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Long-term effects of change in mesh size on yield of summer flounder

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SUMMARY

Length selection curves and selection factors from mesh studies conducted off Long Island, New York during May-June 1983 were used to estimate the long-term effects on yield of summer flounder (Paralichthys dentatus), associated with increases in mesh size used in the trawl fishery. Selection data obtained for experimental codend mesh sizes (about 5.5 in) from three vessel experiments were used in these analyses. Selection curves for the control mesh codends (about 2.5 in) were estimated using three methods.

Estimated changes in yield ranged from 4.3% to 20.1%, dependent on the vessel and control mesh selection curve used. However, biases associated with the unavailability of small summer flounder in the Long Island study area result in some uncertainties in the calculated changes in long-term yield.

Small fish tend to be concentrated south of 39° latitude so analyses were also conducted using length distributions and selectivity information from the North Carolina fishery to determine effects of increasing mesh size in areas where small fish are available to the fishery. Estimated changes in yield for the North Carolina area exceeded 35%. These results correspond to results of yield per recruit analyses which indicated increases in excess of 30% associated with increases in minimum size of retention comparable to those resulting from increasing codend mesh from 2.5 to 5.5 in.

Implications associated with increases in mesh size would vary dependent on the occurence of small fish on the fishing grounds, and a uniform mesh size for summer flounder in all areas may not result in uniform changes in long-term yield.

TABLE OF CONTENTS

INTRODUCTION

Mesh studies conducted off Long Island, New York during May-June 1983 (Anderson et al. 1983) provided information regarding the length distribution of summer flounder (Paralichthys dentatus) taken in nets of various size mesh. Selection curves and selection factors for the experimental meshes used in that study, estimates of the parameters of the length-weight relationship and the von Bertalanffy growth equation, and estimates of total (Z) and natural (M) mortality rates were used to estimate the effects of a change in mesh size from the current (about 2.5 in or 64 mm) to a proposed 5.5 in (140 mm) mesh size, over the lifespan of the species. Significant differences exist between size distributions of summer flounder found off Long Island and those found further south. Analyses were also conducted using length distributions and selectivity information from the North Carolina fishery (Gilliki n et al. 1981). Results were expressed in percent change in yield and were compared with estimated changes in yield per recruit associated with increasing the minimum size of capture (Fogarty 1981).

METHODS

Jones (1981) described methods by which length distribution data from a fishery may be used in cohort analysis to estimate the average numbers of individuals in a stock at each length interval. He used the results of that analysis in conjunction with estimates of the selection curves of present and proposed mesh sizes to provide estimates of percent change in yield (by weight) attributed to proposed increases in mesh size.

Length frequency data and calculated selection curves and selection factors from three of the four vessels (RIANDA S, PATRIOT, and RUTH ANN) which participated in the Long Island mesh study (Anderson et al. 1983) were analysed using Jones' (1981) methods to estimate the long-term effects on yield of summer flounder, resulting from an increase in the mesh size used in the fishery. Data from the fourth vessel (SEAFARER) were not used in this analysis since it did not complete the study and the length frequencies of the few tows made were not considered fully representative of landings in the area.

Data collected from each vessel were assumed to represent separate experiments and to be representative of the entire fleet fishing for summer flounder in the Long Island area. Three separate estimates of potential changes in yield were calculated. Since length cohort analysis is generally based on the average length composition over a period of years, the size distribution taken in each of these experiments was assumed to be representative of the fishable population in recent years.

To examine the potential biases caused by differences in size of summer flounder by area, data from the North Carolina study (Gillikin et al. 1981) were also analysed as described above. Small summer flounder are not generally found in the Long Island area and are not susceptible to the fishery there. Summer flounder of all sizes are found on the fishing grounds off North Carolina and were represented in the data from the mesh study conducted there. Results were analysed from two experiments from the North Carolina study which compared a control (38 mm) codend mesh with 126-mm and the 146-mm experimental mesh codends.

Additional input to the length cohort analyses included estimates of L_{∞} and k from the von Bertalanffy growth equation and total (Z) and natural (M) mortality rates obtained from Fogarty (1981). Fogarty estimated the above parameters for each sex from 1976-79 NMFS, NEFC spring and autumn survey data. The present analyses were based on data for sexes combined. Parameter values were selected to be within the range calculated for males and females. The estimate of the growth constant K was 0.179

for males and 0.164 for females, with 0.17 used in this analysis. The estimate of L_∞ was 72.7 cm for males and 90.6 cm for females, with 90.6 cm used in this analysis since it represented the maximum size for both sexes. Natural mortality was assumed to be 0.2 for both sexes. Total mortality estimates ranged from 0.93 for females to 1.11 for males; 1.0 was used in this analysis. Fishing mortality (F = Z - M) and the exploitation rate (F/Z) were both assumed to be 0.8.

Parameters of the length-weight relationship were needed to convert catch in number to catch in weight. The relationship

$$W = 0.00000163\ L^{3.297}$$

was used which was based on data from 1,001 individuals taken during April-June (Lux and Porter 1966).

The Long Island mesh study provided selection curves for each of the experimental mesh sizes used (141 - 145 mm). However, no information was available on the selectivity of the control mesh sizes (58 - 64 mm). Selectivity for the control mesh was estimated assuming the same shaped selection curve as calculated for the experimental meshes and by calculating the length at 50% retention (L_{50}) using three methods:

1. A constant propogtion was assumed between L_{50} and mesh size (L_{50} = mesh size x selection factor).

2. The cumulative distribution function for the control mesh was assumed to be similar to that for the experimental mesh with L_{50} occurring at the same cumulative proportion of the total distribution.

3. The two vessels from the Shinnecock area (PATRIOT AND RUTH ANN) were assumed to have fished at the same time and in the same area and to have had similar vessel characteristics. Therefore, length distributions from each of their control codends were considered to represent alternate tows using 58-mm and 64-mm mesh. A selection curve and selection factor were calculated for the larger (64 mm) of those two codends, and that selection factor was used for each of the controls to calculate L_{50}.

Selection curves for the North Carolina control mesh were determined as described in Method 1 above.

RESULTS

Each of the methods used to determine lengths at 50% retention (L_{50}) for the Long Island study control mesh resulted in substantially different estimates for each vessel/ experiment. These lengths (cm) were:

	L_{50}		
Mesh	PATRIOT	RUTH ANN	RIANDA S
Experimental	32.5	34.5	37.9
Control - Method 1	13.3	15.7	16.8
Control - Method 2	31.5	32.7	32.5
Control - Method 3	26.0	28.7	28.7

When the selection curves calculated for the experimental mesh used by each vessel in the Long Island study were moved to the left to align with the estimates of L_{50} for the control mesh, estimates of the selectivity of the control mesh were obtained. Method 1 implies, and it is generally assumed, that the selection factor calculated for a given species for any mesh size is consistent for all mesh sizes. In this case, positioning of the selection curve to align with the L_{50} for the control mesh indicates that the control mesh was virtually non-selective over the range of lengths available to the trawl (Table 1). This is consistant with the results presented for the North Carolina study (Gillikin et al. 1981) which indicated that small mesh nets (73 and 97 mm) were non-selective for summer flounder. However, this is probably due to differences in the areal distribution of smaller (<20 cm) summer flounder which remain in sheltered coastal waters or in areas further south than where the Long Island study was conducted, and are not generally taken in the Long Island fishery. If small summer flounder were distributed in the same areas as the adults, some selectivity for the small (<20 cm) size classes would be expected.

The assumption of a constant relationship between the mesh size and L_{50} implies that the length to girth relationship is also constant. Since this is not necessarily the case with flounders, it was reasonable to calculate L_{50} based on other methods. Method 2 produced estimates of L_{50} for the control codends which were very close to those calculated for the experimental codends, the meshes in the latter being more than double the size of those in the control codends. These estimates were probably unreasonable. Method 3 produced estimates of L_{50} which were consistent with the length distributions observed during the mesh study and the apparent unavailability of the small summer flounder to the fishery off Long Island.

Long-term percent changes in yield estimated for each vessel based on the above assumptions were:

		Percent change in yield		
		PATRIOT	RUTH ANN	RIANDA S
L	Control (mm)	58	64	64
method	Experimental (mm)	142	141	145
1		9.8	19.7	18.4
2		4.3	10.7	8.6
3		9.6	20.1	16.0

Selectivity of the control codend for each vessel was probably best represented by the selection curves determined by Methods 1 and 3. Similar results were obtained for these two methods, with changes in yield ranging from about 9.6 to 20.1 percent.

Selection factors for the 126-mm and the 146-mm mesh codends used in the North Carolina study were 2.59 and 2.50, respectively. Using Method 1, these result in L estimates of 9.8 and 9.5 cm, for the 38-mm control codends used in those experiments. The smallest individuals taken in the control codends were 12 cm for the 126-mm mesh experiment and 18 cm for the 146-mm mesh experiment. When the selection curves for each of the experimental nets were moved to the left to align with the estimates of L for the control mesh, the controls were found to be non-selective over the range of sizes taken in the trawl. Most vessels in the current mixed trawl fishery for summer flounder off Long Island employ codends with substantially greater mesh sizes (about 60 mm or larger) than the survey mesh (38 mm) used as the (38 mm) control in the North Carolina study. However, the calculated L_{50} for a 60-mm mesh codend is 15-16 cm. These mesh sizes would, therefore, also be non-selective for the small summer flounder.

If mesh sizes in the fishery were increased to 126 mm, an estimated 100% increase in long-term yield may be expected, based on the North Carolina experiment. An increase of about 36% would result from an increase in mesh size to 146 mm. The apparent inconsistency in these results may be due to the small sample size for each experiment (4 sets for the 126-mm and 5 sets for the 146-mm experiments). These results indicate that if small summer flounder are available in the area of the trawl fishery, significant increases in yield may be expected if mesh sizes are increased to 5.0 or 5.5 in. (126 mm to 146 mm).

Uncertainty in the appropriate values of L_∞, Z, and K prompted simulations using additional values for these parameters to analyse the sensitivity of the method. An L_∞ of 75.0 cm was tested since it more closely reflected the maximum size of individuals found during the Long Island mesh study (71 cm). Fogarty (1981) provided estimates of Z ranging from 0.9 to 2.3 based on commercial age samples (1976-79). To account for Z at the upper end of this range, a value of 2.0 was tested. Estimates of K ranged from 0.164 for females to 0.179 for males. In the initial analyses, k was assumed to be 0.17; during the sensitivity analyses, 0.18 was used.

Results of the sensitivity analyses were as follows:

Parameter varied	PATRIOT Method 1	PATRIOT Method 3	RUTH ANN Method 1	RUTH ANN Method 3	RIANDA S Method 1	RIANDA S Method 3
none	9.8	9.6	19.7	20.1	18.4	16.0
L_∞	8.2	8.1	15.2	15.1	15.0	12.7
Z	9.9	9.7	20.0	19.8	18.6	15.7
K	10.0	9.9	20.2	20.1	18.9	16.0

Sensitivity analyses indicate that fairly significant changes in L_∞, Z, or K do not result in substantial changes in the long-term yield of summer flounder associated with an increase in mesh size from about 2.5 in (64 mm) to 5.5 in (140 mm). Similar changes resulted from sensitivity analyses of the North Carolina data.

Based on these results, the effect on the long-term yield of summer flounder from increasing mesh size to 5.5

in (140 mm) would vary by area, dependent on the availability of small fish to the fishery. This effect would be most dramatic in the more southern area of the fishery where small summer flounder are consistently available on the fishing grounds. In fact, other analyses indicate that substantial increases in yield per recruit would result from increases in minimum size at capture of a similar magnitude to the increases in L_{50} estimated here. In evaluating effects of minimum size regulations, Fogarty (1981) found that a 33-36% increase in yield per recuit could be expected if minimum retention size was increased from 25.4 cm (10 in) to 33.0 cm (13 in) when F = 0.75. An increase of 44-47% would be expected if minimum size was increased to 35.6 cm (14 in, assuming F = 0.75).

CONCLUSION

Biases attributed to the unavailability of small summer flounder in the Long Island study area result in some uncertainties in the calculated changes in long-term yield, but as a 'worst case scenario' indicate that increases in yield on the order of 10 to 20% would result from the use of 5.5-in (140-mm) mesh codends compared to the 2.5-in (64-mm) mesh codends currently in use. However, expected increases in yield are greater in the more southern areas of the fishery, where small summer flounder occur on the fishing grounds. Assuming the presence of small summer flounder in the fishery, expected increases in yield per recruit associated with increasing minimum size of capture could exceed 30%, based on analyses by Fogarty (1981). Implications associated with increases in mesh size would, therefore, vary dependent on the occurence of small summer flounder on the fishing grounds, and a uniform mesh size for summer flounder in all areas would not result in uniform changes in long-term yield.

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Table 1. Length frequency distributions of summer flounder (C) caught by the PATRIOT, RUTH ANN, and RIANDA S in the Long Island mesh study (Anderson et al. 1983), with the control mesh codends, and estimated selectivity at length for the control (58-64 mm, S1) and experimental (141-145 mm, S2) mesh codends.

	PATRIOT 58 - 142 mm					RUTH ANN 64 - 145 mm					RIANDA S 64 - 141 mm				
Length	C	S1	S1	S1	S2	C	S1	S1	S1	S2	C	S1	S1	S1	S2
21	1	1.0	.02	.05	.02						1	.73	.04	.07	.03
22	1	1.0	.03	.05	.02						-	.82	.04	.05	.03
23	-	1.0	.03	.12	.03						1	1.0	.05	.07	.04
24	1	1.0	.04	.25	.03						-	1.0	.05	.10	.04
25	2	1.0	.04	.42	.04	1	1.0	.04	.13	0	1	1.0	.07	.12	.05
26	5	1.0	.05	.59	.04	6	1.0	.05	.15	0	14	1.0	.05	.20	.05
27	10	1.0	.05	.74	.05	5	1.0	.06	.22	.04	13	1.0	.07	.29	.07
28	27	1.0	.05	.88	.05	8	1.0	.07	.33	.05	17	1.0	.10	.42	.05
29	31	1.0	.12	.93	.05	22	1.0	.08	.51	.06	34	1.0	.12	.57	.07
30	69	1.0	.25	.96	.12	36	1.0	.08	.73	.07	94	1.0	.20	.62	.10
31	103	1.0	.42	.92	.25	34	1.0	.11	.97	.08	134	1.0	.29	.66	.12
32	179	1.0	.59	.97	.42	46	1.0	.13	1.0	.08	240	1.0	.42	.67	.20
33	207	1.0	.74	1.0	.59	85	1.0	.15	1.0	.11	292	1.0	.57	.71	.29
34	238	1.0	.88	1.0	.74	108	1.0	.22	1.0	.13	339	1.0	.62	.73	.42
35	200	1.0	.93	1.0	.88	117	1.0	.33	1.0	.15	282	1.0	.66	.82	.57
36	185	1.0	.96	1.0	.93	136	1.0	.51	1.0	.22	233	1.0	.64	1.0	.62
37	136	1.0	.92	1.0	.96	132	1.0	.73	1.0	.33	249	1.0	.71	1.0	.66
38	148	1.0	.97	1.0	.92	154	1.0	.97	1.0	.51	214	1.0	.73	1.0	.67
39	108	1.0	1.0	1.0	.97	100	1.0	1.0	1.0	.73	172	1.0	.82	1.0	.71
40	100	1.0	1.0	1.0	1.0	132	1.0	1.0	1.0	.97	212	1.0	1.0	1.0	.73
41	56	1.0	1.0	1.0	1.0	77	1.0	1.0	1.0	1.0	126	1.0	1.0	1.0	.82
42	58	1.0	1.0	1.0	1.0	64	1.0	1.0	1.0	1.0	84	1.0	1.0	1.0	1.0
43	28	1.0	1.0	1.0	1.0	60	1.0	1.0	1.0	1.0	53	1.0	1.0	1.0	1.0
44	20	1.0	1.0	1.0	1.0	43	1.0	1.0	1.0	1.0	37	1.0	1.0	1.0	1.0
45	14	1.0	1.0	1.0	1.0	27	1.0	1.0	1.0	1.0	28	1.0	1.0	1.0	1.0
46	14	1.0	1.0	1.0	1.0	16	1.0	1.0	1.0	1.0	21	1.0	1.0	1.0	1.0
47	6	1.0	1.0	1.0	1.0	16	1.0	1.0	1.0	1.0	10	1.0	1.0	1.0	1.0
48	5	1.0	1.0	1.0	1.0	15	1.0	1.0	1.0	1.0	20	1.0	1.0	1.0	1.0
49	4	1.0	1.0	1.0	1.0	5	1.0	1.0	1.0	1.0	6	1.0	1.0	1.0	1.0
50	5	1.0	1.0	1.0	1.0	9	1.0	1.0	1.0	1.0	4	1.0	1.0	1.0	1.0
51	3	1.0	1.0	1.0	1.0	5	1.0	1.0	1.0	1.0	5	1.0	1.0	1.0	1.0
52	4	1.0	1.0	1.0	1.0	6	1.0	1.0	1.0	1.0	4	1.0	1.0	1.0	1.0
53	1	1.0	1.0	1.0	1.0	3	1.0	1.0	1.0	1.0	10	1.0	1.0	1.0	1.0
54	14	1.0	1.0	1.0	1.0	4	1.0	1.0	1.0	1.0					
55						20	1.0	1.0	1.0	1.0					