NOT TO BE CITED WITHOUT PRIOR
REFERENCE TO THE AUTHOR(S)

International Commission for the Northwest Atlantic Fisheries

Serial No. 5489

ICNAF Res. Doc. 79/VI/121

ANNUAL MEETING - JUNE 1979

Division 3M redfish mesh assessment

by

W. D. McKone
Fisheries and Oceans Canada
P. O. Box 5667
St. John's, Newfoundland
A1C 5X1

INTRODUCTION

Selectivity studies, to be all encompassing, potentially cover a wide range of topics in gear technology, fish population dynamics, economic impact and other aspects of the enforcement and choice of fishery regulation. To develop a comprehensive study of selectivity of redfish, data would have to be collected on those parameters outlined which, to this date, are areas which have not been looked at in any detail.

Overwhelmingly, selectivity studies carried out in the North Atlantic have been concerned with selection through the codend of trawls. Thus, it is not possible, from available data, to produce a definitive work on selectivity. This work is an attempt to apply available techniques to estimate the effect on catches of Div. 3M redfish, both immediate and long term, of changes in selectivity as a result of reduction in the mesh size of bottom trawls. It must be kept in mind, however, that both practically and administratively the application of minimum mesh size should be as uniform as possible when fishing fleets are expending effort on catching a variety of species in a number of different stock complexes.

Additionally, an attempt will be made to determine the impact of reduced mesh size on the spawning stock and to determine if the commercial frequencies as sampled are much different from those frequencies collected by research surveys.

MATERIALS AND METHODS

Throughout this study, it is assumed that, at the present time, the fishery is being prosecuted by 5-inch mesh or greater and that the stock is in equilibrium. There are a number of retention ogives for redfish, any one of which might be used - recently, for example, Clay 1979 - but for this paper the ogives presented by Hodder (1964) were used because they best represented the fisheries in Newfoundland waters of which Div. 3M is a part (Table 1). Ratios were calculated between 5-inch mesh and 4-inch mesh and between 5-inch mesh and 4-1/2-inch mesh.

Average weight at length was used to calculate the total weight gained in the catch by reducing the mesh size (Table 1).

The method used to compute the effects of decreasing mesh size was, in part, similar to that outlined by Gulland (1961). If the mesh size is decreased, a certain number of small fish will be retained. The number thus retained can be computed from size composition of the original catches taken by the mesh used and the retention curves for the sizes of meshes under consideration.

The ogives are not calculated separately for males and females so that it was necessary to apply the same ogive to each sex which may introduce some bias in the estimates. USSR (1978) commercial length frequencies for both male and female Div. 3M redfish from bottom trawls was used by applying the appropriate ratio from the retention ogives to the length composition to determine immediate gains or losses (Table 2). The length compositions were expressed in weight by applying the length weight key to the numbers. The total weight of those fish retained by the change in mesh was expressed as a percentage of the original catch.

In the long term, the gain or loss from a change in mesh size can be expressed as the percent difference in yield per recruit fishing at $F_{0.1}$ between 5-inch mesh and other mesh sizes. The mean selection length ℓ_c was interpolated as the 50% retention points from the retention ogives of Hodder (1962) and the mean age at first capture t_c from Beverton and Holt (1957). Growth parameters were estimated from a von Bertalanffy growth curve from fish aged by otoliths. These parameters were combined to calculate a Beverton and Holt yield recruit at natural mortality rates of 0.05, 0.10, and 0.15. The natural mortality of a long-lived species, such as redfish, was considered to be 0.10 by Sandeman (1961) so values immediately on either side are given for comparison. The yield per recruit at $F_{0.1}$ was calculated and the percentage lost or gained as a result of the mesh change was calculated.

To determine the effects of reducing mesh size of the codend on spawning stock size, survival rates were determined from $F_{0.1}$ and the retention ogives. For expediency, a fictitious population of 10,000 males and 10,000 females was assumed to determine the relative contribution of a redfish population to the spawning biomass if fished by 4-, 4-1/2- or 5-inch codend mesh size.

For the observation of selectivity differences due to codend mesh size changes, the 1978 USSR commercial length frequencies are compared with USSR research survey and 1978 to 1979 Canadian research survey length frequencies. Canadian research surveys are carried out with a 5-inch codend lined with 1-1/8-inch knotless lining and the USSR use a liner which is less than that used in the Canadian surveys.

RESULTS

The power function:

$$W_t = a\,\ell_t^{\,b}\ , \qquad (1)$$

where W_t = weight at time t, ℓ is length, and a and b are constants, was used to determine the relationship between weight and length. The constants for Div. 3M redfish are a = 0.01659 and b = 2.9548 for males and a = 0.0372 and b = 3.0210 for females (Table 1).

Table 2 gives the numbers and weight from commercial length compositions for the assumed mesh size currently being used for redfish in Div. 3M and the adjusted numbers and weight, length compositions as a result of reducing the mesh size to 4-1/2- and 4-inch. It is evident that immediate gains by number occur in all but very large fish beyond 38 cm for both males and females. The largest gains, however, for both males and females by number are in length groups below 28 cm. However, when the numbers caught are expressed as weight, greater gains will occur in the intermediate size categories for both sexes (28-35 cm). What is not shown in these results are the numbers and weight of lengths less than 21 cm that would be caught by reducing the mesh size which cannot be calculated because the 5-inch mesh ogive should not retain sizes below 21 cm. The mean selection length ℓ_c decreases with decreasing mesh size for both sexes. The ℓ_c ranges from 32 cm when fishing with 5-inch mesh codend to 28 cm when fishing with 4-1/2-inch mesh and 25 cm when fishing with 4-inch mesh (Table 3). Similarly, the mean age at first capture decreases with smaller codend mesh size, from a high of over 16 years for both sexes when a 5-inch mesh codend is used to 12.5 years old for 4-1/2-inch mesh and 10 years old for 4-inch mesh. If the bottom trawl codend mesh size is reduced to 4-1/2 inches, immediate gains would accrue from 39.1% for males and 28.8% for females. Further, if the mesh size of the codend is reduced to 4 inches, gains of 68.7% and 54.2% would occur for males and females, respectively (Table 3).

Yield per recruit decreases with increasing natural mortality (M) for both sexes, but with changing mesh size the yield per recruit decreases with decreasing mesh size if M = 0.05 and increases if M = 0.10 or 0.15 (Table 3). The percent loss or gain in yield per recruit as a result of decreasing the mesh size varies depending on the assumed natural mortality. If M = 0.10 which is the accepted value for redfish is used, the gains in yield per recruit increase from 7.2% to 9% for males and decrease from 3.9% to 1.3% for females, if the mesh size of the codend is reduced to 4-1/2- and 4-inch, respectively, from the mesh size currently used. Losses in yield per recruit would occur if M = 0.05 and substantial gains would occur if M = 0.15.

To determine the impact of changing the codend mesh size on the spawning biomass of redfish, a value of 10,000 males and 10,000 females was used to determine the relative strengths of populations subject to fishing with 4-, 4-1/2- and 5-inch mesh (Table 4). The spawning stock size would be reduced by 20% if the mesh size were reduced to 4-1/2-inches and by 24% if the mesh size were reduced to 4 inches.

A comparison of the USSR commercial length frequencies with research frequencies from USSR and Canada indicate that there is little difference in the relative proportions of the individual length groups caught by the two different mesh sizes used. The relative proportions in the expected length frequencies for 4- and 4-1/2-inch mesh indicate a higher proportion of smaller redfish less than 23 cm would be caught than the larger size categories (Table 2). But in the observed frequencies from research which uses a smaller mesh than the 4-inch mesh indicate that the proportion of size classes of small redfish less than 23 cm is always less than the larger size classes.

DISCUSSION

Selectivity by mesh size can be considered as only one factor that influences the size composition of the catch to be different than that of the population. Differences in area or time fished, differences in the probability of fish of different sizes encountering the gear, and differences in the probability of fish of different sizes being returned by the gear once they have encountered it in commercial operations are all equally important in any consideration of interpreting the data which use the methods in this paper. Redfish are known to increase in size with depth, move into the pelagic zone during the night, and become easily enmeshed in most gears used. This latter phenomenon is particularly evident in the wide variations in the 50% retention points indicated by Clay (1979) from historical data for redfish. Thus, any length frequency used to calculate immediate gains could be biased by any combination of these factors.

The method used to calculate immediate gains does not reflect the potential loss due to yield per recruit, nor the population's ability to sustain an increase in the mortality of smaller fish. As redfish do not mature before 20-24 cm, any increase in mortality on these fish will affect the spawning potential of the stock. Additionally, a change from 5- to 4-inch mesh, as calculated, would reduce the total spawning potential by 24% (Table 4) which, in any case, might affect the stock's ability to sustain these pressures.

The estimates of immediate gains outlined in Table 2 are biased because smaller size categories are not represented in the calculation and the gains are not really an increase in catch but an indication that the catch rate will increase. Also, if mesh size is reduced, the increase in small size classes in the catch may cause discarding to a greater extent than now occurs.

Long-term gains by reducing the mesh size are rather insignificant at the $M = 0.1$ relative to the sources of error, for example the assumption the stock is currently in equilibrium. From the frequencies, a large new year-class is moving into the population and there is evidence another might be in the offing. Additionally, it appears maximum yield per recruit occurs when fishing with 4-1/2-inch mesh and gains are only slight, approximately 5% (Table 3). Thus in the long term, it appears the gains are relatively insignificant within the sources of error.

Calculated increases in yield are due to anticipated larger catches of fish from 28 to 35 cm. The large number of 20-25-cm fish anticipated in catches from smaller mesh gears contribute little to yield but do reduce survival rates. Comparison of 1978 USSR commercial length compositions with USSR and Canadian research vessel catches with small-meshed gears in 1978 indicates that calculated increases in the proportion of 25-35-cm redfish to 35+ cm redfish will not arise in practice although some increase in the proportion of 20-25-cm fish might occur. Thus, the existence of short-term gains from mesh size reduction is questionable. In conclusion, sources of error in this work, the apparent non-selectivity from commercial and research frequencies, and the wide variation in the 50% retention point indicated from historical records would suggest that any change in mesh would be premature.

REFERENCES

Beverton, R. J. H., and S. J. Holt. 1957. On the dynamics of exploited fish populations. Fish. Invest. Lond. (2).

Clay, D. 1979. Current mesh selection studies on the Scotian Shelf in relation to historical selectivity data. ICNAF Sel. Papers No. 5: 49-60.

Gulland, J. A. 1961. The estimation of the effect on catches of changes in gear selectivity. J. Cons. Explor. Mer 25 (2): 204-214.

Hodder, V. M. 1964. Assessment of the effects of fishing and of increases in the mesh size of trawls on the major commercial fisheries of the Newfoundland area (ICNAF Subarea 3). Fish. Res. Board MS Rept. 801.

Table 1. The percent of redfish retained by 4-, 4-1/2-, and 5-inch mesh sizes in the codend of a bottom trawl, the ratios between these ogives, and the mean weight at length for both males and females.

	% from mesh selection ogives			Ratio of % retentions for various mesh sizes		Average weight	
Length (cm)	Mesh size (inch) 4	4-1/2	5	4:5	4-1/2:5	Male (gm)	Female (gm)
20	12	4	-	-	-	116	117
21	18	6	1	18.00	6.00	134	135
22	26	9	2	13.00	4.50	154	156
23	35	13	4	8.75	3.25	175	178
24	44	18	6	7.33	3.00	199	203
25	54	25	8	6.75	3.13	224	229
26	64	33	12	5.33	2.75	252	258
27	73	41	17	4.29	2.41	281	289
28	81	50	23	3.52	2.17	313	323
29	87	59	30	2.90	1.97	347	359
30	92	67	37	2.49	1.81	384	398
31	95	75	45	2.11	1.67	423	439
32	97	82	54	1.80	1.52	465	484
33	98	87	62	1.58	1.40	509	531
34	99	91	70	1.41	1.30	556	581
35	100	94	76	1.13	1.23	606	634
36	-	96	82	1.23	1.17	658	690
37	-	98	87	1.15	1.13	714	750
38	-	99	91	1.10	1.09	772	813
39	-	100	94	1.06	1.06	834	879
40	-	-	96	1.04	1.04	899	947
41	-	-	98	1.02	1.02	967	1,022
42	-	-	99	1.01	1.01	1,038	1,099
43	-	-	100	1.00	1.00	1,113	1,180
44	-	-	-	-	-	1,191	1,265
45	-	-	-	-	-	-	1,350
46	-	-	-	-	-	-	1,447
47	-	-	-	-	-	-	1,544
48	-	-	-	-	-	-	1,646
49	-	-	-	-	-	-	1,752
50	-	-	-	-	-	-	1,862
51	-	-	-	-	-	-	1,977

Table 2. The average numbers/1000 from 1978 USSR commercial sampling for Div. 3M redfish caught by 5-inch mesh bottom trawl, adjusted to catch expected by 4- and 4-1/2-inch mesh and expressed as weight.

	Males						Females					
	Numbers			Weight			Numbers			Weight		
	Mesh size (inch)			Mesh size (inch)			Mesh size (inch)			Mesh size (inch)		
Length	5	4-1/2	4	5	4-1/2	4	5	4-1/2	4	5	4-1/2	4
16	-	-	-	-	-	-	-	-	-	-	-	-
17	1	-	-	-	-	-	-	-	-	-	-	-
18	2	-	-	-	-	-	3	-	-	-	-	-
19	6	-	-	-	-	-	6	-	-	-	-	-
20	12	-	-	-	-	-	11	-	-	-	-	-
21	13	78	234	2	10	31	13	78	234	2	11	32
22	11	50	143	2	8	22	10	45	130	2	7	20
23	4	13	35	1	2	6	4	13	35	1	2	6
24	1	3	7	-	1	1	2	6	15	-	1	3
25	2	6	14	-	1	3	2	6	14	-	1	3
26	3	8	16	1	2	4	4	11	21	1	3	5
27	4	10	17	1	3	5	3	7	13	1	2	4
28	4	9	14	1	3	4	2	4	7	1	1	2
29	18	35	52	6	12	18	11	22	32	4	8	11
30	33	59	82	13	23	31	12	22	30	5	9	12
31	38	63	80	16	27	34	19	32	40	8	14	18
32	62	94	112	29	44	52	33	50	59	16	24	29
33	52	73	82	26	37	42	30	42	47	16	22	25
34	73	95	103	41	53	57	41	53	58	24	31	34
35	76	93	86	46	56	52	39	48	44	25	30	28
36	57	67	70	38	44	46	57	67	70	39	46	48
37	37	42	43	26	30	31	48	54	55	36	41	41
38	20	22	22	15	17	17	35	38	39	28	31	32
39	12	13	13	10	11	11	34	36	36	30	32	32
40	4	4	4	4	4	4	17	18	18	16	17	17
41	1	1	1	1	1	1	9	9	9	9	9	9
42	1	1	1	1	1	1	4	4	4	4	4	4
43	-	-	-	-	-	-	1	1	1	1	1	1
44	-	-	-	-	-	-	1	1	1	1	1	1
45	1	-	-	1	1	1	-	-	-	-	-	-
46	-	-	-	-	-	-	1	1	1	1	1	1
Total				281	391	474				271	349	418

Table 3. Summary of the approximate immediate and long-term gain (loss) if the codend mesh size is changed to 4 or 4-1/2 inches from the present size, the mean selection length ℓ_c, mean age at first capture t_c and yield per recruit at $F_{0.1}$.

Mesh size (inch)	Sex	ℓ_c (cm)	t_c (years)	% gain in catch	Natural mortality (M)	Yield/recruit at $F_{0.1}$	
						grams	% gain or loss
5	Male	32	16.5	-	0.05	0.254	-
					0.10	0.138	
					0.15	0.074	
4-1/2		28	12.4	+ 39.1	0.05	0.241	- 5.1
					0.10	0.148	+ 7.2
					0.15	0.098	+ 32.4
4		25	10.2	+ 68.7	0.05	0.224	- 11.8
					0.10	0.146	+ 9.0
					0.15	0.104	+ 40.5
5	Female	32	16.2	-	0.05	0.289	-
					0.10	0.153	
					0.15	0.085	
4-1/2		28	12.5	+ 28.8	0.05	0.266	- 8.0
					0.10	0.159	+ 3.9
					0.15	0.103	+ 21.2
4		25	10.3	+ 54.2	0.05	0.245	- 15.2
					0.10	0.155	+ 1.3
					0.15	0.108	+ 27.1

Table 4. Theoretically, the effects on the spawning biomass if fishing at $F_{0.1}$ with a codend mesh size of 4-, 4-1/2- and 5-inch mesh.

Years	Survival			Population		
	Mesh size (inch)			Mesh size (inch)		
	4	4-1/2	5	4	4-1/2	5
Males						
				10,000	10,000	10,000
6	0.900	0.901	0.905	9,000	9,010	9,050
7	0.892	0.893	0.905	8,028	8,046	8,190
8	0.875	0.881	0.902	7,025	7,088	7,388
9	0.847	0.863	0.895	5,950	6,117	6,612
10	0.829	0.843	0.887	4,932	5,157	5,865
11	0.808	0.824	0.874	3,985	4,249	5,126
12	0.792	0.806	0.857	3,156	3,425	4,393
13	0.781	0.792	0.839	2,465	2,713	3,686
14	0.773	0.779	0.822	1,906	2,113	3,029
15	0.769	0.769	0.806	1,465	1,625	2,442
16	0.766	0.762	0.789	1,122	1,238	1,927
17	0.765	0.757	0.775	859	937	1,493
18	0.764	0.753	0.764	656	706	1,141
19	0.763	0.750	0.754	501	529	860
20	0.762	0.747	0.745	381	395	641
21	0.762	0.745	0.740	291	295	474
22	0.761	0.744	0.734	221	219	348
23	0.761	0.743	0.730	168	163	254
24	0.761	0.742	0.726	128	121	184
25	0.761	0.741	0.722	97	90	133
26	0.761	0.741	0.731	74	66	97
27	0.761	0.740	0.728	56	49	71
28	0.761	0.739	0.725	43	36	51
29	0.761	0.739	0.713	33	27	37
30	0.761	0.739	0.712	25	20	26
Total (spawning stock 10+)				22,564	24,173	32,278
Females						
				10,000	10,000	10,000
6	0.903	0.905	0.905	9,030	9,050	9,050
7	0.899	0.899	0.905	8,118	8,136	8,190
8	0.890	0.893	0.902	7,225	7,265	7,388
9	0.875	0.882	0.895	6,322	6,408	6,612
10	0.854	0.867	0.889	5,399	5,556	5,878
11	0.834	0.848	0.877	4,503	4,711	5,155
12	0.815	0.830	0.861	3,670	3,910	4,438
13	0.800	0.812	0.844	2,936	3,175	3,746
14	0.789	0.798	0.828	2,316	2,534	3,102
15	0.781	0.785	0.810	1,809	1 989	2,512
16	0.777	0.774	0.792	1,406	1,540	1,990
17	0.774	0.767	0.778	1,088	1,180	1,548
18	0.773	0.762	0.765	841	900	1,184
19	0.772	0.758	0.755	649	682	894
20	0.770	0.755	0.746	500	515	667
21	0.770	0.753	0.739	385	388	493
22	0.770	0.752	0.733	296	292	361
23	0.770	0.750	0.728	228	219	263
24	0.770	0.749	0.724	176	164	190
25	0.770	0.749	0.721	135	123	137
26	0.770	0.749	0.718	104	92	99
27	0.770	0.748	0.716	80	69	71
28	0.770	0.748	0.719	62	51	51
29	0.770	0.748	0.717	48	38	36
30	0.770	0.748	0.712	37	29	26
Total (spawning stock 10+)				26,668	28,157	32,841
Grand total				49,232	52,330	65,119

Table 5. Frequencies for male and female redfish from 1978 USSR commercial sampling and USSR surveys and 1978-79 Canadian research surveys.

Length (cm)	Males				Females			
	USSR		Canadian Research		USSR		Canadian Research	
	Commercial 1978	Research 1978	1978	1979	Commercial 1978	Research 1978	1978	1979
6	-	-	-	-	-	-	-	-
7	-	-	-	2	-	-	-	2
8	-	-	-	2	-	-	-	1
9	-	-	-	-	-	-	-	-
10	-	-	-	1	-	-	-	-
11	-	-	-	1	-	-	-	2
12	-	-	-	-	-	-	-	1
13	-	-	-	-	-	-	-	-
14	-	1	-	-	-	1	-	1
15	-	1	-	1	-	1	-	-
16	-	5	1	2	-	7	1	1
17	1	11	3	3	-	4	2	2
18	2	10	6	2	3	8	5	2
19	6	10	15	3	6	14	10	3
20	12	26	30	4	11	22	22	4
21	13	45	35	8	13	38	29	6
22	11	49	24	19	10	43	20	15
23	4	29	9	29	4	24	7	24
24	1	8	2	33	2	8	2	26
25	2	10	1	16	2	6	1	14
26	3	5	1	5	4	5	1	5
27	4	9	3	1	3	7	1	2
28	4	8	4	6	2	4	1	1
29	18	11	11	13	11	4	3	3
30	33	27	19	30	12	10	6	7
31	38	30	28	39	19	20	12	15
32	62	44	31	55	33	26	19	23
33	52	23	43	60	30	15	19	26
34	73	36	72	69	41	18	19	28
35	76	59	79	61	39	31	21	35
36	57	34	79	44	57	27	29	44
37	37	35	59	24	48	32	35	46
38	20	13	33	10	35	20	34	42
39	12	9	17	4	34	12	30	27
40	4	7	5	1	17	18	22	17
41	1	3	2	-	9	7	13	9
42	1	1	1	-	4	6	9	6
43	-	-	-	-	1	1	4	3
44	-	-	-	-	1	1	3	1
45	1	-	-	-	-	1	1	-
46	-	-	-	-	1	-	-	-
47	-	-	-	-	-	-	-	-