M. Gulf of Maine-Georges Bank Acadian Redfish by **R.K. Mayo and L. Col**

1.0 Background

The most recent stock assessment of Acadian redfish in Subarea 5 was completed in 2001 (Mayo *et al.* 2002), and the results were reviewed at the 33rd Northeast Regional Stock Assessment Workshop in June, 2001 (NEFSC 2001a, 2001b). The assessment was based on several analyses including trends in catch/survey biomass exploitation ratios; a yield and biomass per recruit analysis; an age-structured dynamics model which incorporates information on the age composition of the landings, size and age composition of the population, and trends in relative abundance derived from commercial CPUE and research vessel survey biomass indices; and an age-aggregated biomass dynamics model. Surplus production estimates were derived from the age-structured dynamics model, and information on current biomass and fishing mortality relative to MSY-based reference points were also provided by the biomass dynamics model.

At that time, the NEFSC autumn survey biomass index had increased substantially during the mid-1990s and had remained relatively high through 2000. The rapid increase in abundance and biomass was attributed to recruitment and growth of the 1992 and other early-1990s year classes. The assessment conducted in 2001 provided no basis with which to evaluate the state of the stock relative to the control rule as determined by the Overfishing Definition Review Panel (Anon. 1998).

2.0 The Fishery

During the early development phase of the Gulf of Maine redfish fishery, USA landings increased rapidly to a peak level of about 56,000 mt in 1942 followed by a steep decline through the early 1950s (Table M1; Figure M1). Nominal catches then declined at a more gradual rate to less than 10,000 mt during the 1960s. During the 1970s, USA landings increased again, peaking at 16,000 mt in 1971 and again at 15,000 mt in 1979. During the 1970s, additional catches by Canadian and distant water fleets increased the total redfish catch to a maximum of about 17,000 to 20,000 mt per year from 1970 through 1973; catches of redfish by these fleets declined to negligible levels after 1976. Landings of redfish declined steadily throughout the1980s, remaining below 1,000 mt per year since 1989, and at less than 500 mt per year since 1994. Total redfish landings in 2001 were 360 mt compared to 319 mt in 2000.

3.0 Research Survey Indices

Indices of relative biomass, derived from NEFSC autumn research vessel bottom trawl surveys, although variable, exhibited a steady decline between 1963 and 1982 (Table M2, Figure M2). On average, the biomass index appears to have declined by about 90% over a 20 year period. During this time, only 2 year classes of any significance were produced, 1971 and 1978. Between 1983 and 1993, the biomass index approximately doubled, reflecting the relatively low rate of removals by the fishery and the very slow growth rate of the species. No substantial year classes were detected by research vessel surveys in the inshore survey strata traditionally used to monitor recruitment until autumn 1995 when a substantial number of fish in the 15-19 cm range were noted, suggesting the possibility of above average reproduction in 1990 and/or 1991. This was followed by a very large increase in the index in the offshore strata in the autumn of 1996. The autumn biomass index has fluctuated between 20 and 30 kg per tow since then, a magnitude comparable to the period between 1963 and the mid-1970s.

During the earlier periods, however, redfish were generally first detected in the inshore strata at relatively small sizes (~ 10 cm or less, age 1 or 2), only to appear in the offshore strata after about 5 or six years (Mayo 1993). During the 1990s recruitment event, the year class was not detected until fish were close to 20 cm, or about ages 4 or 5, and the numbers appeared to be present in both inshore and offshore strata. The autumn biomass index increased 4-5 fold between the early 1990s and the mid-1990s, a rate that is inconsistent with the dynamics of this species. The spring index, however, suggests only a very modest change in biomass since the mid-1990s.

4.0 Assessment Results

Since the assessment reviewed at SAW 33 was completed, no additional aging data have become available to allow an assessment update. Landings remained very low in 2001 and the 2001 NEFSC autumn survey biomass index remained similar to that of 2000, indicating no appreciable change in the exploitation rate since 2000. Therefore, the results from the 2001 assessment serve as the basis for the present assessment report.

Exploitation ratios (catch/survey biomass) suggest that fishing mortality has been very low since the mid-1980s compared to previous periods (Table M3; Figure M3). Estimates of fishing mortality derived from the age-structured dynamics model and the age-aggregated biomass model were similar (Mayo *et al.* 2002), both indicating that current fishing mortality is low relative to past decades and less than 5% of F_{MSY}. Spawning stock biomass has increased since the mid-1990s, and was estimated to be 119,600 mt in 2000 (Mayo *et al*. 2002) due, in large part, to strong recruitment from the early 1990s. When measured against the estimates of F_{MSY} and SSB_{MSY} provided in NEFSC (2002), the stock is not overfished, and overfishing is not occurring.

Given the continued extremely low landings of redfish relative to the recent increase in biomass, exploitation is now extremely low compared to the 1960s and 1970s (Table M3; Figure M3). However, in contrast to this earlier period, where a substantial proportion of the stock persisted in the 30-40 cm range (Mayo, 1993), during the 1990s, almost all of the redfish were less than 25 cm, and almost none are greater than 30 cm. This suggests that, given the present demographics of the stock, only a small fraction of the biomass would be considered exploitable.

5.0 Biological Reference Points

Estimates of recruitment obtained from the age-structured biomass dynamics model reviewed at the 33rd SAW were used to imply the probable recruitment that could be produced by a rebuilt stock as described in NEFSC (2002). Recruitment estimates derived by the model from the

1952-1999 yearclasses served as the basis for evaluating trends and patterns in recruitment. The stock-recruitment data suggest an increase in the frequency of larger year classes (> 50 million fish) at higher biomass levels. Therefore, recruitment estimates corresponding to the upper quartile of the SSB range served as the basis for deriving mean and median recruitment estimates. In accordance with the recommendation of the Stock Assessment Review Committee of the 33rd SAW, the estimate of $F_{50\%}$ (0.04) is taken as a proxy for F_{MSY}. This fishing mortality rate produces 4.1073 kg of spawning stock biomass per recruit and 0.1429 kg of yield per recruit. The resulting mean recruitment of 57.63 million fish results in an SSB_{MSY} estimate of 236, 700 mt when multiplied by the SSB per recruit, and an MSY estimate of 8,235 mt when multiplied by the yield per recruit.

Reference points derived from the non parametric approach are:

MSY	8,235mt
B_{MSY}	236,700 mt
F_{MSY}	0.04 = $F_{50\%}$ MSP

It was determined (NEFSC 2002) that the stock could not be rebuilt to B_{MSY} by 2009 even at F=0.0. Therefore, the rebuilding scenario invoked a 20 year plus 1 mean generation time (31 years for Acadian redfish) to achieve rebuilding. This results in an $F_{rebuild}$ = 0.01.

6.0 GARM Panel Comments

A question was raised as to why the catches have not followed the increase in the survey biomass. The current mesh size is too large for the size of the fish which make up the bulk of the biomass. The fishery for redfish from the 1950s to the 1980s used a smaller mesh size for redfish trips (3"). Some fishers claim to be discarding but there do not appear to be any large discarding events in the data. There is no evidence of targeting at present. The market was lost when the stock declined.

The change in mesh size used in the fishery was a concern in the interpretation of exploitation ratios. Ratios of catch to total biomass indices may not be comparable under different mesh regimes because the change in the amount of exploitable biomass would produce different q's. This is probably not a direct concern because exploitation ratios are not the basis for the assessment and the overall conclusion would not change. For species in which larger fish make up the major portion of the catch, this may not be a problem, but it may be for smaller-sized species such as redfish.

There was a question as to whether the year classes from the 1990s may have been inshore of the survey at younger ages. This had not been the case in the past for other large year classes. The Massachusetts survey does occasionally catch small redfish.

Recommendations

- Compute survey biomass indices of exploitable biomass and utilize these for calculating exploitation ratios.

- Perform a more systematic analysis of the data to determine discard rates.

7.0 Sources of Uncertainty

- The sharp increase in the survey biomass index in 1996 is inconsistent with the life history characteristics of this species.

- Given the pelagic diurnal movement and general distribution of redfish, swept area estimates of stock biomass derived from bottom trawl survey data will tend to under-estimate absolute stock size.

8.0 References

Anon. 1998. Evaluation of existing overfishing definitions and recommendations for new overfishing definitions to comply with the Sustainable Fisheries Act. Final Report. Overfishing Definition Review Panel. June 17, 1998.

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Mayo, R.K.. 1993. Historic and Recent Trends in the Population Dynamics of Redfish, *Sebastes* fasciatus, Storer, in the Gulf of Maine-Georges Bank Region. NMFS, Northeast Fisheries Science Center Reference Document 93-03, 24 p.

Mayo, R.K., J. Brodziak, M. Thompson, J.M. Burnett and S.X., Cadrin. 2002. Biological Characteristics, Population Dynamics, and Current Status of Redfish, Sebastes fasciatus Storer, in the Gulf of Maine-Georges Bank Region. NMFS, Northeast Fisheries Science Center Reference Document 02-05, 130 p.

NEFSC 2001a. Report of the 33rd Northeast Regional Stock Assessment Workshop (33rd SAW). Stock Assessment Review Committee (SARC) Consensus Summary of Assessments. NMFS, Northeast Fisheries Science Center Reference Document 01-18, 281 p.

NEFSC 2001b. Report of the 33rd Northeast Regional Stock Assessment Workshop (33rd SAW). The Plenary. NMFS, Northeast Fisheries Science Center Reference Document 01-19.

NEFSC 2002. Working Group on Re-Evaluation of Biological Reference Points for New England Groundfish, . NMFS/NEFSC, Reference Document 02-04, 254p.

Table M1 Nominal redfish catches (metric tons), actual and standardized catch per unit effort, and calculated standardized USA and total effort for the Gulf of Maine-Georges Bank redfish fishery.

	Nominal Catch (Metric tons)			USA Catch per Unit Effort (tons/day)		Calculated Standard Effort (days fished)	
Year	USA	Others	Total	Actual	Standard	USA	Total
1934	519		519				
1935	7549		7549				
1936	23162		23162				
1937	14823		14823				
1938	20640		20640				
1939	25406		25406				
1940	26762		26762				
1941	50796		50796				
1942	55892		55892	6.9	6.9	8100	8100
1943	48348		48348	6.7	6.7	7216	7216
1944	50439		50439	5.4	5.4	9341	9341
1945	37912		37912	4.5	4.5	8425	8425
1946	42423		42423	4.7	4.7	9026	9026
1947	40160		40160	4.9	4.9	8196	8196
1948	43631		43631	5.4	5.4	8080	8080
1949	30743		30743	3.3	3.3	9316	9316
1950	34307		34307	4.1	4.1	8368	8368
1951	30077		30077	4.1	4.1	7336	7336
1952	21377		21377	3.5	3.4	6287	6287
1953	16791		16791	3.8	3.6	4664	4664
1954	12988		12988	3.4	3.1	4190	4190
1955	13914		13914	4.5	4.0	3479	3479
1956	14388		14388	4.4	3.8	3786	3786
1957	18490		18490	4.3	3.6	5136	5136
1958	16043	4	16047	4.4	3.6	4456	4458
1959	15521		15521	4.3	3.5	4435	4435
1960	11373	2	11375	3.8	3.0	3791	3792
1961	14040	61	14101	4.6	3.5	4011	4029
1962	12541	1593	14134	5.4	4.0	3135	3534
1963	8871	1175	10046	4.1	3.0	2957	3349
1964	7812	501	8313	4.3	2.9	2694	2867
1965	6986	1071	8057	7.0	4.4	1588	1831
1966	7204	1365	8569	11.7	6.4	1126	1339
1967	10442	422	10864	12.4	5.6	1865	1940
1968	6578	199	6777	14.7	6.1	1078	1111
1969	12041	414	12455	11.4	4.9	2457	2542
1970	15534	1207	16741	9.0	4.0	3884	4185
1971	16267	3767	20034	7.0	3.2	5083	6261
1972	13157	5938	19095	5.7	2.9	4537	6584
1973	11954	5406	17360	5.3	2.9	4122	5986
1974	8677	1794	10471	5.0	2.6	3337	4027
1975	9075	1497	10572	4.0	2.2	4125	4805
1976	10131	565	10696	4.6	2.3	4405	4650
1977	13012	211	13223	4.9	2.5	5205	5289
1978	13991	92	14083	4.8	2.4	5830	5868
1979	14722	33	14755	3.6	1.9	7748	7766
1980	10085	98	10183	3.2	1.6	6303	6364
1981	7896	19	7915	2.7	1.4	5640	5654
1982	6735	168	6903	2.7	1.5	4490	4602
1983	5215	113	5328	2.1	1.2	4346	4440
1984	4722	71	4793	1.9	1.1	4293	4357
1985	4164	118	4282	1.4	0.9	4627	4758
1986	2790	139	2929	1.0	0.6	4650	4882
1987	1859	35	1894	1.1	0.7	2656	2706
1988	1076	101	1177	0.9	0.5	2152	2354
1989	628	9	637	1.1	0.6	1047	1062
1990	588	13	601				
1991	525		525				
1992	849		849				
1993	800		800				
1994*	440		440				
1995*	440		440				
1996*	322		322				
1997*	251		251				
1998*	320		320				
1999*	353		353				
2000*	319		319				
2001*	360		360				

* Preliminary
CPUE and effort not calculated after 1989 due to sharp reduction in directed redfish trips .

Table M2 Autumn NEFSC bottom trawl survey stratified mean catch per tow indices, average weights and average lengths of redfish in the Gulf of Maine - Georges Bank region.

	INSHORE 1				OFFSHORE 2				COMBINED 3	
	Stratified Mean Catch per Tow		Avg. Wgt.	Avg. Length	Stratified Mean Catch per Tow		Avg. Wgt.	Avg. Length	Stratified Mean Catch per Tow	
Year	Number	kg	(kg)	(cm)	Number	(kg)	(kg)	(cm)	Number	kg
1963	86.3	7.6	0.088	17.4	87.5	27.0	0.309	26.4	87.3	24.1
1964	81.3	13.5	0.166	20.2	122.3	61.8	0.505	30.8	116.3	54.6
1965	189.5	22.3	0.118	17.7	33.9	11.5	0.339	25.3	57.0	13.1
1966	172.8	17.0	0.098	16.2	77.8	31.2	0.401	27.4	91.9	29.1
1967	62.9	5.3	0.084	17.7	107.1	27.6	0.258	23.6	100.5	24.3
1968	41.1	4.7	0.114	18.3	161.3	46.6	0.289	25.1	143.4	40.4
1969	105.9	16.0	0.151	20.7	65.2	24.8	0.380	27.4	71.2	23.5
1970	18.2	2.8	0.154	20.3	107.2	38.2	0.356	26.3	94.0	32.9
1971	20.7	4.7	0.227	21.8	52.8	26.7	0.506	29.7	48.0	23.4
1972	36.4	6.6	0.181	20.8	58.9	27.8	0.472	29.2	55.6	24.6
1973	26.2	2.1	0.080	15.6	41.4	19.7	0.476	29.7	39.2	17.0
1974	44.4	4.7	0.106	18.0	49.0	27.6	0.563	30.1	48.3	24.2
1975	45.7	6.0	0.131	19.6	79.9	45.9	0.574	30.6	74.8	39.9
1976	11.6	2.5	0.216	22.6	31.9	17.5	0.549	30.2	28.9	15.3
1977	54.6	12.3	0.225	23.4	37.9	18.1	0.478	28.5	40.4	17.3
1978	20.4	5.5	0.270	24.6	49.5	23.4	0.473	29.0	45.2	20.7
1979	6.2	2.1	0.339	26.5	32.8	18.4	0.561	30.5	28.9	16.0
1980	20.6	6.2	0.301	24.6	20.6	13.8	0.670	31.8	20.6	12.6
1981	6.8	1.9	0.279	24.9	22.7	14.0	0.617	31.8	20.4	12.2
1982	28.2	4.6	0.163	21.2	5.6	3.2	0.571	31.5	9.0	3.4
1983	30.2	8.7	0.288	24.8	6.5	3.3	0.508	29.1	10.0	4.1
1984	7.7	3.2	0.416	27.9	7.8	4.1	0.526	29.0	7.8	3.9
1985	7.2	2.1	0.292	24.8	14.0	6.3	0.450	28.0	13.0	5.7
1986	67.6	15.3	0.226	23.3	18.8	6.7	0.356	26.1	26.1	8.0
1987	26.5	4.8	0.181	21.9	11.5	5.6	0.487	29.2	13.7	5.5
1988	18.5	5.1	0.276	21.9	11.4	6.5	0.570	29.1	12.4	6.3
1989	14.0	2.9	0.207	22.6	21.3	7.5	0.352	25.9	20.3	6.8
1990	57.6	14.5	0.252	23.8	31.7	11.7	0.369	26.7	35.5	12.2
1991	7.2	1.1	0.153	20.4	21.1	9.6	0.455	28.5	19.1	8.4
1992	7.8	1.2	0.147	20.0	24.9	9.3	0.374	27.3	22.4	8.1
1993	53.7	7.4	0.137	20.0	32.5	11.9	0.366	26.3	35.6	11.2
1994	31.5	5.4	0.171	21.7	19.0	6.0	0.317	25.0	20.9	5.9
1995	109.7	11.1	0.102	18.5	19.9	3.5	0.177	21.3	33.2	4.7
1996	53.8	9.1	0.169	21.5	189.9	34.4	0.181	21.9	169.6	30.6
1997	105.6	15.7	0.149	20.3	57.9	19.5	0.337	26.0	65.0	18.9
1998	48.7	10.7	0.219	20.4	128.9	35.4	0.275	23.6	117.0	31.7
1999	164.2	35.1	0.214	23.2	68.2	20.7	0.304	25.6	82.5	22.9
2000	133.3	21.8	0.164	21.6	99.4	26.9	0.271	24.8	104.4	26.2
2001	144.4	28.9	0.200	22.8	80.2	28.0	0.349	27.3	89.8	28.2

1. Strata Set: 26, 27, 39, 40
2. Strata Set: 24, 28-30, 36-38
3. Strata Set: 24, 26-30, 36-40

Table M3. Commercial landings (mt), NEFSC autumn survey biomass index (kg/tow), and index of exploitation for Gulf of Maine redfish.

Year	Commercial landings (mt)	Biomass Index	Exploitation Ratio
1963	10046	24.1	0.4168
1964	8313	54.6	0.1523
1965	8057	13.1	0.6150
1966	8569	29.1	0.2945
1967	10864	24.3	0.4471
1968	6777	40.4	0.1677
1969	12455	23.5	0.5300
1970	16741	32.9	0.5088
1971	20034	23.4	0.8562
1972	19095	24.6	0.7762
1973	17360	17.0	1.0212
1974	10471	24.2	0.4327
1975	10572	39.9	0.2650
1976	10696	15.3	0.6991
1977	13223	17.3	0.7643
1978	14083	20.7	0.6803
1979	14755	16.0	0.9222
1980	10183	12.6	0.8082
1981	7915	12.2	0.6488
1982	6903	3.4	2.0303
1983	5328	4.1	1.2995
1984	4793	3.9	1.2290
1985	4282	5.7	0.7512
1986	2929	8.0	0.3661
1987	1894	5.5	0.3444
1988	1177	6.3	0.1868
1989	637	6.8	0.0937
1990	601	12.2	0.0493
1991	525	8.4	0.0625
1992	849	8.1	0.1049
1993	800	11.2	0.0714
1994	440	5.9	0.0741
1995	440	4.7	0.0946
1996	322	30.6	0.0105
1997	251	18.9	0.0133
1998	320	31.7	0.0101
1999	353	22.9	0.0154
2000	319	26.2	0.0122
2001	360	28.2	0.0128

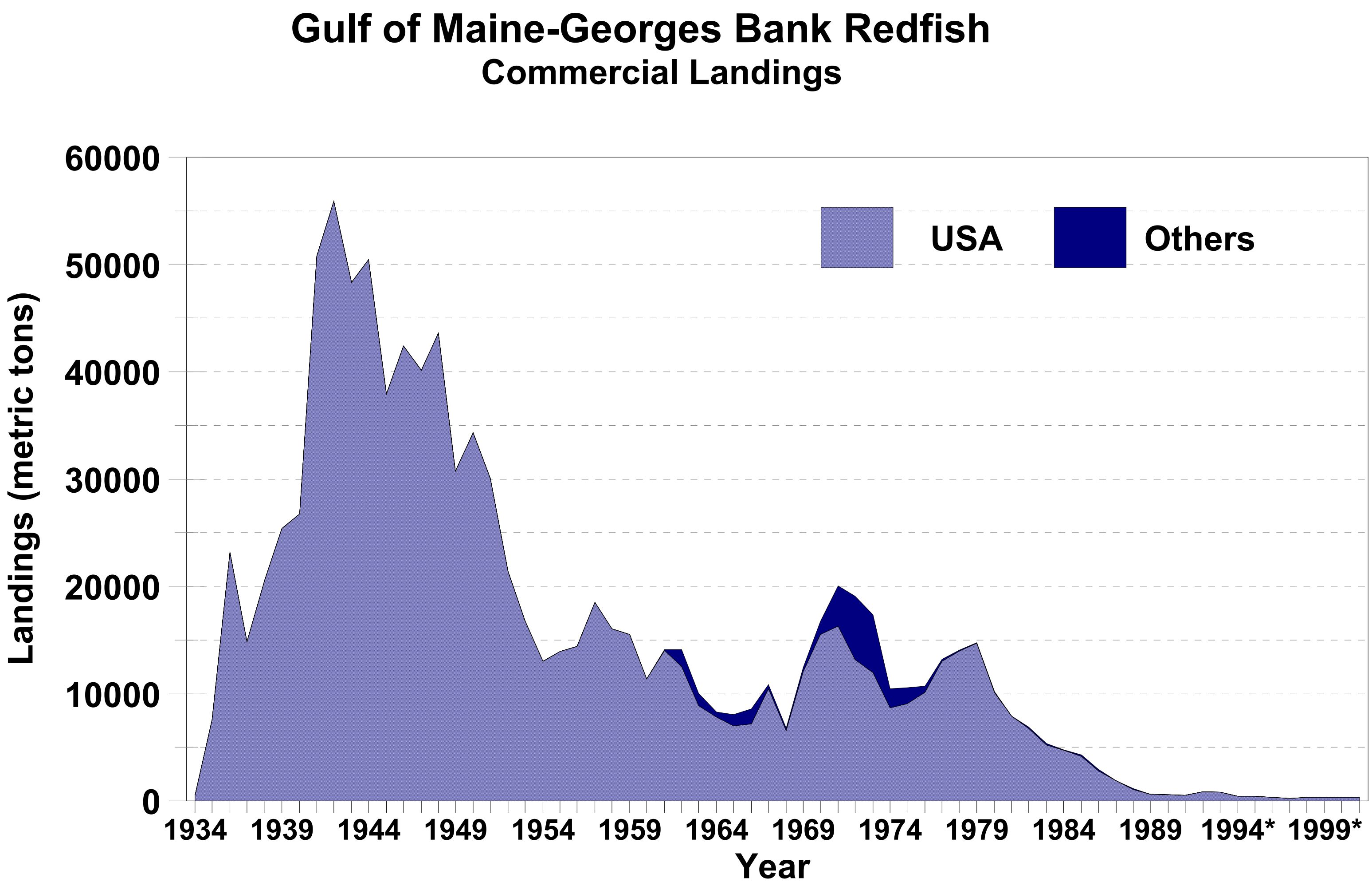

Figure M1. Total commercial landings of Acadian redfish from the Gulf of Maine-Georges Bank region, 1934-2001

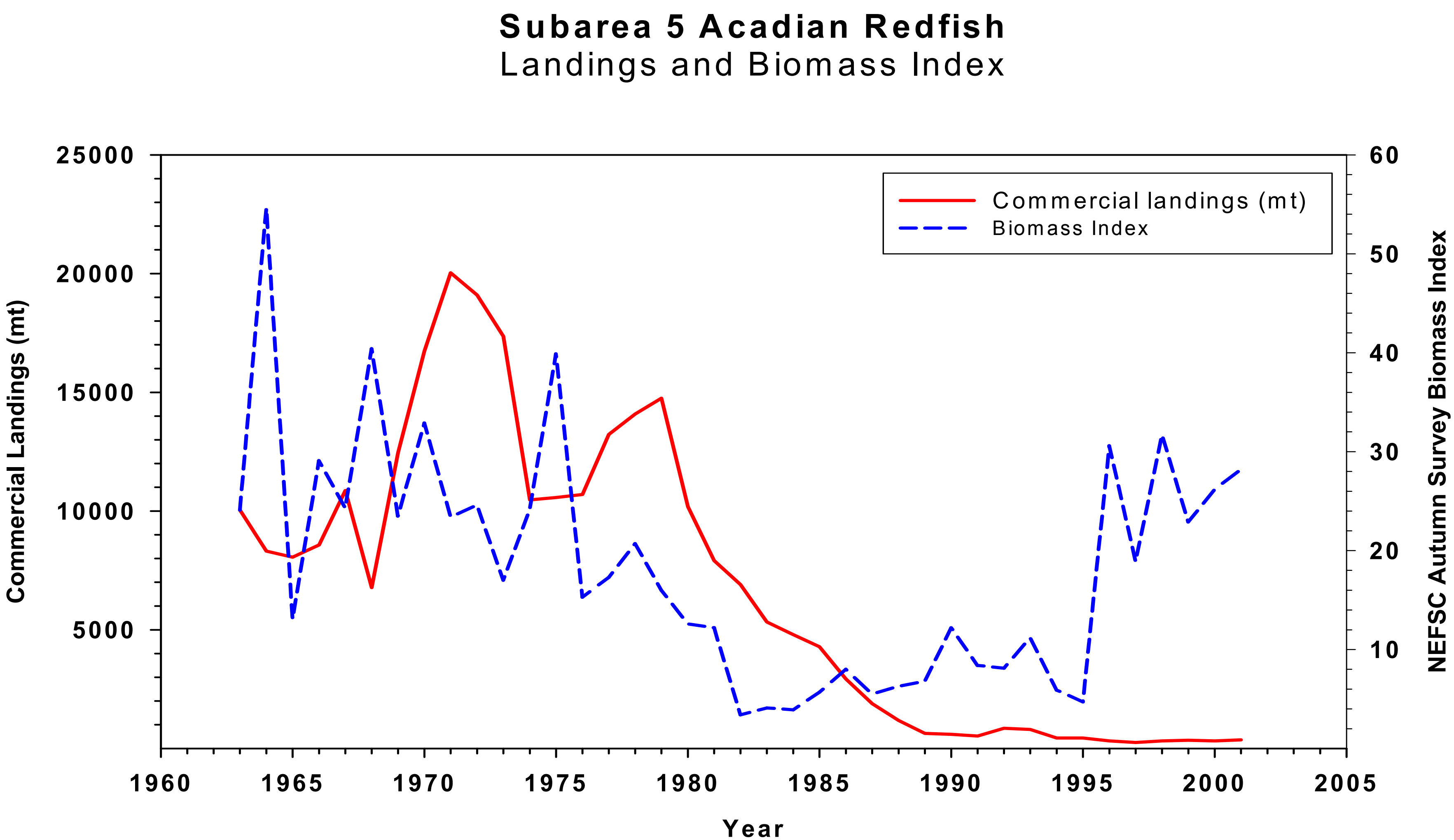

Figure M2. Commercial landings and biomass index derived from NEFSC autumn survey biomass indices for Acadian redfish, 1963-2001.

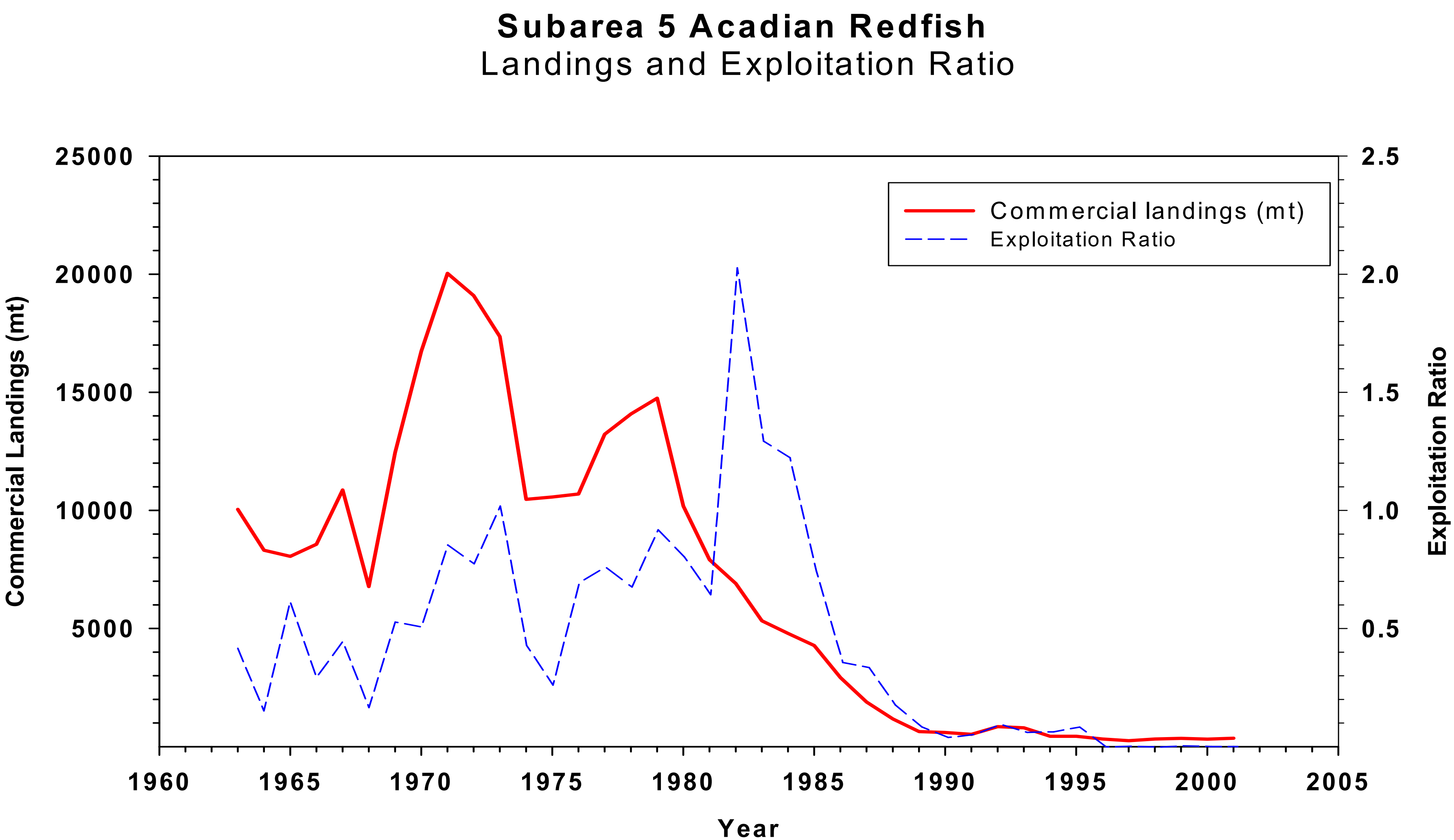

Figure M3. Commercial landings and exploitation ratios derived from NEFSC autumn survey biomass indices for Acadian redfish.