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Distribution of spawning and sex ratio in Greenland halibut

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Abstract

This paper examines spawning area and time and sex ratio by depth from data collected from the commercial fisheries of Canada and Spain and by research vessel surveys conducted by Canada and the EU. The data from commercial fisheries indicate that the proportion female increases with depth. This is particularly evident for depths greater than 600 m. However, the interpretation of the change in sex ratio with depth is complicated by issues of gear selectivity. Spawning fish were found in all areas and in all months. There tended to be a higher proportion of females in spawning condition in the northern areas. Canadian data indicate that spawning is in the summer and autumn while data from Spain seem to indicate more year round spawning. The ability to determine peak spawning time and area is hampered by the lack of sampling throughout the year in all areas.

Key words: Greenland halibut, sex ratio, depth, spawning area, spawning time

Introduction

Although Greenland halibut (*Reinhardtius hippoglossoides*) is an important commercial species, there are many aspects of its basic biology that are little known. In particular, in the Northwest Atlantic, details about the distribution of fish by sex and the timing and location of spawning are not well described. It is thought that the main spawning for the population occurs in the Davis Strait, following an extensive migration. However spawning has been observed elsewhere, including the Flemish Pass (Junquera and Zamarro, 1994; Morgan and Bowering 2000). Greenland halibut appear to have a peak and secondary spawning period with some fish in spawning condition being found in most months (Fedorov, 1971; Junquera, MS 1994; Junquera and Zamarro, 1994). It is known that older/larger fish inhabit deeper waters and that the proportion female increases with depth (Bowering and Nedreaas, 2000; Junquera and Zamarro, 1994). However this pattern is not well described.

The purpose of this study was to examine available data for spawning females and sex ratio to gain more insight into the distribution and timing of spawning as well as the distribution of female fish. This study brings together data collected by Canada and by Spain from both commercial and research vessels to examine the distribution of male and female Greenland halibut and to determine if spawning areas and times can be identified.

Methods

Data consisted of samples collected from both the commercial fishery conducted by Canada and Spain and on research vessel surveys (RV) conducted by Canada and Spain. Collections made by Spain were for age determination and also length, sex and maturity sampling. Spanish data came from Divisions 3LMNO. Commercial data were collected in all months and over the years 1992-2009. Research vessel data were collected in three annual surveys in months 4 to 8, covering different Divisions. Data were collected from 1988-2009 in Division 3M during an EU funded survey in conjunction with Portugal, from 1995-2009 in Divisions 3NO and from 2003 to 2009 in Division 3L.

Canadian data consisted of collections from both commercial and research vessel surveys for the main purpose of age determination which were collected in a length stratified manner and also length, sex, maturity sampling (LSM) which is random. The research vessel data came from all Divisions from 0A to 3O, although SA1 was not included in these analyses. RV data were collected in all months (although not every month in every year) from 1978-2009. Canadian commercial aag data were more extensive than lsm data. Canadian commercial data were available from Divisions 0A to 3O, although there were no data from 3M. Canadian commercial aag data were available from 1965-2008 (continuously from 1993) and over months 1-11. LSM data from the Canadian commercial fishery were available from 1997-2009, for Divisions 0B, 2J, 3K, 3L and 3O for months 1, 2, 4, 5, 6, 7, 8, 9, 11. The collections by the two countries consisted of more than 1 million fish.

To examine sex ratio the proportion female was calculated for each fishing and survey set and plotted relative to depth. Pearson product moment correlations were carried out to determine if sex ratio was related to depth. As the proportion female increases with size, the length of fish caught in each data set was also examined.

Spawning females were identified macroscopically by the presence of hydrated oocytes. The proportion of spawning adult females was calculated from each data source by month and Division.

Results and Discussion

There is a significant change in the proportion female with depth in the Canadian research vessel data (Fig. 1-2, Table 1). However, the correlation coefficients are very low and the significance is mainly the result of very large sample size. The Spanish research vessel survey data show a similarly low correlation coefficient between proportion female and depth, but the correlation is not significant (Fig. 3, Table 1).

Commercial data from both countries show a significant increase in proportion female with depth (Fig. 4-6, Table 1). This is particularly evident for depths greater than 600 m.

The proportion female increases with length in Greenland halibut (de Cardenas MS 1997, Pochtar and Fomin MS 2012). The change in sex ratio with depth may not be detected in the research vessel data because of an inability of the survey gear to catch large fish. This was examined by looking at the length range, the mean length and the proportion of fish greater than 70 cm in the commercial and survey data from each country (Table 2). In the Canadian data the mean length caught is higher in the commercial than RV data but this is at least partly the result of the fact that the commercial fisheries do not capture fish as small as the survey. Small and large fish are present at all depths, although the mean size increases with depth. In the Spanish data, there is also an increase in mean length with depth. In this case the larger mean size caught by the commercial fleet is partly a result of the fact that the maximum size caught in the commercial fishery is generally larger. The proportion of big fish is larger at greater depths in the commercial fishery of both countries than in the RV surveys. The increase in sex ratio at depth is probably a result of the increase in the number of larger fish (which are more likely to be female). However, part of the difference between the results from the commercial fleets and the surveys is likely due to size selectivity differences between them.

Canadian data used to examine spawning area and time extend into SA0. Both Canadian commercial and RV data indicate that more spawning occurs in the north, but that spawning fish are found in most Divisions (Tables 3 and 4). Data from Spain also indicate spawning throughout the area but data are limited to Div. 3LMNO (Table 5 and 6). The presence of spawning fish outside of the Davis Strait is consistent with the findings of Junquera and Zamarro (MS 1994) and Morgan and Bowering (MS 2000) who used some of the same data. Canadian data indicate that spawning is in the summer and autumn, while data from Spain seem to indicate more year round spawning. Junquera and Zamarro (MS 1994) also found spawning in most months but with peaks in July-August (20%), September (7%) and December (7%).

Data on spawning time and area are limited as there is not year round sampling in all areas. It would be difficult for instance to examine any trends in spawning time across years. Some of the differences between the data sets are likely related to difference in sampling coverage. For example, data from the Spanish commercial fishery indicates a high percentage of spawning fish in January, while Canadian data indicate no spawning in that month. The Spanish commercial data are from Div. 3LMN while Canadian sampling was limited in those Divisions in January. Limited sampling may also skew the results either positively or negatively. For example, the large percentage of spawning fish in Div. 2H in July in the Canadian commercial data is based on only 18 adult fish and should be viewed with caution. However, it is still clear that some spawning occurs throughout the area and throughout the year. Although spawning seems more prevalent in the north it is not possible at this time to assign relative importance quantitatively. The data may be too limited to determine if there have been any shifts in spawning area and time. The ability to determine peak spawning time is hampered by the lack of sampling throughout the year in all areas.

Acknowledgments

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Table 1. Correlation of proportion female with depth from various sources

Source	Correlation coefficient	P value	Number of sets
Canadian RV AAG	0.054	<0.0001	12615
Canadian RV LSM	-0.02	<0.05	13047
EU Spain RV	0.015	0.45	2451
Canadian commercial AAG	0.26	0.08	46
Canadian commercial AAG greater than 600m	0.74	<0.0001	33
Canadian commercial LSM	0.39	<0.0001	180
Spanish commercial	0.18	<0.0001	8072

Table 2. Length range and mean length caught at different depths (less than 400m, 400-1000 and greater than 1000 m) by sex (1=male, 5=female) in RV and commercial samples, along with the proportion of fish greater than or equal to 70 cm (propbig) in each depth range.

Canadian commercial LSM

sex	range	FREQ	maxlen	minlen	mnlen
1	gt1000	2245	78.5	34.5	52.3
1	lt1000	17184	76.5	28.5	49.4
1	lt400	4387	64.5	32.5	47.3
5	gt1000	7611	106.5	34.5	63.3
5	lt1000	22671	98.5	28.5	52.7
5	lt400	5535	86.5	26.5	47.9

Canadian RV LSM

sex	range	FREQ	maxlen	minlen	mnlen
1	gt1000	12228	86.5	8.5	46.4
1	lt1000	83704	100.5	8.5	34.1
1	lt400	84766	98.5	4.5	27.6
5	gt1000	11363	100.5	6.5	46.8
5	lt1000	76161	110.5	6.5	33.9
5	lt400	83413	114.5	2.5	27.9

proportion big (ge 70 cm) sexes combined

range	FREQ	nbig	nsmall	propbig
gt1000	9856	2217	7639	0.22
lt1000	39855	1116	38739	0.03
lt400	9922	12	9910	0.00

proportion big (ge 70 cm) sexes combined

range	FREQ	nbig	nsmall	propbig
gt1000	23591	924	22667	0.04
lt1000	159865	1744	158121	0.01
lt400	168179	744	167435	0.00

Spanish commercial

sex	range	FREQ	maxlen	minlen	mnlen
1	gt1000	113148	99	3	48.0
1	lt1000	104351	97	13	43.7
1	lt400	290	59	15	31.4
5	gt1000	244620	110	10	54.5
5	lt1000	177420	120	14	47.5
5	lt400	450	64	16	32.8

Spanish RV

sex	range	FREQ	maxlen	minlen	mnlen
1	gt1000	1818	72	10	47.9
1	lt1000	3649	78	10	36.3
1	lt400	3903	59	8	25.7
5	gt1000	4776	104	10	55.6
5	lt1000	7880	99	10	43.4
5	lt400	7168	81	7	28.6

proportion big (ge 70 cm) sexes combined

range	FREQ	nbig	nsmall	propbig
gt1000	357768	29051	328717	0.08
lt1000	281771	5959	275812	0.02
lt400	740	0	740	0.0

proportion big (ge 70 cm) sexes combined

range	FREQ	nbig	nsmall	propbig
gt1000	6594	728	5866	0.11
lt1000	11529	139	11390	0.01
lt400	11071	5	11066	0.00

Table 3. Percent of adult females that were in spawning condition by Division and month from Canadian RV LSM data.

	month												
Division	1	2	3	4	5	6	7	8	9	10	11	12	total
0A									17.09	0.00			11.59
0B								7.75	9.93	0.00			4.69
2G								0.00	0.00	0.00	33.98		8.62
2H							4.98	0.00	23.81	4.98	2.41	0.00	2.78
2J							0.00	0.00	0.00	3.70	3.96	0.00	2.86
3K				0.00			0.00		2.03	0.00	1.86	0.00	1.14
3L	0.00	0.00	0.00	0.00		0.00			10.22	0.00	0.00	0.00	4.59
3M	0.00	0.00	0.00						0.00	0.00		0.00	0.00
3N		0.00		0.00	0.00				0.00	0.00			0.00
3O					0.00				0.00	0.00			0.00
total	0.00	0.00	0.00	0.00	0.00	0.00	3.06	1.47	6.57	2.02	5.61	0.00	

Table 4. Percent of adult females that were in spawning condition by Division and month from Canadian commercial LSM data.

	month												
Division	1	2	3	4	5	6	7	8	9	10	11	12	total
0A													
0B							14.76		0.00	0.41			7.98
2G							8.48	6.91	0.45				4.29
2H							22.22						22.22
2J					0.00	0.00	1.12	0.00					0.54
3K					1.30	0.14	0.10	6.12	0.92				1.38
3L					0.24	0.00	0.93	3.39					0.66
3M													
3N													
3O	0.00		0.00	1.64									0.72
total	0.00		0.00	1.64	0.84	0.11	6.72	6.43	0.37	0.41			

Table 5. Percent of adult females that were in spawning condition by Division and month from EU Spain RV data.

	month												
Division	1	2	3	4	5	6	7	8	9	10	11	12	total
3L						0.78	0.00	0.11					0.09
3M						0.00	0.00						0.00
3N				1.04	0.68	0.00							0.41
3O					1.50	0.00							0.70
total				1.04	0.84	0.04	0.00	0.11					

Table 6. Percent of adult females that were in spawning condition by Division and month from Spanish commercial data.

	month												
Division	1	2	3	4	5	6	7	8	9	10	11	12	total
3L	3.52	2.69	2.70	3.52	0.50	0.71	3.07	2.71	1.90	3.60	1.68	5.03	2.35
3M	4.42	2.16	2.62	0.36	0.78	1.14	9.95	3.90	0.99	3.78	0.30	0.53	2.22
3N	13.36	0.00	0.87	1.25	0.36	3.86	7.22	4.19	2.84	3.85	1.88	0.96	3.16
3O		0.00		0.71	0.43	0.00	0.00	0.00	3.39	2.13	0.31	0.00	0.59
total	4.40	2.38	2.57	1.88	0.56	1.27	4.83	3.31	2.23	3.73	1.51	3.65	

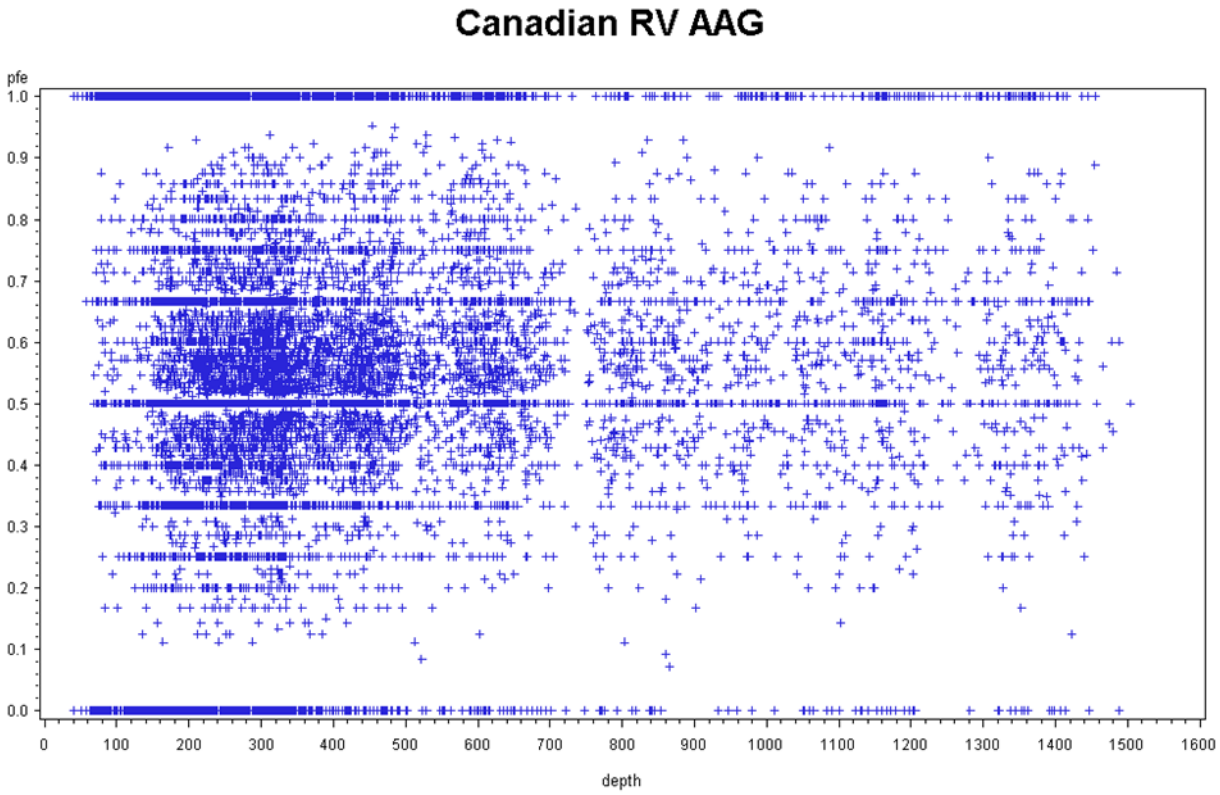

Figure 1. Proportion female by depth from data collected for the determination of age composition by Canadian research vessels.

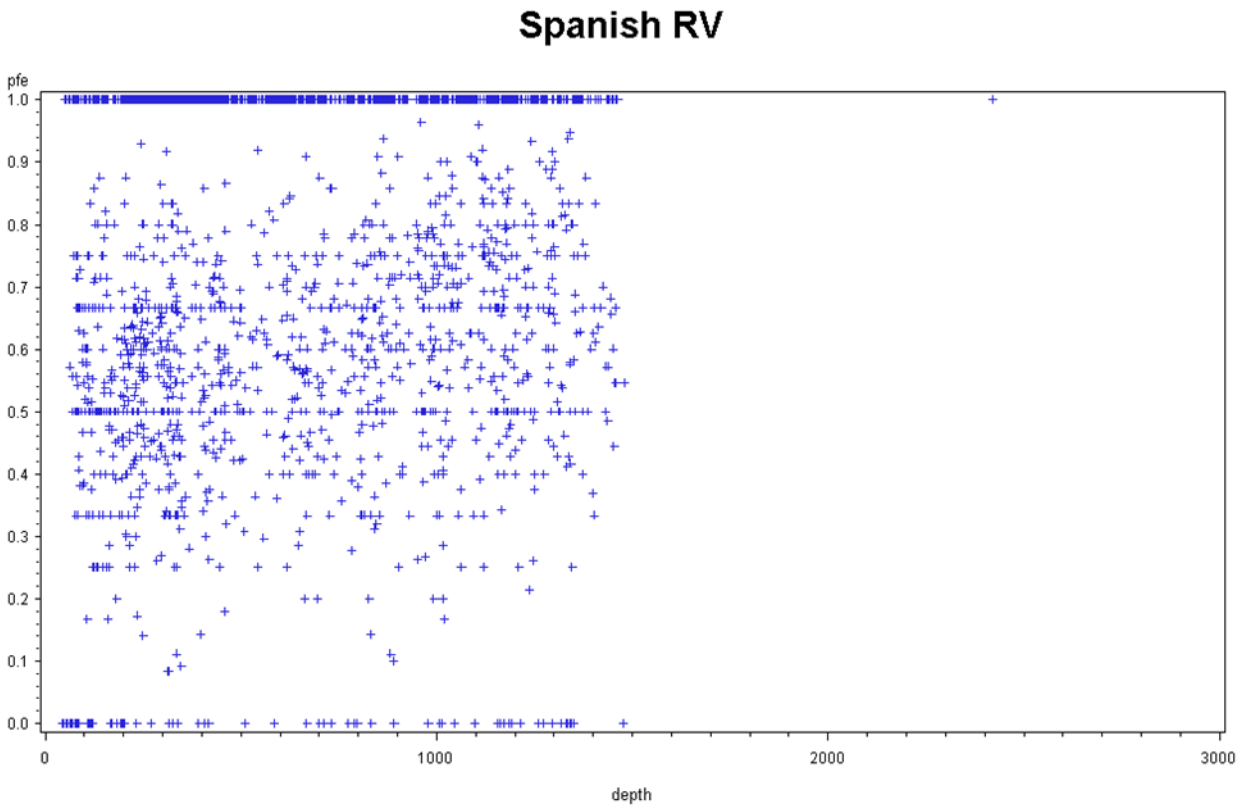

Figure 2. Proportion female by depth from data collected by research vessels from EU-Spain.

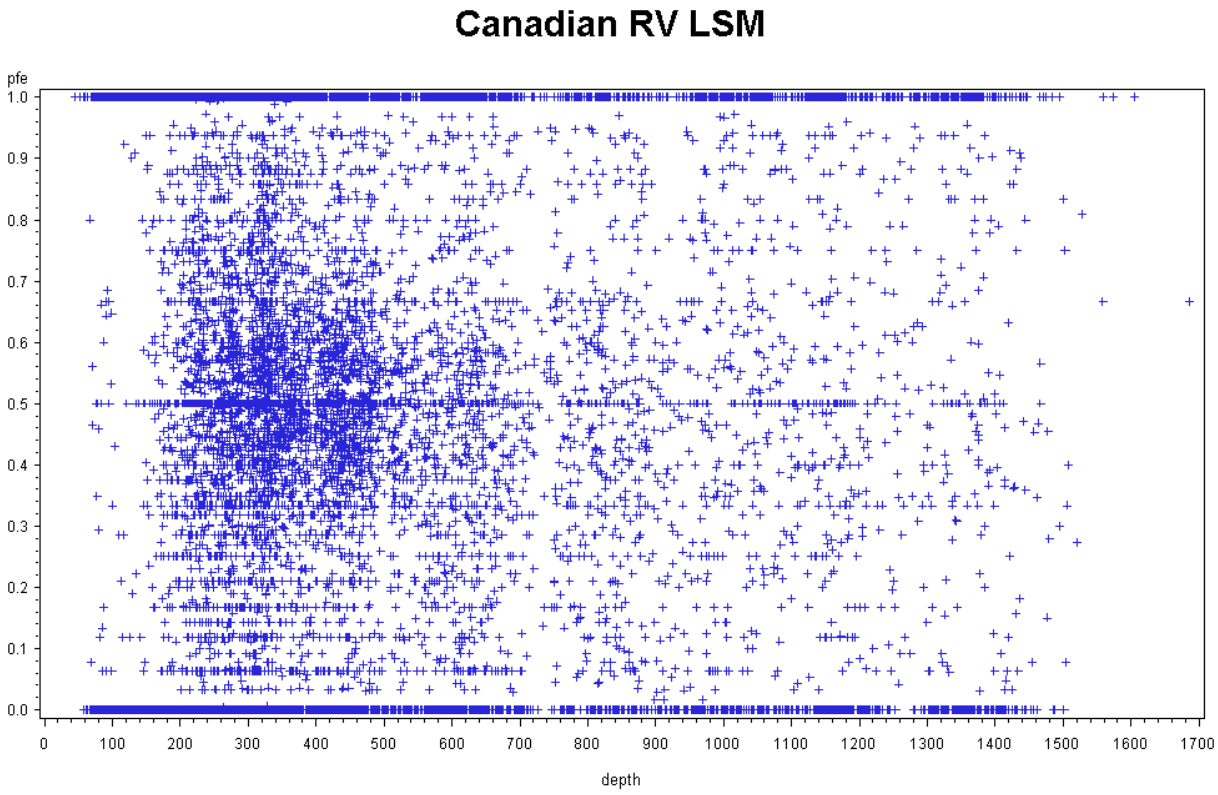

Figure 3. Proportion female by depth from data collected for the determination length, sex and maturity composition by Canadian research vessels.

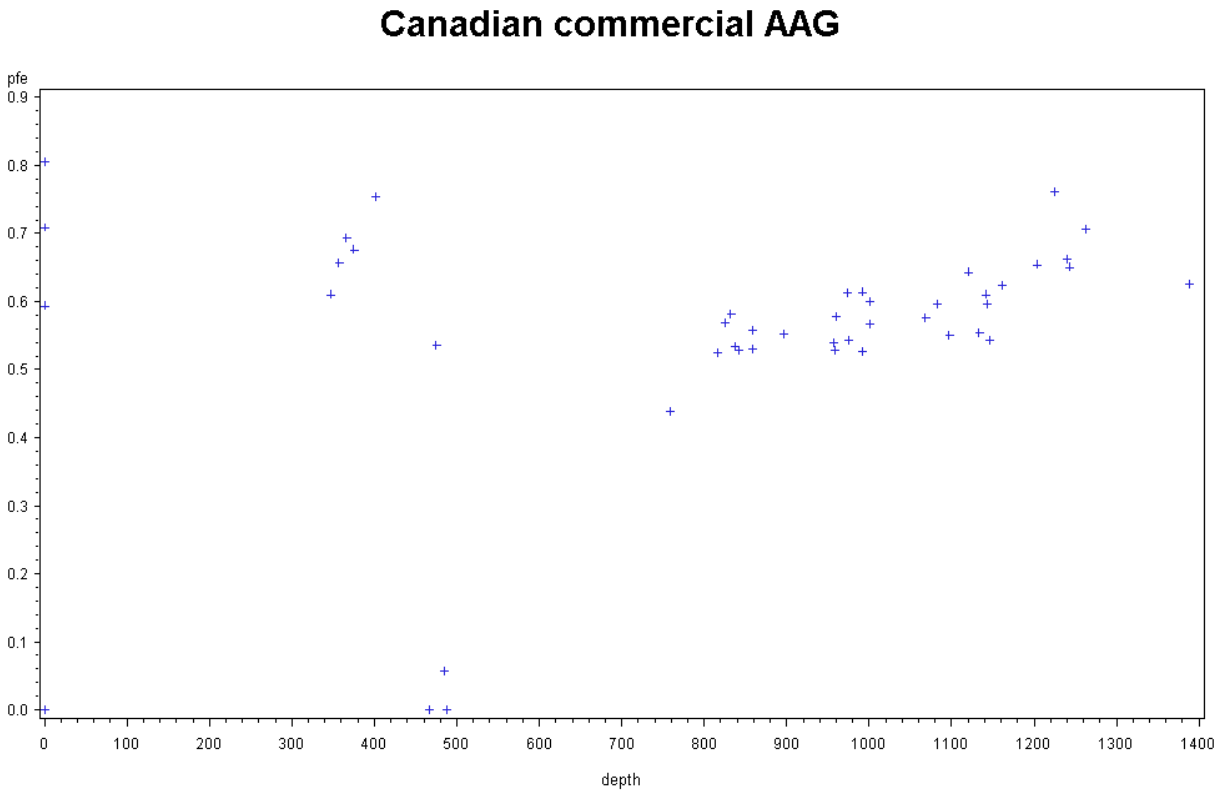

Figure 4. Proportion female by depth from data collected for the determination of age composition from Canadian commercial vessels.

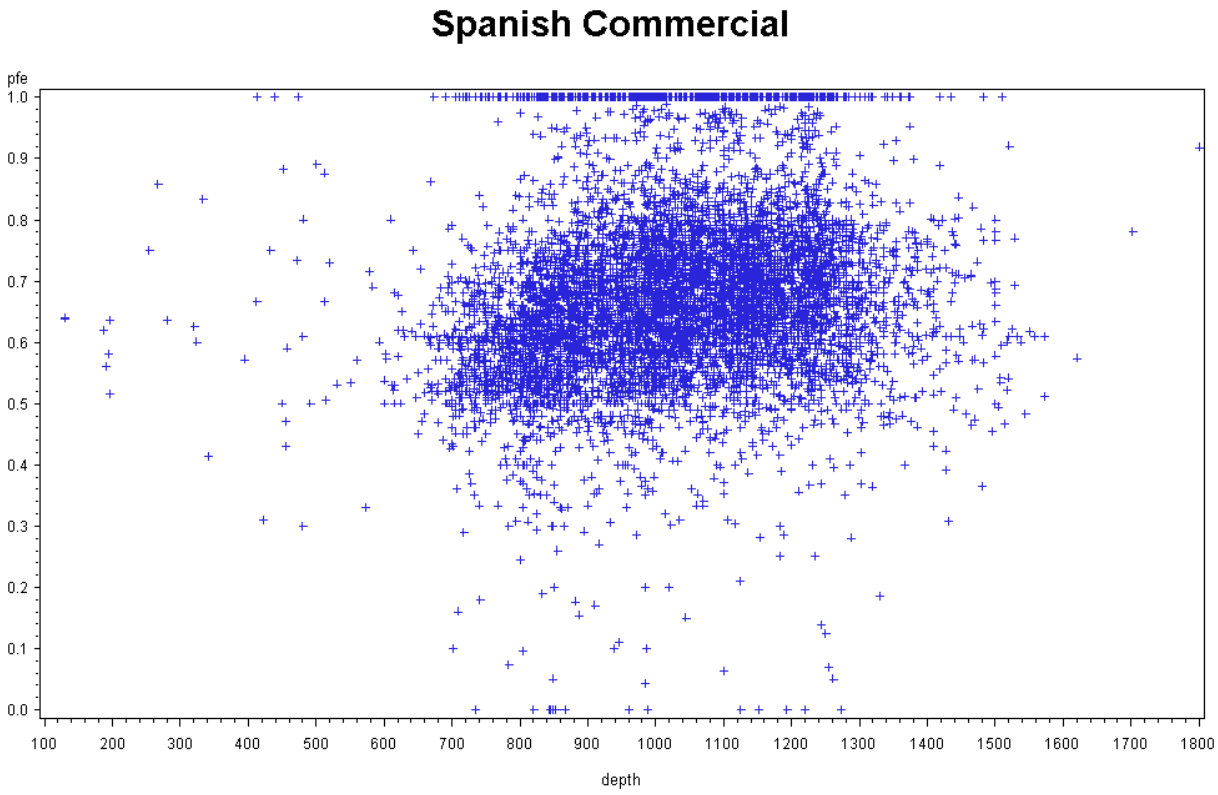

Figure 5. Proportion female by depth from data collected from Spanish commercial vessels.

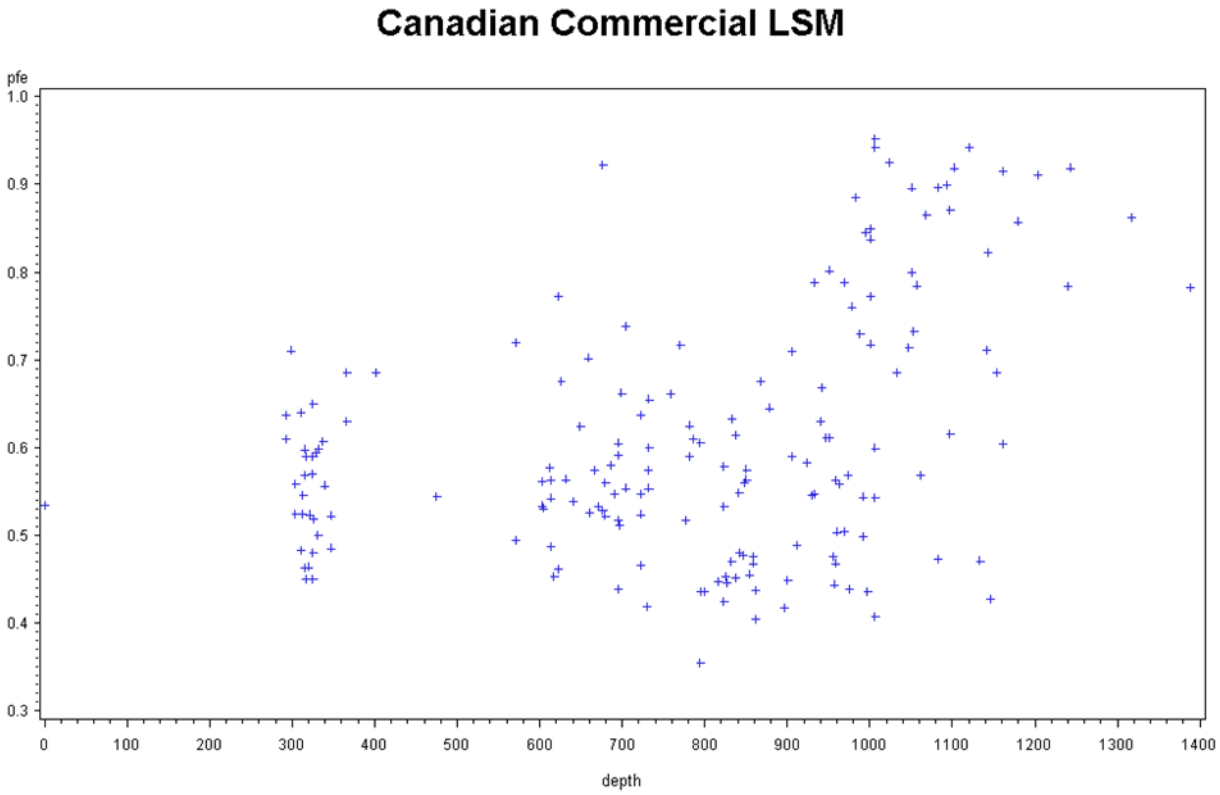

Figure 6. Proportion female by depth from data collected for the determination of length, sex and maturity composition from Canadian commercial vessels.