Escalation in Shrimp Production in the Sierra Leone Industrial Fishery

P.A.T. Showers

Abstract

Applying Tukey's jackknife method on MSY estimates from the surplus production models of Schaefer and Fox showed that the optimum yield for shrimps in industrial fishery in Sierra Leone is estimated at 2 686.8 t with 15 822 fishing days. Annual catch for 1996 was 2 788 t, indicating an escalation in exploitation which, if prolonged, could bring reduced productivity as experienced in the fishery some years ago.

Introduction

When the annual shrimp landings of the fisheries in Sierra Leone reached their historic peak of 3 000 t in 1990 after a rapid escalation in the second half of the 1980s, there was ample evidence that the harvest capacity of the stocks had been stretched excessively and that such a high fishing intensity was already beyond a sustainable level. Analyses undertaken by Willman and Frielink (1987) and Showers (1991) estimated the mean optimum yield of shrimps at 2 610 t and 3 100 t, respectively. Ndomahina and Chaytor (1991) also commented that the landings for 1990 had most likely reached the limits of shrimp production. These estimates indicated a need for reducing catch effort and this was supported by the fact that in the following years the landings and catch rates dropped alarmingly.

The escalating trend started again in the 1990s as soon as the stocks seemed to have recovered sufficiently and annual landings have been increasing from 2 167 t in 1994 to 2 420 t in 1995 and now 2 788 t for 1996.

A previous study (Showers 1991) found the results from the simple Schaefer model well-suited to the good quality of catch data available for shrimps in Sierra Leone, and that this model produced estimates that were similar to those obtained from predictive models for the same period. The present investigation has gone a step further by applying the 'jackknife' method to improve the estimates of Maximum Sustainable Yield (MSY) and the corresponding effort value f_{MSY}.

Table 1. Annual industrial shrimp landings and their corresponding fishing effort.

Years	Catch (t)	Effort (fishing days)	CPUE (kg/day)	ln (CPUE)
1981	642	2 293	279.98	5.63
1982	880	2 424	363.04	5.89
1983	1 196	3 680	325.00	5.78
1984	2 304	8 170	282.01	5.64
1985	2 448	8 298	295.01	5.69
1986	1 944	7 254	267.99	5.59
1987	2 630	14 064	187.00	5.23
1988	2 750	17 628	156.00	5.05
1989	2 870	18 397	156.00	5.05
1990	3 000	20 833	144.00	4.97
1991	1 241	8 862	140.04	4.94
1992	2 484	14 494	171.38	5.14
1993	2 425	12 422	195.22	5.27
1994	2 167	10 547	205.46	5.33
1995	2 420	11 435	211.63	5.35
1996	2 788	16 426	169.73	5.13

Materials and Methods

A 16 years' time series (1981-96) of basic catch statistics (Table 1) comprising annual industrial landings and their corresponding effort has been analysed in this paper. The analytical tools employed are based on the model introduced by Schaefer (1954, 1957) and later reviewed by several authors including Fox (1970), Ricker (1975), Gulland (1983), Pauly (1984) and Sparre and Venema (1992). These tools are the simple surplus production models of Schaefer and Fox, respectively:

$$Y_i = a \cdot f_i + b \cdot f_i^2 \qquad ...1)$$

$$Y_i = f_i\, e^{(c+d \cdot f_i)} \qquad ...2)$$

The results of MSY and their corresponding optimum values for effort were obtained using equations 3, 4, 5, and 6:

Schaefer:

$$MSY = -a^2/(4b) \qquad ...3)$$

$$f_{MSY} -a/(2b) \qquad ...4)$$

Fox:

$$MSY = -(1/d) \cdot e^{(c-1)} \qquad ...5)$$

$$f_{MSY} -1/d \qquad ...6)$$

where **a**, **c** and **b**, **d** are constants for intercept and slope in the linear regression analysis of catch-per-unit effort on effort.

Table 2. Estimates for the surplus production models and their statistical correspondences.

Derived statistics	Derived values	
	Schaefer	Fox
MSY (t)	2 717.63	2 818.71
f_{opt} (f. days)	16 042	21 679
a	338.81918	5.86767
b	-0.01056	-0.00005
r^2	0.731	0.726
No. of observations	16	16
Degrees of freedom	14	14

(f. days): fishing days

Table 3. Estimates involving Tukey's 'jackknife' method, and their statistical correspondences.

Derived statistics	Derived values	
	Schaefer	Fox
Mean MSY_{i-1} (t)	2 690.62	2 803.84
s.d.	32 775.20	31 883.87
CL	15.58	15.16
Mean f_{opt-1}(f. days)	15 970	21 695
s.d.	394	696
CL	187	331
Mean Phi_{msy} (t)	2 686.81	2 791.08
s.d.	524 403.16	510 141.94
CL	249.29	243
Mean Phi f_{opt} (f. days)	15 822	21 428
s.d.	6 301	11 134
CL	2 995	5 292.89

(f. days): fishing days

The 'jackknife method' (Tukey 1977; Mostella and Tukey 1977) as presented in Pauly (1984) was adopted in the form expressed in equations 7, 8 and 9:

$$\Phi_i = (n \cdot MSY_1) - [(n-1) \cdot MSY_{i-1}] \quad ...7)$$

$$MSY_2 = \frac{\Sigma \Phi_i}{n} = \overline{\Phi} \quad ...8)$$

$$s.e._{MSY} \sqrt{(sd_{\Phi}^{2})/n} \quad ...9)$$

where MSY_1 is the MSY estimate obtained using all available data pairs (n), as required in equations 3 and 5; Φ_i is the MSY estimate using n-1 data pairs to give n estimates of Φ_i; MSY_2 is the new estimates of MSY; and s.e. is the standard error of MSY_2.

Results and Discussion

The original catch and effort data are shown in Table 1. The derived catch-per-unit-effort (CPUE) and their logarithmic transformations are used in the production models. The statistical results of the linear regression analysis and the estimates for MSY are shown in Table 2. A slightly higher correlation coefficient of 0.731 was obtained for the Schaefer model compared to 0.726 for the Fox model. Accordingly, a better fit of data to the regression line is evident for the Schaefer model (Fig. 1) than for the Fox model (Fig. 2).

In further comparison, the Schaefer model shows more acceptable estimates than the Fox model because of its more conservative MSY estimate of 2 717.6 t as compared to 2 818.7 t, and its more realistic f_{opt} estimate of 16 042 days, as against 21 679 days (Fig. 3, Table 3). A steady increase is evident for the years 1988, 1989 and 1990, indicating the highest levels of production ever recorded for the industrial shrimp fishery of Sierra Leone. Considerable declines are noted immediately thereafter, whilst fishing intensities again approach that level for 1994, 1995 and 1996.

New and improved estimates using the Tukey's jackknife method (Table 3) are:

	MSY (t)	f_{MSY} (fishing days)
Schaefer	2 686.8	15 822
Fox	2 791.1	21 428

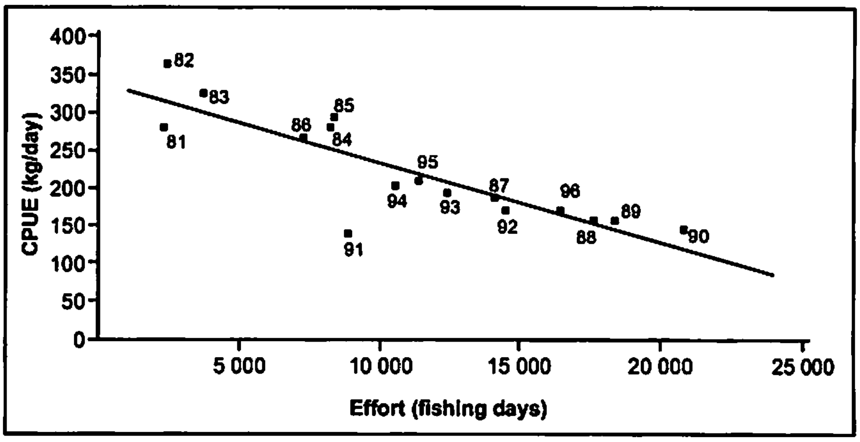

Fig. 1. Linear regression for the Schaefer model.

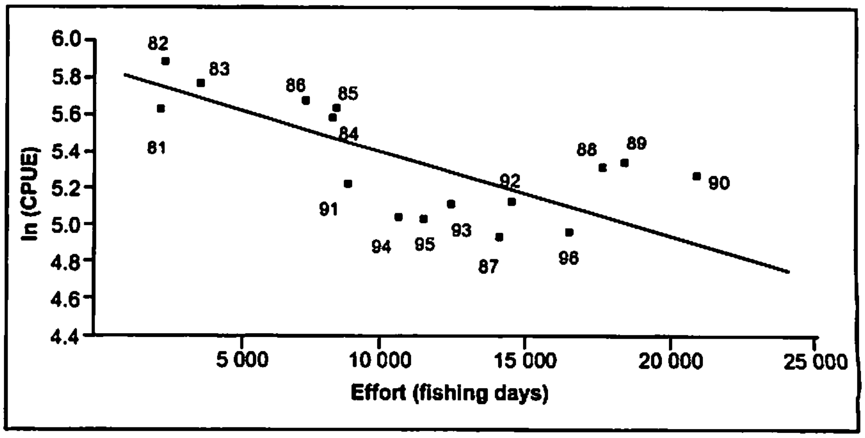

Fig. 2. Linear regression for the Fox model.

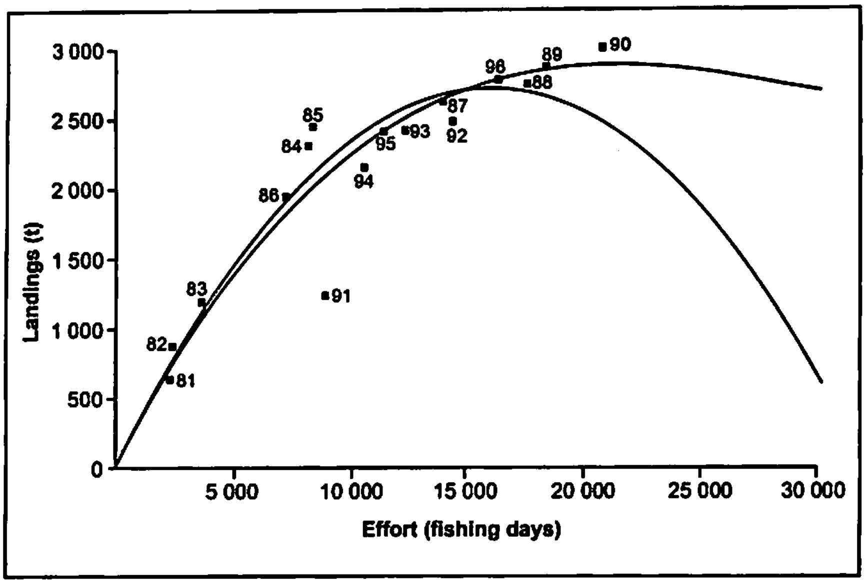

Fig. 3. The derived Schaefer and Fox curves.

Conclusions and Recommendations

The historical trend in production indicates that industrial shrimp fishing may have reached its peak in the late 1980s and is once again heading in that same direction. Although the fact that annual landings are already over the recommended MSY is not by itself conclusive evidence of overfishing, the results of this investigation do provide much food for sober thinking and a warning note is very appropriate.

The magnitude of recorded landings of 2 788 t for 1996 exceeds the MSY estimate of 2 687 t obtained in this analysis. Caution is recommended towards increasing fishing intensity even if it may seem profitable at present.

Since the start of the 1990s the industrial fisheries have been completely dominated by demersal trawling, of which shrimpers account for over 90% of the total number of licensed vessels (Showers 1997). Management should bear in mind the detrimental effect that demersal trawling has on the ecological systems where the targeted stocks are found, and ways should be sought to minimize this environmental stress.

It is recommended that further biological investigations using a predictive model be conducted on the population structure. Such an investigation will provide a more precise optimum level of fishing intensity, an insight into the population dynamics of the exploited stocks, and present concrete management options for the limits on mesh size and fishing effort.

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P.A.T. SHOWERS *is from the Institute of Marine Biology and Oceanography, Fourah Bay College, University of Sierra Leone, Sierra Leone.*