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The International Fishery for Shrimp (*Pandalus borealis*) in Division 3M (Flemish Cap), 1993-1999

by

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1. INTRODUCTION

The fishery for northern shrimp at Flemish Cap began in the spring of 1993 and has since continued with estimated annual catches (unofficial) of approximately 28,000, 24,000, 33,000, 49,000, 25,000 and 30,000 tons from 1993 to 1998, respectively. Removals to October 1999 of about 32,000 tons are higher than those reported for the same period in 1998 (27,000 tons). Vessels from as many as 15 nations have participated in this fishery since its beginning.

The following is an overview of the international fishery for shrimp on Flemish Cap. Trends in catch and effort from data provided by the fleets of several nations are described. Standardized catch per unit effort (CPUE) series, addressing differences in catch rate due to nation, fishing power of individual vessels, seasonality of the fishery, gear type and area fished, are used as possible indicators of change in the stock over time. Sampling of commercial catches provides CPUE indices separated by age and sex.

Background on the assessment and management of this resource since 1993 can be found in Parsons (1998) and NAFO Scientific Council Reports (1998).

2. COMMERCIAL FISHERY

2.1 History of the Fishery

The shrimp fishery in Div. 3M began in late April 1993. Fishing activity (monitored by Canada) increased to include about 50 vessels from several nations in early July but subsequently declined over the remainder of the year. Only 4 vessels were reported fishing shrimp at the end of December. Fishing continued into 1994 at low intensity. Activity increased over winter to 17 vessels by late February and remained near that level until late March, decreasing thereafter. From early April to mid June, the number of vessels increased from 7 to 47 and then decreased steadily to 3 at the end of the year.

The pattern of increasing activity to about mid-year followed by a decrease to the end of the year continued in subsequent years. Since 1994, maximum vessels observed were 71 in July 1995, 91 in July 1996, 34 in June-July 1997, 33 in June 1998 and 38 in July-August 1999.

A summary of the number of vessels by country and year is given below. The numbers represent best estimates of fleet size but might not be accurate for all nations.

VESSELS

Country/Year	1993	1994	1995	1996	1997	1998	1999
CAN	13	7	7	6	4	4	3
E/DNK	2	2	1	-	-	1	1
EST	-	4	6	5	5	7	8
EU	-	2	2	1	1	6	1
FRA	-	-	-	-	1	-	-
FRO	11	10	9	11	8	7	6
GRL	12	8	5	4	2	2	1
ISL	5	9	21	40	14	7	10
LVA	-	2	3	4	2	2	4
LTU	-	2	4	6	5	6	5
NOR	21	19	26	15	2	2	2
POL	-	-	-	-	1	-	1
POR	-	-	1	-	-	-	2
RUS	2	4	15	17	3	-	2
St. Vin	-	1	-	-	-	-	-
N. Zea	-	-	-	1	-	-	-
TOTAL	**66**	**70**	**100**	**110**	**48**	**48**	**46**

2.2. Trends in Catch

2.2.1. By Nation and Year

Preliminary estimates of catch (tons) by nation and year are provided in the following table.

CATCH (TONS)

Nation	1993	1994	1995	1996	1997	1998	1999*
Canada	3724	1041	970	906	807	484	490
EU/Denmark	800	400	200	-	-	437	-
Estonia	-	1081	2092	1900	3240	5694	7142
Faroe Is.	8545	6567	5987	8677	7387	9179	7456
Greenland	3788	2275	2400	1107	105	865	580
Honduras	1265	-	-	-	-	-	-
Iceland	2243	2300	7623	20681	6483	6572	7147
Latvia	-	300	350	1940	997	1191	2393
Lithuania	-	1225	675	2900	1785	3106	2487
Norway	7183	8461	9533	5683	1831	1339	2002
Poland	-	-	-	-	288	148	707
Portugal	300	-	150	-	170	203	
Russia	-	300	2838	4444	1090	-	652
EU/Spain	240	300	158	50	421	913	517
St. Vincent's	-	75	-	-	150	-	-
Total	**28 088**	**24 325**	**32 976**	**48 288**	**24 754**	**30 131**	**31 573**

* Provisional to October.

In 1993, Faroe Islands and Norway took 56% of the estimated total catch in tons. Canada and Greenland each caught approximately 3700 tons, Iceland about 2200 and Honduras 1265. Lesser amounts were reported for other nations.

Faroese and Norwegian vessels accounted for over 60% of the estimated catch in 1994. Estonia, Latvia and Lithuania joined the fishery that year and, combined, caught about 2600 tons. Canadian vessels caught 1041 tons, substantially less than in 1993. Greenlandic and Danish catches were also less than those of the previous year whereas Icelandic catches remained about the same.

Data for 1995 showed some changes in the distribution of the catches by nation. Most noteworthy are the substantial increases in catches by Iceland and Russia. Catches by Canada, Faroe Islands and Greenland were about the same as in 1994. One vessel from Portugal fished for shrimp in 1995 with an estimated catch of 150 tons.

The 1996 data show substantial increases in catch for several nations. Icelandic catches increased from about 7600 tons in 1995 to 21,000 tons in 1996. Catches by Faroe Islands increased from 6000 tons to 8700 tons and Russian catches from 2800 to 4400 tons. Latvia and Lithuania also increased their catches from 1995 to 1996 while catches by Canada, Greenland and Norway decreased.

Catches in 1997 of about 25,000 tons were much lower than in 1996. The reduction was, in part, due to the Icelandic quota of 6800 tons (in effect, about 14,000 tons less catch than in 1996) and possibly a generally depressed market for northern shrimp which affected all nations.

Catches in 1998 of about 30,000 tons were higher than in 1997. Catches to October, 1999 were approximately 32,000 tons.

2.2.2. By Month and Year

Following a recommendation of an *ad hoc* working group on shrimp in Div. 3M (NAFO SCS Doc. 96/19), a standard catch and effort data set was constructed. The current version includes data from Canada, Greenland, Iceland and Norway. Although these data represent only part of the total catch and effort, they are assumed to reflect temporal and spatial trends in the fishery.

CATCH (TONS)

Month/Year	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
JAN	-	485	28	363	73	-	-
FEB	-	975	130	355	133	65	134
MAR	-	679	387	1220	190	203	770
APR	0	501	814	3007	960	371	1314
MAY	837	1740	2611	3647	1049	985	2218
JUN	6129	3593	4754	4730	1235	1758	918
JUL	4098	2645	5439	3761	1396	2026	1850
AUG	1928	1356	2265	2422	1031	1109	919
SEP	1404	593	940	1566	872	1163	286
OCT	876	317	624	973	692	794	-
NOV	542	21	187	397	286	382	-
DEC	281	64	162	136	146	150	-
TOTAL	**16095**	**12969**	**18342**	**22576**	**8063**	**9007**	**10066**

Monthly catches show an increasing trend from January to June or July, followed by a decrease to the end of the year. The June-July period accounted for more than 48% of the logged catch each year from 1993 to 1995 but, since then, adjacent months in spring and fall also have contributed notable catches.

2.2.3. By Area and Year

The standard, four-country data set included a reference to area fished for each nation except Norway. The Cap was separated into four areas (northeast, southeast, southwest and northwest) at 47^0 10' N and 45^0 W. Logbook data showed that most of the recorded catch was taken in the northwest quadrant (area 4) each year. However, changes are evident between years. Most of the catch was taken in the north (areas 1 and 4) in 1993 compared to the west (areas 3 and 4) in 1994. In 1995, the west was again the most productive area but a substantial catch was also taken in the northeast (area 1). All areas produced significant catches in 1996, including the southeast quadrant (area 2). The northwestern sector remained the preferred area in 1997, 1998 and 1999 although records indicate that substantial catches were taken in the northeast (area 1). Preliminary data for 1999 also show notable catch from the southeast (area 2).

CATCH (TONS)

Area/Year	1993	1994	1995	1996	1997	1998	1999
1	2870	294	1365	3079	1492	2304	1825
2	190	1	61	1221	182	88	688
3	1605	1997	3488	4601	1501	853	1294
4	4246	2216	3896	7992	3057	4447	4384
TOTAL	**8911**	**4508**	**8809**	**16893**	**6232**	**7692**	**8191**

2.3. Trends in Effort

The standard, four-country data set also was used to describe trends in fishing effort, assuming the data are representative of total fleet activities. The observations are hours fished for both single and double trawls. Usage of double trawls by nations included in the data increased over time from <5% of total hours in 1993 and 1994 to >50% from 1997 to 1999. Two-thirds of the 1998 effort reported by these nations was due to double trawls.

2.3.1. By Month and Year

The temporal trend in effort is similar to that for catch. Activity generally increased from January to June-July and then decreased to December. The May to August period accounted for more than 50% of the logged effort each year to 1998 and, the June - July period, more than one-third. Activities of some fleets are reported separately in research documents.

EFFORT (HRS)

Month/Year	1993	1994	1995	1996	1997	1998	1999
JAN	-	1887	149	1504	414	-	-
FEB	-	3067	520	1061	626	156	243
MAR	-	3209	1661	3590	574	533	1880
APR	4	2433	3553	12126	2736	959	3634
MAY	1381	5939	8366	14801	4318	2372	6188
JUN	14419	13622	14878	18446	4801	3729	5729
JUL	12634	10669	17864	16850	4605	4837	4271
AUG	6674	6821	10156	11328	3753	3035	1939
SEP	4875	3578	5469	8122	2962	3899	665
OCT	3640	2243	2808	5901	2262	2351	-
NOV	2242	181	1094	2042	945	1233	-
DEC	865	309	942	651	486	513	-
TOTAL	**46734**	**53958**	**67460**	**96422**	**28482**	**23617**	**24549**

2.3.2. By Area and Year

The effort data were further examined based on the spatial designation described above. In 1993, fishing activity was concentrated in the north (areas 1 and 4), particularly in the northwest (area 4). More effort was deployed in the southwest (area 3) in 1994 while there was a large reduction in activity in the northeast (area 1). Effort increased in all areas in 1995 with renewed interest in the northeast. The 1996 effort was extensive over the entire Cap, including the southeast sector (area 2). Effort was greatly reduced over all areas in 1997 and 1998 with most of the reported activity occurring in the northwest. The records available for 1999 show that the northwest continues to be the main fishing area but, as in 1996, there was notable effort in the southeast (area 2).

EFFORT (HRS)

Area/Year	1993	1994	1995	1996	1997	1998	1999
1	7541	1533	5210	11701	5059	5273	4524
2	521	4	215	4583	542	206	1253
3	3543	7411	11772	21019	5848	2642	3804
4	10473	7931	12618	32084	11108	11787	10710
TOTAL	**22078**	**16879**	**29815**	**69387**	**22557**	**19908**	**20291**

2.4. Trends in Catch Rates

The main purpose for constructing the four-country catch and effort data set was for the calculation of catch per unit of effort (CPUE). The summary of the raw data is for single trawl only, as in previous assessments (Parsons, 1998).

2.4.1. By Month and Year

Seasonality in catch rates is evident in the data presented in the tables below. The fishery began in spring 1993 and catch rates in May were about 600 kg/hr. CPUE declined steadily to November and recovered slightly during the December - February period. During the remainder of 1994, CPUE increased from a low of 180 - 200 kg/hr in March to about 290 in May, declining thereafter to November. In 1995, catch rates again were highest in May at 300 kg/hr, declined to August and then varied between 150 and 200 kg/hr to the end of the year. The pattern in 1996 is different in that catch rates were more stable over the year. CPUE's in the second half of the year were lower than those of earlier months when values were about 200 kg/hr or greater. In 1997, catch rates varied during the first half of the year but stabilized during July to October. Data for 1998 indicate an increase to June, a decline to September and an increase, thereafter. Preliminary records for 1999 show high catch rates in February, compared to previous years, and a decline to May followed by some recovery during the summer.

CATCH PER HOUR (KG) - SINGLE TRAWL

Month/Year	1993	1994	1995	1996	1997	1998	1999
JAN	-	251	189	217	175	-	-
FEB	-	281	250	240	213	-	523
MAR	-	178	233	236	341	-	285
APR	63	206	227	213	272	132	277
MAY	606	293	299	210	185	245	269
JUN	420	259	289	221	201	300	341
JUL	317	239	258	202	254	299	332
AUG	273	185	204	196	241	292	335
SEP	258	166	166	174	259	229	-
OCT	230	141	199	155	242	304	-
NOV	187	116	154	180	296	236	-
DEC	262	206	172	209	-	281	-

The general pattern in the first three years was an increase in CPUE to May followed by a decline to November and some recovery during winter. This convention breaks down, beginning in 1996. The pattern for 1999, with partial data, is not yet clear.

2.4.2. By Area and Year

CPUE (excluding Norwegian data) also can be presented spatially, based on the four general areas described above. Catch rates were similar over all areas in 1993, 1995 and 1996. In 1994, catch rates in the northeast (area 1) were lower than to the west (areas 3 and 4) and there was virtually no fishing in the southeast (area 2). Although effort remained relatively low in the southeast, CPUE's from this area were higher than all other areas in 1997 and to date in 1999. The catch rate in the northeast (area 1) also was higher in 1998 and 1999 than in the previous four years.

CATCH PER HOUR (KG) - SINGLE TRAWL

Area/Year	1993	1994	1995	1996	1997	1998	1999
1	371	167	233	207	252	296	295
2	358	-	243	210	328	319	329
3	386	256	237	189	221	226	279
4	396	238	238	204	223	263	264

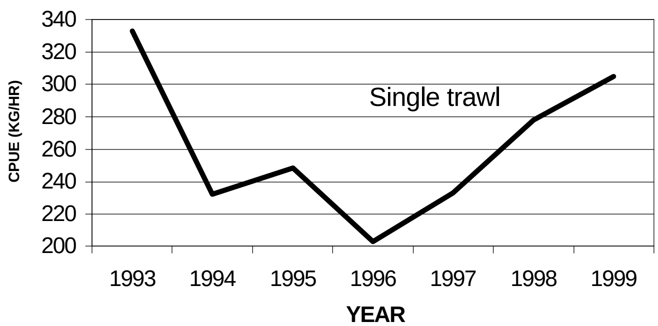
2.4.3. By Nation and Year

Annual catch rates in the following table show variation among nations. CPUE's from all nations declined from 1993 to 1994. Canadian rates continued to decline until 1996 and, except for the single trawl estimate in 1997, have remained low. Greenlandic CPUE from 1995 to 1998 remained below the 1993 estimate but increased notably in 1999. Icelandic rates remained low from 1995 to 1997 but increased in 1998 and 1999. Norwegian CPUE increased from 1996/97 to 1999.

CATCH PER HOUR (KG) - SINGLE TRAWL

Nation/Year	1993	1994	1995	1996	1997	1998	1999
CAN	403	263	235	229	318	223	231
GRL	379	267	294	258	172	215	387
ICE	359	181	232	197	229	270	278
NOR	291	228	253	210	242	335	433

The annual CPUE's (Σ catch ÷ Σ effort) from the standard four country data set for single trawls from all nations were 333, 232, 248, 203, 233, 278 and 305 kg per hour for 1993 to 1999, respectively. The series showed a decrease between 1993 and 1994, some recovery or stability in 1995, a further decrease in 1996 and an increase, thereafter.



2.4.4. Standardized CPUE

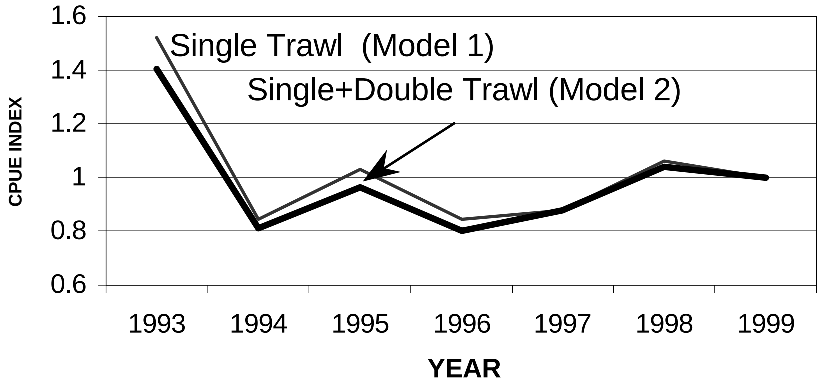
Standardized catch rate series were developed in an attempt to account for effects such as seasonality, fishing power of vessels and/or nations, trawl type and area fished. Two formulations are provided.

<u>Model 1</u>. The single trawl model presented in the previous assessment (Parsons, 1998) was applied using updated information from 1998 and preliminary data for 1999 (to September). The log (ln(catch/effort)) data (Norway omitted) were analysed for year, vessel, month and area effects using a SAS multiple regression procedure (GLM).

The updated model, with 3 outlying observations deleted in the final run (IF -1.5<RESID.<1.5), used records where CATCH > 0 kg and EFFORT > 10 hours. Also, the number of tows associated with each catch-effort record was used as a weighting factor. The model explained 75% of the variation and all class variables except AREA were significant at $P < 0.05$ (Table 1) using type III sum of squares. (For AREA, $P = 0.056$) Results showed that the estimate for all years except 1995 and 1998 were significantly different ($P < 0.05$) from zero, the 1999 standard. A plot of residuals is given in Figure 1.

<u>Model 2</u>. Multiple linear regression was used to standardize single + double trawl (ln(catch/effort)) data after inspection of both gear types showed similar trends. The model accounting for the largest amount of variance in the data (78%; MSE = 1.07) included year, fishing power, month, area (Norway omitted) and gear. As in model 1, only records in which CATCH

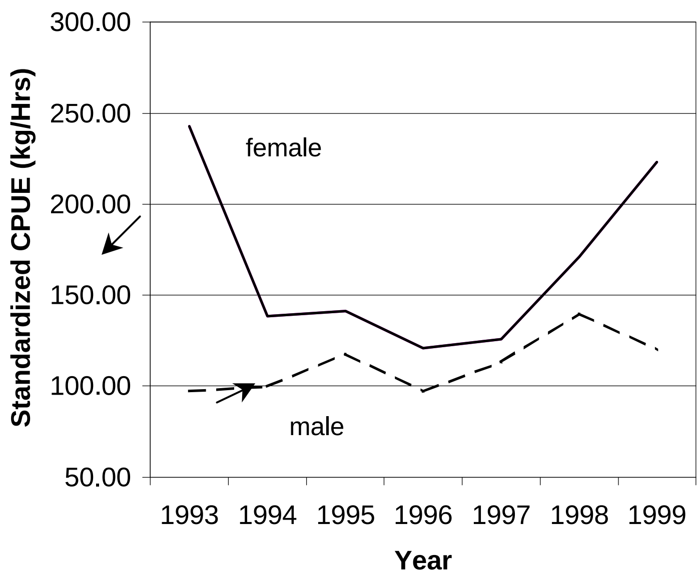
> 0 kg and EFFORT > 10 hours were included, and number of tows associated with each catch-effort record was used as a weighting factor. However, at the November 1999 meeting, it was agreed that residuals would not be used in data deletion. In this model all of the class variables were significant at $P<0.05$ (Table 2) using type III sum of squares. As with model 1, results indicated that estimates for 1995 and 1998 were significantly different ($P <0.05$) from the 1999 standard. A plot of residuals is given in Figure 2.



Although both models follow similar trends, the second model provides CPUE estimates that are usually below standardized single trawl estimates. The differences between the estimates are small, and the proportion of single trawls used in the 3M fishery is decreasing over time, therefore, the multiplicative model using single + double trawl data should be used to track long term changes in CPUE.

2.4.5. Sex Disaggregated CPUE

The following graph presents sex disaggregated catches per unit of effort (kg/hr) for the standardized single + double trawl (model 2) data. Data for sex and age composition were analyzed for January – July, so that data would be comparable throughout all years, and were from the following countries: Canada for the years 1993 – 1995, Iceland for 1996 – 1997, Canada, Greenland and Iceland for 1998 and finally Canada and Iceland for 1999.



For the most part, the same trends as shown in the previous standardized graphs are evident. The ratios of male to female CPUEs were low during 1993 and 1999. However, between 1994 and 1998 the male and female CPUEs were similar. The highest standardized female (243 kg/hr) CPUE was obtained during 1993. The highest standardized male (140 kg/hr) CPUE was obtained during 1998. Between 1994 and 1997 the male and female CPUEs were all relatively low and stable. Since 1997 the female CPUE has been increasing.

2.4.6. Age Disaggregated CPUE

Results of the age analysis of biological samples obtained from Canadian, Icelandic and Greenlandic vessels also were applied to the standardized, international CPUE for both single and double trawls, providing kilograms and number per hour by age and sex.

For preparing the age analysis, oblique carapace length of shrimp in the samples was measured using sliding calipers and grouped in 0.5-mm length-classes. The shrimp were separated into three categories according to the sternal spine criterion (McCrary, 1971): males, primiparous females and multiparous females. Samples were combined by month and adjusted to the monthly catch of shrimp for each nation. (When calculating the CPUE indices for either weight (kg) or numbers per hour, the proportion per age group, male or female was found by applying the modal analysis on the length distributions of males, primiparous and multiparous females respectively.)

First, monthly samples from each country were run through the modal analysis (Macdonald and Pitcher, 1979). From this came mean lengths and proportions at age and sex (3 categories, males, primiparous females and multiparous females). By using the respective weight/length relationships per month (Skúladóttir, 1997), mean lengths were converted to mean weights at age. An international database was formed on a monthly basis using the catch of each country for weighting. As January through July was the main period comparable to the first years, the next step was to calculate weighted mean weights per age and sex-class on one hand and mean proportion on the other for this period. The weighting factor was the total monthly catch of the four countries (Canada, Greenland, Iceland and Norway) which submitted logbook data to the international database for CPUE standardization.

As the Canadian data (Parsons and Veitch 1996) were only available as yearly results for the years 1993-1995 there was need to turn these into numbers and kg per hour per age and sex group for comparison with the years 1996-1999. The length/weight relationships chosen for this purpose were the ones for the month April, from Skúladóttir (1997) namely the two following equations:

For males and primiparous females: $\ln y = 3.037 * \ln x - 7.549$

For multiparous females: $\ln y = 2.778 * \ln x - 6.689$

These equations were applied in the following manner: mean length at age was converted to weight at age only for the years 1993-1995; from the proportions by number the proportions by weight were then calculated.

The results of aging are shown in Table 3 for the period January through July. In this table the results have been weighted together first for all countries combined and then the data of the individual months (the so-called international data) have also been weighted together to get means for the period January-July as described above.

This age assessment must be considered preliminary, as there are more data to be included from the past years that arrived too late for this meeting. Table 3 gives mean weight at age and sex class. The annual standardized CPUE for double and single trawl is shown here divided into sex and age classes. Dividing kg/hr at age by mean weight at age produces estimates of number/hour. Table 4 shows the number per hour at age each year. Number per trawling hour should be proportional to the number in stock if the coverage of samples is sufficient and there is no change in gear technology or catchability.

The 1993 year-class was the strongest in the series at ages 2 and 3. The 1994 year-class dominated ages 4 and 5 and the 1988 year-class was prominent in 1993. In 1995 the no./hr. of the two year olds was very high, i.e. the presumed 1993 year class. This year-class can be followed through to 6 year olds in 1999 when it is still contributed to the commercial catches. On the whole, the four year olds have been quite abundant in the years 1997 through 1999 due first to the 1993 year-class followed by the strong year-classes of 1994 and 1995. At the same time the mean weight of four year old males has dropped from 8.2 g in 1993 to 5.4 g in 1999. But again it must be stressed that there could be a misinterpretation of real age involved here. The coverage of Canadian samples in 1993 to 1995 was reasonable and age assessment had already been carried out, so the proportions of age classes of those years were taken from Parsons and Veitch (1996). The multiparous group was not age assessed by Parsons and Veitch and all the multiparous females were assumed to be of age 6+.

The standardized catch (kg) per trawling hour by age is presented in Table 5. The results are rather similar to that of no. per hour by age group although the shrimp 5 years and older (usually females) are much more important by weight. Note especially the high CPUE of 5 year olds (1994 year-class) in 1999. Presumably, the 6 year olds may turn out to be quite noticeable in the catches in year 2000.

The age at change of sex has been variable if judged from the proportion within the primiparous group. In 1993 and 1994 all males were considered to change sex at the age of 5. Thus all the primiparous females were considered to be of age 5. In 1995 35% of the primiparous females were 4 year olds and the rest were 5 year olds. In 1996 the age at sex change was at its lowest, namely 19% of the primiparous females were considered 3 year olds and 81% four year olds. After this there was a change back where in 1997 all primiparous females appeared to be four year olds. In 1998 86 % of the primiparous females were four years old, the rest were 5 year olds and finally in 1999 44% of the primiparous females were 4 year olds and the rest were 5 year olds. So age at sex change appears to be increasing and getting nearer the results of the years 1993 and 1994. These preliminary results suggest that when the shrimp are older at sex change, the growth rate appears to be reduced.

3. SUMMARY

Catches of shrimp on Flemish Cap have been maintained at a high level (averaging more than 30,000 tons annually since the fishery began) due to: increasing effort up to 1996; an expansion of the fishing grounds to target smaller shrimp in shallower water (NAFO, 1997); and, more recently, a possible increase in biomass (NAFO, 1998). Both the unstandardized and standardized catch rates for 1994 were lower than the 1993 estimate. CPUE varied with no clear trend between 1994 and 1997. The female and combined CPUE estimates increased since 1997. Meanwhile the male CPUE index has been fluctuating throughout the seven year period.

Although the CPUE index has been improved further by standardizing for single and double trawl effort, results are still difficult to interpret as an index of stock size due to changes in fishing pattern between years.

The data suggest that during 1993 and 1994, males underwent sex inversion at 5 years of age. During the mid 90’s, the age of sex inversion decreased to the point at which 19% of the 3 year olds and 81% of the 4 year olds became female during 1996. The proportion of shrimp undergoing sex inversion at early ages decreased since 1997. The 1999 data suggest that the age of sex inversion has once again increased to occur at 5 years of age. There appears to be an inverse relationship between age of sex inversion and growth rate.

4. ACKNOWLEDGEMENT

Appreciation is expressed to all those who provided data for inclusion in this paper in advance of the 1999 November Meeting.

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TABLE 1. Multiplicative, year/vessel/month/area model (1) using single trawl logbook CPUE data for the period 1993 – 1999.

General Linear Models Procedure
Class Level Information

Class	Levels	Values
YEAR	7	93 94 95 96 97 98 99
VESSEL	77	1128 12 1352 1383 1407 1462 1484 1506 1514 1576 1609 1628 1634 1742 1752 1753 1757 1768 1807 1809 1903 1905 1942 2013 2061 21 2155 2190 2197 2204 2206 2211 2212 2216 2218 2220 2237 2242 2244 2249 2258 2259 2262 2266 2279 2286 2288 2332 29 40 41 43 44 47 5 58 66 68 69 70 OUKV OUOQ OWGG OWQU OWTI OWVM OYBZ OYCK OYHO OYKK OYRT OYXT OYZL OZDH OZKQ OZMA ZZZZ
MONTH	12	1 2 3 4 5 7 8 9 10 11 12 99
AREA	4	1 2 3 4

Number of observations in data set = 1027

Dependent Variable: LNCPUE
Weight: WFACTOR

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	96	2723.57845087	28.37060886	28.48	0.0001
Error	930	926.58945969	0.99633275		
Corrected Total	1026	3650.16791056			

R-Square	C.V.	Root MSE	LNCPUE Mean
0.746152	18.13645	0.9981646	5.50363882

Source	DF	Type I SS	Mean Square	F Value	Pr > F
YEAR	6	1352.88764091	225.48127349	226.31	0.0001
VESSEL	76	1222.22938779	16.08196563	16.14	0.0001
MONTH	11	140.90752617	12.80977511	12.86	0.0001
AREA	3	7.55389599	2.51796533	2.53	0.0562

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YEAR	6	464.17418425	77.36236404	77.65	0.0001
VESSEL	76	1090.79233800	14.35253076	14.41	0.0001
MONTH	11	147.47755672	13.40705061	13.46	0.0001
AREA	3	7.55389599	2.51796533	2.53	0.0562

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		5.872553108 B	87.72	0.0001	0.06694476
YEAR	93	0.418685428 B	7.39	0.0001	0.05668765
	94	-0.170338594 B	-3.12	0.0019	0.05463805
	95	0.028372288 B	0.52	0.6039	0.05467563
	96	-0.170464216 B	-3.52	0.0004	0.04838450
	97	-0.132069273 B	-2.52	0.0119	0.05242769
	98	0.057413410 B	1.06	0.2897	0.05419928
	99	0.000000000 B	.	.	.

TABLE 2. Multiplicative, year/vessel/month/area/gear model (2) using single + double trawl logbook CPUE data for the period 1993 – 1999.

General Linear Models Procedure
Class Level Information

Class	Levels	Values
YEAR	7	93 94 95 96 97 98 99
VESSEL	79	1128 12 1352 1383 1407 1462 1484 1506 1514 1576 1609 1628 1634 1742 1752 1753 1757 1768 1807 1809 1903 1905 1942 2013 2061 21 2155 2190 2197 2204 2206 2211 2212 2216 2218 2220 2237 2242 2244 2249 2258 2259 2262 2266 2279 2286 2288 2332 29 40 41 43 44 47 5 58 66 68 69 70 71 OUKV OUOQ OWGG OWQU OWTI OWVM OYBZ OYCK OYCZ OYHO OYKK OYRT OYXT OYZL OZDH OZKQ OZMA ZZZZ
MONTH	12	1 2 3 4 5 7 8 9 10 11 12 99
AREA	4	1 2 3 4
GEAR	2	2 9

Number of observations in data set = 1564

Dependent Variable: LNCPUE
Weight: WFACTOR

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	99	5483.36100675	55.38748492	51.54	0.0001
Error	1464	1573.36582207	1.07470343		
Corrected Total	1563	7056.72682882			

R-Square	C.V.	Root MSE	LNCPUE Mean
0.777040	18.29572	1.0366790	5.66623906

Source	DF	Type I SS	Mean Square	F Value	Pr > F
YEAR	6	1716.03195879	286.00532646	266.12	0.0001
VESSEL	78	3344.17704498	42.87406468	39.89	0.0001
MONTH	11	232.21772312	21.11070210	19.64	0.0001
AREA	3	19.20266864	6.40088955	5.96	0.0005
GEAR	1	171.73161122	171.73161122	159.79	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YEAR	6	620.12605655	103.35434276	96.17	0.0001
VESSEL	78	1486.95282443	19.06349775	17.74	0.0001
MONTH	11	240.26270494	21.84206409	20.32	0.0001
AREA	3	18.44992162	6.14997387	5.72	0.0007
GEAR	1	171.73161122	171.73161122	159.79	0.0001

Parameter		Estimate		T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		5.945622870	B	110.43	0.0001	0.05384279
YEAR	93	0.340283396	B	8.90	0.0001	0.03822190
	94	-0.210330887	B	-5.61	0.0001	0.03745982
	95	-0.036399319	B	-1.03	0.3046	0.03544124
	96	-0.220365003	B	-7.10	0.0001	0.03105712
	97	-0.130054687	B	-3.96	0.0001	0.03285939
	98	0.037537839	B	1.28	0.1994	0.02923633
	99	0.000000000	B	.	.	.
GEAR	2	0.293199510	B	12.64	0.0001	0.02319436
	9	0.000000000	B	.	.	.

Table 3. Proportion of nominal catch by sex and age over period 1993 – 1999. Also provided in this table are the standardized (year/ vessel/ month/ area/ gear (model 2) CPUEs in terms of weight and numbers caught per hour.

1993

Sex	Age	Prop. by no.	Mean weight g	Prop. X mean weight	Nominal catch 28088 tons	kg/hr 340	No./hour
Males	1	0.0041	0.646	0.00265	9	0.1	169
Males	2	0.1148	2.772	0.31823	1083	13.1	4728
Males	3	0.2146	5.225	1.12129	3815	46.2	8838
Males	4	0.1156	8.188	0.94653	3220	39.0	4761
Primip.	5	0.2619	10.441	2.73450	9303	112.6	10785
Multip.	6+	0.2800	11.189	3.13292	10658	129.0	11531
Total		0.9910		8.25611	28088	340	40811

1994

Sex	Age	Prop. by no.	Mean weight g	Prop. X mean weight	Nominal catch 24324 tons	kg/hr 238	No./hour
Males	1			0	0	0	
Males	2	0.1817	2.576	0.46806	1651	16.2	6276
Males	3	0.3629	4.998	1.81377	6398	62.7	12535
Males	4	0.0854	7.101	0.60643	2139	20.9	2950
Primip.	5	0.1944	10.08	1.95955	6912	67.7	6715
Multip.	6+	0.1756	11.664	2.04820	7225	70.7	6066
Total		1		6.89601	24324	238.2	34542

Table 3.
Continued

1995

Sex	Age	Prop. by no.	Mean weight g	Prop. X mean weight	Nominal catch 32977 tons	kg/hr 259	No./hour
Males	1						
Males	2	0.4516	1.965	0.88739	5989	47.0	23937
Males	3	0.2714	4.924	1.33637	9019	70.8	14386
Primip.	4	0.0507	6.462	0.32762	2211	17.4	2687
Primip.	5	0.0962	9.611	0.92458	6240	49.0	5099
Multip.	6+	0.1301	10.84	1.41028	9518	74.8	6896
Total		1		4.88625	32977	259.0	53006

1996

Sex	Age	Prop. by no.	Mean weight g	Prop. X mean weight	Nominal catch 48288 tons	kg/hr 218	No./hour
Males	1						
Males	2	0.0398	1.745	0.06945	529	2.4	1369
Males	3	0.5835	4.678	2.72961	20804	93.9	20078
Primip.	3	0.0448	5.707	0.25567	1949	8.8	1542
Primip.	4	0.1857	9.006	1.67241	12747	57.5	6390
Multip.	3	0.0059	6.327	0.03733	285	1.3	203
Multip.	4	0.0446	8.431	0.37602	2866	12.9	1535
Multip.	5	0.0629	11.439	0.71951	5484	24.8	2164
Multip.	6	0.0328	14.498	0.47553	3624	16.4	1129
Total		1		6.33555	48288	218.0	34409

Table 3. Continued

1997

Sex	Age	Prop. by no.	Mean weight G	Prop. X mean weight	Nominal catch 24754	kg/hr 239	No./hour
Males	1						
Males	2	0.0247	2.19	0.05409	205	2.0	903
Males	3	0.3432	4.018	1.37898	5224	50.4	12553
Males	4	0.2467	6.5	1.60355	6075	58.7	9024
Primip.	4	0.2514	8.335	2.09542	7938	76.6	9196
Multip.	3	0.0024	4.25	0.01020	39	0.4	88
Multip.	4	0.0207	8.259	0.17096	648	6.3	757
Multip.	5	0.0941	10.482	0.98636	3737	36.1	3442
Multip.	6	0.0143	13.905	0.19884	753	7.3	523
Multip.	7	0.0024	14.85	0.03564	135	1.3	88
Total		0.9999		6.53404	24754	239.0	36574

1998

Sex	Age	Prop. by no.	Mean weight G	Prop. X mean weight	Nominal catch 30131	kg/hr 311	No./hour
Males	1			0	0	0	
Males	2	0.0481	1.769	0.08509	423	4.4	2469
Males	3	0.3581	3.867	1.38477	6886	71.1	18379
Males	4	0.2000	5.574	1.11480	5543	57.2	10265
Males	5	0.0048	8.397	0.04031	200	2.1	246
Primip.	4	0.1860	7.386	1.37380	6831	70.5	9546
Primip.	5	0.0293	10.238	0.29997	1492	15.4	1504
Multip.	3	0.0029	4.417	0.01281	64	0.7	149
Multip.	4	0.0777	8.452	0.65672	3265	33.7	3988
Multip.	5	0.0733	10.665	0.78174	3887	40.1	3762
Multip.	6	0.0079	14.463	0.11426	568	5.9	405
Multip.	7	0.0120	16.28	0.19536	971	10.0	616
Total		1.0001		6.05963	30131	311.0	51328

Table 3.
Continued

1999

Sex	Age	Prop. by no.	Mean weight G	Prop. X mean weight	Nominal catch 35000	kg/hr 343	No./hour
Males	1	0.0004	0.122	0.00005	0	0.0	22
Males	2	0.0390	1.869	0.07289	407	4.0	2132
Males	3	0.2338	3.113	0.72782	4059	39.8	12779
Males	4	0.2061	5.378	1.10841	6182	60.6	11265
Males	5	0.0165	6.56	0.10824	604	5.9	902
Primip.	4	0.1130	6.501	0.73461	4097	40.2	6177
Primip.	5	0.1438	8.443	1.21410	6772	66.4	7860
Multip.	3	0.0027	4.217	0.01139	64	0.6	148
Multip.	4	0.0650	7.065	0.45923	2561	25.1	3553
Multip.	5	0.0975	9.214	0.89837	5011	49.1	5329
Multip.	6	0.0802	11.343	0.90971	5074	49.7	4384
Multip.	7	0.0020	15.2	0.03040	170	1.7	109
Total		1		6.27521	35000	343.0	54660

Table 4. Number of shrimp per hour at age (based on Table 3 results).

Age gr.	1993	1994	1995	Age gr.	1996	1997	1998	1999
1	169			1				22
2	4728	6276	23937	2	1369	903	2469	2132
3	8838	12535	14386	3	21822	12641	18526	12927
4	4761	2950	2687	4	7924	18977	23799	20995
5	10785	6715	5099	5	2164	3442	5512	14091
6+	11531	6066	6896	6	1129	523	405	4384
				7		88	616	109
Total	40812	34542	53005		34408	36574	51327	54660

Table 5. Standardized kg per hour at age (based on Table 3 results).

Age gr.	1993	1994	1995	Age gr.	1996	1997	1998	1999
1	0.1			1				
2	13.1	16.2	47.0	2	2.4	2	4.4	4.0
3	46.2	62.6	70.8	3	103.9	50.4	71.7	40.4
4	39.0	20.9	17.4	4	70.5	141.6	161.4	125.8
5	112.6	67.6	49.0	5	24.8	36.1	57.6	121.4
6+	129.0	70.7	74.8	6	16.4	7.3	5.9	49.7
				7		1.3	10.0	1.7
Total	340	238	259		218	239	311	343

Figure 1. Residuals for the Year/Month/Vessel/Area model (1) for single trawl CPUE logbook data for the period 1993 – 1999.

```
                 Plot of R2*P2.  Legend: A = 1 obs, B = 2 obs, etc.

    R2 ,
   1.5 ˆ
       ,
       ,
       ,
       ,
       ,
       ,                                    A
   1.0 ˆ                                               A
       ,                                             A
       ,                                    B
       ,                                               A
       ,                                             A
       ,                                A          B     A    A           A
       ,                                 A     A       A                    A
   0.5 ˆ                                  A    A  B      A
       ,                                 A     B AAA A  AAB   A   C
       ,                       A  A    BA   AAB AA  BA A C B A      A   A      A
       ,                             AA   B ABBACD DACAB B C A AA A   AA       A
       ,                         A   BABAAB ECEBB CADBBBAACB DC CAC B BD BAAA   A
       ,                A      A    A AA CCDCFCDCDKGEG DAEAABAAADBBAA B AA   A   A
       ,                 B          A BCDABFADCDCGCFFGFHDFECDCDBD  BBABAAB  AA
   0.0 ˆ    A                   AAA A A BAEHCCCFFHIEKFECFBAF CACABBBBBADAAA B A A
       ,                       B A  A DCD CDFJCCAEDDEEEECFDGBCCDABA CBB      A
       ,                  A     B AAA C  ABABAEADHBFCHCHDBFACADG  DCA ABAAAA A
       ,                       AABA A  A C CDACACAB BFCBDCBABCDA BA AAA AAA   B
       ,                            A     ACCABDAA DABFBABBBAABAA BAAAA A AA
       ,                                A A  ABBBBBA BD ABB A AB A  A   B   A
       ,                        A A  AA    A DA BBBA AAA BAA  A  AB A     A       A
  -0.5 ˆ                                   B AA  B BB     AA B         A  A
       ,                                   AAA AA   A  A AA     BA          A
       ,                                    A   AA       A    A              A
       ,                                      A  A  AA             A A
       ,                                          A     A A   A A A    A
       ,                                                     A A  A              A
       ,                                   A          A   AA  A
  -1.0 ˆ                                                      A
       ,                             A      A
       ,                                        A
       ,                                                        A         B
       ,
       ,
       ,
  -1.5 ˆ                                       A                 A
       Šƒƒˆƒƒƒƒƒƒƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒƒƒƒƒƒƒˆƒƒ
         4.0            4.5            5.0            5.5            6.0            6.5

                                               P2
```

Figure 2. Residuals for the Year/Month/Vessel/Area/Gear model (2) for single + double trawl CPUE logbook data for the period 1993 – 1999.