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The Canadian Fishery for Northern Shrimp (Pandalus borealis) on Flemish Cap (NAFO Division 3M), 1993 to 1996

by

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INTRODUCTION

Six vessels participated in the Canadian fishery for shrimp in Div. 3M from February to June, 1996, with reported catches to date (August 31) of 920 tons. This compares to 7 vessels and 970 tons in 1995, 8 vessels and 1041 tons in 1994 and 13 vessels and 3724 tons in 1993. Sorting grates were used by all Canadian-licensed vessels in 1994, 1995 and 1996 to reduce the by-catch of other species, notably redfish (Sebastes spp.). Maximum bar spacings for grates were regulated at 28 mm in 1994 and 22 mm in 1995 and 1996.

Data from the Canadian 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 four years. Information for years prior to 1996 is updated from that reported previously (Parsons and Veitch, 1995) and the 1996 data are preliminary for the February to May 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 extensively from that reported in Parsons and Veitch (1995) for the 1993 - 1995 period and the 1996 samples are preliminary to May.

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). The 1996 analysis was done similarly except that the separation between males occurred at 15.75 mm. Ovigerous females occurred only incidentally in samples taken during the period fished in each of the four years (< 3% by number) and were separated by age using the same ratios as determined by sternal spines for the non-ovigerous females. 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 estimates of the proportions of discarded shrimp were derived from the observer set and catch data.

RESULTS

Catch, effort and CPUE

Logbook records showed that, in 1993, most of the catch (56%) and effort (53%) occurred in June. Substantial fishing activity was 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 fishing in March, April and December. The main fishery extended from March to July in 1995, with 81% of the catch taken and 73% of the effort expended during the April - June period. All logbooks for 1996 are not yet available and there is no information beyond May from that source. April appears to have been the most important month, accounting for 57% of both the catch and effort to date. 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	841	3897	2538	23		7303	9241
1994	Tons		66	86	513	252			13	930	1041
	Hours		382	406	1832	825			97	3542	3958
1995	Tons		73	196	196	301	72		23	860	970
	Hours		466	859	484	958	271		125	3163	3566
1996	Tons	24	20	357	224					625	920
	Hours	134	104	1544	949					2731	4017

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 CPUE derived from the logbook catch and effort.

Fishing positions recorded in logbooks of Canadian vessels in 1993 showed that the fishery was initiated on the western slope 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 47^0 N in an arc extending from approximately $46^0 30'$ W to 44^0 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 45^0 W, especially in May and June when most of the catch was taken. Substantial effort was located in western and southwestern regions, in contrast to the previous year. High catch rates (> 500 kg/hr) occurred sporadically throughout the western areas in May and June but were not encountered in the northeast 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 45^0 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 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 concentrated mainly in the southwest in May but areas of high density (> 500 kg/hr) were scarce.

Monthly catch rates in 1993 decreased sharply from over 650 kg/hr in May to about 290 in July, increasing to 484 kg/hr in August. In 1994, there was a steady increase from 174 kg/hr in March to 305 in June and 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 267 kg/hr in July. The December rate again was low compared to those of the April - July period. CPUE's in 1996 increased from 178 kg/hr in February to about 230 kg/hr in both April and May.

Year	Month	Feb.	Mar.	April	May	June	July	Aug.	Dec.	Total
1993	kg/hr			63	654	424	287	484		403
1994	kg/hr		174	212	280	305			132	263
1995	kg/hr		156	228	404	315	267		181	272
1996	kg/hr	178	196	231	236					229

Annual CPUE estimates showed a large decrease from 1993 to 1994/95 and a further decrease in 1996. However, because the seasonal data suggest an increasing trend during the first half of the year followed by a decrease during the second half, a simple comparison of annual rates might not be representative of changes in the stock over time, given the inconsistency in months fished between years. May was the only month fished intensively each year and, although the general trend for May alone is similar to that seen in the annual estimates, the 1995 catch rate was substantially higher than that of 1994. The catch/effort data also were analyzed for year, month and vessel effects using a SAS multiple regression procedure (GLM) to produce a standardized, annual catch rate series. The results (Table 1) showed a large decrease from 1993 to 1994, some increase between 1994 and 1995 and another decrease between 1995 and 1996. The difference between the 1993 and 1996 estimates was significant ($P = 0.0001$) whereas the 1994 and 1995 rates were not significantly different from the 1996 estimate ($P > 0.15$). The standardization might be improved in future by including area (e.g. north, south, east, west) and/or depth as class variables, given the changes in preferred fishing grounds between months and years.

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. Preliminary data for 1996 indicate 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.

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, which dominated the catch in numbers (55%), were split into primiparous (48%) and multiparous (52%) groups using the sternal spine characteristics and were assigned ages 5 and 6+, respectively.

Age	1	2	3	4	5	6+
Sex	Male	Male	Male	Male	Primi. Fe.	Multi. Fe.
CL(mm)	10.4	16.8	20.7	24.0	26.0	26.5
Per cent	0.41	11.48	21.46	11.56	26.19	28.90

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, 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 (see below). The multiparous group was unimodal at 27 mm (age 6+).

Age	1	2	3	4	5	6+
Sex	Male	Male	Male	Male	Primi. Fe.	Multi. Fe.
CL(mm)	-	16.4	20.4	22.9	25.7	26.9
Per cent	-	18.17	36.29	8.54	19.44	17.56

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 (interpreted as ages 4 and 5) and 13% were multiparous females (age 6+).

Age	1	2	3	4	5	6+
Sex	Male	Male	Male	Primi. Fe.	Primi. Fe.	Multi. Fe.
CL(mm)	-	15.0	20.3	22.2	25.3	26.2
Per cent	-	45.16	27.14	5.07	9.62	13.01

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 (ages 4 and 5) and 7% were multiparous females (age 6+).

Age	1	2	3	4	5	6+
Sex	Male	Male	Male	Primi. Fe.	Primi. Fe.	Multi. Fe.
CL(mm)	-	13.8	19.3	21.9	24.5	25.6
Per cent	-	2.57	77.72	4.58	8.39	6.74

Using total catch weight and data on size composition, it was estimated that approximately 395 million, 123 million, 176 million and 169 million shrimp were caught by Canadian vessels in 1993, 1994, 1995 and 1996 (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	5	6+	Total (N)
1993	$Nx10^{-6}$	1.62	45.38	84.83	45.69	103.52	114.24	395,284,064
1994	$Nx10^{-6}$	-	22.30	44.55	10.48	23.86	21.56	122,753,042
1995	$Nx10^{-6}$	-	79.32	47.67	8.90	16.90	22.85	175,636,541
1996	$Nx10^{-6}$	-	4.34	131.32	7.74	14.18	11.39	168,963,475
1993	No./hr.	175	4911	9180	4944	**11202**	**12362**	42775
1994	No./hr.	-	5634	11256	2648	6028	5447	31014
1995	No./hr.	-	**22243**	13368	2496	4739	6408	49253
1996	No./hr.	-	1080	**32691**	1927	3530	2835	42062

Catch rates for ages 4+ declined from 28,500 animals per hour in 1993 to 8300 in 1996 while those for ages 2+3 increased form 14,000 per hour in 1993 to 35,600 in 1995, decreasing slightly in 1996. The results also show the importance of the 1988 and 1987 year classes in 1993 and the emergence of the 1993 year class at age 2 in 1995. Both the 1988 and 1993 year class appeared to be stronger than those of 1990 and 1991 but there is no basis for comparison of 1988 with 1993. The 1988 year class appeared stronger than the 1989 and the 1993 stronger than 1992.

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 and, in 1996, they comprised 1% or less of the total catch in all months from March to June..

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 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 be the same cohort as seen at 14 cm in 1993. There were very few redfish taken in 1994 which were larger than 21 cm. In 1995 and 1996, bar spacings of 22 mm were enforced and redfish by-catch in both years was very low compared to the previous two years.

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 both 1995 and 1996 (see above), discard levels remained low and were estimated at slightly more than 1% in 1995 and slightly less than 1% in 1996.

DISCUSSION

Commercial catch rates in 1994, 1995 and 1996 were substantially lower than those achieved in the virgin fishery but the 1995 rate showed some improvement over 1994. The unstandardized annual and May estimates for 1996 were the lowest in the short time series and standardized estimate for 1996 was significantly lower than the 1993 value. 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 and 1996. Also, the fishery along the eastern slope has dissipated since 1993. High catch rates (> 500 kg/hr), which were frequent throughout the area fished in 1993, occurred only sporadically in 1996.

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. In 1995 and 1996, the catches depended, almost entirely, upon males - 2 and 3 year olds in 1995 and 3 year olds in 1996. The improvement in CPUE in 1995 was due to the recruitment of the strong 1993 year class at age 2.

The age analysis also revealed indications of a change in the age at sex reversal between 1994 and 1995. 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. This bimodality is difficult to interpret but it is possible that a portion of the strong 1988 year class did not spawn at age 5 in 1993, retaining the sternal spines in the spring and summer of 1994. Nicolajsen (1994) presented data which showed some non-ovigerous females with sternal spines (i.e. primiparous) in late 1993 but the low proportions he noted would not appear to account for the distinct bimodality evident in the 1994 Canadian samples. 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. However, given the market preference and higher prices for large shrimp, it can be concluded that the major decline in CPUE for older animals (ages 4+) is real. It is also clear that the 1988 year class has passed through the population and that the fishery in 1995 and, particularly, 1996 was supported on the strength of the 1993 year class. Given the apparent lack of other year classes, as evidenced in the 1996 Canadian catch data, it is possible that the 1997 fishery also will rely on what remains of the 1993 year class.

Redfish by-catch in the Canadian fishery for shrimp on Flemish Cap was much reduced in 1995 and 1996 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 year class emerges. When this happens, small redfish by-catch will again pose a problem for a few years.

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TABLE 1. STANDARDIZATION OF CPUE - MULTIPLICATIVE, YEAR-MONTH-VESSEL MODEL, 1993 - 1996

General Linear Models Procedure

Dependent Variable: LNCPUE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	14	9.98662796	0.71333057	20.77	0.0001
Error	45	1.54556911	0.03434598		
Corrected Total	59	11.53219707			

R-Square	C.V.	Root MSE	LNCPUE Mean
0.865978	3.292730	0.18532669	5.62835940

Source	DF	Type I SS	Mean Square	F Value	Pr > F
YEAR	3	4.69475390	1.56491797	45.56	0.0001
MONTH	4	2.14197482	0.53549370	15.59	0.0001
VESSEL	7	3.14989924	0.44998561	13.10	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YEAR	3	2.24501411	0.74833804	21.79	0.0001
MONTH	4	1.47407292	0.36851823	10.73	0.0001
VESSEL	7	3.14989924	0.44998561	13.10	0.0001

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		5.391574677 B	40.33	0.0001	0.13367937
YEAR	93	0.497705420 B	5.35	0.0001	0.09304681
	94	-0.074322355 B	-0.91	0.3690	0.08190501
	95	0.123534985 B	1.37	0.1771	0.09009979
	96	0.000000000 B	.	.	.
MONTH	3	-0.176377169 B	-1.55	0.1275	0.11360105
	4	0.013727705 B	0.13	0.8962	0.10465792
	5	0.316302824 B	3.46	0.0012	0.09143829
	6	0.228233800 B	2.80	0.0076	0.08161151
	7	0.000000000 B	.	.	.
VESSEL	29	0.186399995 B	1.56	0.1260	0.11956396
	41	-0.066609130 B	-0.52	0.6043	0.12762121
	43	-0.377368244 B	-3.24	0.0022	0.11636450
	44	0.048492490 B	0.35	0.7315	0.14042096
	58	-0.089210193 B	-0.71	0.4802	0.12531430
	67	0.214361307 B	1.81	0.0765	0.11821898
	68	-0.409138859 B	-3.28	0.0020	0.12487244
	69	0.000000000 B	.	.	.

Univariate Procedure

Variable=R

Moments

N	60	Sum Wgts	60
Mean	0	Sum	0
Std Dev	0.161852	Variance	0.026196
Skewness	0.074756	Kurtosis	-0.40787
USS	1.545569	CSS	1.545569
CV	.	Std Mean	0.020895
T:Mean=0	0	Pr>|T|	1.0000
Num ^= 0	60	Num > 0	30
M(Sign)	0	Pr>=|M|	1.0000
Sgn Rank	-5	Pr>=|S|	0.9710
W:Normal	0.985505	Pr<W	0.8793

Quantiles(Def=5)

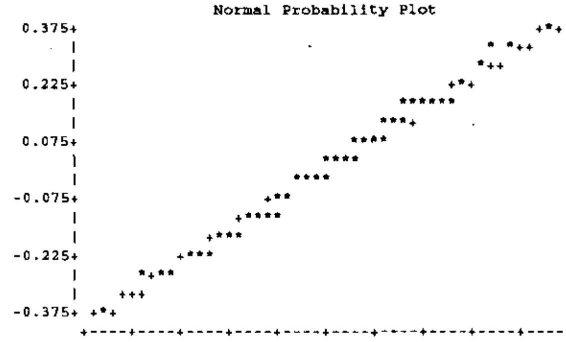
100% Max	0.377355	99%	0.377355
75% Q3	0.117754	95%	0.284469
50% Med	-0.00282	90%	0.193022
25% Q1	-0.12095	10%	-0.21563
0% Min	-0.36033	5%	-0.25614
		1%	-0.36033
Range	0.73769		
Q3-Q1	0.238704		
Mode	-0.36033		

Extremes

Lowest	Obs	Highest	Obs
-0.36033(	58)	0.225277(	1)
-0.28142(	18)	0.266084(	20)
-0.25868(	26)	0.302854(	37)
-0.25361(	57)	0.323345(	49)
-0.24586(	59)	0.377355(	56)

```
   Stem Leaf                     #             Boxplot
      3 8                        1                |
      3 02                       2                |
      2 7                        1                |
      2 3                        1                |
      1 55666799                 8                |
      1 0134                     4             +-----+
      0 55566789                 8             |     |
      0 02234                    5             |  +  |
     -0 4333211                  7             *-----*
     -0 88775                    5             |     |
     -1 2221                     4             +-----+
     -1 8776655                  7                |
     -2 21                       2                |
     -2 8655                     4                |
     -3                                           |
     -3 6                        1                |
        ----+----+----+----+
   Multiply Stem.Leaf by 10**-1
```

Normal Probability Plot



..g. 1. Distribution of Canadian fishing effort in NAFO Div. 3M, 1993-1996.

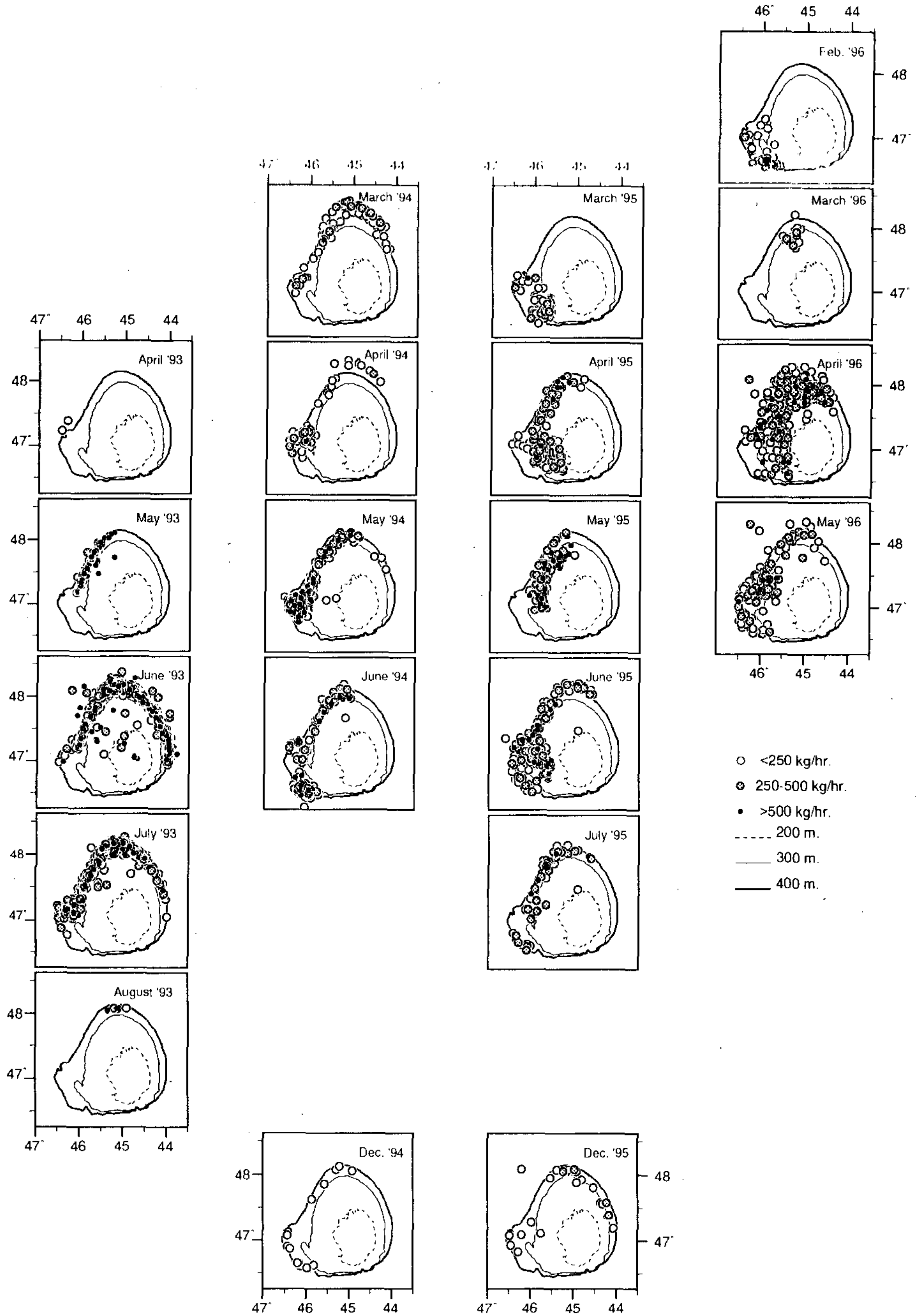


Fig. 2. Catch-at-length (millions) in NAFO Division 3M, 1993-96. Solid line = males, broken line=females.