ANALYSIS OF THE CLEAR LAKE COMMERCIAL FISHERY USING DIFFERENT SURPLUS YIELD MODELS

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Abstract. The status of the Clear Lake carp (Cyprinus carpio) and blackfish (Orthodon microlepidotus) are examined using the trends of the data and four surplus-yield models. All models, regardless of precision, seem to indicate that both the carp and blackfish populations are declining.

INTRODUCTION

Commercial fishing for carp (Cyprinus carpio) and blackfish (Orthodon microlepidotus) has been in nearly continuous operation since 1932. Blackfish are the most valuable species of the fisheries and are wholesaled in Chinese communities in California, bringing a price of eighty cents a pound to the fishermen (Department Fish and Game administrative report). Carp are harvested as a requirement imposed by contract with the California Department of Game. The contract in 1957 was to remove ten pounds of carp for every pound of blackfish harvested. Carp has minimal economic value; it brings its highest value prior to the Jewish high holidays and the oriental new year. In many Asian cultures, it is believed that releasing a live carp in a river will bring good luck. A small amount is sold to reduction fertilizer plants.

The commercial fishermen use beach seines 1,200 feet long by 12 to 16 feet deep. Two mesh sizes are used 2 inch and 4 inch stretch. Two boats are employed in the set which is winched into shore. The net is retrieved to the bag after which the fish are brailed and segregated; blackfish are placed into a live car, carp dumped into a barge and all other fish are returned to the lake. The fishermen are required to submit monthly reports on the weight of the commercial catch, the numbers of each species returned to the lake, and the effort expended in each area fished.

The objectives of this study were to examine the status of the commercial populations, and to estimate maximum (optimal) sustained yield using different modifications of the surplus-yield model.

MODELS EMPLOYED

Surplus-yield models are essentially modifications of the logistic model. The major modification is a change of expression from absolute to relative population size. As first formulated by M. B. Schaefer (1954), a second major assumption was that the change in relative population size (catch per unit effort) was negatively correlated to the effort expended in fishing:

$$U = U_{max} - \frac{1}{b} f \qquad (1)$$

where U = catch/effort, U_{max} = highest relative size of the population (catch/effort), 1/b = the slope of the regression and f = effort.

Equilibrium yield (Y_e) at any given level of consistent effort is then:

$$Y_e = fU_{max} - \frac{1}{b} f^2 \qquad (2)$$

The surplus yield model has had several assumptions which limit its usefulness: (1) not all relationships between catch/effort and effort are linear, (2) lag time between generations is not accounted for, and (3) the model assumes that the fishery has been at equilibrium. However, recent work has strengthened the surplus yield concept. Pella and Tomlinson (1967) have developed a modification which assumes that there is a nonlinear relationship between catch/effort and effort:

$$U = U_{max} e^{-xf} \qquad (3)$$

where x is a fitted constant.

Recently Walter (1973) and Marchesseault et al. (1976) devised modifications to allow lag time to be introduced. Basically, these techniques rely heavily on multiple linear regression analysis. The two models differ in that independence between effort, the current population and past populations (expressed in terms of catch/effort) is assumed by Walter (1973)

$$\ln\frac{U_i}{U_{(i-w)}} = b - a_{11} U_i + a_{12} U_{(i-w)} - qf_i \qquad (4)$$

where U_i = catch/effort at time i, $U_{(i-w)}$ = catch/effort at some lag time w, q = catchability coefficient, and b, a_{11}, and a_{12} are fitted coefficients. The model of Marchesseault et al. assumes that there is interaction between the lag population and the present population:

$$2 \; \frac{U_{(i+1)} - U_i}{U_{(i+1)} + U_i} = b - a_{11} U_i + a_{12} \frac{U_{(i-w)}}{U_i} - qf \qquad (5)$$

The left hand part of the equation is an approximation of (1/U)(dU/dt). One must be careful using multiple regression models as they assume independence between independent variables and secondly, the curve fitting process may be such that the signs of the coefficients generated are not conceptually acceptable although a high multiple correlation coefficient is obtained.

Walter (1975) has devised a method for adjusting the data such that the steady state assumption is no longer critical. Briefly, the method is this: first the relationship between effort and catch/effort is established using the Schaefer method. Then the slope of the equation and the value of U_{max} derived from the equation are substituted into the following equation:

Table 1. A summary of the surplus-yield models employed to determine maximum sustained yield (MSY) and optimal effort (f opt).

Model	Relation between catch and effort	MSY	F opt
Schaefer (1954)	$U = U_{max} \frac{-1}{b} f$	$\frac{b(U_{max})^2}{4}$	$\frac{U_{max} b}{2}$
Pella & Tomlinson	$U = U_{max} e^{-xf}$	$\frac{U_{max}}{xe}$	$\frac{1}{x}$
Marchesseault, et al. (1976)			
a) modified Schaefer	$\frac{1}{U}\frac{dU}{dt} = U_{max} + a_{11}U - qf$	$\frac{(U_{max})^2}{4a_{11}q}$	$\frac{U_{max}}{2q}$
b) proposed delay	$\frac{1}{U}\frac{dU}{dt} = b - a_{11}U_1 + a_{12}\frac{U(1-w)}{U_1} - qf$	$\frac{(b+a_{12})^2}{4a_{11}q}$	$\frac{(b+a_{12})}{2q}$
Walter (1975)	see text	after correction, the same as the Schaefer model.	

Table 2. Seasonal catch statistics for carp and blackfish, 1961 to 1975-76. f = effort, c = catch, c/f = catch/effort.

	Carp			Blackfish	
	f	c	c/f	c	c/f
Season	Hauls	Lbs.	Lbs./haul	Lbs.	Lbs./haul
1961	151	153,060	1,013	75,114	497
1962	174	236,230	1,358	164,790	947
1963/No data	-	-	-	-	-
1964-65	222	267,375	1,204	322,938	1,454
1965-66	80	124,900	1,561	209,550	2,619
1966-67	84	206,543	2,459	208,172	2,478
1967-68	115	183,860	1,599	147,170	1,280
1968-69	95	99,355	1,046	142,600	1,501
1969-70	162	331,110	2,044	351,730	2,172
1970-71	267	345,550	1,294	389,656	1,459
1971-72	304	273,449	899	367,373	1,208
1972-73	335	272,951	814	458,910	1,370
1973-74	357	201,451	564	265,742	744
1974-75	297	109,480	369	197,790	666
1975-76	211	103,330	490	129,175	612

$$\alpha = \left(\sum_{i=o}^{n-1} U_{max} - \overline{U}_i - \frac{1}{b} \overline{f}_i \right)^{-1} \left(\ln \frac{U_n}{U_o} \right) \qquad (6)$$

where $\overline{U}_i$ is the average catch/effort for the ith season, $\overline{f}_i$ is the average effort expended in the ith year, and U_o is the amount of effort expended in the first year. The value of α is used to calculate U_e, the corrected value for the catch/effort. Each value of catch/effort from a fishery not in equilibrium can be thus adjusted:

$$U_e = U_i + \frac{1}{U\alpha} \frac{\Delta U}{\Delta t} \qquad (7)$$

Once values of U_e for each year are obtained, the Schaefer method is used to establish the relationship between U_e and effort. Formulae used to calculate maximum sustained yield MSY are listed in Table 1.

METHODS

Data were obtained from the California Department of Fish and Game. The history of the fishery extends back to 1932. Unfortunately, only monthly data dating back to 1961 could be obtained as effort data prior to that data had been destroyed. Data were grouped by fishing seasons rather than by calendar years. The years 1961 through 1963 were 12 month seasons; 1964-65 was a season of 16 months; 1965-66 and beyond are seasons of 6 to 7 months duration. Trends of the data were analyzed as well as application of the different models to these problems.

RESULTS AND DISCUSSION

It is apparent that the commercial fishery at Clear Lake is declining. From 1969-70 onwards, the trend is increasing effort concomitant with decreasing catch/effort (Table 1). Both species are experiencing a parallel decline, the correlation of the catch/effort between the two species is 0.76. The average sizes of the blackfish taken during the years from 1970 to 1976 are less than the 2.5 lbs/fish as reported by Pintler (1956) for the 1955 season; but there is no similar trend for carp.

Average yield/fish (lbs.)

	1970-71	'71-'72	'72-'73	'73-'74	'74-'75	'75-'76
blackfish	1.89	1.71	1.44	1.74	1.84	1.60
carp	7.63	6.83	2.11	6.18	9.38	8.17

Estimates for maximum sustainable yield (MSY) are similar for all models employed. The critical decision then is to choose the most accurate model. This was done by process of elimination. Time lags were inappropriate for assessing blackfish dynamics because the highest autocorrelation was between time i and time i-1 (Table 5). A three year lag for carp seemed to be appropriate (Table 5). However, the fitted constants and the signs of the regression coefficients were unacceptable. As the fishery was not in equilibrium, only the Walter (1975) model is appropriate; although from the practical viewpoint of a fisheries manager, the modified Schaefer model is extremely appealing because of its conservative estimates.

It appears that maximum sustainable yield (MSY) as estimated using the Walter (1975) model, was exceeded four seasons out of seven for both species and optimal effort was exceeded in five seasons for carp and twice for blackfish during that seven year period.

Although fishing seems to be the major factor in the decline of these fishes, the introduction of the Mississippi silverside (*Menidia audens*) cannot be discounted without further investigation. Both juvenile carp and

Table 3. Estimates of maximum sustainable yield (MSY) for blackfish and optimal effort (f opt) from surplus-yield models.

Model	r	MSY lbs.	f opt hauls
Schaefer (1954)	-.53*	300,028	283
Walter (1975) equilibrium compensated	-.67**	327,461	278
Marchesseault, et al. (1976)			
a) Modified Schaefer	-.82**	284,741	252
b) Proposed delay	Not applicable		
Walter (1973)	Not applicable		
Pella & Tomlinson	-.44	301,661	418

*Statistically significant at 95% level.

**Statistically significant at 99% level.

Table 4. Estimates of maximum sustainable yield (MSY) for carp and optimal effort (f opt) from surplus yield models.

Model	r	MSY lbs.	f opt hauls
Schaefer (1954)	-.68*	249,880	244
Walter (1975)	-.67*	252,072	217
Marchesseault, et al. (1976)			
a) Modified Schaefer	-.92*	245,914	215
b) Proposed delay	Not applicable		
Walter (1973)	Not applicable		
Pella & Tomlinson	-.67*	221,237	262

*Statistically significant at 99% level.

Table 5. Autocorrelation values of catch/effort at time i versus time i-w for carp and blackfish.

	Lag time (w)				
Species	1	2	3	4	5
Blackfish	0.55	0.14	0.11	-0.24	-0.32
Carp	0.53	0.27	0.58	0.06	-0.44

blackfish feed on zooplankton, although they adopt a detritivore mode as adults. Perhaps some interspecific competition is confounded with the fishing pressure.

As maximum sustainable yield is by definition the same as half the carrying capacity of the system, an estimate can be made of the carrying capacity for these two species during the past 15 years: 534,568 lbs. for carp and 673,908 lbs. for blackfish. MSY is also a measure of production. Production of carp and blackfish in Clear Lake is approximately 6.74 Kg/hectare and 8.34 Kg/hectare. As a comparison, more precise production estimates from Elephant Butte Lake are available (Jester, 1976). Production values for river carp sucker, smallmouth buffalo, and carp are 7.20, 71.40, and 17.70 Kg/hectare, respectively.

The value of these models has been to detect the role of fishing upon carp and blackfish dynamics and also a means to approximate very roughly, the production of these fishes. The surplus yield approach is a black box approach that requires only catch and effort data. For that reason, it is extremely appealing and a useful tool for first approximations of impact. Further analysis on yield/recruit will be necessary for a more detailed look at these populations. In conclusion, it seems clear, regardless of the precision of the models used that both carp and blackfish are declining. The decline of the carp brings us no great sorrow; however, we are very concerned about the status of the native blackfish.

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