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The Canadian Fishery for Northern Shrimp (*Pandalus borealis*) on Flemish Cap (NAFO Division 3M), 1993 to 1998

by

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INTRODUCTION

Only two vessels participated in the Canadian fishery for shrimp in Div. 3M from March to June, 1998, with reported catches of 426 tons. This compares to 3 vessels and 807 tons in 1997. Data from the fishery since it began in 1993 were obtained each year from fishing logbooks and from observers' reports and biological sampling. Distribution of catch and effort, catch per unit effort (CPUE) and size 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 recorded in vessel logs for 1993 to 1996 and from observer set-and-catch records for 1997 and 1998, were available for all six years. Information for years prior to 1998 was updated from that reported previously (Parsons and Veitch, 1997) and the 1998 data are preliminary for the March to June period. Unstandardised CPUE's (kg/hr) were calculated by month and year and standardised, annual rates were estimated by multiple regression analysis to account for month and vessel effects. Also, the distribution of fishing effort and catch rate pattern over the grounds were examined by month for each year of the fishery.

Size composition of shrimp catches sampled by observers before processing were summarised 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 database was updated from that reported in Parsons and Veitch (1997) for the 1993-1997 period.

Age compositions of the Canadian catches are included in a standardised analysis which estimates catch at age (numbers and weights) based on sampling data from several nations (Skuladottir, 1998).

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

Records showed that, in 1993, most of the catch and effort (>50%) 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. Most of the fishery occurred in April and May in both 1996 and 1997 with more than 80% of the catch and effort reported for those months. Information for 1998 is incomplete but April and May again appear to have been the most important months, accounting for 72% and 75% of the catch and effort, respectively. A summary of catch (tons) and effort (hours fished) by month and year, as provided in vessel logs and observer records, 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		111	507	176	13				807	807
	Hours		326	1305	672	56				2359	2359
1998	Tons		37	169	139	80				426	426
	Hours		113	495	344	172				1124	1124

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. Observer set-and-catch records for 1997 and 1998 provided the most complete source of fishery information for those years and no effort adjustment was necessary.

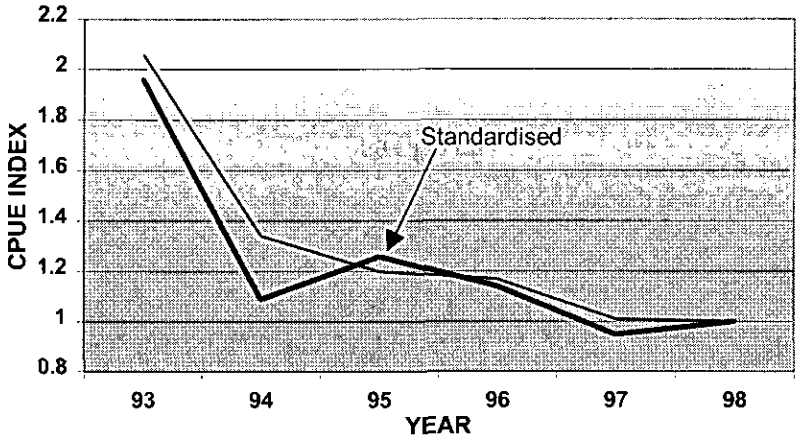
Fishing positions of Canadian vessels showed that the fishery in 1993 was initiated on the western edge in April and expanded along the northwestern slope in May (Fig. 1). Fishing records for June and July indicated a concentration of activity north of 47°N in an arc extending from approximately 46°30' 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 activity was reported for December.

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 occasionally throughout the western area in May and June and were most frequent in shallower water. The extreme western and southwestern slopes, 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 southwest 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 and April 1997, fishing was concentrated west of 45°W in depths between 200 and 300 m. Effort shifted to the west and



deeper water in May and to the north in June. High catch rates were observed only sporadically in March and April.

Another shift in fishing activity was observed in 1998. Effort was concentrated in the north and east, particularly in May when some high catch rates were obtained.

CPUE

Single trawls were used exclusively from 1993 to 1996 but double trawling dominated in 1997 and 1998. Effort was doubled in those instances for the calculation of CPUE but it is recognised that this might underestimate the single trawl catch rate (i.e. actual conversion factor <2).

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 173 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. The catch rate in March 1997 was higher than those for the same month in previous years while the April rate was similar. Values for May and June were the lowest observed for those months. Catch rates in 1998 remained low but increased steadily from 162 kg/hr in March to 240 kg/hr in June.

Year	Month	Feb.	Mar.	April	May	June	July	Aug.	Dec.	Annual
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		341	218	134	112				198
1998	kg/hr		162	172	221	240				196

Annual, unstandardized CPUE estimates showed a large decrease from 1993 to 1994 and a further, less dramatic decrease to 1998. 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 one outlier removed based on the penultimate run (IF -1.00<RESIDUAL<1.00), 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.

The model explained 78% of the variation and all class variables (YEAR VESSEL and MONTH) were highly significant using type III sum of squares (Table 1). Results showed that the positive coefficients for 1993 and 1995 were significantly different ($P < 0.05$) from zero, the 1998 standard, whereas the other YEAR coefficients were not ($P > 0.10$). The standardized series showed a decline between 1993 and 1994, an increase in 1995 followed by another decline.

Except for the lower estimate in 1994, 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 that formed a single mode about 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.

The 1997 data showed the dominance of a male component at approximately 18 mm CL. Other male components were represented in very low numbers near 14 and 22 mm. Primiparous females formed a mode at 23 mm and multiparous at 25 mm. There also was an indication of smaller primiparous females at 18 mm.

The male component at 17-18 mm again dominated the 1998 catches but overlapped with a size group of larger males near 20 mm. Also, smaller males about 12 mm were present, particularly in April. Primiparous females formed a mode at 23 mm and occurred only in small numbers at sizes less than 20 mm. Multiparous females were unimodal at 25 mm.

By-catches

Catch composition data from observer records showed that redfish (*Sebastes* spp.) occurred most frequently as by-catch while 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, from 1996 to 1998, redfish comprised less than 1% of the total catch of all species. In both 1997 and 1998, the estimated by-catch of all species was only about 2%.

Shrimp discards

Despite the dominance of small shrimp in the catches since 1995, discard levels remained low and were estimated at less than 2%, annually, for the 1995–1998 period.

DISCUSSION

Commercial catch rates of Canadian vessels from 1994 to 1998 were substantially lower than those achieved in the first year of the

fishery. Standardisation of the CPUE showed that the low catch rates of 1996 and 1997 were not significantly different from the 1998 estimate. 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 since then. High catch rates (>500 kg/hr), which were frequent throughout the area fished in 1993, occurred only sporadically in recent years.

Samples analysed for size and sex composition showed major changes over time. In 1993, catches were dominated by females with modal length of about 26 mm CL, many of which belonged to the abundant 1988 year-class. The effects of mortality on this group were apparent in 1994 when CPUE's were lower and the catches contained higher proportions of males. From 1995 to 1998, the catches by Canadian vessels depended, to a large extent, upon males (assumed as mostly 2 and 3 year olds in 1995 and 3 year olds in 1996, 1997 and 1998).

Details of estimated age composition of the catches were described in Parsons and Veitch (1997) and Skuladottir (1998). A reduction in the size/age at sex reversal over time have been noted previously (e.g. NAFO, 1998). Apparent changes in mean length at age over time might reflect differences in growth between cohorts but also might result from sampling catches from different areas and depths between years.

By-catch of redfish and other species was low in the Canadian fishery for shrimp on Flemish Cap in 1998. Assuming that the use of sorting grates with 22 mm bar spacings or less will continue in 1999 and that no strong year class of redfish or other species with small individual size emerges, by-catch is expected to remain low.

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TABLE 1. STANDARDISATION OF CPUE - MULTIPLICATIVE, YEAR-VESSEL-MONTH MODEL FOR CANADA, 1993 - 1998

General Linear Models Procedure
Class Level Information

Class	Levels	Values
YEAR	6	93 94 95 96 97 98
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 = 157

Dependent Variable: LNCPUE
Weight: WFACTOR

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	18	660.72341037	36.70685613	27.94	0.0001
Error	138	181.32987088	1.31398457		
Corrected Total	156	842.05328125			

R-Square	C.V.	Root MSE	LNCPUE Mean
0.784657	20.34354	1.14629166	5.63467106

Source	DF	Type I SS	Mean Square	F Value	Pr > F
YEAR	5	329.27971985	65.85594397	50.12	0.0001
VESSEL	9	279.99559660	31.11062184	23.68	0.0001
MONTH	4	51.44809393	12.86202348	9.79	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YEAR	5	142.34950688	28.46990138	21.67	0.0001
VESSEL	9	212.31377705	23.59041967	17.95	0.0001
MONTH	4	51.44809393	12.86202348	9.79	0.0001

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		4.609948889 B	22.51	0.0001	0.20480465
YEAR	93	0.672111499 B	6.26	0.0001	0.10733375
	94	0.092893530 B	0.90	0.3676	0.10276349
	95	0.231717243 B	2.17	0.0318	0.10685656
	96	0.129392585 B	1.29	0.1996	0.10034183
	97	-0.053506355 B	-0.48	0.6291	0.11053007
	98	0.000000000 B	.	.	.
VESSEL	12	0.193096524 B	1.05	0.2948	0.18360921
	29	0.710578032 B	4.32	0.0001	0.16631308
	41	0.482888508 B	2.80	0.0059	0.17254890
	43	0.202456361 B	1.18	0.2399	0.17153784
	44	0.664808122 B	3.76	0.0003	0.17697779
	5	0.262354699 B	1.52	0.1300	0.17225270
	58	0.444543372 B	2.52	0.0129	0.17640957
	67	0.804116742 B	4.75	0.0001	0.16938744
	69	0.139221440 B	0.76	0.4459	0.18212037
	70	0.000000000 B	.	.	.
MONTH	3	0.051807512 B	0.46	0.6431	0.11154359
	4	0.171374718 B	1.95	0.0534	0.08796709
	5	0.358044419 B	4.62	0.0001	0.07752481
	6	0.281187038 B	4.17	0.0001	0.06750320
	7	0.000000000 B	.	.	.

Univariate Procedure

Variable=R

Moments

N	157	Sum Wgts	157
Mean	-0.03147	Sum	-4.94007
Std Dev	0.259294	Variance	0.067233
Skewness	-0.07474	Kurtosis	0.87529
USS	10.64381	CSS	10.48837
CV	-824.059	Std Mean	0.020694
T:Mean=0	-1.52052	Pr>|T|	0.1304
Num ^= 0	157	Num > 0	75
M(Sign)	-3.5	Pr>=|M|	0.6322
Sgn Rank	-748.5	Pr>=|S|	0.1905
W:Normal	0.995152	Pr<W	0.9983

Quantiles(Def=5)

100% Max	0.859568	99%	0.65114
75% Q3	0.126615	95%	0.3753
50% Med	-0.00977	90%	0.279254
25% Q1	-0.21961	10%	-0.34696
0% Min	-0.91709	5%	-0.47592
		1%	-0.60216
Range	1.776658		
Q3-Q1	0.346221		
Mode	-0.91709		

Extremes

Lowest	Obs	Highest	Obs
-0.91709(	63)	0.415689(	89)
-0.60216(	56)	0.445278(	141)
-0.5922(	125)	0.480592(	109)
-0.57977(	94)	0.65114(	38)
-0.54933(	136)	0.859568(	37)

```
Stem Leaf                          #        Boxplot
  8 6                              1           0
  7                                            |
  6 5                              1           0
  5                                            |
  4 288                            3           |
  3 1378889                        7           |
  2 12333456678888                 14          |
  1 011111222233334455667889 9     25      +-----+
  0 00112333444455555667789 9      24      |     |
 -0 99988776666544433321100        23      *--+--*
 -1 9998665542100000               16      |     |
 -2 988776444333332222 10          20      +-----+
 -3 87555333210                    11          |
 -4 885422                         6           |
 -5 9853                           4           |
 -6 0                              1           |
 -7                                            |
 -8                                            |
 -9 2                              1           0
    ----+----+----+----+----+
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Normal Probability Plot

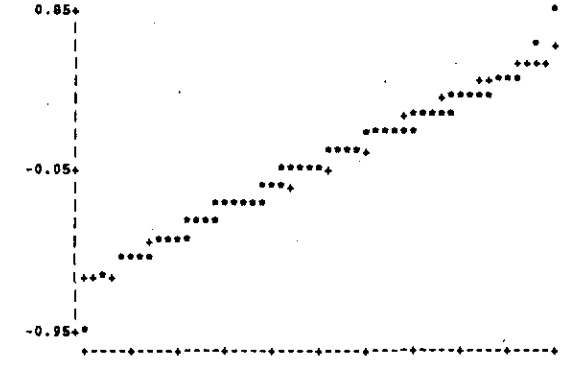

Fig. 1. Distribution of Canadian fishing effort in NAFO Div. 3M, 1993-1998.

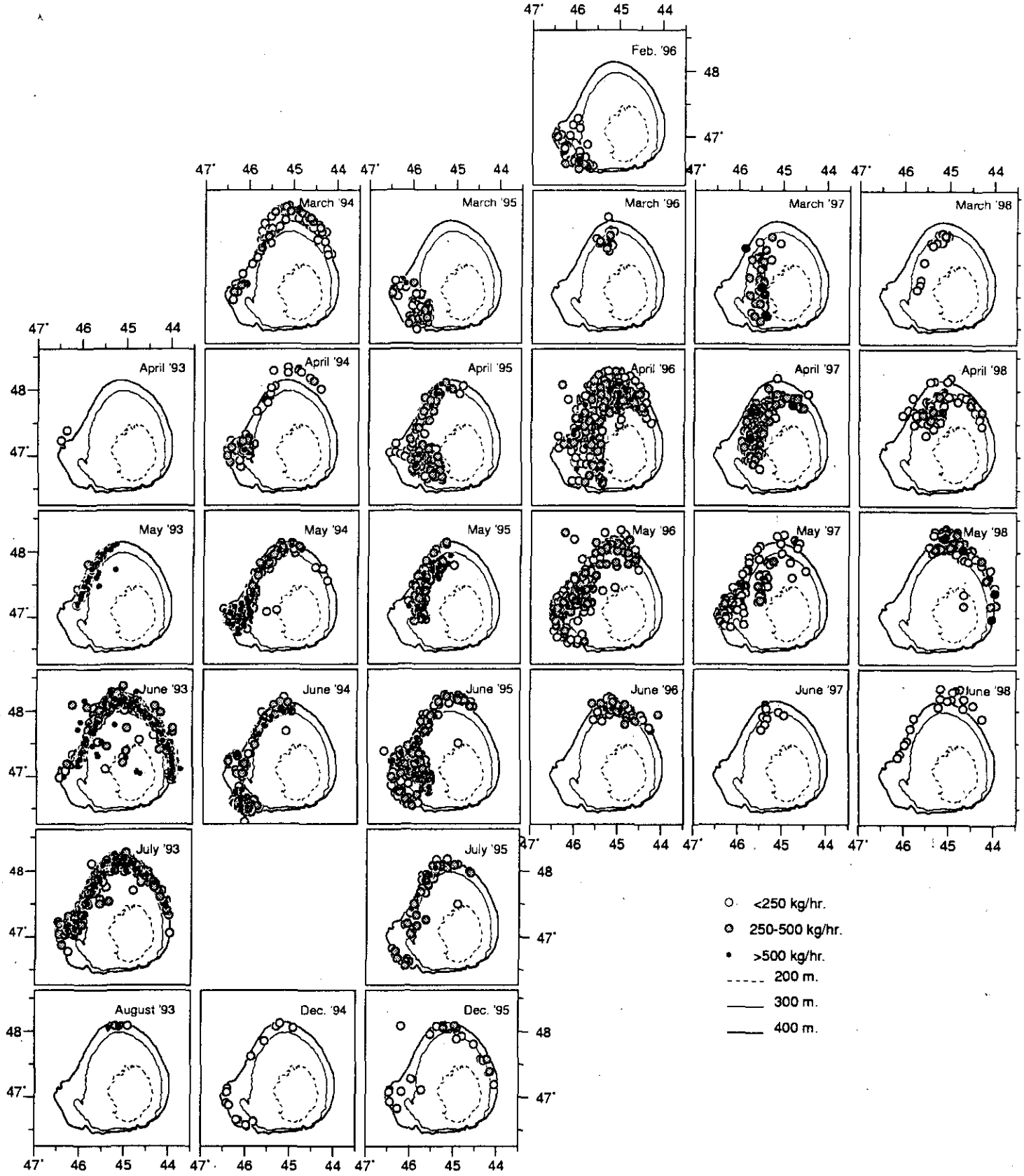

Fig. 2. Catch-at-length (millions) in NAFO Division 3M, 1993-98. Solid line = males, broken line=females.