Stock Assessment of the Spiny Lobster (*Panulirus argus*) in Jamaica

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ABSTRACT

A time series of length frequency data on the spiny lobster (*Panulirus argus*) collected from commercial fisheries in Jamaica between November 1985 and March 1987 is analyzed to obtain estimates of population parameters. The von Bertalanffy growth parameters L_∞ and K are estimated using the ELEFAN 1 routine and modal progression analysis. A length converted catch-curve is constructed from which total mortality and mean selection size are estimated. Total mortality (Z) is split into natural mortality (M) and fishing mortality (F). Population size and exploitation pattern are estimated by Jones length cohort analysis.

INTRODUCTION

The spiny lobster, *Panulirus argus*, is widely distributed in the coastal waters and on the offshore banks around Jamaica. It is a highly priced resource and represents an important component of the total landings of Jamaican commercial fisheries. The largest concentration of lobsters are to be found on the Pedro Bank which accounts for the major part of the fishery (Figure 1) .

Landings of lobster in Jamaica have increased from about 260 tonnes in 1981 to about 680 tones in 1986 (Anon., 1987). This increase in landings has been accompanied by a major increase in effort resulting from a substantial increase in the number of traps and in the number and size of fishing vessels entering the fishery (Aiken and Haughton, 1987). Consequently, fears have been expressed that the rapid expansion of the industry may be at the expense of a considerable depletion of the spawning stock biomass, with the concomitant risk of fishery-induced recruitment failure.

Behavior and general biology of the spiny lobster in the Caribbean and Gulf of Mexico have been investigated in considerable detail (see Aiken, 1983 and references therein), but little is know about the population dynamics of the species in Jamaican waters. The study by Munro (1983a) is the only significant account relating to the dynamics and management of this resource that has been published in the open scientific literature. The present paper gives details of the growth, mortality and potential yield of the Jamaican lobster, and reviews these results in relation to the management and conservation of the species.

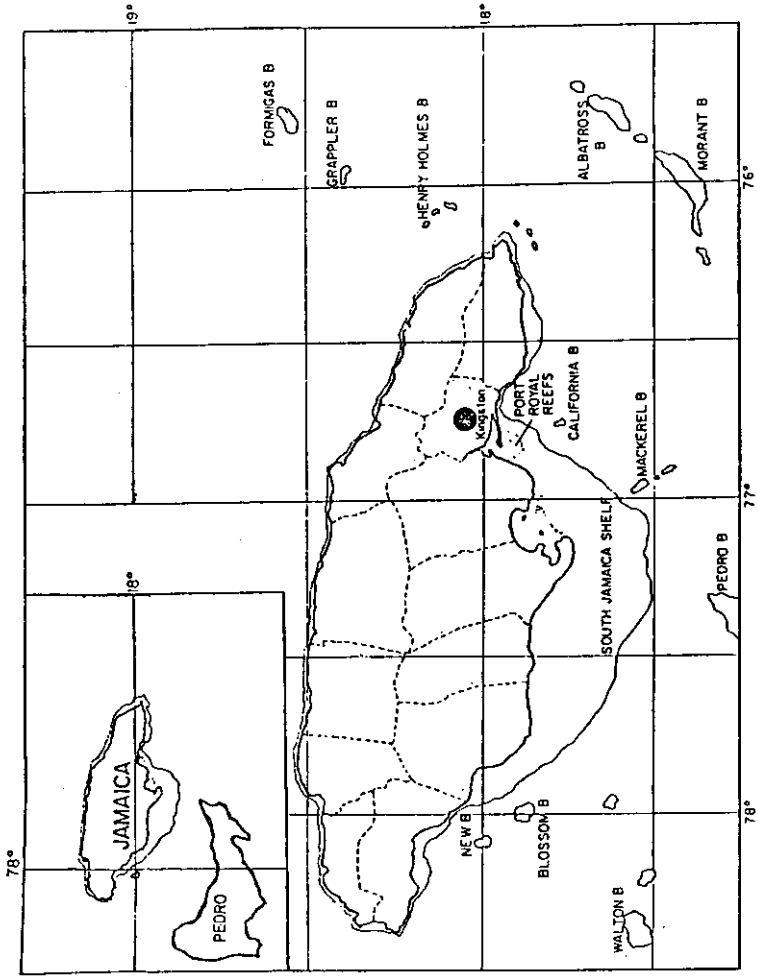

Figure 1. Map of Jamaica and Pedro Bank.

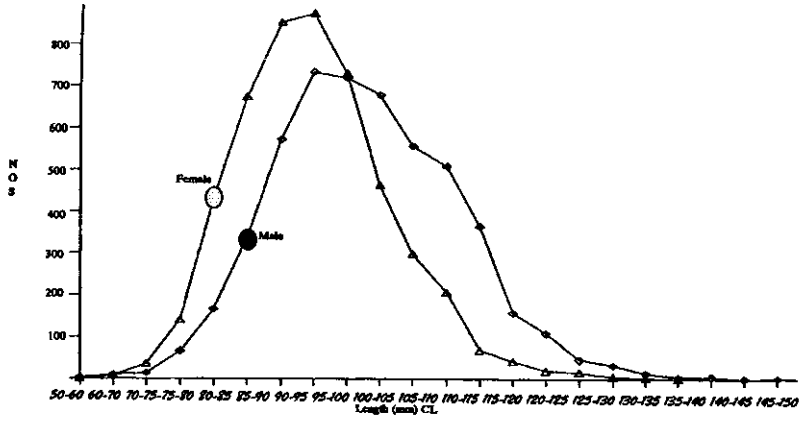

Figure 2. Length frequency data for *P. argus* collected from Pedro Bank.

MATERIAL AND METHODS

The length composition data used in this study were collected from the commercial fishery during the period November 1985 to March 1987. All the data analyzed were from the Pedro Bank except those used in the calculation of the length-weight relationship, when samples taken from the southern shelf and Morant Bank were included in the analyses.

The sampling and measurement procedures were as described by Haughton and Shaul (1989). The data was analyzed with the aid of the length composition based fish stock assessment computer programs "LFSA" (Sparre, 1987) and "ELEFAN" (Brey and Pauly, 1986).

RESULTS

Size Composition

During the study period, 9,968 lobsters were collected, of which 5,096 were males and 4,872 females. Hence, the sex ratio was close to unity: (1.04 males to 1.00 females). The size range was from 55 mm to 177 mm carapace length (CL) (Figure 2), but the single largest specimen (177 mm CL) was not used in the

analyses to avoid having a length class (*i.e.*, 170 – 175 mm) with zero frequency. The mean carapace length of the males and females was 100.5 mm and 92.5 mm respectively. The modal lengths for males and females were 92.5 – 97.5 mm CL and 87.5 – 92.5 mm CL respectively. The carapace lengths of the males are consistently larger than those of the females. Males and females combined had a mean size of 96.5 mm CL and a modal size of 90 – 95 mm CL.

Full recruitment to the fishery at Pedro Bank occurs at 90 – 95 mm CL for both sexes. The mean length of the fully recruited males and females was 105.6 mm CL and 100.4 mm CL respectively.

Length-Weight Relationship

Samples of 178 female and 211 male *P. argus* collected from the southern Jamaican shelf and Pedro Bank produced the following length/weight relationships:

FEMALE: $W = 0.00499*CL^{2.62}$ (grams, millimeters)
MALE: $W = 0.00316*CL^{2.71}$ (grams, millimeters)

The 95% confidence interval constructed around the coefficients have ranges of 2.64 – 2.78 for males and 2.52 – 2.73 for females. The overlapping confidence intervals indicate, therefore, that male and female *P. argus* do not differ significantly in their length-weight relationship.

Growth and Recruitment Pattern

Estimates of the growth parameters and their corresponding ESP/ASP ratios computed from the ELEFAN program are given in Table 1.

The ESP/ASP ratios for the males and females are substantially different. The higher ratio (0.526) obtained for the females suggests that the estimated growth parameters gave a better fit for the female than the corresponding parameters for the males. Moreover, females have a higher growth rate and attain their maximum size more quickly than the males.

Mortality Rates and Selection Ogives

The instantaneous rate of total mortality (Z) was estimated by length converted catch curve analysis. The vales of Z obtained were, 2.19 for males, 2.88 for females, and 2.50 for both sexes combined.

The instantaneous rate of natural mortality was estimated from Pauly's empirical formula (1984):

$$Ln(M) = -0.0152 - 0.279*Ln(L_{\infty}) + 0.6543*Ln(K) + 0.463*Ln(T)$$

Table 1. Von Bertalanffy growth parameters for *P. argus* derived from ELEFAN 1 (K = growth coefficient; L_∞ = asymptotic length).

	K(y-1)	L_∞(mm)	ESP/ASP
MALE	0.24	210	0.354
FEMALE	0.28	195	0.526
COMBINED	0.26	205	0.443

Table 2. Selection parameters for *P. argus* from Pedro Bank.

	Males	Females	Combined
L_c(50%) mm CL	94.4	87.8	92.0
T_c (50%) rel. yrs	2.49	2.09	2.29

where K = growth coefficient
L_∞ = asymptotic length
T = temperature of the fishing ground in degrees centigrade

The value of T used to determine M was 28 degrees centigrade. The estimated values of M were 0.59 for males, 0.67 for females, and 0.62 for both sexes combined.

The instantaneous rates of fishing mortality F and the exploitation rates E were computed from the estimates of Z and M obtained above. The fishing mortality for the females was F = 2.21, compared to F = 1.60 for the males. The estimates of exploitation rate were E = 0.77 for females and E = 0.73 for males.

Theoretical estimates of selection ogives for the lobster fishery at Pedro Bank were obtained using the results of catch curve analyses. The mean selection ages (relative) and lengths are presented in Table 2.

Population Estimates and Exploitation

Estimates of stock size and fishing mortality were obtained using Jones' Length Converted Cohort Analysis (Jones, 1984; Sparre, 1986). The total catch for 1986 was approximately 0.56 million lobsters weighting 454 t. The total number of survivors in the population on Pedro Bank at the end of 1986 was estimated at 8.9 million individuals, with a biomass of approximately 4,000 t. The mean fishing mortality on the fully recruited length groups was F = 1.28 for males and F = 2.11 for females.

DISCUSSION

Munro (1983a) studied the lobster populations on Pedro Bank between

1969 and 1973 when they were still largely unexploited. The mean lengths of males and females calculated from the data collected by Munro (1983a) were 118.2 mm CL and 102.3 mm CL respectively, compared with 100.5 mm CL and 92.5 mm CL obtained by the present investigation. Munro (1983a) reported modal lengths of 110 – 119 mm CL and 90 – 99 mm CL for males and females compared with 92.5 – 97.5 mm CL for males and 87.5 – 92.25 mm CL for females obtained during the present study. The mean and modal size classes obtained during this investigation are, therefore, significantly lower than those obtained by Munro. The size class at which full recruitment to the fishery at Pedro Bank occurs is 90 – 95 mm CL for both sexes. The mean length of the fully recruited males and females are 105.6 mm CL and 100.4 mm CL, compared to 126.7 mm CL and 104.7 mm CL reported by Munro (1983b). The reduction in the mean and modal size of the lobster population on Pedro Bank is almost certainly due to the increase in fishing pressure that has occurred over the last decade. The mean and modal size of the lobster population obtained during this study are still well above the minimum legal size of 76 mm CL, and slightly greater than the mean size at maturity of 84 – 90 mm CL reported by Aiken (1983).

Munro (1983a) calculated growth parameters from the results of tagging experiments in Belize, and obtained a K value of 0.21 per year and L_{∞} of 109 mm CL for males and females combined. The Gulf of Mexico and South Atlantic Fishery Management Councils (1982) reported that the most likely range of K was 0.20 – 0.30 per year and selected the midpoint of the range (K = 0.25) as the best estimate for male and female combined. This is very close to the value of (K = 0.26) obtained in this study for the combined data.

It should be emphasized that the von Bertalanffy growth curve describes the average growth of a cohort of *P. argus* rather than the growth of an individual lobster, which would be represented by a "stepwise" curve as a consequence of the molting process. Furthermore, the curve does not describe the growth during the early life stages of the lobster. It seems reasonable, however, to assume that the curve would include the juvenile and adult exploited stages of the life history. If the assumption is made that the larval life span is about 6 months, then crude approximations of the absolute age may be obtained by adding six months to the relative age derived from the growth analysis. Lobsters measuring 47 mm CL would, therefore, be approximately 1.6 years old, and the mean age at first capture, T_c, should be about 2.8 years.

Estimates of total mortality Z reported in the literature vary from $1.72 \leq Z \leq 2.73$ for K = 0.20, to $2.59 \leq Z \leq 4.09$ for K = 0.30 (The Gulf of Mexico and the South Atlantic Fishery Management Councils, 1982). The values of Z obtained in this study (Z = 2.19 and 2.88 for males and females respectively) are within these ranges.

The selection curves presented in the present study are not true selection

ogives but rather resultant curves, because they reflect the combined effect of gear selection and recruitment (Sparre, 1986). Small lobsters, therefore, may not occur in the catch, either because they are not present on the fishing ground, or because they are small enough to escape from the traps.

The results of Jones length cohort analysis suggest that approximately 1.3 million lobsters in the 55 – 60 mm range are recruited to the fishery each year at Pedro Bank. The population size is approximately 4.9 million, and approximately 0.60 million individuals were captured by the fishery in 1986. Fishing mortality on the length groups that are fully recruited to the fishery appears to be very high. The exploitation rates (E = 0.77 and E = 0.73) for the males and females respectively are greater than the accepted optimum level of 0.5 or less (Pauly, 1984) and suggest that the lobster population on Pedro Bank is being exploited at a rate which is not sustainable.

To summarize the lobster population on Pedro Bank has changed considerably since Munro's (1983a) study and the fishing effort has increased significantly over this period. Although the mortality estimates may be subject to considerable error as a consequence of the biases in the data collected from the commercial fishery and the assumptions made during analyses, the present level of fishing mortality appears to be much greater than the optimum required for the fishery. Fishing mortality should be reduced to reduce the risk of over-exploitation. Much more research is needed to clarify the uncertainty which exists regarding the source of recruits for the fishery, the settlement of the puerului, the period of larval life, and for refinement of growth, mortality, and selection estimates.

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LITERATURE CITED

Aiken, K.A. 1983. Further investigation of the Jamaica spiny lobster fishery. *FAO Fish. Rep.* No. 278, Suppl: 177-191.

Aiken, K.A. and M. Haughton. 1987. Status of the Jamaica reef fishery and proposals for its management. *Proc. Gulf Carib. Fish. Inst.* **38**:469-484.

Anon., 1987. Fisheries Division file on the spiny lobster, 1988. Fisheries Division, Marcus Garvey Drive, Kingston, Jamaica.

Brey, T. and D. Pauly. 1986. Electronic length frequency analysis. A revised and expanded user's guide to ELEFAN 0, 1 and 2. ICLARM Contrib. No. **261**. Manila, Philippines.

Gulf of Mexico and South Atlantic Fishery Management Councils. 1982. Fishery management plan, environmental impact assessment and regulatory impact review for spiny lobster in the Gulf of Mexico and South Atlantic. Charleston, SC.

Haughton, M.H. and W. Shaul. 1989. Estimation of growth parameters for the spiny lobster (*Panulirus argus*) in Jamaican waters. *Proc. Gulf Carib. Fish. Inst.* **39**: 279-288.

Jones, R. 1984. Assessing the effects of changes in exploitation pattern using length composition data (with notes on VPA and cohort analysis). *FAO Fish. Tech. Pap.* (256):118 pp.

Munro, J.L. 1983a. The biology, ecology and bionomics of spiny lobster (Palinuridae), spider crab (Majidae) and other crustacean resources. Pages 206–222 *in* J.L. Munro, ed. *ICLARM, Resources Management Studies and Reviews* **7**. Manila, Philippines. 276 pp.

Munro, J.L. 1983b. Epilogue: Progress in coral reef fisheries research: 1973–1982. Pages 249–265 *in* J.L. Munro, ed. *ICLARM Studies and Reviews* **7**. Manila, Philippines. 276 pp.

Pauly, D. 1984. Fish population dynamics in tropical waters: a manual for use with programmable calculators. *ICLARM Studies and Reviews* **8**. Manila, Philippines. 325 pp.

Sparre, P. 1987. Computer programs for fish stock assessment. Length-based fish stock assessment (LFSA) for Apple II computers. FAO Fish. Tech. Pap. (101) Suppl. 2:218 pp.

Sparre, P. 1986. Introduction to tropical fish stock assessment. Based on preliminary versions of lecture notes prepared by the team of lecturers in the FAO/DANIDA Project, Training in fish stock assessment. FAO, Rome, Italy.