Consideration of the Maximum Sustainable Yield from the Northwestern Atlantic Butterfish Stock

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ABSTRACT

The equilibrium yield, fishing at $F_{0.1}$ from the Northwestern Atlantic butterfish stock, assuming a constant annual recruitment of 1138.5×10^6 fish is 21,635 MT, at a mesh size of 82 mm (stretched). However, fluctuations in the annual abundance of young-of-year fish as evidenced in autumn offshore bottom trawl surveys, and by virtual population analyses (VPA) suggest that the assumption of constant annual recruitment is not met. The mean size of the 0+ cohort estimated from the VPA varied from 368.1×10^6 to 1976.8×10^6 ($\bar{x} = 1138.5 \times 10^6$, 95% C.I. = $\pm$ 453.0×10^6) from 1968-1975. The autumn young-of-year abundance index for 1976 was 48% above the 1968-1975 average. The total catch of butterfish under FCMA regulation in 1977 (3,439 MT) was 78% lower than the previous year (15,837 MT). Above average young-of-year abundance combined with the reduction in total removals suggests a healthy population. Fishing above $F_{0.1}$ might not produce an increase in sustainable yield due to stock-recruitment considerations. Therefore, for planning purposes a value of 21,635 MT may be regarded as "MSY". However, it should be noted that lower yields result from mesh sizes smaller than 82 mm.

INTRODUCTION

The total yield of a cohort (year-class) of fish over its lifespan is a function of the number of fish entering the population, the annual fishing mortality rate, and the age at selection (entry). For a stock with constant annual recruitment, the total yield in any particular year equals the yield over the lifespan of any of the constituent year classes (Beverton

and Holt 1957). Murawski and Waring (1978) indicated that the average annual production of juveniles for the Northwestern Atlantic butterfish stock from 1968-1975 was approximately 1138.5 x 10^6 fish. Projected annual removals based on yield per recruit studies and $F_{0.1}$ values were 14,540 MT for a 30 mm mesh net (t_c = 0.275 yr), and 18,945 MT for a 60 mm one (t_c = 0.767 yr). In the present study yields from various mesh sizes were again simulated assuming constant annual recruitment, to calculate the maximum sustainable yield, and the implications of variations in annual recruitment on these analyses are discussed.

METHODS

The total yield from the average annual juvenile production (1138.5 x 10^6 fish) over its lifespan for combinations of F and t_c was calculated utilizing Paulik and Gales' (1964) yield per recruit methodology (Murawski and Waring 1978). The loci of yield values for various mesh sizes (and thus ages at entry based on the selection factor of 1.8) were determined at values of $F_{0.1}$ since transverse isopleth sections are generally flat in appearance, and result in very little marginal yield at large F values (near F_{max}). Although arbitrary, values of $F_{0.1}$ are preferable to those resulting in the maximum Y/R (F_{max}) when stock-recruitment relationships are considered. For many species, including butterfish recruitment to the fishery occurs prior to first spawning. The reduction in fishing mortaltiy rate from F_{max} to $F_{0.1}$ results in only minor decreases in Y/R, while preserving a larger portion of the spawning stock. A positive

stock-recruitment relationship has not been conclusively demonstrated for butterfish but it is clear that more progeny will be generated by fishing at $F_{0.1}$ than at F_{max}. Values of $F_{0.1}$ were calculated by determining the points at which marginal increases in Y/R (0.01 intervals of F) were 10% of the Y/R at F = 0.01. Other parameters used in the Y/R analysis are listed in Figure 1. Maximum yield at $F_{0.1}$ was thus desired by iterating with respect to mesh size (in 1 mm increments). Total production was calculated by multiplying the Y/R values by the number of fish alive at the age of recruitment (t_r = 0.25 yr). Resultant yield calculations are presented in Table 1.

DISCUSSION

Maximum catch at $F_{0.1}$ given constant recruitment, was calculated to be 21,635 MT at a mesh size of 82 mm, and $F_{0.1}$ = 1.01. Substantial decreases in total yield, however, are evident when mesh sizes smaller than 82 mm are used. Yield per recruit at $F_{0.1}$ is also reduced if the nets are larger than 82 mm. Presently, offshore bottom trawls must be at least 60 mm, and pelagic trawls may be 45 mm.

Estimates of relative juvenile abundance from autumn offshore bottom trawl surveys and total 0+ stock size estimates from virtual population analyses for 1968-1976 suggest substantial variations in annual recruitment (Table 2). The total estimated 0+ population size from the VPA ranged from 368.1 x 10^6 to 1976.8 x 10^6 fish (95% C.I. = 453.0 x 10^6). Autumn catch per tow indices (in numbers) varied from 29.95 to 231.58. The

catch per tow index for the 1976 year class was the third highest for the time-series of data, and 48% greater than the 1968-1975 average. The total catch of butterfish under FCMA regulation during 1977 was 3,439 MT; a 78% decline from the previous year (15,837 MT). The above average recruitment index in 1976, combined with the dramatic reduction in total removals indicates that the current condition of the stock is probably good relative to previous years. For planning purposes the value of 21,635 MT (mesh = 82 mm, $F_{0.1}$ = 1.01) can be used as an estimate of "MSY". However, it should be noted that if smaller mesh nets are utilized in the butterfish fishery, total sustainable yields are less (Table 2). If average recruitment continues to fluctuate about the mean (1138.5×10^6), then the long-term MSY will remain at 21,635 MT, however, if a significant shift in recruitment values occurs over a persistent time interval, then MSY values should be adjusted accordingly.

REFERENCES

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Table 1. Yield per recruit data, and estimates of maximum equilibrium yield for various mesh sizes (selection factor = 1.8, M = 0.8).

Mesh Size (mm)	$Y/R_{0.1}$ (g)	$F_{0.1}$	Age at Selection t_c (yr)	Yield for average Recruitment At $F_{0.1}$ (MT)[1]
30	15.60	0.47	0.275	14,540
60	20.32	0.69	0.767	18,945
76	22.75	0.90	1.154	21,206
77	22.80	0.91	1.186	21,252
78	22.93	0.93	1.203	21,374
79	22.96	0.94	1.236	21,402
80	23.04	0.96	1.271	21,476
81	23.15	0.99	1.306	21,579
82	23.21	1.01	1.338	21,635
83	23.21	1.02	1.362	21,635
84	23.17	1.03	1.395	21,597
85	23.13	1.05	1.440	21,560
86	23.08	1.07	1.482	21,513
100	19.57	1.38	2.182	18,242

[1]Assuming that $F_{0.1}$ is the maximum F that will not adversely effect recruitment, then this is the maximum long-term average yield from the fishery equivalent to the current interpretation of MSY.

Table 2. Estimates of relative juvenile (age 0+) abundance from NMFS autumn offshore bottom trawl surveys, and total 0+ stock size for year classes 1968-1976.

Year Class	Autumn Catch Per Tow Index ($\bar{x}$ N/tow Age 0+)	Estimate of 0+[1] Population Size From VPA ($x10^6$)
1968	46.19	1684.2
1969	44.61	823.3
1970	30.06	847.5
1971	231.58	1215.3
1972	79.59	1976.8
1973	135.02	1168.8
1974	92.02	1024.0
1975	29.95	368.1
1976	127.50	-

[1] Source: Murawski and Waring 1978

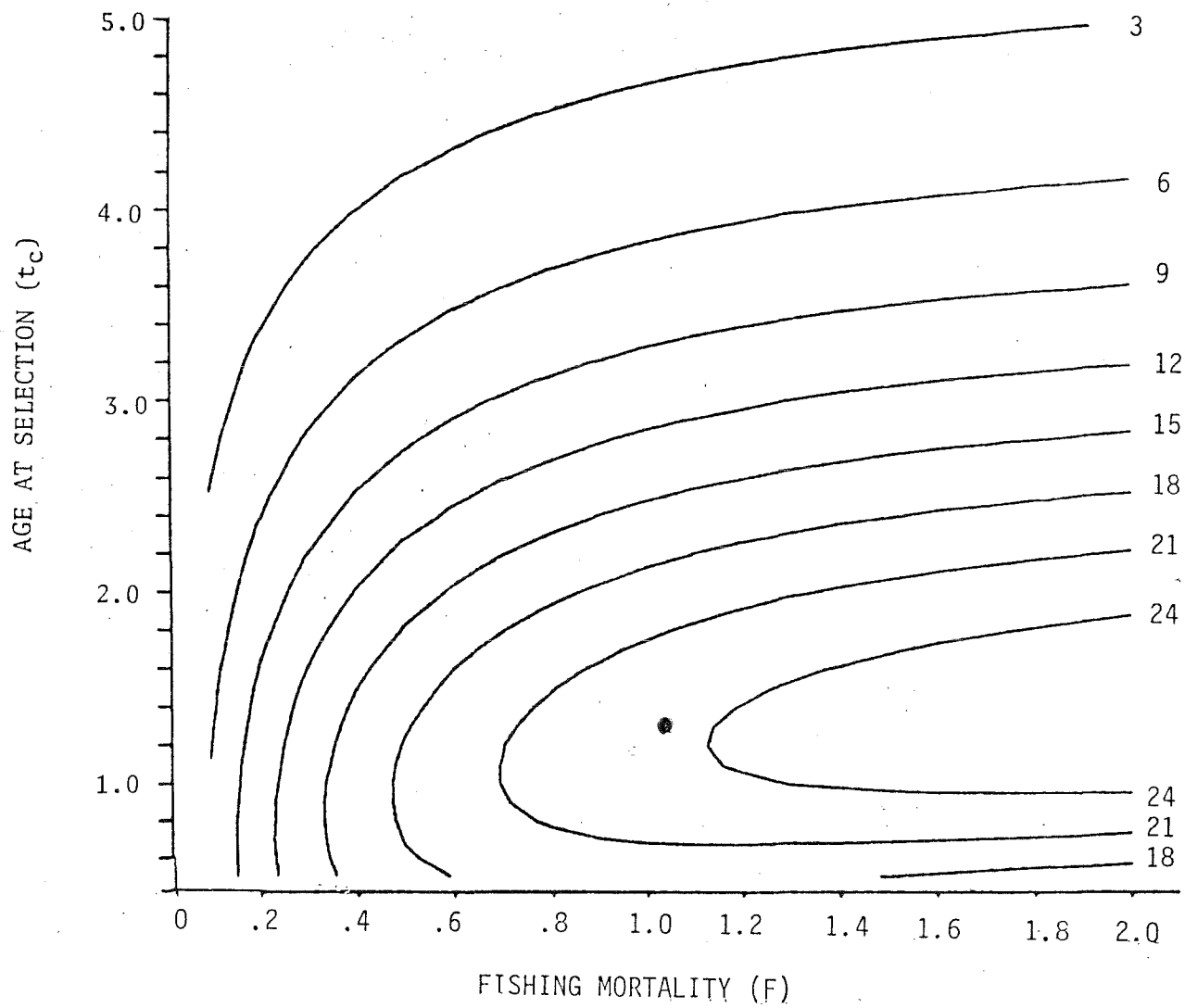

Figure 1. Butterfish yield per recruit isopleth (grams), assuming $M = 0.8$, W_∞ 210.9 g, $K = 0.8618$, $t_o = -0.0699$ yr, $t_r = 0.25$ yr, $B = 3.4920$, $t_\lambda = 6.0$ yr. Dot indicates maximum yield at $F_{0.1}$ ($t_c = 1.388$ yr, $F_{0.1} = 1.01$).