and lobsters were attempting to feed from them. The bait container was reached by the animal in two ways: (1) by crawling from the floor, up the wall to the ceiling, and then onto the container; or (2) by curling the tail-fan (telson and uropods) under the abdomen and rearing up on the posterior walking legs, grabbing the container with the front walking legs, and pulling themselves up onto the container. The animals, in moving around on the bait container, crawled into, up, and out of the adjacent entrance funnel and escaped. In one instance, a lobster leaving the trap through the funnel was pushed back into the trap by a lobster entering the funnel. Some lobsters climbed out of the funnel onto the top of the trap, tried to reach the bait container from the roof, then re-entered the funnel and climbed back onto the bait container. Lobsters only escaped when trying to feed at the bait containers.

BEHAVIOR OF SPINY LOBSTERS TO THE BAR-ROOM TRAP

Behavior Outside the Trap

The behavior of lobsters to the Bar-room trap differed from behavior to the Florida trap because of the wide entrance near the trap's base. Lobsters generally found the entrance to the trap during their first circuit around the trap while probing between laths. Upon locating the entrance, the animals climbed up onto the board ledge and used their antennae to touch and probe the metal wires obstructing their passage. With antennae folded back, the lobsters walked head-first through the entrance, pushing from three to five wires inward in the process. Lobsters hesitated briefly when partially through the wires, then continued into the trap without any difficulty. The time from when the lobsters were first observed outside the trap until they entered it was usually less than 4 minutes.

Behavior Inside the Trap

The behavior of lobsters in the Bar-room trap was similar to that observed in the Florida trap. After feeding at the bait container on the floor of the trap, lobsters pushed against the glass wall, climbed the lath walls, and tried to squeeze between the laths to get out of the trap. Some lobsters tried to escape by going under the board ledge at the entrance, rather then over it; others used the ledge to hide or rest under. They frequently located the trap's large entrance, but started searching for another place to escape after they were stopped by the wires guarding the entrance. The wires were spaced across the entrance at intervals designed to allow escapement of "shorts" and to retain large animals. The lobsters, however, often placed their antennae on either side of individual wires, rather than between them, resulting in the lobsters butting and pushing against the wires. Eventually, all lobsters in our study escaped between the wires.

SUMMARY

Florida Trap

Spiny lobsters spend considerable time and effort entering a baited trap. Their search outside the trap is orientated towards the bait. Bait containers attached to the ceiling of the trap attract lobsters to the top of the trap, whereas containers on the trap floor attract lobsters to the trap's base. Lobsters generally enter a trap by crawling head-first down the funnel entrance. Lobsters escape from a trap while attempting to feed at the bait containers when the containers are mounted near the entrance. Lobsters did not escape by swimming out through the funnel entrance.

Bar-room Trap

Lobsters locate and enter the large entrance near the trap's base in minimal time. Wires at the trap entrance are not a hinderance to entry. Appropriate spacing of the wires across the entrance allows illegal-size lobsters to escape.

ACKNOWLEDGMENTS

We thank Gary Davis and Dan Robbins, U.S. National Park Service, for assistance in obtaining the spiny lobsters used in our study. Alan Craig, Florida Atlantic University, kindly imparted knowledge to us on the biology and fishery for the spiny lobster at the start of this study.

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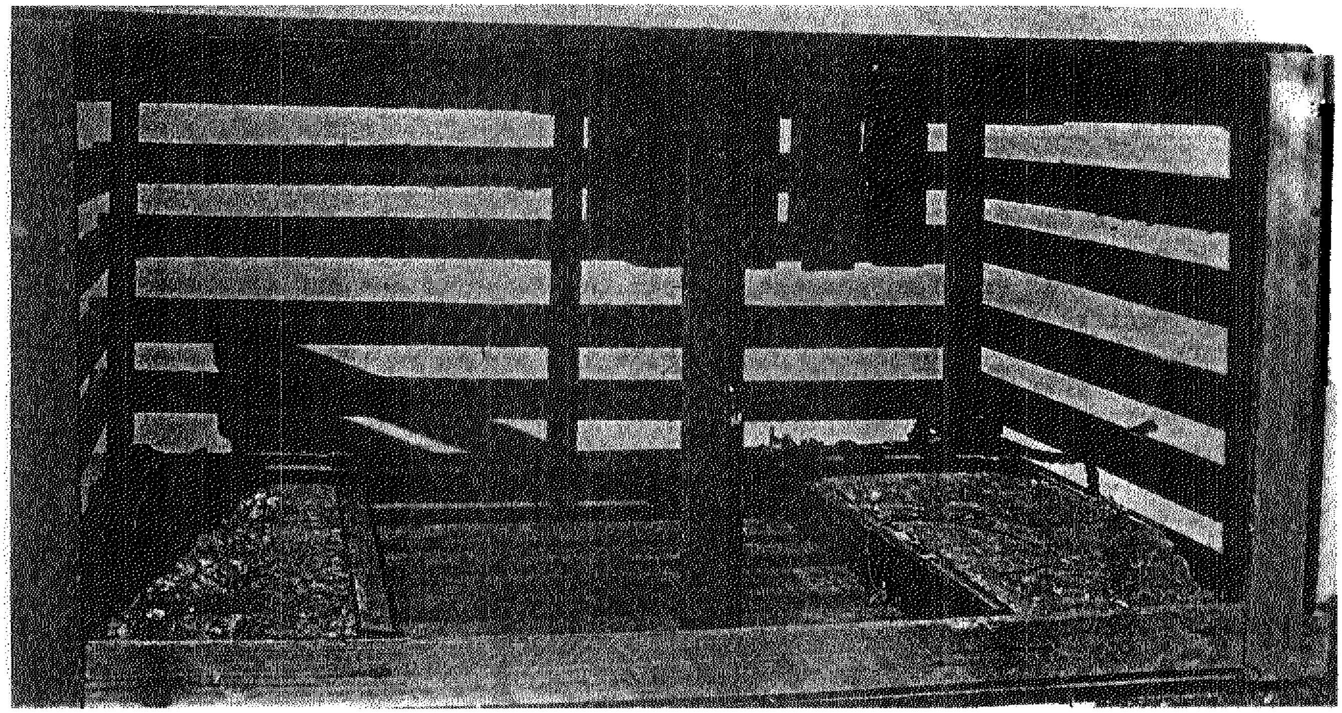

Figure 1. Glass side view of Florida spiny lobster trap.

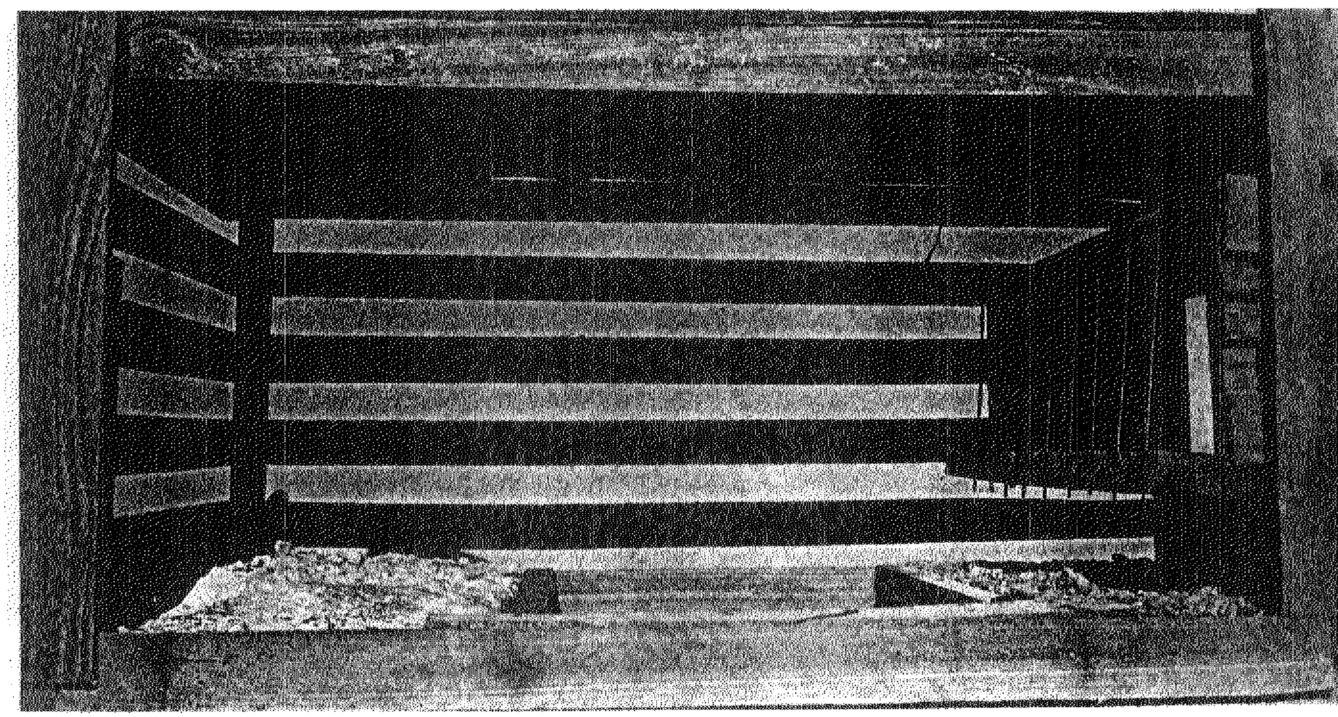

Figure 2. Glass side view of prototype "Bar-room" trap.

ATTRACTANTS OF THE SPINY LOBSTER, *Panulirus argus*

by

Barry W. Ache[1]

Research in our laboratory is directed towards understanding chemical sensing in the Spiny Lobster. One project, supported by the Florida Sea Grant Program, evaluates the possibility that simple organic compounds are sufficiently attractive to lobsters that, when appropriately packaged for release, they will serve as a convenient, economical, effective trap bait for the fishery. First, it was established that low molecular weight compounds are effective chemostimulants for this organism. Then 113 specific compounds were assayed and ranked for their ability to physiologically stimulate known low threshold chemoreceptor organs of the lobster. The 18 most stimulatory of these compounds were, in turn, assayed for their ability to behaviorally attract lobsters to sources of these odorants.

Compounds varied in their behavioral attractiveness, but the most attractive single compound was citric acid. L-ascorbic acid and succinic acid ranked 2nd and 3rd, respectively, when tested over three ranges of concentration. Nicotinic acid was the only compound appearing to elicit repulsion at the concentrations tested, although the assay was not designed to test repulsion, *per se*. These studies indicate that simple organic compounds, by themselves, are functional attractants for the Spiny Lobster.

Concomitant laboratory experiments evaluated the effectiveness of potential release vehicles. Membrane-limited diffusion chambers, agar and gelatin gels, and plaster of paris blocks leached too quickly (24 hr) for presently used trap fishing intervals. Retention of up to several weeks was obtained from a patented laminate timed-release system developed by Herculon, Inc., N.Y., N.Y. Subsequent initial field testing of the laminate system using standard commercial fishing technique indicated that citric acid at concentrations of 1 and 10 gm/trap/4 day set fished better than empty traps, but less well than cowhide controls ("concentration" unknown, but maintained at saturation levels in the bait container). Variability in catch/trap, however, statistically invalidated the observed differences. Further field testing is planned.

Company estimates that dry chemicals like citric acid can be manufactured into laminate-release form for approx. $.10 per pound (454 gm) suggest that the citric acid/laminate system would be economically compatible with presently used baits. Final economic considerations, however, await field trial determination of effective concentrations. Convenience and ease of handling of the laminate would certainly be superior to natural baits. Consideration has also been given to the availability of citric acid as a by-product of Florida's citrus industry.

<u>1</u> Department of Biological Sciences, Florida Atlantic University, Boca Raton, Florida, 33431. B. Johnson and E. Clark participated in this study.

BIOCHEMICAL SYSTEMATICS AND PROBLEMS OF LARVAL RECRUITMENT IN THE SPINY LOBSTER, *Panulirus argus*

Robert A. Menzies, J. Michael Kerrigan and Paul Kanciruk[1]

The maintenance of an exploitable animal resource such as the lobster fishery depends on a number of factors, not the least of which is the rate at which young enter the fishery. Our studies have focused on identification of adult populations giving rise to the larvae which support the Florida industry.

The problem is crystallized by models of two extreme possible situations. Larvae entering the Florida nursery were believed to have originated principally from Florida (lower portion Figure 1). However, studies in the 1960's principally sponsored by the now Florida Department of Natural Resources, suggested a quite different pattern of larval transport and recruitment to Florida (Sims and Ingle, 1966). This view is schematized in the upper portion of Figure 1. Larvae spawned in Central and South America are "trapped" in currents eventually feeding the Gulf Stream. In the terminal planktonic stage they move (or are transported) shoreward and enter the closest nursery area. Surface currents off the Southeast Florida coast are predominantly unidirectional north-flowing (east in the lower keys) and it was assumed that Florida-spawned larvae were transported out of the area. The existence of countercurrents and gyres (long known to local fishermen and mariners) were not believed to be sufficiently strong or prevalent to counteract the net removal of Florida-spawned larvae. In the past few years however, more precise measurements of rate and direction of current flow have been made. Data emerging indicate that not only are there strong counter and shoreward currents but some of these are persistent for large portions of the year. Notable among these studies has been the work of Brooks and Niiler (1975) of the Nova University Oceanographic Center. In 1972, they measured current intensity and direction as well as other physical parameters at numerous stations along a line from Key West to Matanzas, Cuba. Their studies revealed a countercurrent extending approximately 25 km from shore (Key West). The countercurrent was contiguous from surface to bottom and persisted throughout the measurement period (spring and summer). Thus, not only do strong countercurrents exist, but they are present at the time of maximum spawning in the Florida Keys. Conceivably, a large portion of Florida larvae could contribute to local recruitment by developing within this countercurrent and associated eddies. The knowledge of the relative size of this possible contribution compared to foreign recruitment is necessary for fishery management.

Our approach to the problem involves concepts of population and biochemical genetics. The former is best exemplified by the following illustrations. The frequency of blond hair/blue eye individuals is higher in Sweden than in most areas of Asia. These frequencies will remain the same generation after generation, i.e., in an equilibrium state, as long as these populations remain reproductively isolated. In the Spiny Lobster's case, the principal mode of

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1. Life Sciences Center and Academy of Marine Sciences Laboratory, Nova University, Fort Lauderdale, Florida, 33314.

gene flow between populations would be at the larval stage. Ignoring for the present natural selection at sea, the gene frequencies of post-larvae entering a nursery should reflect: a) a single parental population if stocks are locally sustained; or b) a composite of all parental populations contributing to the pool of larvae mixing at sea.

Since genetically controlled morphological features such as blond hair and blue eyes are of limited use in studying lobsters, we have resorted to genetic markers that can be detected by biochemical techniques. Every enzyme is a reflection of the gene(s) specific for that enzyme. Differences in enzyme structure which can be detected with biochemical techniques therefore reflect differences in the information content of genes coding for that enzyme.

Many of these differences are revealed as different rates of movement by enzyme molecules in an electrical field (electrophoresis). Within a class of enzymes all catalyzing the same reaction several subgroups with different charge per molecule may exist. The frequencies of animals in a population possessing different subgroups reflect different frequencies of alleles* for a particular gene. Figure 2 illustrates principles of our approach. The figure shows two chromosomes and the position (locus) of a gene, "A". One chromosome contains the "a_1" allele at the A locus and the other chromosome contains the "a_2" allele. This individual is thus heterozygous at the "A" locus. In the cell, the process of protein synthesis "translates" the genetic information into enzyme molecules. The biochemist can make a tissue extract containing the enzymes and separate them in an electrical field. After performing a staining reaction specific for all "A" locus enzymes in our heterozygous lobster example, enzyme product bands would appear at the a_1 and a_2 positions in this gel. In the electrophoretogram (Figure 2), the patterns for two homozygous individuals are also shown. Only the a_1 band is present in the a_1/a_1 individual. The heterozygous animal is denoted a_1/a_2. By examining a sample of individuals from a population and enumerating electrophoretic phenotypes, the frequencies of alleles a_1 and a_2 can be estimated. Table 1 is a summary from three hypothetical populations with different allele frequencies for a_1 and a_2. Populations can be compared on the basis of allele frequencies, p and q, or directly from phenotypic frequencies.

Figure 3 is a summary of our methods. Tissues are dissected and stored in vials at -20°C. For analysis, a small portion, 200-300 mg, is homogenized in two ml. of medium H (0.25 M sucrose; 10 mM $MgCl_2$; 50 mM KCl, 50 mM Tris-HCl, pH 7.5). After centrifugation at 30,000 x g for 30 minutes in the cold, a portion of the supernatant (5-50 µl) is removed for electrophoretic analysis and the rest stored at -20°C. Electrophoresis is performed on polyacrylamide gels in the cold (approximately 4°C). The gel concentration used in obtaining data in this report was 8.5% acrylamide and 3% bisacrylamide. After electrophoresis, gels were sliced longitudinally and each half stained for esterase activity with α-napthylacetate as substrate (Shaw and Prasad, 1970). Figure 4 shows the distribution of bands in tail muscle with esterase activity. In the Spiny Lobster over 16 bands of esterase activity can be detected. A preliminary estimate of the number of esterase genes (loci) is 8. Some tissues

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* Allele is the term used to denote subtle differences in the same gene set (locus). Since lobsters are diploid, i.e. have two sets of chromosomes, each individual can have either two of the same alleles (homozygous state) or one each of two different alleles (heterozygous state).

such as hepatopancreas show many bands while others such as tail muscle contain only a few in reproducibly detectable amounts. However, in the latter case interpretation of phenotypic patterns is less complicated. In Figure 4 the predominantly staining area at the anodal end is designated the EF 4 locus. This region appears to contain a single polypeptide enzyme system with four alleles designated as -3, 0, 5 and 10. The designations are based on electrophoretic mobility relative to an index band in the standard. We used this hypothesis to calculate the expected zygotic frequencies as predicted by the Hardy-Weinberg Law for several populations of adults. Expected and observed frequencies are described for animals from Elliot Key Marina in Biscayne National Monument (Table 2). Chi-Square tests yielded non-significant differences indicating the data are consistent with the Hardy-Weinberg hypothesis.

One of our goals is to determine which genes might be influenced by physiological or environmental factors. A preliminary investigation as to the influence of some parameters was made with the Elliot Key population. Phenotypes were constructed based on bands 27, 24, 17, 10, 5, 0, -3. Eleven phenotypic groups were obtained. Neither sex nor size affected the distribution of phenotypes among animals. Molt condition and/or season did not appear to affect distributions of phenotypes when band 24 was deleted. However, band 24 did occur in higher frequencies in post-molt animals, most of which were collected during the winter. Similar correlation analyses were performed on the distribution of the EF 4 locus alone. No effect of size, sex, season or molt condition was detected (Table 3).

Preliminary population comparisons (Chi-Square) for the EF 4 locus are shown in Table 4. The five populations compared are Mores Island, Walker Cay (both Bahamian - Little Bahama Bank), Belize (C.A.), Boca Raton and Elliot Key, Florida. Between population comparisons showed Elliot Key and Boca Raton to have significantly different allele frequencies as compared to Belize and Walker Cay. All other tests were non-significant.

It must be stressed that the data presented here are preliminary. Population comparisons, to be valid, must be done for several genes, i.e., other enzyme systems. Our prime objectives now are to continue working out details (genetics, physiological and environmental influence) of several more enzyme systems primarily in adults and to verify the use of these systems in comparisons between post-larvae and adults. With the collaboration of Mr. Ed Little (D.N.R.) and Mr. Gary Davis (U.S. National Park Service) we hope to obtain post larvae from the Boca Chica (Key West) area and Elliot Key area. Ultimately, it may be necessary to obtain phyllosome larvae from plankton tows to complete the circle of population comparisons. When these studies are complete it should be possible to delineate the geographic domain of all populations studied.

We would like to acknowledge the collaboration of Mr. Gary Davis of the National Park Service and everyone at Biscayne National Monument who aided in animal collections at that site; Dr. Alan Craig for the Boca Raton animals; Mr. Hartly Lowe of Walker Cay for animals from that location; The International Trading Corp. for animals from Mores Island and Dr. Albert Jones of National Marine Fisheries Service for the animals from Belize. This work was supported in part by a grant from the Florida Sea Grant Program.

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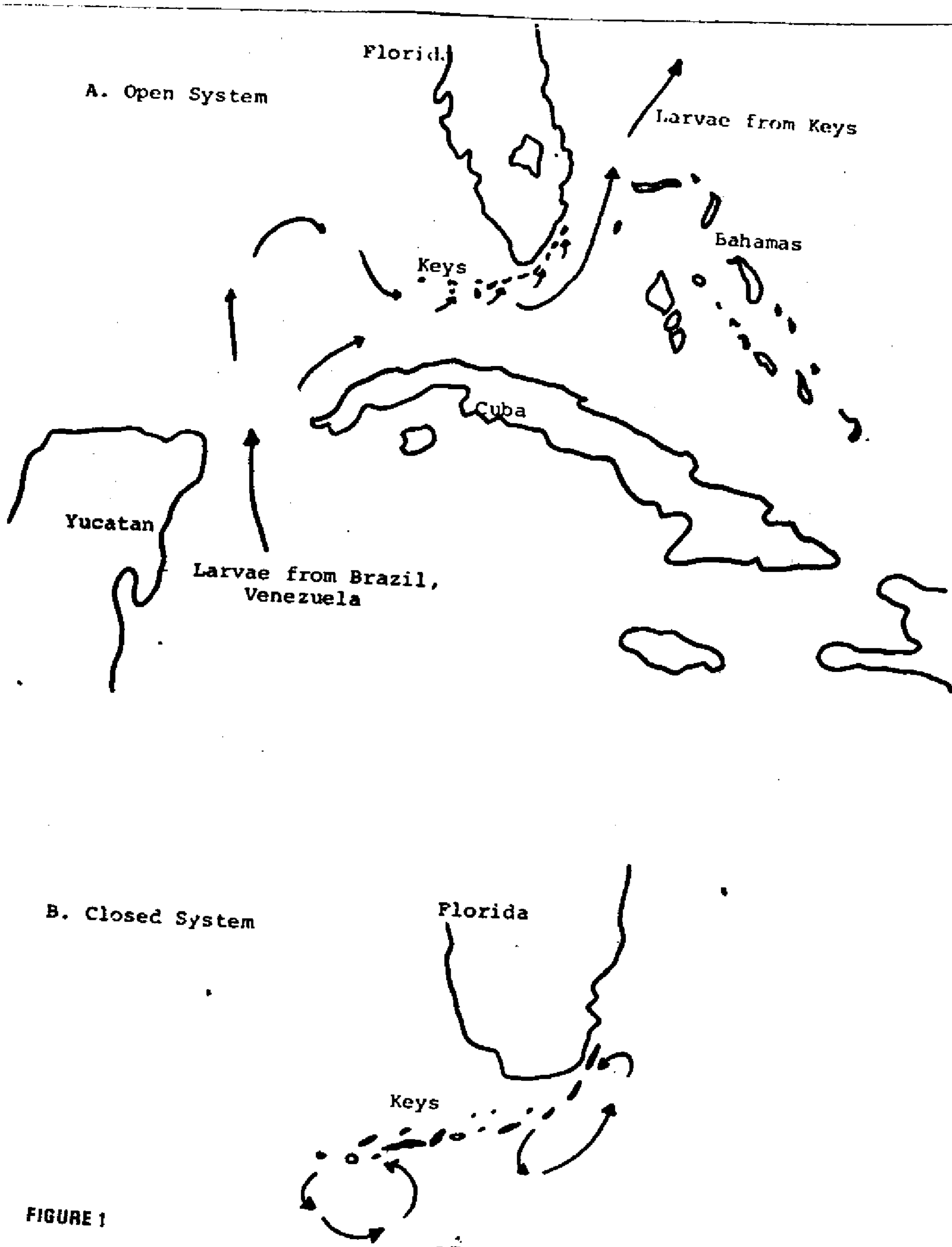
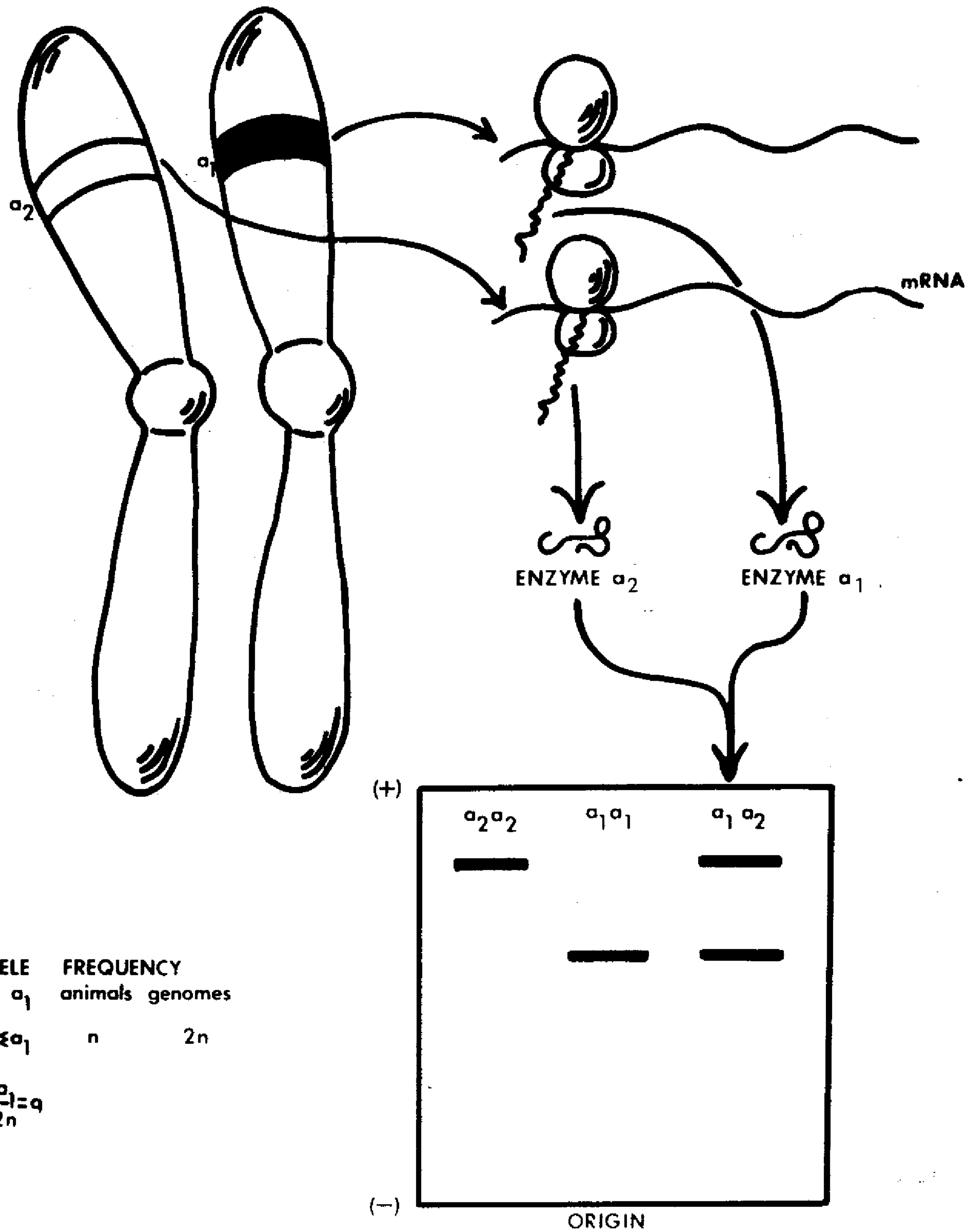


FIGURE 1



ALLELE		FREQUENCY	
a_2	a_1	animals	genomes
Σa_2	Σa_1	n	2n

$\frac{\Sigma a_2}{2n} = p$ $\frac{\Sigma a_1}{2n} = q$

FIGURE 2

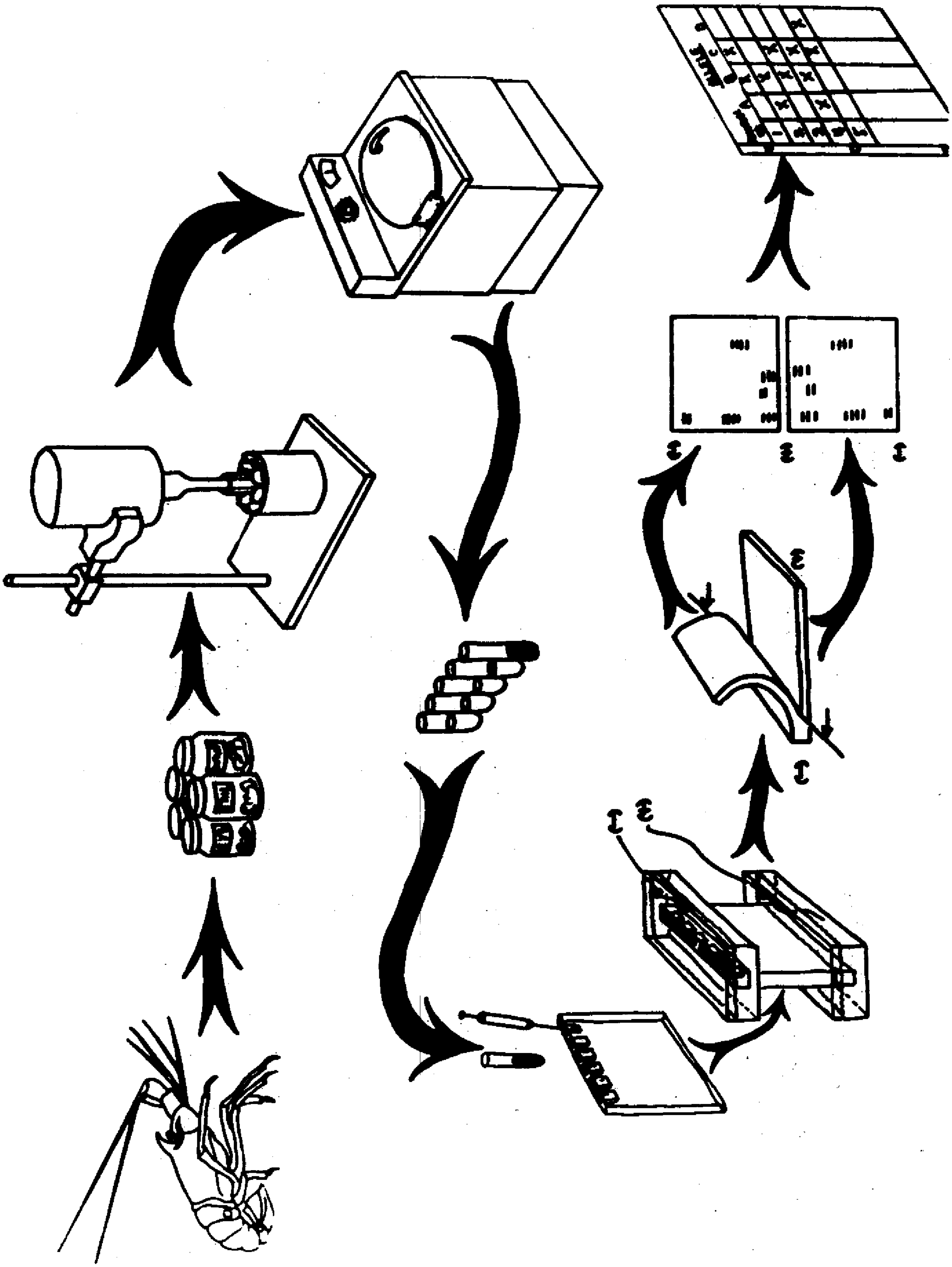


FIGURE 3

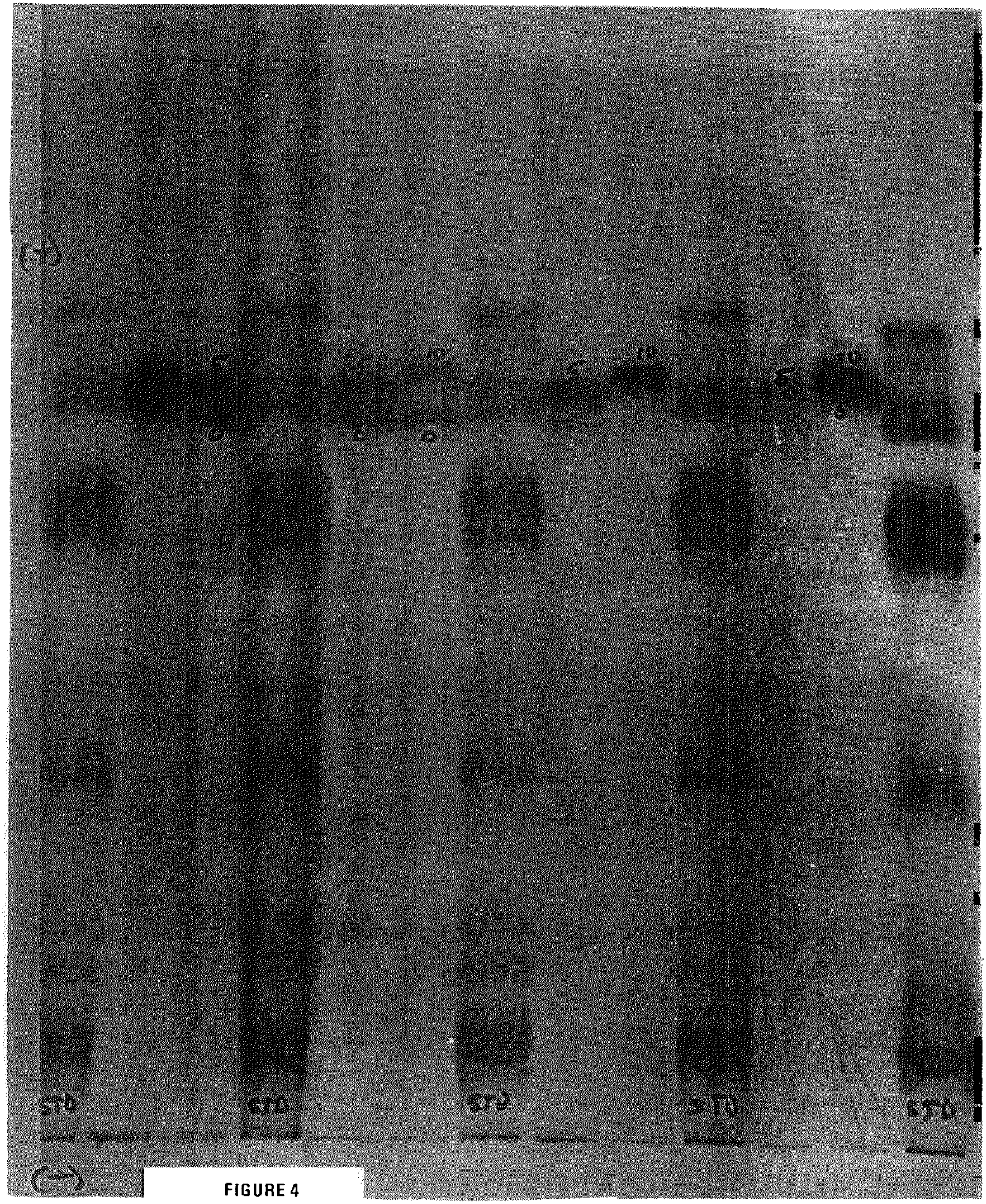


FIGURE 4

TABLE 1

COMPARISON OF HYPOTHETICAL POPULATIONS

Population	Allele Freq.		Zygotic Freq.		
	a_1 p	a_2 q	a_1/a_1 p^2	a_1/a_2 $2pq$	a_2/a_2 q^2
1	.10	.90	.01	.18	.81
2	.25	.75	.06	.38	.56
3	.50	.50	.25	.50	.25

TABLE 2

HARDY-WEINBERG FIT OF EP4 LOCUS

Sample Area N	Observed and Expected Zygotic Expression										
	-3/-3	0/0	-3/0	-3/5	-3/10	5/5	10/10	0/5	0/10	5/10	x^2
Walkers Cay 49	0 .005	0 .02	1 .02	0 .44	0 .5	8 10.3	11 12.7	1 .9	1 1.0	27 22.7	1.4_5
Boca Raton 46	0 0	0 .27	0 0	0 0	0 0	13 10.3	14 9.6	5 3.3	2 3.2	12 19.6	7.44_5
Marathon Key 50	0 0	0 .5	0 0	0 0	0 0	11 9.7	10 10.6	3 4.4	7 4.6	19 20.2	2.25_4
Elliott Key 124	0 0	2 .6	0 0	0 0	0 0	38 33.5	22 20.9	4 4.4	9 7.0	49 53.0	1.00_4
Boca Chica pueruli 46	0 .09	0 .09	0 .18	3 2.2	1 3.1	12 13.4	6 6.3	3 2.2	1 1.5	20 18.4	2.69_6
Mores Is. 22	0 0	0 .06	0 0	0 0	0 0	5 4.6	7 5.5	2 1.0	0 1.1	8 10.1	2.81_4
Belize 46	0 0	0 0	0 0	0 0	0 0	3 6.3	15 15.9	4 1.5	0 2.3	24 20.0	9.32_4

all X^2 values not sig. at the .05 level or better

TABLE 3

EF4 LOCUS TESTED FOR VARIANCE CORRELATED WITH MORPHOMETRIC CHARACTERISTICS AND SEASON

Variable	X^2	N
Winter/Summer	$.66_4$	124
Male/Female	3.46_4	124
Molt; Hard/Soft	1.19_4	122
Size; <60mm, 61-70mm, >70mm	4.85_8	123

all X^2 values not sig. at the .05 level or better

TABLE 4. Population Comparisons At The EF4 Locus (Chi-Square Of Zygotic Expression)

	B.R.	E.K.	M.I.	W.C.
Boca Raton	-	-	-	-
Elliot Key	4.89	-	-	-
Mores Island	1.14	4.40	-	-
Walkers Cay	9.62**	9.29*	2.14	-
Belize	12.96¢	17.38¢	4.33	3.08

* sig. at .1 or better
** sig. at .05 or better
¢ sig. at .025 or better

A DATA MANAGEMENT SYSTEM FOR THE FLORIDA SPINY LOBSTER FISHERY[1]

David C. Simmons, James R. Zuboy, and Edward A. Perez[2]

INTRODUCTION

The National Marine Fisheries Service (NMFS), Miami Laboratory, is developing a data management system for the Florida spiny lobster fishery. By working closely with industry and other agencies, we intend to utilize data sources presently available and coordinate some primary data collectionto construct a spiny lobster data base. This base will be accessible by remote computer terminal and will provide information on the fleet, landings, commercial catch and fishing effort, biology, economics, and recreational aspects of the fishery. An important aspect of the design of this system is that it will be cost effective, and the information will be available on a real-time basis. This concept of handling spiny lobster fishery data is applicable to other fisheries.

DATA BASE

The data base is comprised of eight files designated LAND1, LAND2, FLEET1, FLEET2, COMMER, SPORT, BIOLOG, AND ECONOM (Figure 1).

LAND1 and LAND2

Each fish dealer is required to submit a monthly report to NMFS on the pounds of fish and shellfish purchased from fishermen or produced by the dealer. Data on pounds landed and average price of spiny lobster from these reports are included in the data base in file LAND1. Monthly reports for 1975 and 1976 have been entered into the system. NMFS routinely contacts several major dealers by phone to determine the quantities of lobster landed on a daily basis. These data are also being entered into the data base in file LAND2.

FLEET1 and FLEET2

Information on the commercial fishing fleet is supplied by the Florida Department of Natural Resources and is composed of two files. FLEET1 consists of information taken from spiny lobster license applications and includes name and address of license holder, permit number, boat documentation or Florida registration number, etc. FLEET2 consists of information taken from lists of vessel documentation and Florida registration and describes each fishing craft by vessel size, year built, hull material, etc. Both of these files are in the system and accessible by computer terminal.

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1. Contribution Number 475. Miami Laboratory, Southeast Fisheries Center, National Marine Fisheries Service, NOAA, Miami, Fl., 33149

2. U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration National Marine Fisheries Service, 75 Virginia Beach Drive, Miami, Fl.

COMMER

No data are presently collected on catch per unit of fishing effort for the commercial spiny lobster fishery. To monitor the fishery, it will be necessary to obtain these data - logbooks are a good method of doing this. For a logbook system to succeed, support and cooperation of the industry are essential. A draft logbook has been developed, and we have solicited comments and suggestions on the design from fishermen and biologists. Catch and effort data are to be entered daily and each book covers one month. Completed logs will be mailed postpaid to the NMFS Miami Laboratory and the data entered into file COMMER. The National Park Service intends to collect similar data from lobster fishermen working within the boundaries of Biscayne National Monument, and they also plan to use the logbook. The University of Florida Marine Advisory Program will help publicize and distribute logbooks.

SPORT

The magnitude of the recreational fishery is unknown and before optimum harvest can be determined, the total harvest, both commercial and recreational, must be known. C. Bruce Austin (University of Miami, Rosenstiel School of Marine and Atmospheric Science) has developed an efficient method for studying recreational fisheries and his report is included in this Proceedings. By taking Bruce Austin's methods into consideration, the data management system calls for NMFS to contract out for a survey of the recreational fishery. The results will compose file SPORT.

BIOLOG

The University of Florida Sea Grant Program, the National Park Service, and the Florida Department of Natural Resources are carrying out active programs of biological research on spiny lobsters. We do not intend to begin new studies of biological research, but will rely on input from these agencies. Their continued work in areas such as migration, growth, stock abundance, mortality, and recruitment is essential to the understanding of the dynamics of the resource and the eventual management for optimum harvest. We will include their biological observations in file BIOLOG, which will form a base from which future observations can be compared.

ECONOM

Guidelines need to be developed for making economic surveys of fisheries for management programs based on optimum harvest. In this way, standard economic surveys can be made by different groups that will be comparative from one time interval to another. The data management system calls for NMFS to contract out for an economic survey of the industry. The results will comprise file ECONOM.

COMPUTER SYSTEM

Description

We are using the time-sharing services of First Data Corporation[3] (FDC),

3. Reference to this particular computer system does not imply endorsement by NOAA, NMFS

Waltham, Massachusetts, to implement the data management system. FDC features multiple DECsystem 10 computers, over 4 billion characters of disk storage, and nationwide access to time-sharing and batch services. FDC supports all 110, 300, and 1200 baud ASCII terminals, 134.5 baud EDCDIC terminals, and remote batch terminals. For data base management FDC provides two systems, IMARS and System 1022.

We are using System 1022 for the spiny lobster data base. System 1022 is a sophisticated, general purpose data management system for any application that involves generation, storage, maintenance, and retrieval of information. System 1022 features include the following.

1) easy-to-use commands:
   a) English-like commands for all operations;
   b) standard default values for commands reduce the amount of user entered information required.

2) efficient operation:
   a) immediate access to records based on user-defined keys;
   b) any number of fields may be used as keys;
   c) time consuming searches of entire data bases are seldom required.

3) convenient manipulation of large data bases:
   a) a data base may contain up to 13 data sets, logically related to form networks or hierarchical data structures;
   b) each data set may contain up to 260,000 records;
   c) records may be any size and may contain any number of fields;
   d) fields may be integer, real, date, or text formats;
   e) fields are compressed internally to as little room as necessary to represent the data.

4) sophisticated report generator:
   a) a few simple commands can easily generate reports as described by the user;
   b) an efficient sorting command is available;
   c) options for automatic pagination, titling, and formatting are provided;
   d) routine arithmetic functions such as row or column totaling are standard;
   e) comprehensive output editing features are available.

5). FORTRAN/COBOL interface:
   permits skilled users to write efficient, customized programs to handle complex data management applications.

Costs

The three primary costs of time-sharing services are for computer resource units (CRU), connect time, and storage. FDC provides toll-free phone lines from/to anywhere within the continental United States. There is no initiation of service fee and no minimum monthly charge.

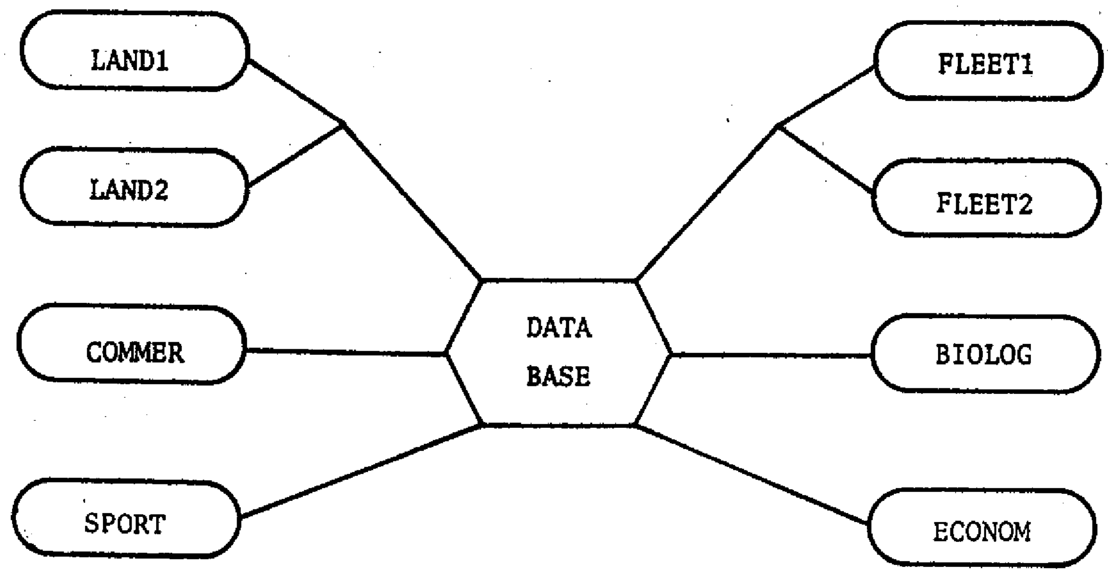

Figure 1. Conceptual design of the spiny lobster data base.

The use of First Data's system resources is measured in computer resource units. CRU's are derived from an algorithm which considers such factors as: central processing unit (CPU) usage, duration of a session, number of input/output transfers, number of file accesses, and the size of the workspace allocated. The prime time (generally corresponds to normal working hours) rate is 1.1¢/CRU; the non-prime time (evenings and weekends) rate is 0.75¢/CRU, for interactive services.

Connect time, the actual time the terminal is connected to the computer via telephone line, is based on two rates. The prime time rate is $7.50/hour. The non-prime time rate is $5.00/hour. This cost can be minimized by efficient use of the system, i.e., when you are not actually working log off the system.

The cost for on-line disk storage is computed on the average number of characters in storage per day. The following table illustrates this cost schedule:

Number of Characters	Cost per 1000 characters/day
0 - 5 million	1.00¢
5 - 10 million	0.83¢
10 - 25 million	0.67¢
25 - 50 million	0.50¢
Over 50 million	0.40¢

Tape storage is also available and is preferable for files that will be used infrequently. The cost is $2.50/month per tape and each tape holds 360,000 characters.

CONCLUSION

We have described a data management system for monitoring the Florida spiny lobster resource, which provides for data storage and retrieval via computer terminal, timely data summaries, and other data management applications[4] Implementation of this system will provide a cost effective management tool with the potential for generating analyses, which will lead to the eventual optimization of resource use. The Florida Department of Natural Resources, National Park Service, and University of Florida Sea Grant Program are cooperating agencies.

4. Since this paper was presented, NMFS Southeast Fisheries Center has established a new division called Technical Information and Management Services (TIMS). The primary function of TIMS is to develop a data management system for fisheries in the southeastern region of the United States. The spiny lobster data base described in this paper will form part of this regional multi-fishery data base.

SIMPLE AND INEXPENSIVE WAYS TO MONITOR DIVING FOR SPINY LOBSTER IN THE FLORIDA KEYS

C. Bruce Austin[1]

INTRODUCTION

I think we would all agree that we presently need, and will more urgently need in the near future, at least some minimal knowledge about the amount of sport diving for Spiny Lobster in order to adequately assess alternative commercial as well as sport fishery policies. The primary obstacle is that we simply haven't come up with a way to obtain this information in a reasonably inexpensive fashion. There are at least two costly factors. The diving grounds are spread over a chain of islands with numerous land departure and return sites. This makes any type of traditional creel census or even the most superficial site interviews costly and complicated in terms of the experimental design. Equally important (and frequently ignored by "comprehensive" one-time studies) is that the monitoring must be conducted, if not constantly, at least on some regular basis to develop time trends which constitute the most important type of information, namely, is the number of divers increasing or decreasing from year to year (and during each season).

MONITORING THE FIRST PRESEASON OPENING FOR DIVERS

During the first two day preseason opening (July 20 - 21, 1975) for Spiny Lobster, Rick Warner and myself with the assistance of NMFS Southeast Fisheries Center staff made an attempt at monitoring sport diving for Spiny Lobster in Monroe and Dade Counties*. This was done by interviewing at four popular Monroe County departure sites (Garrison Bight, Key West; Bahia Honda State Park; Knight Key Park, Marathon; and Indian Key Fill, Islamorada) and three Dade County sites (Homestead Bayfront Park, Matheson Hammock Park, and Crandon Park).

Instead of the conventional creel census method of interviewing every "Kth boater" encountered, the interviewers approached all trailerable boats that were retrieved on a specific portion of the boat ramp. The portion varied from the whole ramp (where traffic was light) to approximately sixty linear water-front feet at the busiest sites. Upon their return, boaters interviewed were asked about that day's offshore destinations and activities. When diving for Spiny Lobster was reported, the number of active divers, hours spent diving, and total lobster catch were recorded. As is the case with most recreational fisheries, the catch per unit of effort (as measured by divers or boats) had a large variance.

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1. Assistant Professor, Dept., of Economics, School of Business and Division of Biology and Living Resources, Rosenstiel School of Marine and Atmospheric Sciences.

* Supported by Uni. of Miami Sea Grant and NMFS, Southeast Fisheries Center

Table A. Spiny Lobster Catches By Sport Divers, Dade And Monroe Counties, July 20 - 21, 1975

		No. of Divers per boat	Catch	Catch per Diver	% of all Boats Lobster Fishing	% of Boats from Dade Co.	% of Boats from Monroe Co.	% of Boats from Other Counties or States
DADE	$\bar{x}$	3.21	8.31	2.52	44	97	0	03
COUNTY	$S_{\bar{x}}$	1.33	9.63	2.72				
	n	244	244	244				
MONROE	$\bar{x}$	3.07	6.13	1.96	60	22	50	28
COUNTY	$S_{\bar{x}}$	.24	1.80	.49				
	n	32	32	32				

The sample size in Monroe County was small because of the large number of departure and return sites. This makes it impractical to cover a sufficient number of sites to obtain a large number of interviews.

The sample size in Dade County was larger (244) because departures and returns were concentrated at a small number of marinas. In Dade the sample size was large enough to experiment with various alternatives for reducing the variances of the estimators. For example, dividing diving by offshore area, "Skill factors" based on reported annual frequency of lobster diving, and SCUBA vs. free diving. None of these distinctions significantly reduced the variances. This problem is a familiar one in the analysis of recreational fishing. The statistical advantages of disaggregations according to expected important fishing characteristics are offset (or made impossible) except with extremely large sample sizes because of the rapidly diminishing number of observations in each category.

While the catch per diver was relatively low, the total amount of sport diving for Spiny Lobster was substantial. Total diving was estimated by combining the percent of boats diving for Spiny Lobster (Table A) with aerial counts of total boats offshore on each day. From knowledge of departure and return times obtained from the interviews, it was possible to estimate what percent of the total daily boating traffic was offshore at the time of the aerial boat census. This facilitated adjustment of the instantaneous boat count to reflect total traffic for the entire day.

Multiplying the estimated catch per diver times the number of divers per boat times the number of boats resulted in an estimation that in Dade County 1289 pleasure craft with 4138 divers captured 10,712 legal size (approximately one pound) lobsters. Because of data limitations such calculations are not presented for Monroe County.

LESS AMBITIOUS PLANS

While monitoring the first preseason opening was a valuable exercise, this conventional approach is not a feasible way to monitor diving for Spiny Lobster because it is too expensive to conduct on a continuous basis (over one season, much less from year to year as would be required to obtain important seasonal and intra-seasonal trends).

We might ask ourselves what information we really need for present or anticipated decision on Spiny Lobster. I believe that catch data may not be that important. As with most recreational fisheries, catch data are of questionable statistical reliability because of the large variances in the estimators. Furthermore, as Gary Davis and others have pointed out, the ultimate influence of divers on Spiny Lobster stocks may be more related to diver contact with the animals than direct fishing mortality from capturing them. There is little doubt that divers come into direct contact and handle many more lobsters than they catch. How divers injure lobsters while trying to catch them or alter their natural aggregations is not known. However, whatever the influences, they would not be reflected by catch data. In this regard total diving "pressure" on the resource would appear to be a better index than a poorly estimated indication of catch.

A SIMPLE WAY TO MONITOR DIVING

If we were satisfied with only monitoring total diving activity (from boats), there may be a relatively simple and certainly inexpensive method to obtain this information on a continuous basis (seasonally and intra-seasonally). The method draws on a basic theory that recreators have established recreational patterns with regard to time (time of day, day of week, season of year). During the 1975 pre-season opening we observed that divers have identifiable daily time patterns. Using some rather crude estimating methods, this is how we attempted to adjust instantaneous aerial boat counts to reflect total daily traffic.

In September 1975 we began a comprehensive one-year study of recreational boating in Dade County.* This study was a first formal attempt to use time-of-day (preference) curves to estimate total daily boating traffic from instantaneous aerial boat counts. What was informally observed in the first Spiny Lobster preseason opening and a year later documented in the boating study was that boating traffic in the categories of linefishing, diving, surface contact (e.g. skiing), and cruising have unique and relatively stable daily time patterns.

Cumulative departures (D) and returns (R) follow logistic patterns (Figure 2). The percent of boats that are offshore at any time of day is D-R. If there were 100 boats observed offshore at 1200 hours then it can be estimated that $100/D_{1200} - R_{1200}$ is the number of boats that will go offshore over the entire day. If there is more than one offshore activity (e.g. fishing and diving) then D-R used in the calculation of total daily traffic must be calculated from D-R for each offshore activity weighted by relative amounts of

* Supported by Metropolitan Dade County Department of Parks and Recreation and University of Miami Sea Grant.

each activity. (See the technical appendix analog computer circuit used to calculate D-R for four activities).

The time of day curves (Table B and Figures 1 and 2) for each activity and the prevailing mix of offshore activities were obtained from site interviews. The site interviews were the time consuming and costly component of the study. Aerial boat census was a minor component. This leads to an idea about monitoring the amount of diving by regular aerial boat census <u>without</u> site interviews.

At the offshore areas where diving for Spiny Lobster is most prevalent there are probably only two primary offshore activities: linefishing and diving (including spearfishing). If the time curves for these two activities were known and if they were statistically distinct and stable (low variances), then the activity mix (proportions of boats engaged in linefishing and diving) and total activity in both categories could theoretically be estimated solely from aerial boat counts. Some simple arithmetic calculations demonstrate how this could be done.

Imagine if an aerial boat count was taken at a specific time, for example 1200 hours. We know from the time curves:

(1) $\emptyset d(t)\ Nd + \emptyset f(t)\ Nf = n(t)$ where :

$\emptyset d(t)$ = percent of diving boats offshore (D-R) at time (t).

$\emptyset f(t)$ = percent of fishing boats offshore (D-R) at time (t).

Nd = total boats engaged in diving on that day.

Nf = total boats engaged in fishing on that day.

n(t) = number of boats observed offshore (aerial census) at time (t)

At a particular time (t) we know:

$\emptyset d(t)$ from time curves
$\emptyset f(t)$ from time curves
n(t) from aerial count of boats offshore

We cannot solve equation (1) for the number of boats engaged in diving (Nd) or fishing (Nf) because there are two unknowns and only one equation. We must know one of the values (e.g. Nf) to solve for the other (Nd). However, if there were two aerial counts on the same day at different times we can solve for the number of boats diving and fishing.

(2) first observation (t=1): $\emptyset d(1)Nd + \emptyset f(1)Nf = n(1)$
(3) second observation (t=2): $\emptyset d(2)Nd + \emptyset f(2)Nf = n(2)$

Solving equation (2) for Nf

(4) $Nf = \dfrac{n(1) - \emptyset d(1)Nd}{\emptyset f(1)}$

TABLE B. Departure And Return Times By Activity Averaged Over Five Dade County Marinas, 1975-76.

Time of Day	Percent Departures and Returns by Activity																			
	Cruise				Water surface contact				Dive/Spearfish				Linefish				Other			
	$\bar{D}$	$\bar{R}$	D	R	$\bar{D}$	$\bar{R}$	D	R	$\bar{D}$	$\bar{R}$	D	R	$\bar{D}$	$\bar{R}$	D	R	$\bar{D}$	$\bar{R}$	D	R
Pre 0600	.8	0	.8	0	.3	0	.3	0	.6	0	.6	0	1.8	.1	1.8	.1	7.0	.4	7.0	.4
0600-0800	2.5	0	3.3	0	.6	0	.9	0	13.1	0	13.7	0	25.5	.1	27.3	.2	3.1	2.0	10.1	2.4
0800-1000	13.5	0	16.8	0	18.3	0	19.2	0	42.6	0	56.3	0	35.9	.1	63.2	.3	18.1	2.5	28.2	4.9
1000-1200	35.4	3.4	52.2	3.4	37.5	1.2	56.7	1.2	29.8	1.9	86.1	1.9	20.4	5.6	83.6	5.9	14.2	6.5	42.4	11.4
1200-1400	29.1	12.4	81.3	15.8	31.9	9.9	88.6	11.1	9.7	13.1	95.8	15.0	8.3	20.1	91.9	26.0	10.3	8.9	52.7	20.3
1400-1600	14.0	29.1	95.3	44.9	9.0	25.1	97.6	36.2	2.8	32.9	98.6	47.9	2.9	34.6	94.8	60.6	18.3	24.8	71.0	45.1
1600-1800	3.1	41.5	98.4	86.4	1.5	46.7	99.1	82.9	.3	39.6	98.9	87.5	1.3	28.8	96.1	89.4	4.4	22.8	75.4	67.9
Post 1800	1.6	13.6	100.0	100.0	.9	17.1	100.0	100.0	1.1	12.5	100.0	100.0	3.8	10.6	99.9	100.0	24.6	32.1	100.0	100.0

$\bar{D}$ = percent of activity departing in time interval

$\bar{R}$ = percent of activity returning in time interval

D = cumulative percent of activity that has departed

R = cumulative percent of activity that has returned

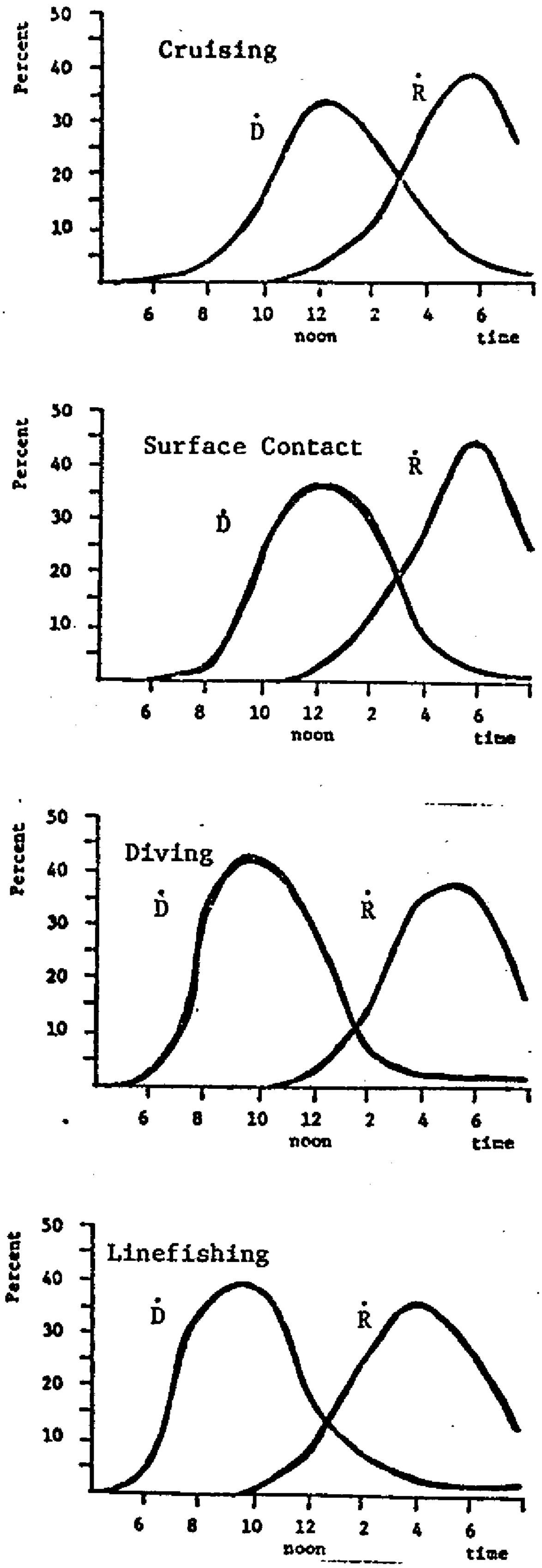

Figure 1. Percent departures (Ḋ) and returns (Ṙ) in the summer (July-September, 1976) by activity

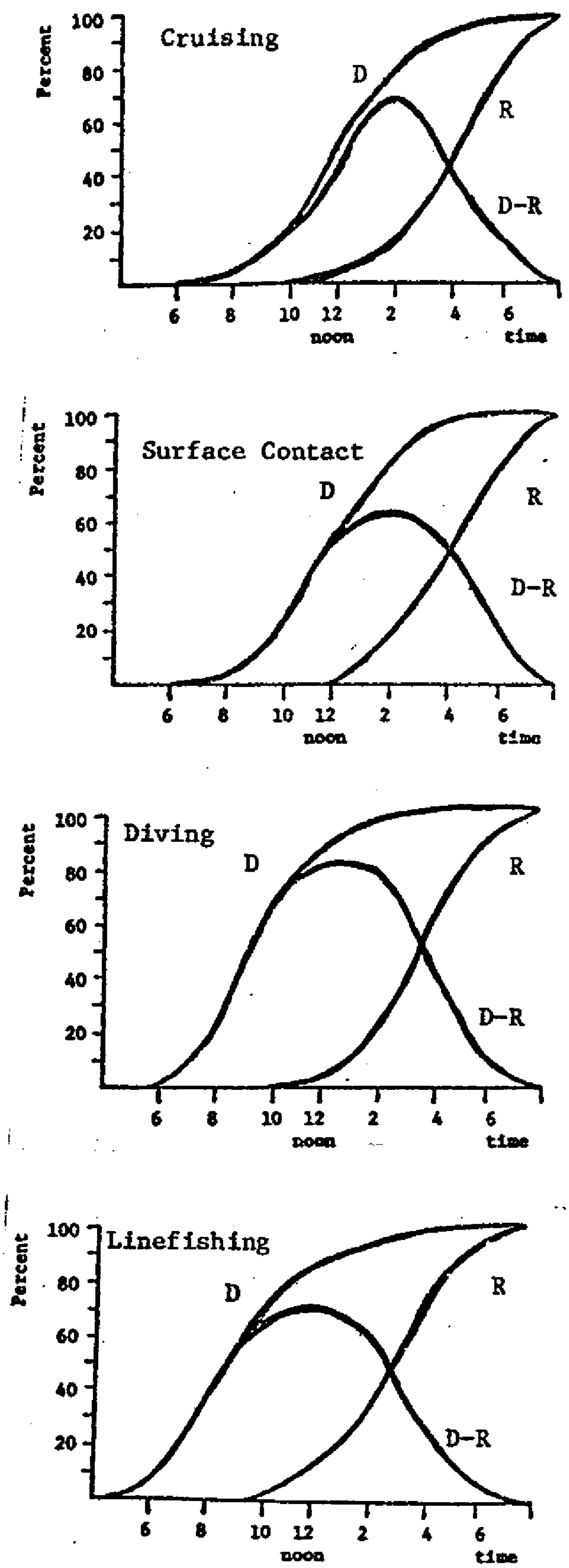

Figure 2. Cumulative percent departures (D) and returns (R) in the summer (July-September, 1976) by activity

Substituting (4) into (3) and solving for Nd:

$$(5)\ Nd = \frac{\frac{n(2)}{\emptyset d(2)} - \frac{\emptyset f(2) n(1)}{\emptyset f(1) \emptyset d(2)}}{1 - \frac{\emptyset f(2) \emptyset d(1)}{\emptyset f(1) \emptyset d(2)}}$$

For expository purposes we can assign values to the parameters in equation (5) from Table B. Let us assume the aerial counts were made at 1100 and 1500 hours (mid-points in the time intervals). Further, assume 155 boats were observed at 1100 hours and 100 boats at 1500 hours.

Table C. Hypothetical observations at 1100 and 1500 hours

Time	D-R for diving	D-R for fishing	Number of boats observed
1100	$\emptyset d(1) = .555$	$\emptyset f(1) = .777$	155
1500	$\emptyset d(2) = .507$	$\emptyset f(2) = .342$	100

Substituting the values in Table C into equation (5) indicates that a total of 119 boats were engaged in diving on that day.

DISCUSSION

This method is very sensitive to the reliability of the time curves. In addition, of course, it is necessary to know the time curves. The curves that have been developed for Dade County might be satisfactorily applied to Monroe County. The results of the recreational boating study in Dade suggest that a modest amount of site interviewing in Monroe could test the applicability of Dade's curves or construct new ones that would be more applicable for Monroe. Fortunately, there is good reason to believe the curves are stable from year to year. However, this is an hypothesis that can be easily tested with a modest amount of interviewing each year.

Once the curves are known, aerial counts at two times on each sample day in each designated offshore area could ascertain (without site interviews):

(1) number of boats at time of aerial count engaged in diving;
(2) total number of boats engaged in diving on that day;
(3) number of boats at time of aerial count engaged in fishing;
(4) total number of boats engaged in fishing on that day.

This may not appear to be sufficient information, but it is probably the best we can hope for unless a very large amount of research money is spent that, I believe, may not be justifiable given the additional information that would be obtained from a more conventional type of creel census. This method could answer the most important immediate and future question about sport diving for spiny lobster, namely, is the number of divers increasing or decreasing (over each season and intra-seasonally).

Of course this method does not distinguish between all divers and those diving for Spiny Lobster. However, I believe this can be done with a reasonable degree of accuracy from the monthly trends in the numbers of divers. Aerial counts would be required outside of the lobster season (August - March) for comparative purposes. We would expect a significant increase in summer diving activity at the beginning of the lobster season (August) followed by a gradual reduction through perhaps November. We don't know what to anticipate during the winter tourist season beginning in December. However, with one year's diving trends guiding the collection of additional information, I believe we could readily interpret future diving trends in terms of diving for Spiny Lobster. Then regular aerial boat counts (approximately seven per month) could provide the basic data on diving for Spiny Lobster in Monroe and Dade Counties.

REPRODUCTIVE POTENTIAL AS A FUNCTION OF FEMALE SIZE IN *Panulirus argus*

By

Paul Kanciruk[1] and William F. Herrnkind

Specimens of the Caribbean Spiny Lobster, *Panulirus argus*, were diver collected during the autumns of 1971-74 at and near the twin islands of Bimini, Bahamas, as part of a larger study into the migratory behavior of this species. This investigation into the reproductive potential of the population was made with special reference to the Florida legal size (76 mm or 3-inch carapace length).

Autumnal reproductive activity was high (40-60% gravid females) in localized deep water populations at Bimini (Kanciruk and Herrnkind, 1976), in contrast to that reported in much of the literature. We believe that these data point out: 1) the superiority of diver sampling over trap sampling (Morgan, 1974); 2) caution when averaging data from differing habitats (breeding females were quite localized along the deep fringing reef areas and were wholly absent from the shallow bank area); and 3) caution when generalizing data obtained from one population/habitat to another. Reliable diver survey at the Dry Tortugas (Gary Davis, pers. comm.) indicates a lack of autumnal reproductive activity.

In all, 1438 females were diver-collected from varying habitats (shallow bank sponge-sea whip areas and the deep coral habitats) and examined. Size and presence of eggs were noted. In order to rank each size class in terms of contribution to the estimated population egg production, an Index of Class Reproductive Potential was developed:

$$\text{Index} = A \times B \times C/D$$

Where : A = # females in class/total sample
B = propensity of class to carry eggs
C = egg carrying capacity of average class female
D = constant (31.27)

The constant, D, was chosen to set the 76-80 mm (carapace length) class's index to 100 as the standard. For example, the 76-80 mm class, which made up 21.2% of the sample, had a 5.9% propensity to carry eggs, and, when gravid, a female of this size range will carry approximately 2.5×10^5 eggs (Mota-Alves and Bezarra, 1968). The calculated index is:

$$\text{Index} = .212 \times .059 \times (2.5 \times 10^5) / 31.27$$

$$\text{Index} = 100.0$$

1 - Present Address: Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37830.

Frequency of egg bearing, egg carrying capacity, Index of Class Reproductive Potential, % contribution to total egg production, and a relative measure of class productivity for each size class are given in the table and figure.

The size frequency for the sample (Figure 1) indicates the population is lightly fished. Larger lobsters are quite abundant in contrast to size-frequencies of heavily fished populations where the frequency drops off sharply at or near the legal size. The solid inverted triangles indicate the 76 mm carapace length Florida legal size. Approximately 25% of the sample consisted of females 76 mm or smaller, yet only 1.9% were observed to carry eggs. In contrast, in the 96 - 100 mm females (comprising only 3.6% of the sample) 19.2% were observed to be gravid. It has been estimated that a 71 - 75 mm female when gravid carries 2.3×10^5 eggs and a 96 - 100 mm female carries 5.3×10^5 eggs.

When these factors are integrated by the Index of Reproductive Potential an interesting pattern emerges (Table A; Figure 3). The size class most productive is the 81 - 85 mm class, producing 26.3% of the estimated total egg production (index = 233), although comprising only 9.6% of the total population. Very large females ($\geq$101 mm) are relatively less productive. The size class that would be legally protected in Florida waters ($\leq$ 76 mm) appears to contribute insignificantly to total egg production, producing only 3.2% of the eggs although comprising 25% of the population. As a class, the 71 - 75 mm females exhibited a productivity of .15 as compared to 3.9 for the 76 - 100 mm class (a 26 fold increase).

In summary, the data for Bimini suggest that in the autumn small females (<80 mm) are quite unproductive in their contribution to total egg production. Larger females contribute the most. In addition, a female captured just at or slightly larger than legal size (76 - 78 mm) probably has not had the chance to mate and produce eggs.

These data are not unique to Bimini or to the Autumn. Recently, a large sample (1574 females) from an unfished population at the Dry Tortugas in the Spring (Davis, 1975), yielded similar results. The smallest berried female captured measured 78 mm and the percent berried by size class peaked at 96 - 125 mm.

The importance of this information to the Florida fishery is unknown. There are many factors other than egg production that can influence population size. However, if further investigation indicates that egg production is critical in maximizing population size, then these data are of importance. We then must insure the reproductive potential of the population acting as larval source for our fishery (whether it be local or foreign). If these data can be extrapolated to the unknown source population(s), they indicate that a 76 mm carapace length legal size may be an inadequate protector of reproductive potential in *P. argus*. An additional consideration is protection of potential autumnal and other late-breeding stocks. For example, selective habitats where late reproduction occurs might be closed to fishing.

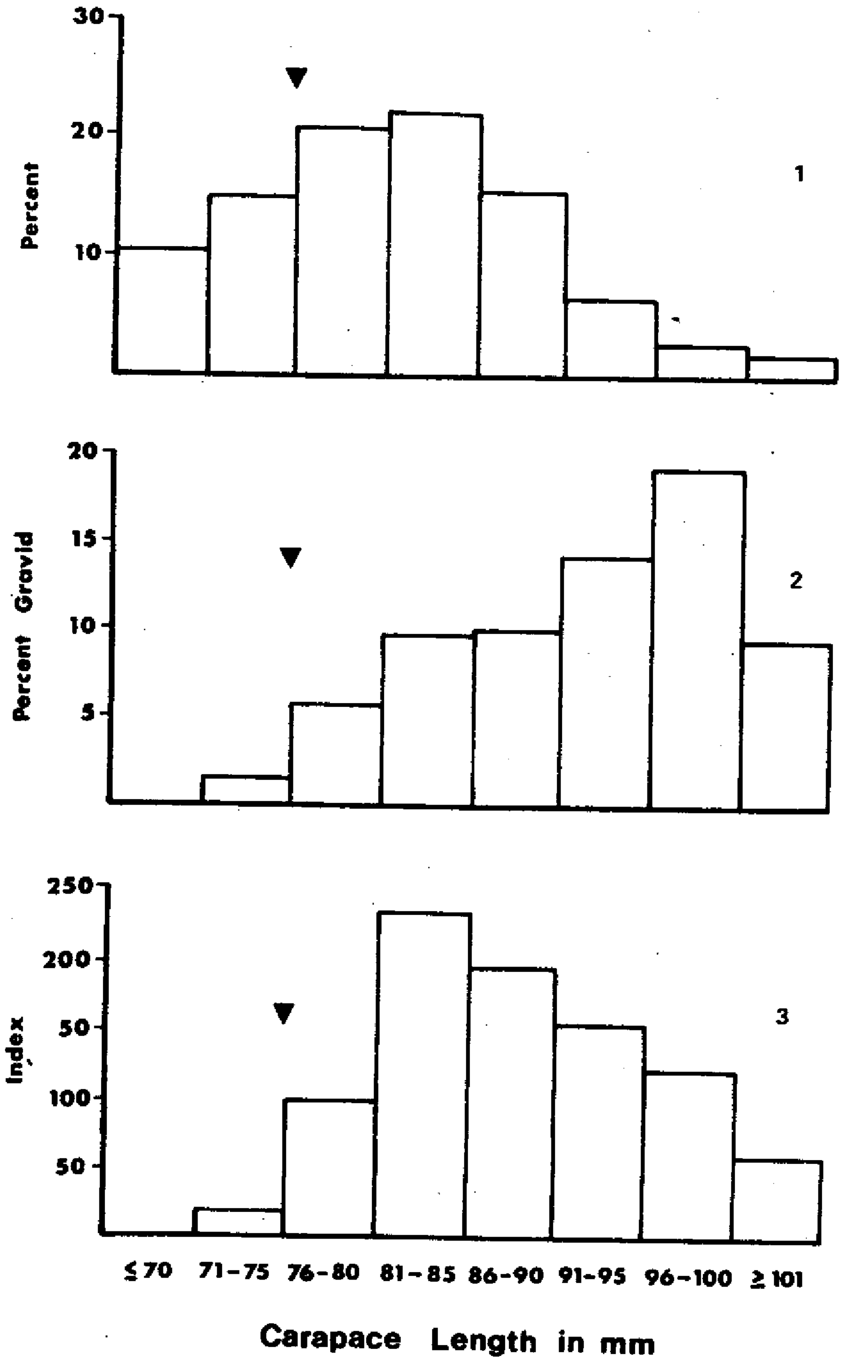

Figure 1. Size-Frequency of all Females.
Arrow indicates minimum legal size.

Figure 2. Percent of all Gravid Females vs. Size Class.
Note larger females were more frequently observed to carry eggs.

Figure 3. Index of Reproductive Potential vs. Carapace Length.
The bulk of egg production is generated by large females in the population even though they make up a small proportion of total females.

TABLE A

INDEX OF REPRODUCTIVE POTENTIAL

Size Class of Female (Carapace Length) n = 1438

		_70mm	71-75mm	76-80mm	81-85mm	86-90mm	91-95mm	96-100mm	_101mm
A	% of total	10.4	14.9	21.2	23.8	15.7	7.4	3.6	2.9
B	% with eggs	0.0	1.9	5.9	9.6	9.7	14.0	19.2	9.5
C	estimated # eggs carried when gravid ($x10^5$)	2.0	2.3	2.5	3.2	4.0	4.7	5.6	7.0
D	index of reproductive potential	0.0	20.5	100.0	233.8	194.8	155.7	123.8	61.7
E	% of total egg production	0.0%	2.3%	11.2%	26.3%	21.9%	17.5%	13.9%	6.9%
F	productivity (E/A)	0.0	.15	.52	1.1	1.4	2.4	3.9	2.4

After Kanciruk and Herrnkind, 1976

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FLORIDA'S PROGRAMS OF DATA RETRIEVAL AND ANALYSIS FOR THE SPINY LOBSTER FISHERY

Charles R. Futch[1]

In addition to Spiny Lobster recruitment studies being conducted through the Marine Research Laboratory, the Florida Department of Natural Resources Bureau of Marine Science and Technology is working toward development of a data retrieval system to more accurately assess dynamics of the fishery. A computer-based system for issuing lobster trapping licenses has been designed; implementation awaits funding. Such a system will allow interface of other data files, including Florida boat registrations and commercial landings statistics. The Bureau is also engaged in a cooperative program with the National Marine Fisheries Service, Southeast Fisheries Center, Miami Laboratory, to describe the capabilities of Florida's lobster fleet and to derive catch per unit effort statistics for a sub-sample of the fishery.

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1. Bureau of Marine Science and Technology, Florida Dept. of Natural Resources, Tallahassee, Florida.

POPULATION STRUCTURE OF JUVENILE SPINY LOBSTER, *Panulirus argus*, IN THE GRAND BAHAMA AREA

Gregg T. Waugh, B.Sc.[1]

A complete understanding of the spiny lobster, *Panulirus argus* (Latreille) resource, requires information covering its complete life cycle. Considerable effort has been directed towards larval, post-larval and adult stages, but the juvenile stage has been practically ignored. Lewis (1951) described the phyllosoma larvae of *P. argus* and was first to mention that foreign recruitment may take place; that is, the local population may depend upon an external supply of larvae. Lobsters in the Bahamas may come from eggs of lobsters in the southeast Caribbean. Lewis, et al. (1952) described the first 11 post-larval stages of *P. argus* from animals reared in the laboratory. Witham, et al. (1968) wrote on the ecology and physiology of pueruli and post-larvae of *P. argus*.

Adult spiny lobsters have been studied by many workers, e.g., Sweat (1968)- growth and tagging, *P. argus*, Florida; Buesa (1969)- biology and fishery, *P. argus*, Cuba; Morgan (1974a, b)- population dynamics, *P. cygnus*, Australia. Juvenile studies are less numerous, e.g., Chittleborough (1970)- recruitment, *P. longipes*, Australia; Eldred, et al. (1972)- growth rate, *P. argus*, Florida; Chittleborough (1974)- home range, homing and dominance, *P. longipes*, Australia.

Various means of collecting post-larvae and small juveniles have been documented: Witham (1968)- post-larvae, *P. argus*, Florida; and Phillips (1972)- pueruli, *P. longipes cygnus*, Australia.

In Florida, work on adult spiny lobsters is being conducted by Warner, Combs, and Gregory (University of Florida) and Davis (National Park Service). Little (Florida Department of Natural Resources) intends to study early post-larval stages. No one has proposed to study juveniles as intensively as is needed, although Davis is doing some work on juvenile growth rates.

Not only are most researchers not collecting data on juveniles, but their collecting techniques actually select against obtaining such data (Chittleborough, 1974). This occurs due to the dominance exerted by adults collected in standard traps which prevents juveniles from entering the traps.

The objectives of my study are to:

1) determine number of juvenile lobsters in the study area. This information is required to determine numbers of potential recruits to the fishery and to help estimate the maximum sustainable yield (MSY);

2) determine their survival rate, and attempt to identify the juvenile lobster's major predators. This will aid in

1. Post Office Box F-3, Freeport, Grand Bahama, Bahamas

predicting future catches and also is a factor in determining optimum harvest size for the individual, i.e., minimum carapace length. Lobsters should be harvested before there is a large loss due to natural mortality. If they must die, it would be better if they were used by man and not lost to nature;

3) determine growth rate of juvenile lobsters. This will be used to determine optimum individual harvest size and possibly predict (with survival data) future yields;

4) determine rate of recruitment of juveniles into the fishable stock. By knowing the number of lobsters present at the beginning of the juvenile stage and those remaining at the harvestable size I will be able to calculate losses during the juvenile stage. Knowing the numbers present when lobsters enter the fishery, I should be able to predict potential catches of legal-sized lobsters.

The study area is located on the north side of Grand Bahama Island in the Bahamas, near Man-o-War Bush Point (Figure 1). This area was chosen because of the known abundance of juvenile lobsters and my familiarity with this part of the Island. Figure 1 is a map of the West End area showing the study site.

Any ecological study must encompass at least one year, thereby showing seasonal variations. For results of this study to be conclusive, data should be collected over a three-year period to give annual variations. I will be able to carry out this research for only one year for my Master's thesis. This research will yield seasonal results and will be a valuable addition to our knowledge of juvenile lobster biology in the Bahamas. The project should be continued in the future to support or modify conclusions resulting from this study.

As fishing effort increases, the need for proper management of spiny lobsters becomes more apparent to ensure the future of the fishing industry. This research could aid future management decisions by providing information, conclusions, and recommendations concerning the population structure of juvenile spiny lobsters.

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AN ECONOMICAL METHOD OF TRAP FISHING FOR SPINY LOBSTER, *Panulirus argus*, IN THE BAHAMAS

Gregg T. Waugh and Harold R. H. Waugh[1]

Fishing for spiny lobster, *Panulirus argus*, in the Bahamas with wooden traps was first legalized for the 1973/1974 season. Spiny lobsters are commonly referred to as "crawfish" by most Bahamians.

Prior to the 1973/1974 season the only legal method of harvesting spiny lobster commercially was bully netting; traps or pots were outlawed. With the advent of spearfishing and the increased value of catches, numerous spiny lobsters are now captured by divers using a spear.

Converting our village fishermen from the spearfishing and bully netting styles of commercial fishing to the use of wooden traps need not involve the previously anticipated vast capital outlay.

For the past two seasons (1975/1976; 1976/1977) we were granted a trapping license K-1 by the Ministry of Agriculture and Fisheries, which authorized us to fish in the Grand Bahama area (Figure 1). A 16-foot Boston Whaler was outfitted with a trap puller obtained from the Fisheries Store. A homemade tripod with an open block was installed, traps, ropes and floats were purchased, bait obtained, and we were ready to begin trapping.

Our traps were set in 80-100 feet of water, thus making them invisible to the naked eye, and too deep for us to be affected by spear-fishermen or divers. Each trot-line had a buoy line 100 feet in length, rigged with a pop-up or time-delayed release device (Richard, 1971). This device is made of an alloy of magnesium and zinc, which corrodes or dissolves in salt water at a known rate. A wire is attached through a braid of the rope approximately 40 feet below the float, with a second wire some 20 feet above the trap. After connecting the two wires with the pop-up, the first trap overboard pulls the float down below the surface of the water (Figure 2).

The capital investment necessary to organize a one-boat, 300-trap fishing unit is outlined in Table A. Two village fishermen could be established as a fishing unit with a $12,000 investment.

The cost analysis covers 3 years, which equals the life time of the weakest gear component, i.e., the traps (Table B). The traps and engines were depreciated over three years, whereas the rest of the gear was depreciated over five years.

A summary of actual catch and effort data appears in Table C. Our average catch rate of 0.3789 pounds (lb.) per trap day (td) is the figure used in estimating the potential returns from this fishery. Trap day is defined as one trap fishing a 24-hour period.

1. Post Office Box F-3, Freeport, Grand Bahama, Bahamas

Fishing 300 traps with an average soak time or fishing time of 30 days per month results in 9000 trap days per month. Using our average catch rate of 0.3789 lb./td, the potential monthly catch equals 3,410.1 lb. This weight, sold at the average ~~price per~~ pound whole weight of $1.50, would gross the fishermen $5,115.15 per month. Based on an eight-month season, the theoretical gross per year equals $40,921.20, quite a high return for an investment of only $12,000. The potential earnings of our fishing unit over a three-year period appears in Table D.

It is our contention that with the adoption of the outlined fishing method, a fleet of small fishing boats could be outfitted at a much reduced cost, which would also provide a significant boost to the local economy. A loan program could be developed by the Ministry whereby interested fishermen would be set up to trap spiny lobsters for $12,000 per fishing unit. Projecting our catch rates the loan could be repaid within the first year. Thus a large expenditure is not necessary to establish a spiny lobster industry, and those funds which could be allocated would assist a greater number of fishermen by using our small but efficient fishing units.

In conclusion, by adopting our recommendations and fishing methods a fleet of small Bahamian fishing boats could start to harvest the vast quantity of spiny lobsters available in our nation's waters.

Figure 1. Grand Bahama (*) Study Area

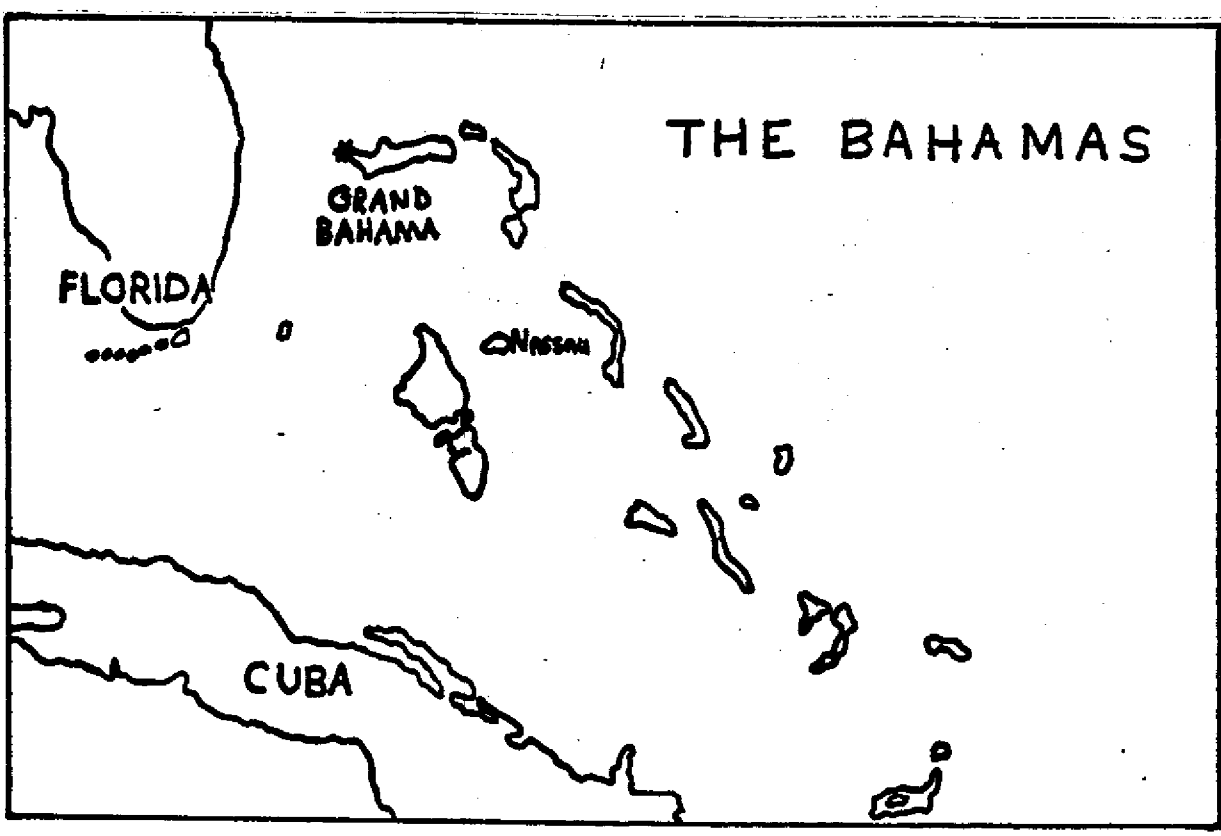

Figure 2. Method Of Attaching Pop-ups To Buoy Line. Total Length Of Buoy Line Is 100 Feet. Depth Of Water Fished Is A Factor Of Length Of Buoy Line And Positioning Of Pop-up.

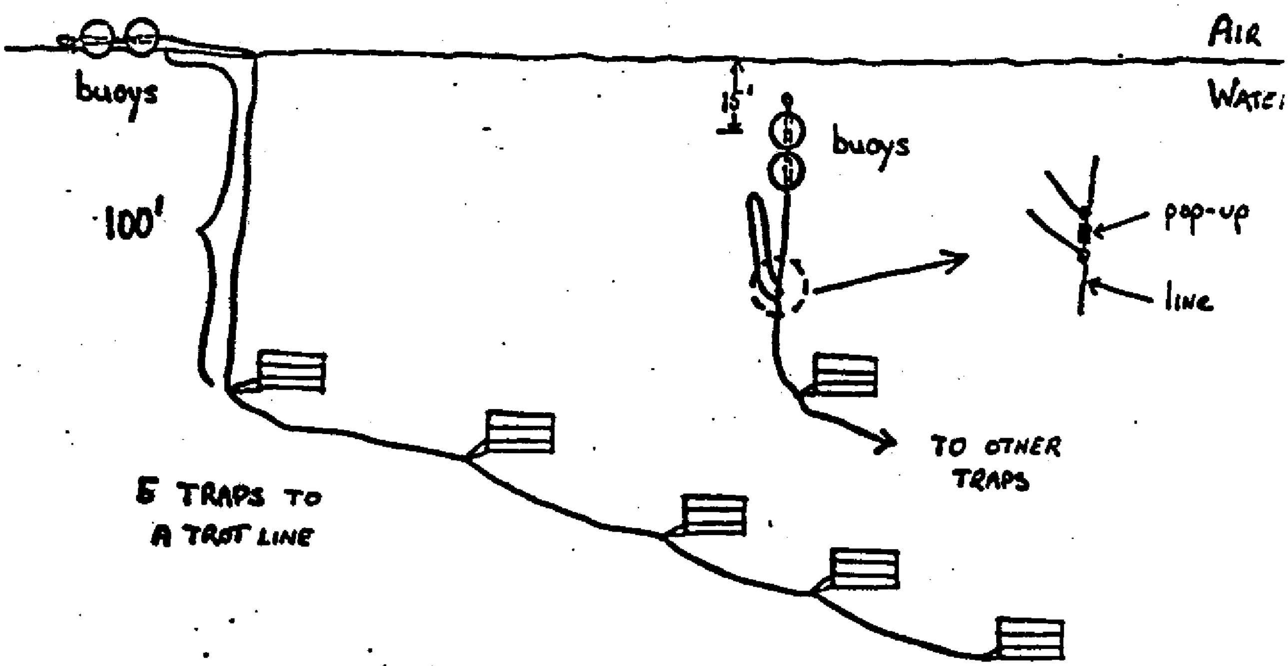

TABLE A. Capital Investment Necessary In Organizing A One Boat (16 ft), 300 Trap Spiny Lobster Fishing Unit.

Item	Cost ($)
Boat (New Boston Whaler)	$ 3,000.oo
Trap Puller (New 7 H.P. Gas Puller)	400.oo
Mounting	400.oo
Traps ($16 ea. rigged)	4,800.oo
Bait Cans (350 @ 34¢ ea.)	125.oo
Engine (New 85 H.P. Outboard)	2,200.oo
Other Expenses & Working Capital	1,075.oo
TOTAL	$12,000.oo

TABLE B. Cost Analysis For A Small Bahamian Spiny Lobster Boat Fishing 300 Traps.

Item	Dollar Cost For Years 1 To 3		
	Year 1	Year 2	Year 3
Variable Costs			
Fuel	$ 720.oo	720.oo	720.oo
Oil and Oil Change	160.oo	160.oo	160.oo
Bait	960.oo	960.oo	960.oo
Brush	17.oo	17.oo	17.oo
Gloves	60.oo	60.oo	60.oo
Rain Gear	70.oo	70.oo	70.oo
Vests	20.oo	20.oo	20.oo
Wages	8,000.oo	8,000.oo	8,000.oo
Repairs & Maintenance	1,000.oo	2,000.oo	3,000.oo
Total Variable Costs	11,007.oo	12,007.oo	13,007.oo
Fixed Costs			
Depreciation			
Traps	1,600.oo	1,600.oo	1,600.oo
Boat	600.oo	600.oo	600.oo
Trap Puller	133.34	133.33	133.33
Engine	733.34	733.33	733.33
Boat Cans	41.67	41.67	41.66
Loan	12,000.oo	---	---
8% Interest on Loan	960.oo	---	---
Total Fixed Costs	16,068.35	3,108.35	3,108.35
Total All Costs	27,075.35	15,115.35	16,115.35

TABLE C. Summary Of Actual Catch And Effort Data For March, August, September, October, And November 1976. Trap Day (td) Is Defined As One Trap Fishing A 24-Hour Period.

Date	Number Legal Lobsters	Weight (lb.)	Number Shorts	Total Number Lobsters	Number Fish	Trap Day (da.)	Average Legal Catch Per td(lb.)	Income ($)
March	803	1,162.0	259	1,061	13	2,700	0.4304	$2,033.50
August	407	486.5	-	-	-	1,525	0.3190	851.38
September	214	272.0	424	538	25	1,805	0.1507	476.00
October	1,199	1,241.0	342	1,541	38	2,220	0.5590	2,171.75
November	1,671	1,835.5	748	2,419	35	4,214	0.4356	3,212.13
TOTALS	4,294	4,997.0	1,773	5,559	111	12,464		$8,744.76
Average Catch							0.3789	

TABLE D. Summary Of Costs And Returns For A Small Boat Spiny Lobster Fishery. No Estimate Of Marketing Costs Has Been Included Because This Would Be Highly Variable, Depending On Where The Fishery Was Based.

Item	Year 1	Year 2	Year 3
Total Costs	$ 27,075.35	$ 15,115.35	$ 16,115.35
Gross Return	40,921.20	40,921.20	40,921.20
Net Return	13,845.85	25,805.85	24,805.85
Return Rate	1.15	2.15	2.07

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