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STATUS OF LOBSTER STOCKS IN THE NORTHWESTERN HAWAIIAN ISLANDS, 1989

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ABSTRACT

In 1989 combined landings of the slipper lobster *Scyllarides squammosus* and the spiny lobster *Panulirus marginatus* totaled 1.16 million from 1.07 million trap-hauls of fishing effort. The maximum sustainable yield based on a dynamic Gompertz model is estimated at about 1.0 million lobsters from an effort of about 1.0 million trap-hauls. Estimated fishing mortality at the 1989 effort levels is about equal to natural mortality, and spawning stock biomass per recruit at this level of fishing is 52% of the spawning stock biomass per recruit in the absence of fishing. The average annual increase in exploitable stock size is 2.7 million lobsters.

INTRODUCTION

This is the fifth annual report on the status of lobster stocks in the Northwestern Hawaiian Islands (NWHI). This report uses catch and effort data reported in the logbooks of commercial lobster fishermen, to make inferences about changes in stocks of the slipper lobster Scyllarides squammosus and the spiny lobster Panulirus marginatus and to estimate optimum levels of exploitation.

ANNUAL TRENDS

The commercial logbooks do not distinguish between fishing effort targeting slipper and spiny lobsters and instead report total fishing effort. In 1989, fishing effort was 1.07 million trap-hauls, a 27% increase from 1988, while catch per unit effort (CPUE) for both species combined was 1.08 lobsters/trap-haul, a 14% decrease from 1988 (Table 1). Spiny lobsters represented 81% of the landings, slightly less than the 89% in 1988 but substantially more than 1987 and 1986 when more slipper than spiny lobsters were caught (Table 1). Except for Necker Island, the CPUE at each of the major banks declined from 1988 levels (Table 1).

In previous years, the lobster stock assessments used production modeling based on a dynamic Schaefer model (Polovina and Moffitt[1]). However, this year, a dynamic Gompertz production model is used because, as effort exceeds the level that achieves maximum sustainable yield (MSY), the asymmetrical shape of the Gompertz curve appears to better represent the dynamics of heavily exploited lobster stocks than the symmetrical curve of the Schaefer model. A dynamic version of the Gompertz model has been developed (Clarke et al.[2]). This model has been fit simultaneously to annual catch and effort data from 1983 to 1989 for Necker Island, Gardner Pinnacles, Maro Reef, and the entire NWHI to obtain estimates of MSY and corresponding fishing effort (F_{msy}) for each region (Table 2; Fig. 1). The annual catch and effort trajectories display the looped shape indicative of the "fishing down" process (Fig. 1). The MSY is estimated as the maximum level of the equilibrium yield curves; this level is

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[1]Polovina, J. J., and R. B. Moffitt. 1989. Status of lobster stocks in the Northwestern Hawaiian Islands, 1988. Southwest Fish. Cent. Admin. Rep. H-89-3, 10 p.

[2]Clarke, R. P., S. S. Yoshimoto, and S. G. Pooley. In prep. A bioeconomic analysis of the Northwestern Hawaiian Islands lobster fishery. Southwest Fisheries Center Honolulu Laboratory, National Marine Fisheries Service, NOAA, 2570 Dole St., Honolulu, HI 96822-2396.

assumed to represent the long-term relationship between catch and effort after the "fishing down" process is complete (Fig. 1). For the entire NWHI, MSY and $\underline{F}_{msy}$ are estimated at about 1.0 million lobsters and trap-hauls, respectively, and the 1989 catch and effort are close to these levels (Table 2; Fig. 1). By comparison, MSY and $\underline{F}_{msy}$ in 1989 are estimated with the Schaefer model to be 1.14 million lobsters and 848,000 trap-hauls, respectively (Polovina and Moffitt fn. 1). The MSY for Maro Reef is about 45% of the estimate for the entire NWHI, and the 1989 catch and effort are slightly below the estimated MSY and $\underline{F}_{msy}$ (Table 2; Fig. 1). Most striking are the 1989 effort levels at Necker Island and Gardner Pinnacles, which are more than double the $\underline{F}_{msy}$ estimates and the 1988 effort levels. Further, the catches at these high levels substantially exceed those expected from the dynamic production model (Table 2; Fig. 1). One explanation is that these values represent only annual variation around the model's expected values because of, for example, a strong year class or very good catchability. Another explanation is that the estimates of bank productivity (MSY and $\underline{F}_{msy}$) are simply too low. Future catch and effort should be lower at these banks if the former explanation is correct, while the 1989 catch and effort levels should be sustainable if the latter explanation is correct.

MONTHLY AND QUARTERLY CPUE DATA

An approach has recently been proposed for estimating natural mortality ($\underline{M}$), catchability ($\underline{q}$), and recruitment to the fishery ($\underline{R}$) from a time series of catch, effort, and, if available, size-frequency data (Schnute et al. 1989). I modified this model to make it a recursive model for CPUE, expressed in numbers, by computing CPUE at the beginning of period $\underline{t}$+1 ($CPUE_{t+1}$) from the previously computed $CPUE_t$ as

$$CPUE_{t+1} = R + \exp(-M)*(1 - q*f_t)*CPUE_t;$$

where $\underline{f}_t$, $\underline{R}$, and $\underline{M}$ are fishing effort, recruitment to the fishery, and natural mortality, respectively, during period $\underline{t}$. Simply stated, the model describes the change in lobster abundance, measured as change in CPUE, from period $\underline{t}$ to $\underline{t}$ + 1 as the combination of a loss of lobsters (due to fishing and natural mortality) and a gain (due to recruitment to the fishery). The model is fit to monthly CPUE and effort data for legal-sized slipper and spiny lobsters combined for the entire NWHI from 1984 to 1989 (Table 3; Fig. 2). Slipper lobster catches used in the model for the period prior to a minimum size limit are the estimated legal catches computed at 0.72 times the total slipper lobster catches. The model is based on the assumptions of constant monthly recruitment to the fishery and constant monthly catchability. Two trends are apparent in the CPUE time series data. First, considering an average annual level of CPUE, a steep decline is apparent during 1984-86 and is followed by a constant or slightly increasing CPUE during 1987-89 (Fig. 2). This trend is due to the fishing down process in 1984-86 and reflects an equilibrium stock level that has persisted since then. The CPUE model fits this trend very well. Second, within any year, monthly CPUE is generally relatively low at the beginning of the year, increases to a peak in summer, then declines toward the end of the year (Fig. 2). The CPUE model does not anticipate the strong monthly changes in CPUE very well, suggesting that this variation in CPUE may be due to variable recruitment or catchability.

Both the monthly CPUE model and the dynamic Gompertz model estimate catchability, and the two estimates are similar even though the models are based on different assumptions (Tables 2 and 3). The annual instantaneous natural mortality is estimated at 0.9/year, and the average annual recruitment to the exploitable stock at 2.7 million lobsters (Table 3). Fishing mortality (F) for 1989 is estimated at 0.8 from the Gompertz model and 0.6 from the CPUE model; therefore, in either case, it is a little less than natural mortality. Using the residuals from the fit of the model, it is possible to estimate the annual increase in exploitable stock.

The average number of juvenile lobsters which annually recruit to the fishery is estimated to be 2.7 million (Table 3). However, the annual increase in exploitable biomass is estimated to vary from a high of 3.0 million lobsters in 1984-85 to a low of 2.1 million in 1987 (Table 4).

The variation in the annual increase in exploitable lobsters may be due to variation in the number of juveniles recruiting to the fishery or in the number of lobsters catchable with fishing gear. This latter source of variation can be due to environmental factors such as sea state and water temperature.

The past 3 years, 1987-89, have experienced one above average and two below average increases in exploitable biomass (Table 4). It is likely that this variation represents natural variation in recruitment and catchability rather than recruitment changes due to fishing. The recruitment to the fishery for 1987-89 would probably come from spawning in 1983-85, and catch rates indicate the stocks were relatively large for each of those years. The declining trend in the annual increase in exploitable biomass over the period 1984-89 may be due to the fishing down of slipper lobster stocks.

RELATIVE SPAWNING STOCK BIOMASS PER RECRUIT

Based on fishing effort and the estimate of catchability from the Gompertz model, annual fishing mortality in 1989 is estimated at 0.8 (Table 2). Natural mortality (M) is estimated with the CPUE model to be 0.9, and the von Bertalanffy growth parameter has been previously estimated from length-frequency data at 0.30, so M/K is 3.0. Using the Beverton-Holt yield equation, the ratio of spawning stock biomass per recruit under current fishing levels, where F/M is 1.0, to that in the absence of fishing is estimated at 0.52 for both slipper and spiny lobsters based on the current minimum sizes. This ratio is used as an index of the reproductive potential of the stock, and it has been recommended that it exceed 0.20 to prevent recruitment overfishing (Goodyear 1989).

CONCLUSIONS

1. For the entire NWHI, the Gompertz model indicates the 1989 fishing effort is at the level which achieves MSY, and current landings are at about the MSY level. Further, the CPUE model indicates that fishing mortality is about equal to natural mortality, which protects adequate spawning stock biomass with the minimum size and escape vent regulations. Thus, overall, the 1989 fishing effort appears at the level which produces the average long-term maximum landings. However, 1989 effort levels at Necker Island and Gardner Pinnacles were about twice the levels that produce MSY, with higher catch rates than expected based on current model parameters.
2. The CPUE model indicates that 1987 and 1989 had below average increases, and 1988 had above average increases, in exploitable biomass due to recruitment, changes in catchability, or both. This variation is probably due to natural variation rather than recruitment changes due to fishing, because spawning biomass appears to have been large in each of the years 1983-85 that produced 1987-89 recruitment.

LITERATURE CITED

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Table 1.--Absolute and relative catch per unit effort (CPUE) for spiny and slipper lobsters in 1986-89, based on commercial logbook data.[a] The 1988-89 CPUE's are based on legal slipper and legal spiny lobsters; 1986-87 CPUE's are based on all slipper and legal spiny lobster catches.

Location	CPUE				
	1989	1988	1987	1986	1989/1988
Necker Island	1.11	1.08	0.98	1.22	1.03
French Frigate Shoals	0.68	0.97	0.74	1.47	0.70
St. Rogatien Bank	0.95	1.46	0.59	1.51	0.65
Gardner Pinnacles	1.00	1.17	0.87	1.07	0.85
Maro Reef	1.25	1.39	1.44	1.80	0.90
Total	1.08	1.25	1.08	1.53	0.86
Percent of spiny lobster to total	81	89	45	42	--
Total effect (1000's of trap-hauls)	1,071	845	805	1,353	1.29

[a]Data on file at Southwest Fisheries Center Honolulu Laboratory, National Marine Fisheries Service, NOAA, 2570 Dole St., Honolulu, HI 96822-2396.

Table 2.--Estimates for the combined slipper and spiny lobster stocks of maximum sustainable yield (MSY; No. of lobster), corresponding fishing effort (F_{msy}; in trap-hauls), catchability (q), and fishing mortality (F) for Necker Island, Gardner Pinnacles, Maro Reef, and the entire Northwestern Hawaiian Islands (NWHI) from the fit of the dynamic Gompertz model to commercial catch and effort data, 1983-89.

Location	MSY	(SE)	F_{msy}	(SE)	1989 Catch (lobsters)	1989 Effort (trap-hauls)	q	1989 F
Necker Island	195,111	(26,689)	154,012	(43,012)	349,329	314,356	0.5×10^{-5}	1.5
Gardner Pinnacles	157,097	(21,487)	91,328	(21,320)	271,497	271,289	0.8×10^{-5}	2.3
Maro Reef	446,076	(61,013)	436,286	(107,940)	417,354	334,563	0.2×10^{-5}	0.6
Entire NWHI	1,019,853	(139,492)	1,013,090	(249,827)	1,160,253	1,071,538	0.8×10^{-6}	0.8

Table 3.--Estimates of natural mortality, catchability, and average recruitment to the fishery from the times series of monthly commercial catch per unit effort data for slipper and spiny lobsters combined from the Northwestern Hawaiian Islands, 1984-89.

Natural mortality (year)	Catchability	Recruitment to fishery lobster/year
0.90	0.6×10^{-6}	2.7×10^{6}

Table 4.--The number of lobsters added to the exploitable stock annually due to recruitment and changes in catchability.

Year	Number of lobsters (in millions)
1984	3.0
1985	3.0
1986	2.9
1987	2.1
1988	2.8
1989	2.6

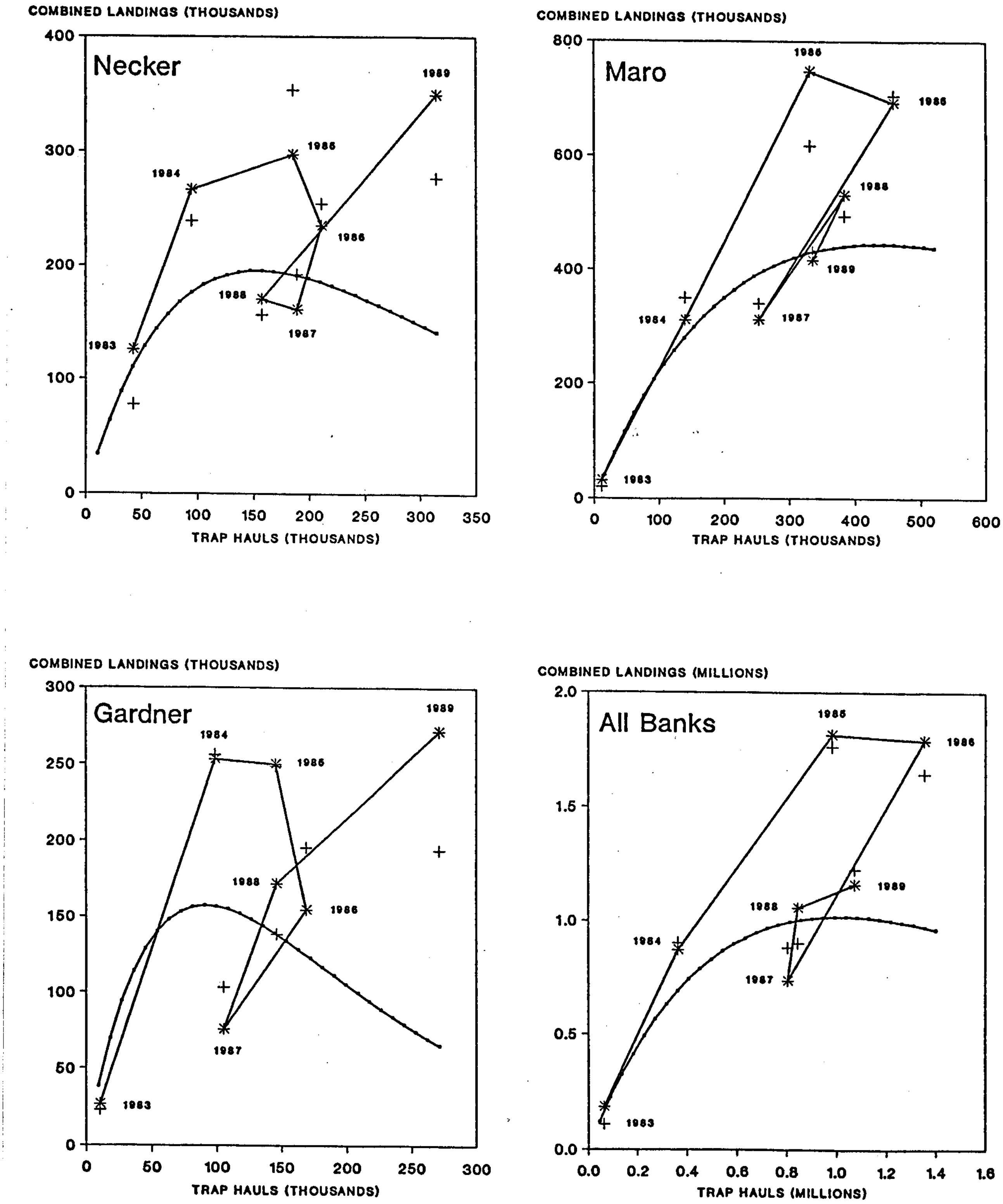

Figure 1--The combined legal landings of slipper and spiny lobsters, the estimated landings based on a Gompertz dynamic production model, and the equilibrium catch and effort curves for Necker Island, Gardner Pinnacles, Maro Reef, and the entire NWHI. * = actual landings, + = estimated landings based on Gompertz dynamic model, and —·— = estimated equilibrium catch and effort Gompertz curve.

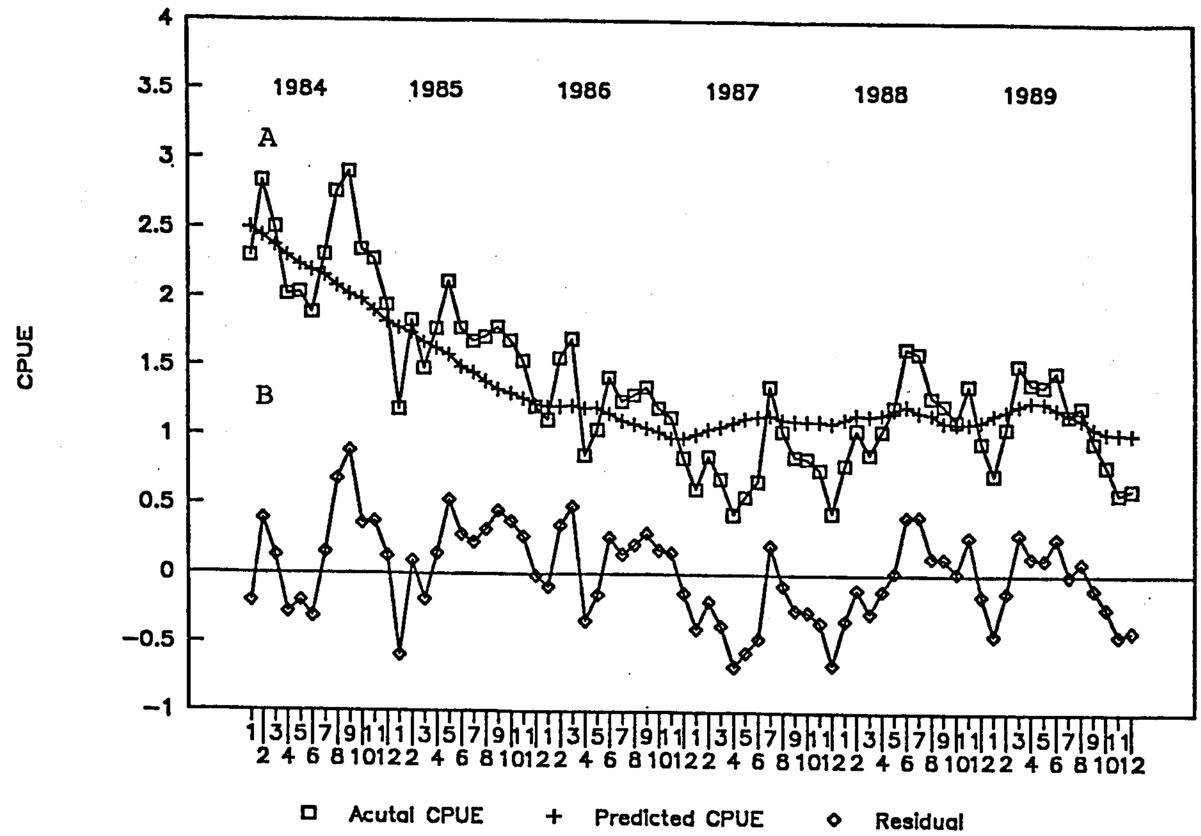

Figure 2--(A) Monthly catch per unit effort (CPUE) for legal slipper and spiny lobsters with predicted CPUE based on constant catchability, recruitment, and natural mortality. (B) Residuals of actual and predicted monthly CPUE.