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The Canadian Fishery for Northern Shrimp (Pandalus borealis) on Flemish Cap (NAFO Division 3M), 1993 to 1997

by

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INTRODUCTION

Only three vessels participated in the Canadian fishery for shrimp in Div. 3M from March to June, 1997, with reported catches to date (August 27) of 793 tons. This compares to 6 vessels and 906 tons in 1996. Data from the fishery since 1993 were obtained each year from fishing log books and from observers' 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) data from individual fishing sets, as reported in vessel logs, were available for all five years. Information for years prior to 1997 is updated from that reported previously (Parsons and Veitch, 1996) and the 1997 data are preliminary for the March to June period. Unstandardized CPUE's (kg/hr) were calculated by month and year and standardized, annual rates were estimated by multiple regression analysis to account for month and vessel effects. Also, the distribution of fishing effort and catch rate patterns over the grounds were examined by month for each year of the fishery.

Size composition of shrimp catches sampled by observers before processing were summarized by month 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 were then measured to the nearest 0.5 mm using Vernier calipers. The data base was updated from that reported in Parsons and Veitch (1996) for the 1993 - 1996 period but only April samples were available for 1997.

Age composition of the catches of male shrimp in 1993 and 1994 was estimated by modal analysis of length distributions using the MIX program (Macdonald and Pitcher, 1979). The 1995 modal analysis for males was a simple grouping of animals less than and greater than 17.75 mm CL and the 1996 analysis was done similarly except that the separation between males occurred at 15.75 mm. The MIX program was again employed for males in 1997. Following the recommendation of the *ad hoc* working group on shrimp in Div. 3M, female ages were treated primarily as a composite group (NAFO SCS Doc. 96/19).

Data on by-catches were compiled as percentages of the total observed catch and estimates of the proportions of discarded shrimp were derived from the observer set and catch data.

RESULTS

Catch and effort

Logbook records showed that, in 1993, most of the catch (56%) and effort (53%) occurred in June. Substantial fishing activity also was 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 fishing in March, April and December. The fishery extended from March to July in 1995, with June accounting for 32% and 27% of the catch and effort, respectively. In 1996, most of the fishery (87% of the catch and effort) occurred in April and May. All logbooks for 1997 are not yet available but April appears to have been the most important month, accounting for 58% and 51% of the catch and effort, respectively. A summary of catch (tons) and effort (hours fished) by month and year, as provided in vessel logs, is given in the table below.

Year	Month	Feb.	March	April	May	June	July	Aug.	Dec.	Sum	Total
1993	Tons			<1	550	1652	729	11		2943	3724
	Hours			4	840	3896	2539	22		7301	9239
1994	Tons		66	86	513	252			13	930	1041
	Hours		383	407	1831	826			97	3544	3967
1995	Tons		73	196	196	295	149		23	931	970
	Hours		466	860	484	1062	968		125	3965	4131
1996	Tons	24	20	420	356	70				891	906
	Hours	137	104	1844	1533	266				3884	3949
1997	Tons		110	332	124	11				577	793
	Hours		326	914	511	50				1801	2475

The "Total" column, above, refers to the estimated total catch for the year (provisional) and to the estimated total effort. The latter was calculated by dividing the total catch by the ratio of catch and effort obtained from the logbook data.

Fishing positions recorded in logbooks of Canadian vessels showed that the fishery in 1993 was initiated on the western edge in April and expanded along the northwestern slope in May (Fig. 1). Fishing records for June and July 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. Catch rates greater than 500 kg/hr occurred throughout the area fished in June but were less frequent along the eastern slope in July.

In 1994, most fishing occurred west of 45° W, especially in May and June when most of the catch was taken. Substantial effort was located in western (May) and southwestern regions (June), in contrast to the previous year. High catch rates (> 500 kg/hr) occurred sporadically throughout the western areas in May and June but were encountered infrequently earlier in the year. Only a small amount of catch and effort was reported for December and catch rates were low throughout the same area fished as in spring.

The fishery in most months of 1995 also was concentrated west of 45° W but effort was more widespread, especially from April to June, extending into much shallower waters than in the previous two years. Highest catch rates (> 500 kg/hr) occurred occasionally throughout the western area in May and June and were most frequent in shallower water. The extreme western sector and the southwest corner, which were productive in May and June of 1994, yielded lower catch rates in 1995. A small amount of fishing was conducted in December but indicated low shrimp densities over a large area.

Fishing resumed at low effort in the southwestern sector in February, 1996, and shifted to the north in March but catch rates were low in both cases. In April, effort increased markedly and was spread over a large area of the Cap in depths greater than 200 m. The area fished by Canadian vessels in April, 1996, was greater than that fished in any other period since the fishery began. Catch rates greater than 500 kg/hr occurred sporadically throughout the area, particularly in shallow water. Fishing activity shifted to the west and deeper water in May and areas of high density (> 500 kg/hr) were scarce. June activity was reported from the northernmost grounds.

In March, 1997, fishing was concentrated west of 45° W in depths between 200 and 300 m. Effort shifted to the northwestern sector in April within a similar depth range.

CPUE

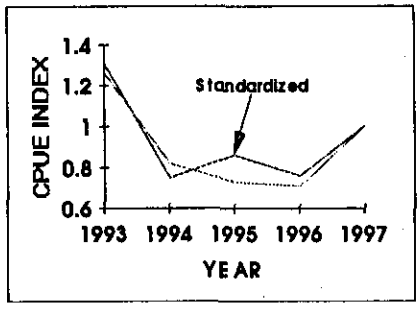
Monthly catch rates in 1993 decreased sharply from over 650 kg/hr in May to about 290 in July,

increasing to 506 kg/hr in August. In 1994, there was a steady increase from 174 kg/hr in March to 305 in June followed by a low rate of 132 kg/hr in December when vessels returned briefly to the area. In 1995, catch rates increased from 156 kg/hr in March to 404 in May but then declined to 154 kg/hr in July. The December rate again was low compared to those of the April - June period. CPUE's in 1996 increased steadily from 178 kg/hr in February to 262 kg/hr in June. Catch rates in March and April, 1997 were higher than those of the same months in previous years while those for May and June, except in one case (May 1996), were lower.

Year	Month	Feb.	Mar.	April	May	June	July	Aug.	Dec.	Total
1993	kg/hr			63	655	424	287	506		403
1994	kg/hr		173	212	280	305			132	263
1995	kg/hr		156	227	404	278	154		181	235
1996	kg/hr	178	196	228	232	262				229
1997	kg/hr		336	363	242	227				320

Annual CPUE estimates showed a large decrease from 1993 to 1994, a further, less dramatic decrease to 1996 and a substantial increase in 1997. However, because the seasonal data show an increasing trend during the first half of the year followed by a decrease during the second half and because different areas were fished each year, a simple comparison of annual rates might not be representative of changes in the stock over time. Therefore, the catch per effort data were investigated for year, month, area and vessel effects using a SAS multiple regression procedure (GLM) to produce a standardized, annual catch rate series. A preliminary run showed that AREA was not a significant class variable and it was excluded from further analyses. The final model, with outliers removed based on the penultimate run (IF -0.75<RESIDUAL<0.75), included records for the March - July period where CATCH > 0 kg and EFFORT > 10 hrs for vessels with a history of at least two years in the fishery. The number of tows associated with each catch/effort record was used as a weighting factor.

About 80% of the variation was explained by the model and all class variables (YEAR VESSEL and MONTH) were highly significant using type III sum of squares (Table 1). Results showed that the positive coefficient for 1993 and the negative values for 1994 and 1996 were significantly different ($P < 0.05$) from zero, the 1997 standard, whereas the negative coefficient for 1995 was not ($P > 0.10$). The standardized series showed a decline between 1993 and 1994, an increase in 1995, a decrease in 1996 and an increase in 1997. Except for 1995, the trend was similar to the unstandardized series.



Length distributions

The estimated size compositions of the 1993 Canadian catches in May and June (Fig. 2) showed that large, female shrimp with a modal length of about 26 mm CL dominated both by number and weight. Three size groups of males were consistently represented with modes at approximately 17, 21 and 24 mm.

Similarly, male modes occurred at roughly 16, 20 and 23 mm in the 1994 sampling data. However, males of the first two size groups were dominant by number in the 1994 catches, in contrast to 1993, and the male component at roughly 23 mm was poorly represented. Further, the female component showed bimodality and separation of primiparous and multiparous animals by sternal spines revealed that the former comprised two modes at 25 and 27 mm and the latter was unimodal at 27 mm.

In 1995, catches in numbers again consisted mainly of males with modal lengths of approximately 15 and 20 mm, the smaller size group dominating in May and June. However, there was no evidence of the size group of males 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. Separation of primiparous and multiparous females showed that there were two distinct size groups of primiparous females at 22 and 25 mm but no component at 27 mm as seen in 1994. The modal structure was unclear within the multiparous group.

Samples for 1996 indicated that catches in all months were composed primarily of male shrimp which formed a single mode between 19-20 mm CL. Other male and female size groups, which were evident in previous years, were notably lacking in the Canadian catches of 1996. Primiparous female size compositions were, again, bimodal at 22 and 25 mm.

For 1997, samples were available only for April. These data showed the dominance of male shrimp between 16 and 20 mm CL (Fig. 3). As in 1996, other size groups of males and females were low in numbers. Primiparous females showed a distinct mode at 23 mm and multiparous at 25 mm. There also was an indication of smaller primiparous females at 18 mm.

Age composition

1993

Modal analysis of the composite male length distribution for 1993 readily separated the four size groups (without constraints) 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. About one-third of the sample was ages 2 and 3 males with twice as many 3's as 2's. Females (ages 5+), which dominated the catch in numbers (55%), were split into primiparous (48%) and multiparous (52%) groups using the sternal spine characteristics.

Age	1	2	3	4	5+
Sex	Male	Male	Male	Male	Female
CL(mm)	10.4	16.8	20.7	24.0	26.0, 26.5
Per cent	0.41	11.48	21.46	11.56	55.09

1994

Only two size groups of male shrimp (ages 2 and 3) were clearly evident in samples taken in 1994, accounting for 55% of the total catch in numbers. The third male component at roughly 23 mm (age 4) appeared weak and was partially obscured by the dominant male group at 20.4 mm (age 3). Females (ages 5+), which comprised 37% of the catch numbers, were 53% primiparous and 47% multiparous. The primiparous group was bimodal at approximately 25 and 27 mm, raising the question of whether or not this group was composed primarily of age 5 animals. The multiparous group was unimodal at 27 mm.

Age	1	2	3	4	5+
Sex	Male	Male	Male	Male	Female
CL(mm)	-	16.4	20.4	22.9	25.7, 26.9
Per cent	-	18.17	36.29	8.54	37.00

1995

The interpretation of age composition for 1995 was confounded by the absence of males at 23 - 24 mm and the appearance of a female component at 22 mm. The assumption here is that, in 1995, there were 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 at 22 and 25 mm supports that assumption. Over 70% of animals caught in 1995 were male and 62% of those belonged to the 1993 year class (age 2). About 15% of the catch in numbers consisted of primiparous females and 13% were multiparous females.

Age	1	2	3	4+
Sex	Male	Male	Male	Female
CL(mm)	-	15.0	20.3	22.2, 25.3, 26.2
Per cent	-	45.16	27.14	27.70

1996

In samples taken in 1996, there was also an absence of males at 23 - 24 mm and an additional component of primiparous females at 22 mm. More than 80% of animals caught were males, 97% of which belonged to the 1993 year class (age 3). About 13% of the catch in numbers were primiparous females and 7% were multiparous females.

Age	1	2	3	4+
Sex	Male	Male	Male	Females
CL(mm)	-	13.8	19.3	21.9, 24.5, 25.6
Per cent	-	2.57	77.72	19.71

1997

In 1997, 73% of animals caught were males, 85% of which belonged to the 1994 year class (age 3). Also, there was a small component of males at 21 mm which were assumed to be age 4. About 15% of the catch in numbers were primiparous females (age 4) and 12% were multiparous females (ages 5+).

Age	1	2	3	4	4+
Sex	Male	Male	Male	Male	Females
CL(mm)	-	13.9	17.8	21.1	22.7, 25.0
Per cent	-	6.07	62.45	4.58	26.9

Using total catch weight and data on size composition, it was estimated that approximately 395 million, 123 million, 176 million, 169 million and 187 million shrimp were caught by Canadian vessels from 1993 to 1997 (to date), 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 detect trends and compare year-class strengths.

Year	Age	1	2	3	4 or 4+	5+	Total (N)
1993	$Nx10^{-6}$	1.62	45.38	84.83	45.69	217.76	395,284,064
1994	$Nx10^{-6}$	-	22.30	44.55	10.48	45.42	122,753,042
1995	$Nx10^{-6}$	-	79.32	47.67	48.65		175,636,541
1996	$Nx10^{-6}$	-	4.28	129.32	32.80		166,392,292
1997	$Nx10^{-6}$	-	11.32	116.47	58.71		186,507,706
1993	No./hr.	175	4911	9180	4944	**23564**	42775
1994	No./hr.	-	5634	11256	2648	11475	31014
1995	No./hr.	-	**22243**	13368	13643		49253
1996	No./hr.	-	**1083**	**32748**	8305		42135
1997	No./hr.	-	4574	**47060**	23722		75357

Catch rates in numbers for ages 4+ declined from 28,500 per hour in 1993 to 8300 in 1996 and increased to 23,700 in 1997 with the inclusion of the strong 1993 year class (age 4). Rates for ages 2+3 increased form 14,000 per hour in 1993 to 35,600 in 1995, decreased slightly in 1996 and increased to a high of 51,600 in 1997 with the recruitment of the 1994 year class (age 3). The results also show the importance of the 1988 year class in 1993, the emergence of the 1993 year class at age 2 in 1995 and the dominance of the 1994 year class in 1997. Both the 1988 and 1993 year class were strong but there is no basis for a comparison of their abundance. The 1988 year class appeared stronger at age 5 than the 1989 and the 1993 stronger than any years class at age 2. However, at age 3, the 1994 year class produced higher catch rates than those of 1990 to 1993, inclusive.

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. In 1993 and 1994, redfish by-catch was problematic but in 1995 conditions improved and, in 1996 and 1997, redfish comprised less than 1% of the total catch of all species.

Shrimp discards

Despite the decrease in size of shrimp in the catches due to the dominance of the 1993 year class in 1995 and 1996 and the 1994 year class in 1997 (see above), discard levels remained low and were estimated at approximately 1% in 1995 and 1996 and 2% in 1997.

DISCUSSION

Commercial catch rates from 1994 to 1997 were substantially lower than those achieved in the virgin fishery. Standardization of the CPUE showed that the 1996 estimate was significantly lower than the 1997 but the 1995 estimate was not. Associated with the changes in CPUE are major shifts in the distribution of fishing effort - to the west and southwest in 1994 and over much shallower depths in 1995, 1996 and 1997. High catch rates (> 500 kg/hr), which were frequent throughout the area fished in 1993, occurred only sporadically in 1996 and 1997.

Samples analyzed for size and age composition showed major changes over time. In 1993, catches were dominated by females, many of which belonged to the abundant 1988 year class. The effects of mortality on this year class were apparent in 1994 when CPUE's were lower and the catches contained higher proportions of males, especially the 1991 year class. From 1995 to 1997, the catches by Canadian vessels depended, to a large extent, upon males - 2 and 3 year olds in 1995 and 3 year olds in 1996 and 1997. The increase in CPUE in 1995 over 1994 was due to the recruitment of the strong 1993 year class at age 2 and the increase in 1997 to the recruitment of the 1994 year class at age 3.

The age analysis also revealed changes in the age at sex reversal over time. In 1993 and 1994, age 4 males were present at 23 - 24 mm CL but, in 1995 and 1996, 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 either 1993 or 1994. Also, in 1994, bimodality was evident in the primiparous female component at 25 and 27 mm CL. In 1997, a small component of age 4 males was evident but most of the animals caught from this year class (1993) were primiparous females. The implications of changes in the length and age at sex reversal are not entirely clear for this population but substantial variation already has been seen over a relatively short time series, confounding the age analysis.

The inferences on trends in the population and year-class strengths from the age analysis of the commercial fishery data are influenced by the continuing changes in fishing pattern and variation in age and length at sex inversion. The changes in the fishery (i.e. females to males, deep to shallow) prevent a direct comparison of catch per hour at age, especially for the younger ages. It is clear that the fishery in 1995 and, particularly, 1996 was supported on the strength of the 1993 year class and the 1997 fishery on the 1994 year class.

Redfish by-catch in the Canadian fishery for shrimp on Flemish Cap has been much reduced since 1995 and, assuming that the use of sorting grates with 22 mm bar spacings will remain in effect, is expected to remain low until another strong redfish year class emerges.

REFERENCES

Macdonald, P.D.M., and T.J. Pitcher. 1979. Age-groups from size-frequency data: A versatile and efficient method of analyzing distribution mixtures. J. Fish. Res. Board Can., 36: 987-1011.

McCrary, J.A. 1971. Sternal spines as a characteristic for differentiating between females of some Pandalidae. J. Fish. Res. Board Can., 28: 98-100.

Parsons, D.G., and P.J. Veitch. 1996. The Canadian fishery for northern shrimp (Pandalus borealis) on Flemish Cap (NAFO Division 3M), 1993 to 1996. NAFO SCR Doc. 96/93, Serial No. N2776: 12p.

Rasmussen, B. 1953. On the geographical variation in growth and sexual development of the deep sea prawn (Pandalus borealis Kr.). Norweg. Fish. and Mar. Invest. Rep., 10(3): 1-160.

TABLE 1. STANDARDIZATION OF CPUE - MULTIPLICATIVE, YEAR-VESSEL-MONTH MODEL FOR CANADA, 1993 - 1997

General Linear Models Procedure
Class Level Information

Class	Levels	Values
YEAR	5	93 94 95 96 97
VESSEL	10	12 29 41 43 44 5 58 67 69 70
MONTH	5	3 4 5 6 7

Number of observations in data set = 143

Dependent Variable: LNCPUE
Weight: WFACTOR

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	17	566.99605265	33.35270898	29.30	0.0001
Error	125	142.29364316	1.13834915		
Corrected Total	142	709.28969581			

R-Square	C.V.	Root MSE	LNCPUE Mean
0.799386	18.76799	1.06693446	5.68486342

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YEAR	4	128.54408464	32.13602116	28.23	0.0001
VESSEL	9	178.91716599	19.87968511	17.46	0.0001
MONTH	4	62.89720681	15.72430170	13.81	0.0001

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		5.002486837 B	26.34	0.0001	0.18989242
YEAR	93	0.267977396 B	2.86	0.0050	0.09369474
	94	-0.281591047 B	-3.29	0.0013	0.08571735
	95	-0.151683585 B	-1.63	0.1053	0.09296872
	96	-0.280725035 B	-3.53	0.0006	0.07957758
	97	0.000000000 B	.	.	.
VESSEL	12	0.193032854 B	1.13	0.2617	0.17119617
	29	0.734177979 B	4.74	0.0001	0.15498558
	41	0.480682842 B	2.99	0.0034	0.16086774
	43	0.190330598 B	1.19	0.2361	0.15988209
	44	0.664964246 B	4.03	0.0001	0.16503927
	5	0.342926702 B	2.10	0.0378	0.16337995
	58	0.446554499 B	2.71	0.0076	0.16461645
	67	0.745915115 B	4.72	0.0001	0.15799571
	69	0.090163063 B	0.53	0.5974	0.17028512
	70	0.000000000 B	.	.	.
MONTH	3	-0.036728187 B	-0.34	0.7357	0.10855699
	4	0.162919351 B	1.93	0.0564	0.08459416
	5	0.374298458 B	5.14	0.0001	0.07287479
	6	0.293525270 B	4.65	0.0001	0.06318361
	7	0.000000000 B	.	.	.

Univariate Procedure

Variable=R

Moments

N	143	Sum Wgts	143
Mean	-0.03186	Sum	-4.55547
Std Dev	0.234942	Variance	0.055198
Skewness	-0.21563	Kurtosis	0.092589
USS	7.983229	CSS	7.838108
CV	-737.505	Std Mean	0.019647
T:Mean=0	-1.62145	Pr>|T|	0.1071
Num ^= 0	143	Num > 0	67
M(Sign)	-4.5	Pr>=|M|	0.5036
Sgn Rank	-634	Pr>=|S|	0.2025
W:Normal	0.987008	Pr<W	0.8380

Quantiles(Def=5)

100% Max	0.649905	99%	0.443137
75% Q3	0.142233	95%	0.288925
50% Med	-0.02623	90%	0.247694
25% Q1	-0.18166	10%	-0.32706
0% Min	-0.67552	5%	-0.44429
		1%	-0.59199
Range	1.325421		
Q3-Q1	0.323895		
Mode	-0.67552		

Extremes

Lowest	Obs	Highest	Obs
-0.67552(	143)	0.381042(	65)
-0.59199(	55)	0.416044(	87)
-0.57775(	92)	0.424533(	130)
-0.54842(	123)	0.443137(	107)
-0.5437(	61)	0.649905(	37)

```
Stem Leaf                     #        Boxplot
   6 5                        1           0
   5                                      |
   4 224                      3           |
   3 348                      3           |
   2 033444555666889          15          |
   1 011112233445666667899999 23          +-----+
   0 122222333344455679999    22          |     |
  -0 99988877665443333321 00  22          *--+--*
  -1 98888666554222211000     20          +-----+
  -2 9987754444332211         16          |
  -3 77643220                 8           |
  -4 6422                     4           |
  -5 98540                    5           |
  -6 8                        1           0
     ----+----+----+----+---
  Multiply Stem.Leaf by 10**-1
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Normal Probability Plot

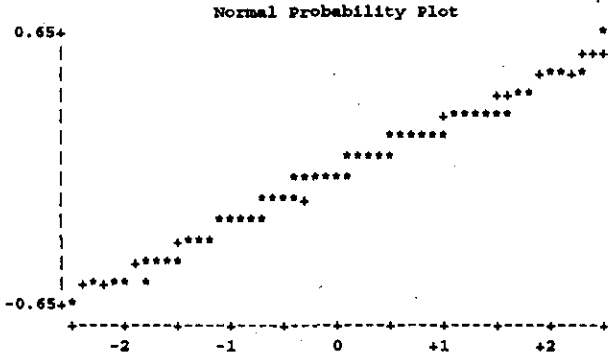


Fig. 1. Distribution of Canadian fishing effort in NAFO Div. 3M, 1993-1997.

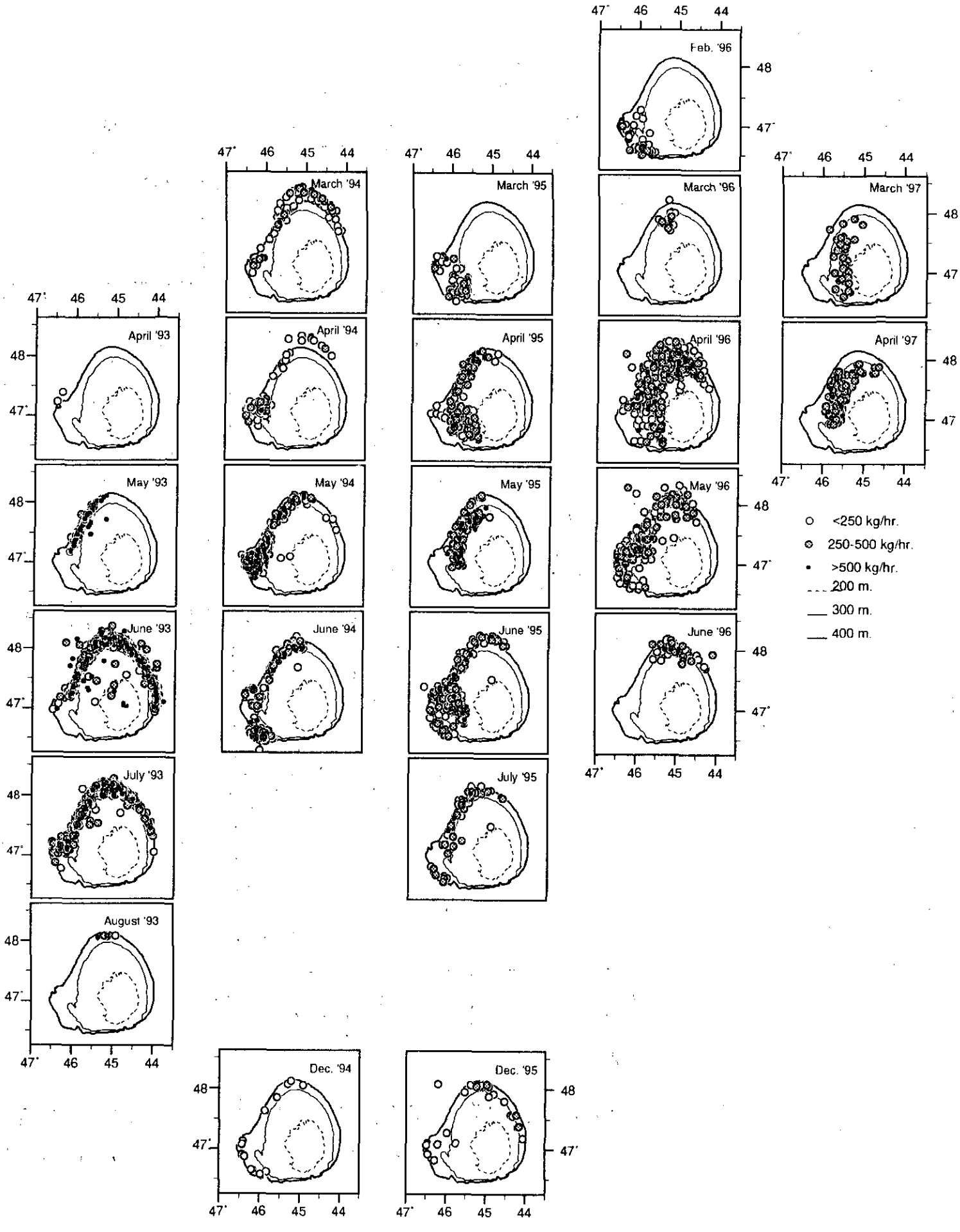
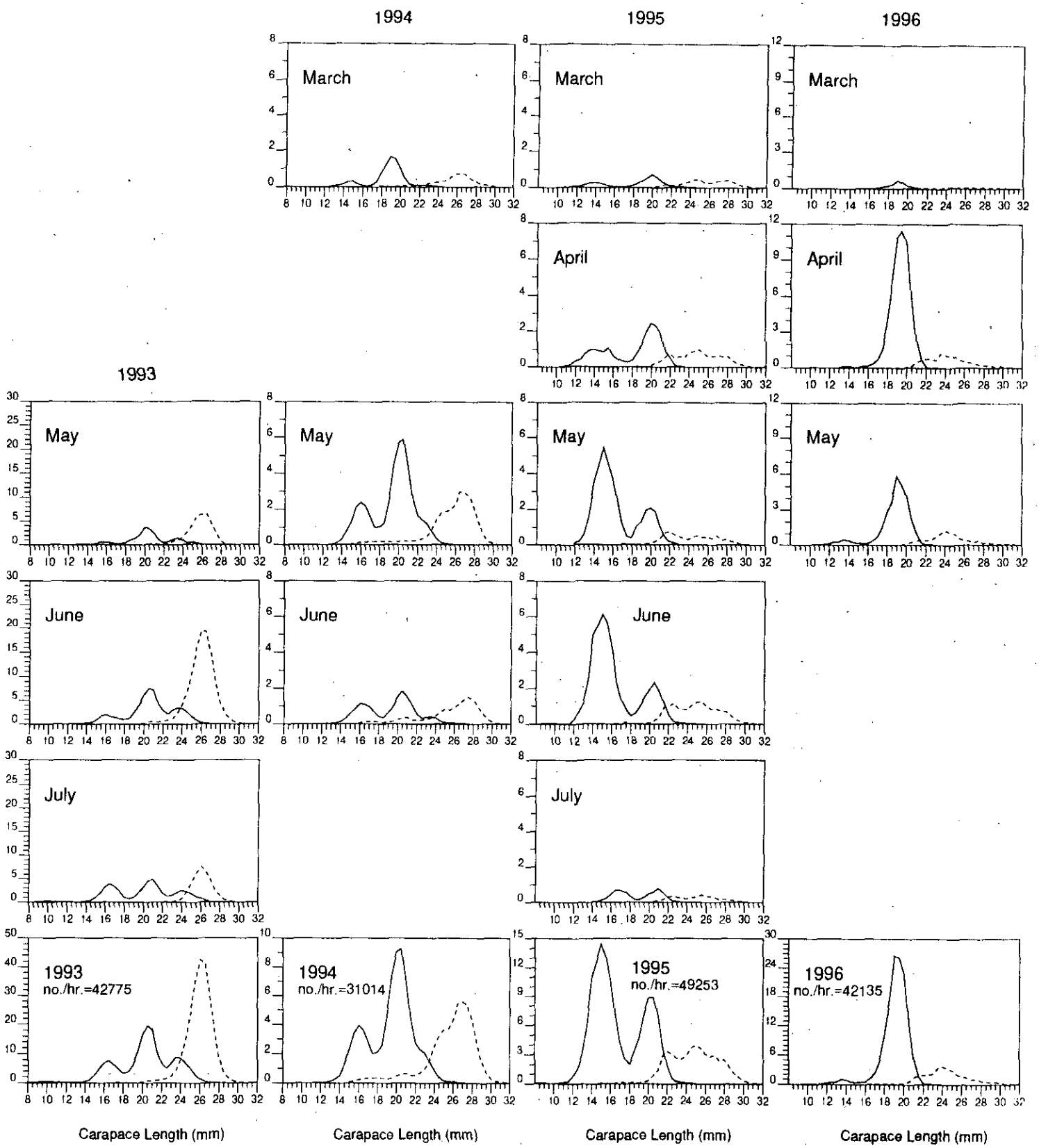


Fig. 2. Catch-at-length (millions) in NAFO Division 3M, 1993-96. Solid line = males, broken line=females.



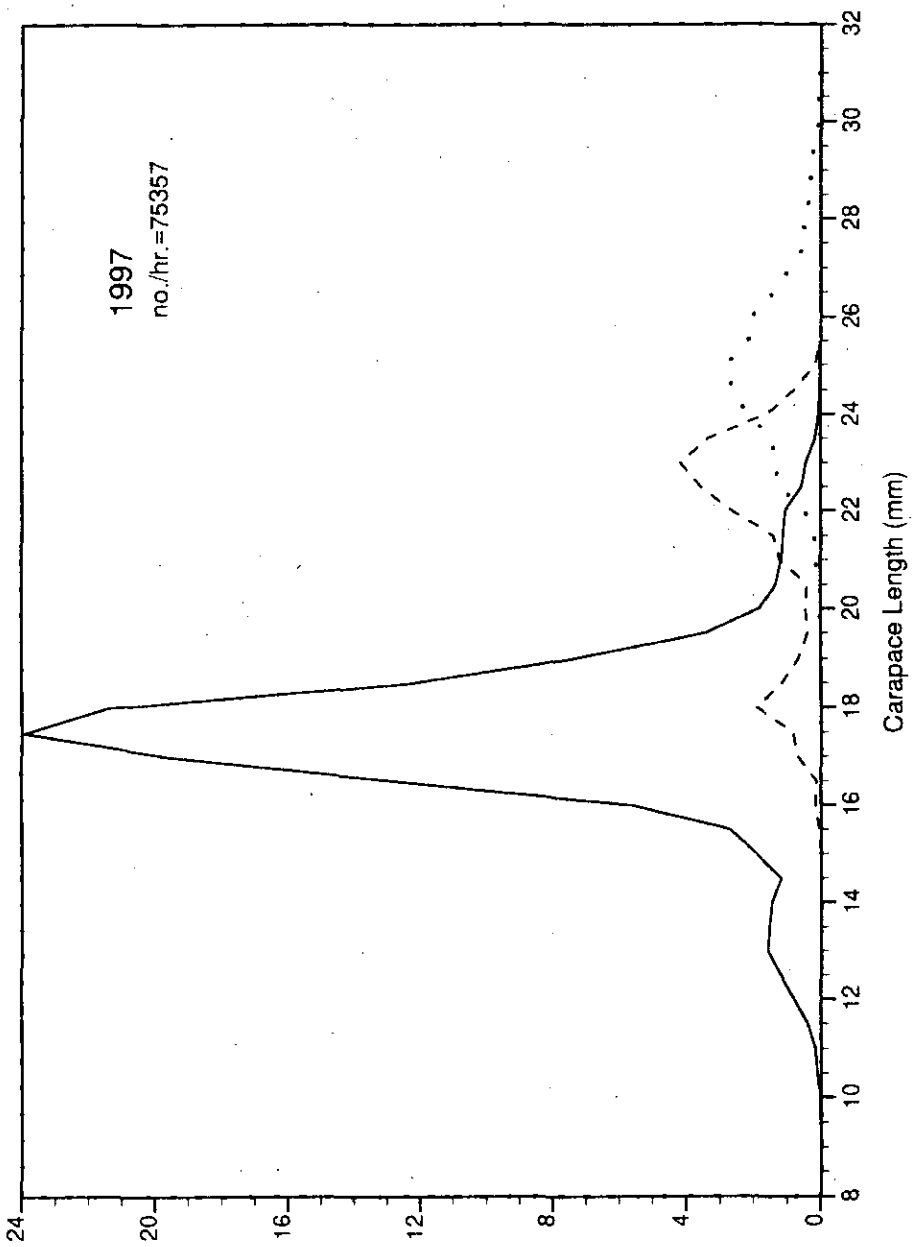


Fig. 3. Catch-at-length (millions) in NAFO Division 3M, 1997. Solid = males, broken = primiparous, dotted = multiparous.