Yield - per - Recruit Analysis of Surf Clams in the Middle Atlantic Bight

by

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INTRODUCTION

Yield-per-recruit analysis was conducted for surf clams inhabiting offshore areas (>15 meters deep) in the Middle Atlantic Bight. Additionally, data were analyzed from the inshore Long Island area. The yield model of Paulik and Gales (1964) was used since an isometric growth relation between shell length and drained meat weight could not be assumed.

METHODS

Five different sets of Von Bertalanffy growth parameters were utilized due to the differences in growth rate between samples. Growth equations were fit to length-at-age information from two NMFS samples taken off the Maryland coast (1975-1976). Additional functions were calculated with data derived from Loesch (1975) and Westman and Bidwell (1946) (inshore Long Island). The growth curve calculated by Chang et al., (unpublished data) was also included in the yield-per-recruit evaluation. Population parameters associated with each growth curve are listed in Table 1.

The length/weight relation calculated by Chang et al. (unpublished data) was used to compute values of W_∞ from L_∞:

$$DMW_{(g)} = 0.0001264\ SL_{(mm)}^{2.776}$$

where: DMW = drained meat weight in grams;

SL = shell length in mm.

The instantaneous natural mortality rate used in the analysis (M=0.25) approximates the total mortality rate ($Z \approx 0.2$) of an unexploited surf clam population in the Gulf of St. Lawrence (Caddy and Billard 1976). Age at recruitment to the exploitable population was assumed to be 0.25 years.

Yield-per-recruit values were calculated for the five different growth curves varying length at selection (l_c) from 2" - 5" in 0.5" increments. Levels of the instantaneous fishing mortality rate (F) in all analyses ranged from 0.1 to 2.0 in increments of 0.1. Yield values were computed to the nearest 0.1 g.

RESULTS AND DISCUSSION

Absolute values of yield-per-recruit for the five growth curves and various assumptions of l_c are listed in Tables 2-6. The percent changes in maximum yield-per-recruit associated with a change in length at selection were calculated for all pairs of selection lengths for each growth curve (Table 7). Values of F that result in maximum yield-per-recruit for each growth curve and l_c are listed in Table 8.

Maximum yields obtained with the smallest minimum selection lengths (2.0"-3.0") range from 10.7 to 28.7 g at fishing mortality rates of 0.3-0.5. For intermediate values of l_c (3.5"-4.0") greatest yield-per-recruit varies from 13.9 to 33.1 g at F = 0.5-1.4. The largest selection lengths analyzed (4.5"-5.0") result in maximum yields of 14.3-37.3 g,

with F ranging from 0.8-2.0. Average gains in yield-per-recruit resulting from an increase in minimum size are positive for all pairs of selection lengths except for a shift from 4.5" to 5.0". However, for selection lengths greater than 3.5", levels of fishing mortality giving maximum yield-per-recruit (F = 0.7-2.0) would result in substantial reductions in the proportion of larger clams in the populations. At extreme fishing intensities (F = 1.0-2.0) spawing stocks may be reduced to such an extent that continued recruitment to the fishery is adversely affected. Sets of harvestable clams appear to occur irregularly as pre-recruit indices are quite variable (Brown et al. 1977). If substantial recruitment does not occur for a period of several years, and the standing stock grows to exploitable size, the adult stock would be reduced significantly by the heavy fishing pressure.

Values of F_{max} range from F = 1.4 @ l_c = 4.0" for the Westman and Bidwell curve, to F = 1.5 @ l_c = 5.0" for the NMFS #2 growth curve. In all cases, however, absolute values of Y/R at F_{max} represent only negligible increases over Y/R at more reasonable F's. Clearly, if the stocks were regulated at F_{max}, an undesirable level of fishing mortality would be generated with regard to stock/recruitment considerations.

LITERATURE CITED

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Table 1. Growth Studies and Associated Population Parameters used in Yield-per-recruit analysis of Surf Clams.

	---------Population Parameter---------						
Growth Curve	L_∞(mm)	W_∞(g)	t_0(yr)	K	M	t_λ(yr)	t_r(yr)
NMFS Maryland #2	177.94	223.10	0.4759	0.3726	0.25	14	0.25
NMFS Maryland #1	162.74	174.12	0.1679	0.3270	0.25	15	0.25
Loesch (1975)	147.34	132.13	-0.0062	0.3840	0.25	16	0.25
Westman & Bidwell (1946)	171.54	201.53	-0.5607	0.1619	0.25	17	0.25
Chang et al. (unpubl. data)	174.80	212.35	-0.8100	0.1900	0.25	17	0.25

Table 2. Yield-per-recruit (g) for various lengths at selection using the NMFS Maryland #2 Growth Curve.

	---------Length at selection---------						
F	2.0"	2.5"	3.0"	3.5"	4.0"	4.5"	5.0"
0.1	17.9	18.2	18.4	18.5	18.3	17.8	16.9
0.2	23.6	24.6	25.5	26.1	26.5	26.3	25.4
0.3	24.9*	26.5	28.0	29.3	30.2	30.6	30.0
0.4	24.5	26.6	28.7	30.5	32.0	32.8	32.6
0.5	23.5	25.9	28.5	30.8	32.8	34.0	34.2
0.6	22.2	25.0	27.9	30.6	33.0	34.7	35.3
0.7	21.0	24.1	27.3	30.3	33.1	35.1	35.9
0.8	19.9	23.1	26.6	29.9	32.9	35.3	36.4
0.9	18.8	22.2	25.9	29.4	32.7	35.3	36.7
1.0	17.9	21.4	25.2	28.9	32.5	35.3	36.9
1.1	17.0	20.6	24.6	28.5	32.2	35.3	37.0
1.2	16.2	20.0	24.0	28.1	32.0	35.2	37.1
1.3	15.5	19.3	23.5	27.7	31.7	35.1	37.2
1.4	14.9	18.8	23.0	27.3	31.5	35.0	37.2
1.5	14.4	18.2	22.6	26.9	31.3	34.9	37.3
1.6	13.8	17.8	22.2	26.6	31.0	34.8	37.3
1.7	13.4	17.3	21.8	26.3	30.8	34.7	37.3
1.8	13.0	16.9	21.5	26.0	30.6	34.6	37.3
1.9	12.6	16.6	21.1	25.8	30.4	34.5	37.2
2.0	12.2	16.2	20.8	25.5	30.3	34.4	37.2

*Underlined values indicate maximum yield-per-recruit for a given selection length.

Table 3. Yield-per-recruit (g) for various lengths at selection using the NMFS Maryland #1 Growth Curve.

	---------Length at selection---------						
F	2.0"	2.5"	3.0"	3.5"	4.0"	4.5"	5.0"
0.1	13.5	13.8	13.9	13.8	13.4	12.6	11.1
0.2	17.8	18.6	19.3	19.6	19.5	18.7	16.9
0.3	18.7*	20.1	21.3	22.2	22.5	22.0	20.3
0.4	18.5	20.3	22.0	23.3	24.1	23.9	22.3
0.5	17.8	20.0	22.1	23.8	24.9	25.0	23.6
0.6	17.0	19.4	21.8	23.9	25.4	25.8	24.6
0.7	16.1	18.8	21.5	23.9	25.6	26.3	25.2
0.8	15.4	18.3	21.1	23.8	25.7	26.6	25.7
0.9	14.6	17.7	20.8	23.6	25.7	26.8	26.1
1.0	14.0	17.2	20.4	23.4	25.7	27.0	26.4
1.1	13.4	16.7	20.0	23.2	25.7	27.1	26.6
1.2	12.9	16.2	19.7	23.0	25.6	27.1	26.8
1.3	12.4	15.8	19.4	22.8	25.5	27.2	27.0
1.4	12.0	15.5	19.1	22.6	25.5	27.2	27.1
1.5	11.6	15.1	18.8	22.4	25.4	27.3	27.2
1.6	11.3	14.8	18.6	22.3	25.3	27.3	27.3
1.7	11.0	14.6	18.4	22.1	25.2	27.3	27.4
1.8	10.7	14.3	18.2	22.0	25.2	27.3	27.4
1.9	10.4	14.1	18.0	21.8	25.1	27.3	27.5
2.0	10.2	13.8	17.8	21.7	25.0	27.3	27.5

*Underlined values indicate maximum yield-per-recruit for a given selection length.

Table 4. Yield-per-recruit (g) for various lengths at selection using the Loesch (1975) Growth Curve.

	---------Length at selection---------						
F	2.0"	2.5"	3.0"	3.5"	4.0"	4.5"	5.0"
0.1	12.7	12.9	12.9	12.8	12.2	11.1	9.0
0.2	16.9	17.7	18.2	18.4	18.0	16.7	13.9
0.3	18.1*	19.3	20.4	21.0	21.0	19.8	16.8
0.4	18.1	19.8	21.3	22.4	22.7	21.7	18.6
0.5	17.6	19.6	21.5	23.0	23.7	23.0	19.9
0.6	16.9	19.3	21.5	23.3	24.3	23.8	20.9
0.7	16.2	18.8	21.3	23.4	24.7	24.4	21.5
0.8	15.5	18.3	21.1	23.4	24.9	24.8	22.1
0.9	14.9	17.8	20.8	23.3	25.1	25.2	22.5
1.0	14.3	17.4	20.5	23.3	25.1	25.4	22.9
1.1	13.7	17.0	20.2	23.1	25.2	25.6	23.1
1.2	13.2	16.6	20.0	23.0	25.2	25.8	23.4
1.3	12.8	16.2	19.7	22.9	25.2	25.9	23.6
1.4	12.4	15.9	19.5	22.7	25.2	26.0	23.8
1.5	12.0	15.6	19.2	22.6	25.2	26.1	23.9
1.6	11.7	15.3	19.0	22.4	25.2	26.1	24.0
1.7	11.4	15.0	18.8	22.4	25.1	26.2	24.1
1.8	11.1	14.8	18.6	22.3	25.1	26.2	24.2
1.9	10.8	14.5	18.5	22.2	25.1	26.3	24.3
2.0	10.6	14.3	18.3	22.1	25.0	26.3	24.4

*Underlined values indicate maximum yield-per-recruit for a given selection length.

Table 5. Yield-per-recruit (g) for various lengths at selection using the Westman and Bidwell (1946) Growth Curve.

	---------Length at selection---------						
F	2.0"	2.5"	3.0"	3.5"	4.0"	4.5"	5.0"
0.1	8.1	8.2	8.2	7.8	7.2	6.2	4.9
0.2	10.3	10.9	11.2	11.1	10.5	9.3	7.5
0.3	10.7*	11.7	12.3	12.5	12.1	10.9	9.0
0.4	10.5	11.8	12.8	13.2	13.0	11.9	9.9
0.5	10.1	11.7	12.9	13.6	13.5	12.5	10.6
0.6	9.7	11.5	12.9	13.8	13.9	13.0	11.0
0.7	9.3	11.2	12.9	13.9	14.1	13.3	11.3
0.8	9.0	11.0	12.8	13.9	14.2	13.5	11.6
0.9	8.7	10.8	12.7	13.9	14.3	13.7	11.8
1.0	8.4	10.6	12.6	13.9	14.4	13.8	12.0
1.1	8.1	10.4	12.5	13.9	14.5	13.9	12.1
1.2	7.9	10.3	12.4	13.9	14.5	14.0	12.2
1.3	7.7	10.1	12.3	13.8	14.5	14.1	12.3
1.4	7.6	10.0	12.2	13.8	14.6	14.1	12.4
1.5	7.4	9.9	12.1	13.8	14.6	14.2	12.4
1.6	7.3	9.8	12.1	13.8	14.6	14.2	12.5
1.7	7.2	9.7	12.0	13.7	14.6	14.3	12.5
1.8	7.0	9.6	11.9	13.7	14.6	14.3	12.6
1.9	6.9	9.5	11.9	13.7	14.6	14.3	12.6
2.0	6.9	9.4	11.8	13.7	14.6	14.3	12.7

*Underlined values indicate maximum yield-per-recruit for a given selection length.

Table 6. Yield-per-recruit (g) for various lengths at selection using the Chang et al. (Unpubl. data) Growth Curve.

	---------Length at selection---------						
F	2.0"	2.5"	3.0"	3.5"	4.0"	4.5"	5.0"
0.1	11.3	11.5	11.6	11.3	10.7	9.7	8.2
0.2	14.3	15.1	15.7	15.8	15.4	14.3	12.4
0.3	14.8*	16.1	17.2	17.8	17.7	16.7	14.7
0.4	14.4	16.2	17.7	18.6	18.8	18.1	16.1
0.5	13.8	15.9	17.7	19.0	19.5	18.9	17.1
0.6	13.2	15.5	17.6	19.2	19.9	19.5	17.7
0.7	12.6	15.1	17.4	19.2	20.1	19.9	18.2
0.8	12.0	14.7	17.2	19.2	20.3	20.2	18.5
0.9	11.5	14.3	17.0	19.1	20.3	20.4	18.8
1.0	11.1	14.0	16.8	19.0	20.4	20.5	19.0
1.1	10.7	13.7	16.6	18.9	20.4	20.6	19.2
1.2	10.4	13.4	16.4	18.8	20.4	20.7	19.4
1.3	10.1	13.2	16.2	18.8	20.4	20.8	19.5
1.4	9.8	13.0	16.1	18.7	20.4	20.8	19.6
1.5	9.6	12.8	15.9	18.6	20.4	20.9	19.7
1.6	9.4	12.6	15.8	18.5	20.4	20.9	19.8
1.7	9.2	12.4	15.7	18.5	20.4	21.0	19.8
1.8	9.0	12.3	15.6	18.4	20.4	21.0	19.8
1.9	8.9	12.1	15.4	18.3	20.3	21.0	19.9
2.0	8.7	12.0	15.3	18.3	20.3	21.0	20.0

*Underlined values indicate maximum yield-per-recruit for a given selection length.

Table 7. Percent increase in maximum yield-per-recruit between various lengths at selection (l_c), (F = 0.1-2.0)

	----------GROWTH STUDY----------					
Increase in l_c from:	NMFS #2	NMFS #1	LOESCH	WESTMAN & BIDWELL	CHANG et al.	Mean of 5 curves
2.0" - 2.5"	6.8	8.6	9.4	10.3	9.5	8.9
2.0" - 3.0"	15.3	18.2	18.8	20.6	19.6	18.5
2.0" - 3.5"	23.7	27.8	29.3	29.9	29.7	28.1
2.0" - 4.0"	32.9	37.4	39.2	36.5	37.8	36.8
2.0" - 4.5"	41.8	46.0	45.3	33.7	41.9	41.7
2.0" - 5.0"	49.8	47.1	34.8	18.7	35.1	37.1
2.5" - 3.0"	7.9	8.9	8.6	9.3	9.3	8.8
2.5" - 3.5"	15.8	17.7	18.2	17.8	18.5	17.6
2.5" - 4.0"	24.4	26.6	27.3	23.7	25.9	25.6
2.5" - 4.5"	32.7	34.5	32.8	21.2	29.6	30.2
2.5" - 5.0"	40.2	35.5	23.2	7.6	23.5	26.0
3.0" - 3.5"	7.3	8.2	8.8	7.8	8.5	8.1
3.0" - 4.0"	15.3	16.3	17.2	13.2	15.3	15.5
3.0" - 4.5"	23.0	23.5	22.3	10.9	18.6	19.7
3.0" - 5.0"	30.0	24.4	13.5	-1.6	13.0	15.9
3.5" - 4.0"	7.5	7.5	7.7	5.0	6.3	6.8
3.5" - 4.5"	14.6	14.2	12.4	2.9	9.4	10.7
3.5" - 5.0"	21.1	15.1	4.3	-8.6	4.2	7.2
4.0" - 4.5"	6.7	6.2	4.4	-2.1	2.9	3.6
4.0" - 5.0"	12.7	7.0	-3.2	-13.0	-2.0	0.3
4.5" - 5.0"	5.7	0.7	-7.2	-11.2	-4.8	-3.4

Table 8. Values of fishing mortality rate (F) resulting in maximum yield-per-recruit for various lengths at selection (l_c) (F = 0.1-2.0)

	-------length at selection-------						
Growth Curve	2.0"	2.5"	3.0"	3.5"	4.0"	4.5"	5.0"
NMFS #2	0.3	0.4	0.4	0.5	0.7	0.8	1.5
NMFS #1	0.3	0.4	0.5	0.6	0.8	1.5	1.9
Loesch (1975)	0.3	0.4	0.5	0.7	1.1	1.9	2.0
Westman & Bidwell (1946)	0.3	0.4	0.5	0.7	1.4	1.7	2.0
Chang et al. (unpubl. data)	0.3	0.4	0.4	0.6	1.0	1.7	2.0