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The Canadian Fishery for Northern Shrimp (*Pandalus borealis*) on Flemish Cap (NAFO Division 3M), 1993 to 1995

by

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INTRODUCTION

Thirteen vessels participated in the Canadian fishery for shrimp in Div. 3M from late April to early August, 1993, taking 3724 tons. The fleet returned to the area in March, 1994, when access to shrimp resources on northern grounds was restricted by ice and/or quotas. Eight vessels fished mostly during the March - June period in 1994 and caught 1041 tons. The 1995 fishery was similar to that of 1994, beginning in March and continuing into early July. To date (August 31), 939 tons have been reported from seven vessels.

Sorting grates were used by all Canadian-licensed vessels in both 1994 and 1995 to reduce the by-catch of other species, notably redfish (Sebastes spp.). Maximum bar spacings were regulated at 28 mm in 1994 and 22 mm in 1995.

Data from the Canadian fishery for 1993, 1994 and 1995 were available from fishing log books, observer reports and biological sampling. Distribution of catch and effort, catch per unit effort (CPUE) and size/age composition of the catches are presented along with information on by-catches and shrimp discards.

MATERIALS AND METHODS

Catch (kilograms) and effort (hours fished) from individual fishing sets, as reported in vessel logs, were compiled by month for all three years. Unstandardized CPUE's (kg/hr) were calculated by month and year and the distribution of effort and catch rate patterns over the grounds were examined by year.

Size composition of shrimp catches sampled by observers before processing were summarized by month and year and a single length frequency distribution representing the total Canadian catch at carapace length (CL) was constructed for each year. Observers sorted the samples by sex (Rasmussen, 1953) and separated females into primiparous, multiparous (McCrary, 1971) and ovigerous groups. Oblique carapace lengths then were measured to the nearest 0.5 mm using Vernier calipers.

Age composition of the catches in 1993 and 1994 was estimated by modal analysis of male length distributions and the primiparous - multiparous separation of females by sternal spines (McCrary, 1971). The 1995 modal analysis for males was a simple grouping of animals less than and greater than 17.75 mm CL whereas components within the primiparous female group were estimated using the MIX program (Macdonald and Pitcher, 1979). Ovigerous females occurred in insignificant numbers during the period fished and sampled in 1993 and 1994 and were not factored into the age analysis. In 1995, however, over 17% of females caught were ovigerous and

these were included in the multiparous group (having been either primiparous or multiparous in the previous year). The age interpretation is based on the findings of Parsons and Veitch (1993).

Data on by-catches were compiled as percentages of the total observed catch and, for redfish, as kg per hour. The data available for 1995 on the size composition of the redfish by-catches were summarized by bar spacings of 22 and 19 mm. Estimates of the proportions of discarded shrimp also were obtained from the observer data.

RESULTS

Catch, effort and CPUE

Logbook records showed that, in 1993, most of the catch and effort occurred in June when an estimated 2100 tons were caught. Significant catch and effort were also reported in May and July but only a few hours were fished at the end of April and beginning of August. In 1994, 82% of the catch and 75% of the effort occurred during May - June with considerably less amounts in March, April and December. In 1995, about 90% of the catch was taken during the April - June period. A substantial amount of effort (631 hours) occurred in March but produced only 97 tons. A summary of catch (tons) and effort (hours fished) by month and year is given below.

Year	Month	March	April	May	June	July	August	Dec.	Total
1993	Tons	-	<1	696	2091	922	14		3724
	Hours	-	5	1082	5494	4441	28		11050
1994	Tons	74	97	575	281			14	1041
	Hours	435	461	2088	937			114	4035
1995	Tons	97	259	259	319	5			939
	Hours	631	1151	648	997	25			3452

Fishing positions recorded in logbooks of Canadian vessels in 1993 indicated a concentration of activity north of 47°N in an arc extending from approximately 46°30'W to 44°W, in close association with the 400 m contour (Fig. 1). High catch rates (> 800 kg/hr) occurred throughout the area fished but were more frequent in the northern and western areas. In 1994, most fishing was reported west of 45°W and substantial effort was located in western and southwestern regions, in contrast to the previous year. High catch rates (> 550 kg/hr) occurred sporadically throughout the western areas but were not encountered in the northeast. The fishery in 1995 was again located mainly west of 45°W. However, effort was widespread, extending into much shallower waters than in the previous two years. Highest catch rates (> 550 kg/hr) occurred throughout the western area and were most frequent in the shallow depths. The extreme western sector and the southwest corner, which were productive in 1994, yielded much lower catch rates in 1995.

Monthly catch rates in 1993 decreased sharply from over 600 kg/hr in May to about 200 in July whereas, in 1994, there was a steady increase from 171 kg/hr in March to 300 in June. In 1995, rates increased from 150 kg/hr in March to 400 in May but then declined to about 200 kg/hr in July. CPUE's for May, June and the year in 1993 were higher than those for the same periods in both 1994 and 1995 but 1995 showed some improvement over 1994.

Year	Month	March	April	May	June	July	August	Dec.	Total
1993	kg/hr		63	644	381	208	506		337
1994	kg/hr	171	209	275	300			126	258
1995	kg/hr	153	225	400	320	211			272

Length distributions

The estimated size compositions of the 1993 Canadian catches in May, June and July showed that large, female shrimp with a modal length of 26.5 mm CL dominated both by number and weight (Fig. 2) in all three months. Three size groups of males also were consistently represented at approximately 17, 21 and 24 mm. The occurrence of modes was similar in the 1994 sampling data with males at roughly 17, 21 and 23 mm and females at 27 mm. Males were much more prevalent in the catches of 1994 compared to 1993, despite low numbers in the size group at 23 mm. In 1995, catches were dominated by males with modal length of approximately 15 mm CL, especially in May and June. A male component also occurred at 20 mm but there was no evidence of a size group at 23 - 24 mm, present in the previous two years. Further, as many as three female size groups were evident at, roughly, 22, 25 and 27 mm CL. The separation of females by sternal spines showed that there were two distinct size groups of primiparous females at 22 and 25 mm whereas modal structure was unclear in the multiparous group.

Age composition

Modal analysis of the composite male length distribution for 1993 readily separated the four size groups which were interpreted to represent ages 1 through 4. The component at 10 mm (age 1), evident only in July, comprised less than 1% of the total sample. Females, which dominated the catch in numbers (63%), were split more or less evenly into primiparous (49%) and multiparous (51%) groups using the sternal spine characteristics and were assigned ages 5 and 6+, respectively.

1993

Age	1	2	3	4	5	6+
Sex	Male	Male	Male	Male	Primi. Fe.	Multi. Fe.
CL(mm)	9.9	17.0	20.7	24.0	25.9	26.9
Per cent	0.44	8.20	17.95	10.39	31.04	31.97

Only three size groups of male shrimp (ages 2, 3 and 4) were evident in samples taken from the catches in 1994. Also, the component at roughly 23 mm (age 4) appeared weak and was partially overlapped by the dominant male group at 20.5 mm (age 3). Females comprised 42% of the catch in numbers and most of those (68%) were multiparous (age 6+).

1994

Age	1	2	3	4	5	6+
Sex	Male	Male	Male	Male	Primi. Fe.	Multi. Fe.
CL(mm)	-	16.6	20.5	22.7	25.4	27.6
Per cent	-	16.17	33.12	8.74	13.49	28.52

The interpretation of age composition for 1995 is confounded by the absence of males at 23 - 24 mm and the appearance of a female component at 22 mm. Inconsistency in age at sex inversion has already been noted for this population (Parsons and Veitch, 1994) and the simple assumption here is that, in 1995, there are two ages within the primiparous female group - the 1990 year class which changed sex between ages 4 in 1994 and 5 in 1995 and the 1991 year class which changed sex between ages 3 and 4 over the same period. The distinct bimodality in the length distribution for primiparous females supports that assumption.

Over 78% of animals caught in 1995 were male and 70% of those belonged to the 1993 year class (age 2). About 12% of the catch in numbers consisted of multiparous females and the remaining 10% was split more or less evenly between primiparous females of ages 4 and 5.

1995

Age	1	2	3	4	5	6+
Sex	Male	Male	Male	Primi. Fe.	Primi. Fe.	Multi. Fe.
CL(mm)	-	15.1	20.3	21.85	24.61	26.9
Per cent	-	54.83	23.61	4.58	4.99	11.98

Using total catch and data on size distribution, it was estimated that approximately 400 million, 130 million and 190 million shrimp were caught by Canadian vessels in 1993, 1994 and 1995, respectively. The results of the age analyses (above) were applied to these estimates, providing a breakdown of catch at age. These were further divided by the hours fished (unstandardized) in each year, producing age-specific catch rates which can be used to make inferences on year-class strength and some preliminary calculations of total mortality (Z) between years.

Year	Age	1	2	3	4	5	6+
1993	$Nx10^{-6}$	1.77	32.94	72.11	41.74	124.69	128.43
1994	$Nx10^{-6}$	-	21.67	44.38	11.71	18.07	38.22
1995	$Nx10^{-6}$	-	105.50	45.43	8.81	9.60	23.05
1993	No./hr.	160	2985	6535	3782	11300	11638
1994	No./hr.	-	5371	10999	2902	4478	9472
1995	No./hr.		30562	13160	2552	2781	6677
1993/94	Z		-3.52	-1.31	0.81	-0.17	0.88
1994/95	Z			-0.90	1.46	0.04	0.74

In this case, Z is calculated for individual cohorts except for 6+ which is 5+ in year i to 6+ in year i+1. For ages 3+ in 1993 to 4+ in 1994, Z = 0.67 and for ages 4+ to 5+, Z = 0.64. Similar calculations for 1994/95 are 0.84 and 0.58.

By-catches

Catch composition data by species, month and year from observer records showed that redfish (Sebastes spp.) occurred most frequently as by-catch. Other commercially valuable species, such as cod and Greenland halibut, were taken only in small quantities. The proportion of redfish in the total catch (weight) of all species in 1993 increased from 9% in May to 13% in June and 44% in July. Data for 1994 indicate 21% redfish in March, 31% in April, 20% in May and 16% in June. In 1995, redfish by-catch was much lower, increasing from less than 1% in March to 4.7% in June.

Catch rates of redfish were estimated at 64, 62 and 186 kg/hr for May, June and July, 1993 and 45, 149, 82 and 59 kg/hr from March through June, 1994. In 1995, CPUE for redfish increased from 0.6 kg/hr in March to 24 kg/hr in June.

Using monthly effort values derived above and assuming the data on redfish catch rates are representative, it is possible that over 1200 tons of redfish were taken as by-catch in the Canadian fishery in 1993, about 300 tons in 1994 and 40 tons in 1995.

Measurements of redfish obtained by observers showed a single mode of small fish at 14 cm in May, 1993 (Parsons and Veitch, 1994). This size group, the 1989 year class (Saborido-Rey, 1995), was clearly evident in June and July but was accompanied by larger/older fish forming modes at 23 cm in June and 19 cm in July. Redfish caught from April to June, 1994, despite the mandatory sorting grate (28 mm bar spacings), were unimodal at 17 - 18 cm and were presumed to belong, primarily, to the 1989 year class. There were very few redfish taken in 1994 which were larger than 21 cm. In 1995, bar spacings were reduced to 22 mm and redfish by-catch was very low compared to the previous two years. Only two measured samples of redfish were

available from the Canadian fishery in 1995 and they show a dominant mode at 17 - 18 cm and another at 12 cm (1992 year class) using 22 mm bar spacings in the sorting grates (Fig. 3). One sample was available from a vessel of another nation which used 19 mm bar spacings. Those data show that the larger sizes (17 - 18 cm) were largely avoided with the mode at 12 cm clearly dominating.

Shrimp discards

Shrimp discards in 1993 were estimated by observers at 1.3% of the total shrimp catch in May, 1.7% in June and 6.3% in July. For 1994, the estimates decreased from 2.4% in March to 2% in June. Despite the decrease in size of shrimp in the catches due to the dominance of the 1993 year class in 1995 (see above), discard levels remained low, ranging from 1.3% in April to 0.6% in July. No length measurements of discarded shrimp are currently available to infer whether discarding is due to size or quality.

DISCUSSION

The data from the Canadian fishery for shrimp on Flemish Cap suggest that the population has undergone significant changes in abundance and/or distribution since the fishery began in 1993. Commercial catch rates in both 1994 and 1995 were substantially lower than those achieved in the virgin fishery but the 1995 rates improved slightly over 1994 values. Associated with the changes in CPUE are major shifts in the distribution of fishing effort - to the west and southwest in 1994 and over shallower depths in 1995. Also, the fishery along the eastern slope has dissipated since 1993 and catch rates in the west and southwest declined between 1994 and 1995.

Samples analyzed for size and age composition show substantial changes over time, as well. In 1993, catches were dominated by females, many of which represented the very abundant 1988 year class. The effects of mortality on this year class were evident in 1994 when CPUE's were lower and the catches contained higher proportions of males. In 1995, the 1988 year class contributed little or nothing to the catches which depended, almost entirely, upon males which were only 2 and 3 years old. Poor catches of larger shrimp in deeper water apparently forced vessels to move into shallower depths where catch rates improved but smaller/younger shrimp were abundant.

The age analysis also revealed early sex reversal for the 1991 year class. In 1993 and 1994, age 4 males were apparent at 23 - 24 mm CL but, in 1995, there was no component of males at this length. Instead, a size group of primiparous females emerged at roughly 22 mm which was not evident in 1993 or 1994. The implications of early sex reversal are not yet clear for this population but substantial variation has already been detected over the relatively short time series.

The preliminary estimates of total mortality (Z) and inferences on year-class strength from the age analysis of the commercial fishery data are confounded by the continuing changes in fishing pattern and variation in age at sex inversion. The changes in the fishery prevent a direct comparison of catch per hour at age, especially for the younger ages. The variable age at sex change likely resulted in underestimates of the 1988 year class in 1993 and the 1990 year class in 1994 and an overestimate of age 6+ in 1995. It is clear, however, that the 1988 year class is history and that the future of the fishery in the short term will depend largely on the strength of the 1993 year class which, even at age 2, made a substantial contribution to the 1995 fishery.

Redfish by-catch was much reduced in 1995. One obvious explanation is the reduction of maximum bar spacings from 28 mm in 1994 to 22 mm in 1995. However, the limited data available suggest that the main reason might be due more to the growth of the 1989 year class between years than the reduction in bar spacings. Data from Canadian vessels which followed the 22 mm regulation in 1995 showed that 17 - 18 cm fish were still being retained in the trawl. These were possibly the smallest fish of the 1989 year class, the majority being large enough in 1995 for exclusion by either 22 or 28 mm grates. A 19 mm grate, however, appeared to be more effective in eliminating fish in the 16 - 20 cm range (see NAFO, 1995).

CONCLUSION

The radical changes observed both in the fishing pattern and catch composition since 1993 suggest that the shrimp resource on Flemish Cap is currently vulnerable to overexploitation. Although it is not possible, at present, to quantify and compare the effects of fishing with natural events, it is clear that the continuation of an intensive fishery directed towards animals as young as

age 2 has serious implications for both growth and recruitment overfishing. The 1993 year class appears to be strong. It was produced by a healthy spawning biomass, dominated by the strong 1988 year class which, itself, was never fished prior to 1993. The current spawning biomass is much weaker and may remain depressed if younger male ages continue to be heavily exploited before they have the opportunity to change sex and spawn at least once as females.

Attempts at minimizing the redfish by-catch by reducing the bar spacings in sorting grates have been partially successful but it appears that spacings as low as 19 mm might be required to eliminated by-catch of ages 5+ redfish. Even if that is achieved, redfish by-catch will continue to be a problem for a few years, whenever a significant year class is produced.

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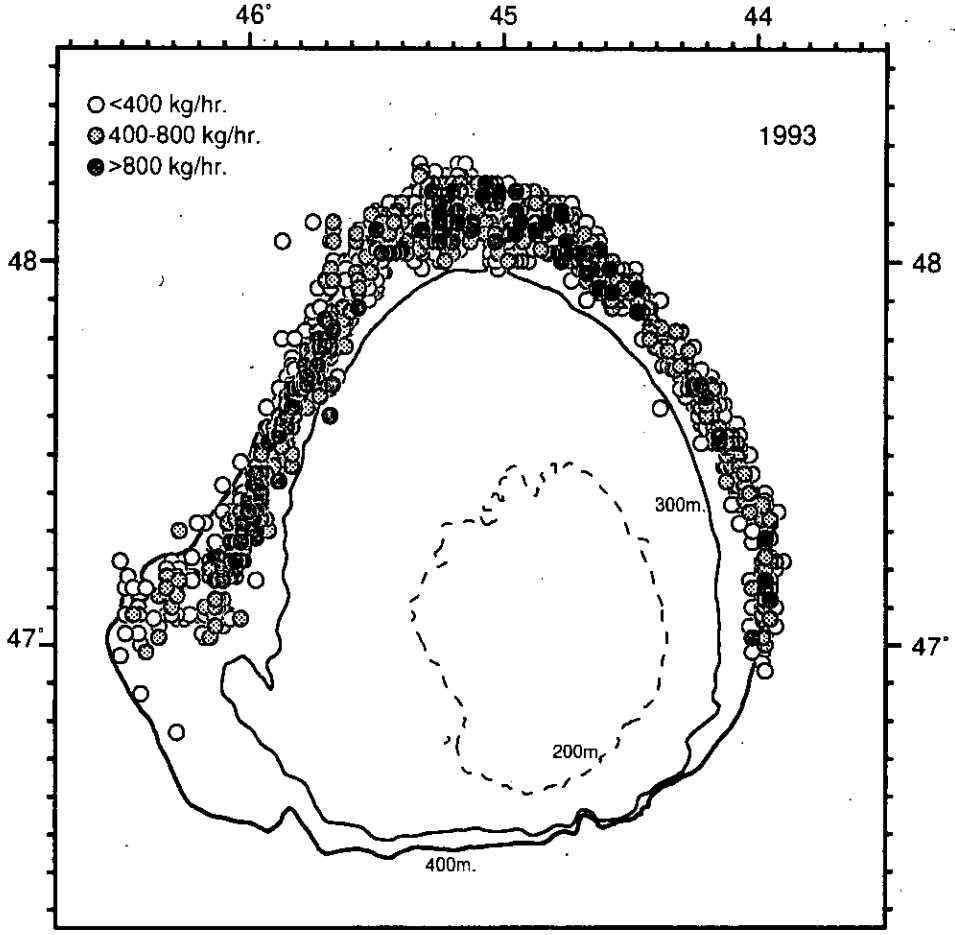
Fig. 1. Northern shrimp fishing locations with CPUE indices in Div. 3M , 1993-1995.



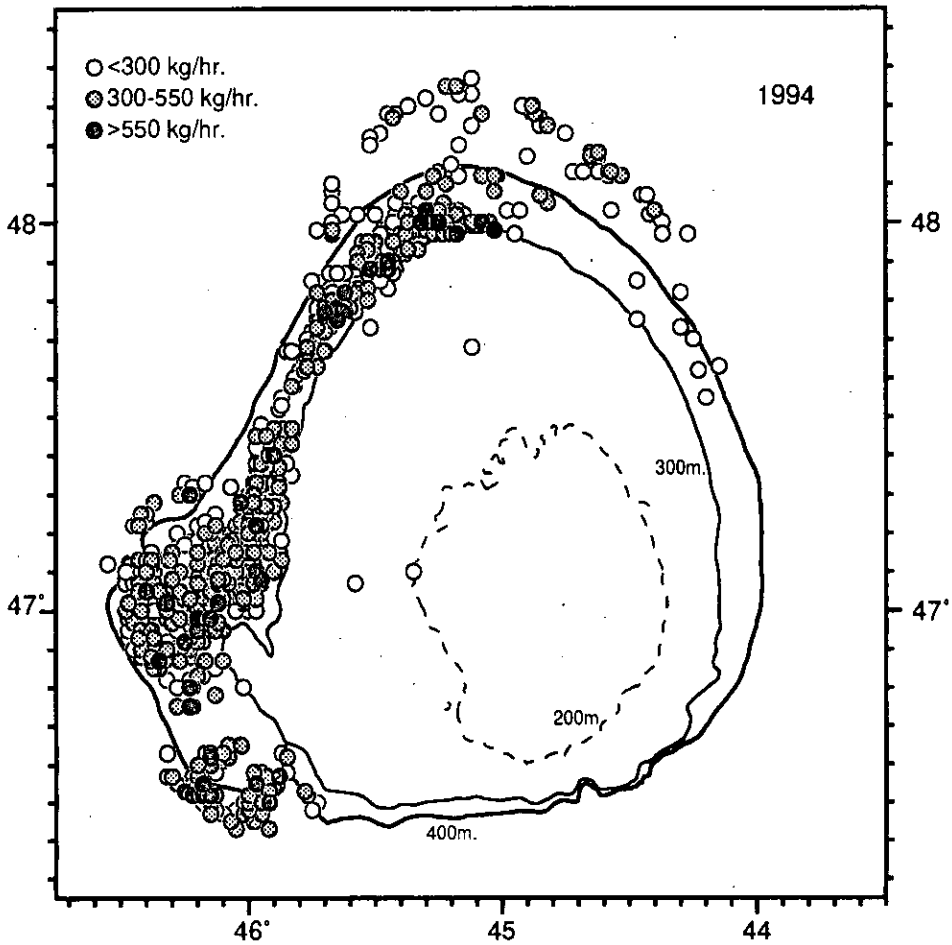


Fig. 1. Continued.

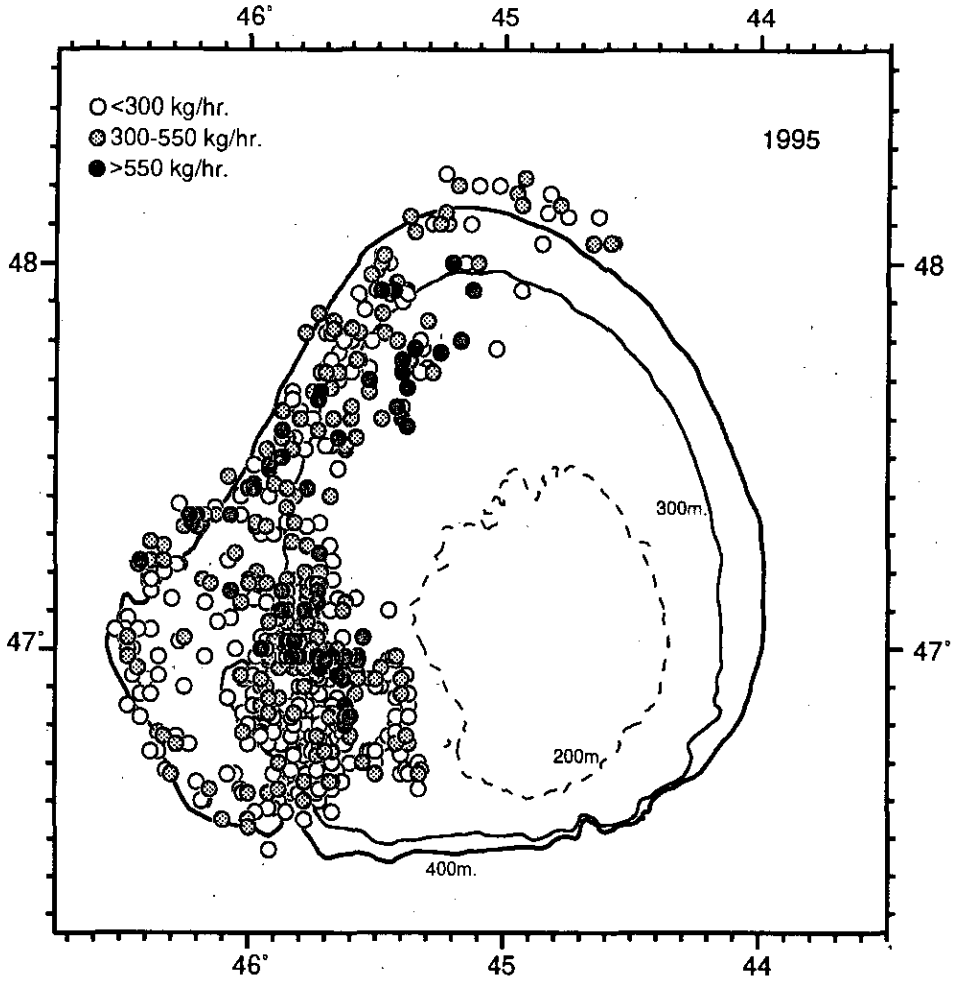


Fig. 2 Catch (numbers caught 000000's) in Div. 3M from 1993-95, (broken line=females).

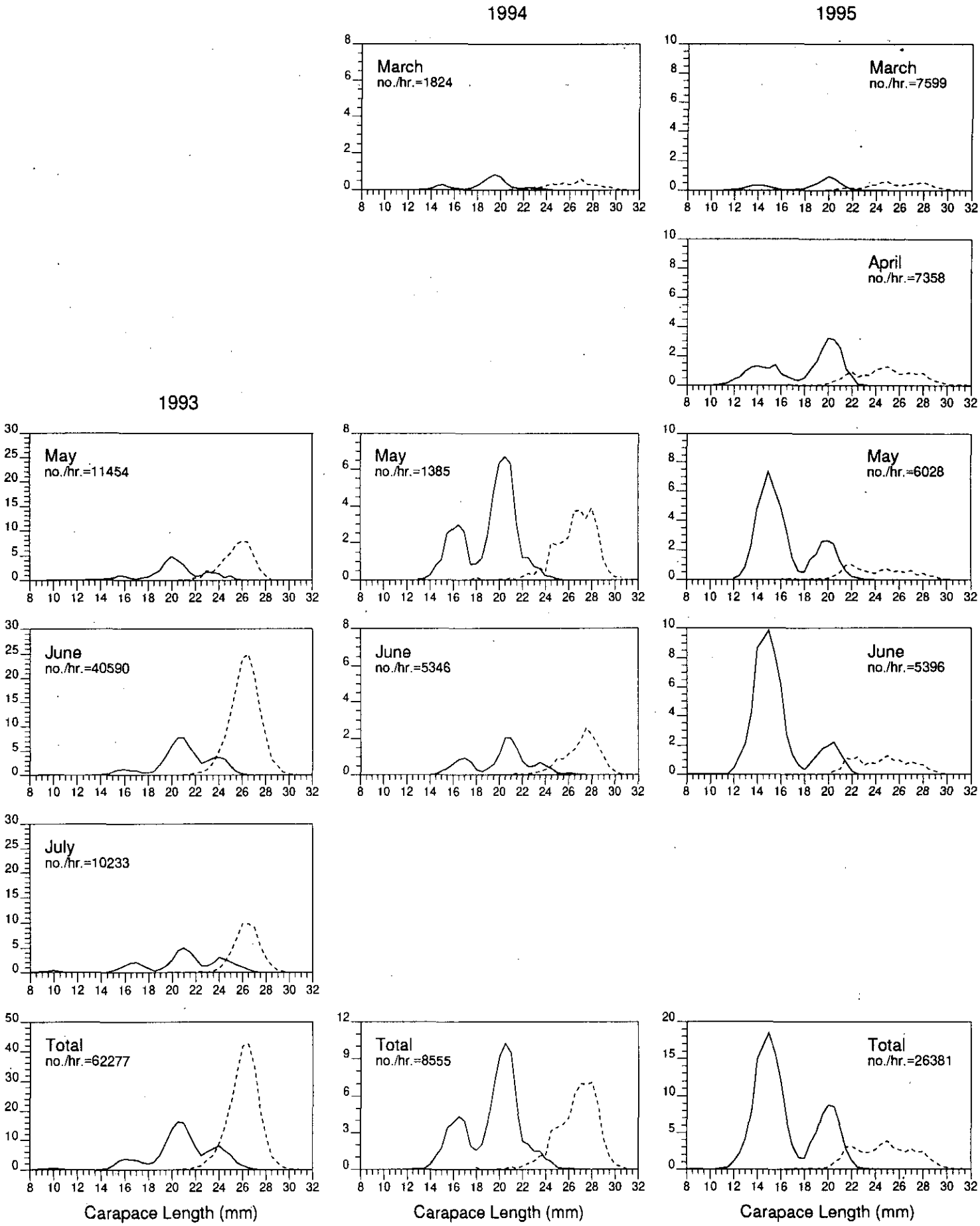


Fig. 3 Redfish length distributions using Nordmore grate spacings of 19 mm. and 22 mm., Div 3M, 1995. (Broken line is spacing=22 mm.)