SIZE AT SEXUAL MATURITY AND CATCH CHARACTERISTICS OF THE YELLOWTAIL AND WINTER FLOUNDER FISHERY IN THE MAGDALEN ISLANDS

Context

Because of the decline in the herring and mackerel catches, coastal flounder species (especially yellowtail flounder, *Limanda ferruginea,* and winter flounder, *Pseudopleuronectes americanus*) make up a significant portion of the bait supply for Magdalen Islands fishers. Yellowtail and winter flounder make high-quality bait and are an important resource for lobster fishers. These fish are harvested in the spring, once the ice has melted, by vessels equipped with trawls, seines or gillnets. Since 2001, a certain number of lobster fishers have been authorized to engage in non-commercial fishing to obtain bait. Although the catch for each species appears to have decreased since 2006, the proportion of catches made by vessels engaging in non-commercial fishing increased in 2007 and 2008 (Table 1). Non-commercial fishing is done by small vessels with small trawls and 130-mm cod-end mesh. Commercial fishing is done by larger vessels with trawls, seines or gillnets with mesh measuring 140 mm or more. Landings of these two species in the Islands have amounted to between 200 and 400 tonnes annually since 2001 (Table 1).

In 2006, the DFO managers of the Magdalen Islands Area office expressed interest in acquiring more biological knowledge of these species, especially the length at which yellowtail and winter flounder reach sexual maturity. That information was not available from the research surveys conducted each year in the fall or summer (Morin and Forest-Gallant 1996). Sampling programs to monitor the biological characteristics of these species in the fishery were carried out from 2006 to 2008. The goal of the monitoring was to characterize, in the Magdalen Islands area, the relationship between sexual maturity and length, as well as the size composition and sex ratio for each species in the catches from the various types of fishing gear. The information obtained on the biology of these species will help with defining and/or modifying the management protocol aimed at protecting juvenile fish.

A request for scientific advice was submitted by DFO’s Fisheries and Aquaculture Management sector for an evaluation of the results of the data gathered during the three years of monitoring of the fishery. The evaluation was reviewed on October 16, 2009, and this document presents the results and conclusions relating to the questions raised. Size at sexual maturity, estimated using this study, is not considered representative of the population around the Islands. However, the size frequency distributions demonstrate that a large proportion of the yellowtail flounder catches are currently below the minimum size of 25 cm.

Background

In the spring of 2006, with the assistance of biologists from DFO Science (Gulf Region) and observers from Biorex, initial sampling was conducted to determine the sexual maturity of the local yellowtail and winter flounder populations around the Magdalen Islands. In 2007 and 2008, additional samples were collected by a sampler from the Area office (non-commercial fisheries) and a sampler from the DFO Science office (Quebec Region, commercial fisheries). Table 2 summarizes the levels of sampling during the three years of the study.

The yellowtail and winter flounder catches were sampled to determine the size frequency distribution, and then subsampled to determine the sex and stage of sexual maturity of the fish. The sampling, carried out in conjunction with the fishers, took place in the spring during the reproductive period for the two species, from the start of May to the end of June. The physical appearance of the gonads at that time of the year makes it easier to identify spawners, either by the presence of gametes in spawning condition or by gonad appearance shortly after spawning. The samplers were given a picture guide and a description of the three stages of maturity (Table 3).

Maps showing the annual distribution of the catches sampled by type of fishing gear are presented in Figures 1, 2 and 3. The samples came mainly from along the shore at depths ranging from 2 to 8 m, with some collected at depths of 20 m or more.

Analysis and Results

Analytical model

With a view to determining size at sexual maturity, the proportion of mature fish relative to size was analyzed using a logistic model. Formally, the model consists of a set of fish lengths x_i where $i = 1, \ldots, n$, and y_i is an indicator variable for the stage of sexual maturity of fish i. It is assumed that the probability that a fish of size x is mature follows a logistic curve parameterized as follows:

$$p(x) = \frac{1}{1 + \exp\left(-4m(x - x_{50\%})\right)}$$

where $x_{50\%}$ is the size at which a fish has a 0.5 probability of being either immature or mature, and m is the slope of this curve at size $x_{50\%}$. The statistical model is given by the following:

$$Y_i \sim Bern\left(p(x_i)\right)$$

which means that each observation of stage of sexual maturity y_i follows a Bernoulli distribution with probability $p(x_i)$. The likelihood function of the observations is therefore:

$$L(m, x_{50\%}) = \prod_{i=1}^{n} \left[1 - p(x_i)\right]^{1-y_i} p(x_i)^{y_i} \ .$$

The parameters $x_{50\%}$ and m were estimated by maximum likelihood, and their errors were determined via their second partial derivatives of the log-likelihood function. Maximization was performed using R (Ihaka and Gentleman 1996).

Results

The summary results of each analysis by species, sex and year are presented in Tables 4 and 5. The values of log-likelihood, $x_{50\%}$ and its error, and m, as well as the number of immature and mature fish used in the analysis, are also presented. Graphs of the average curves as well as the empirical proportions relative to size are found in Figures 4, 5 and 6.

For the yellowtail flounder, there were generally few immature fish in all the data, which made adjustment and estimation of size at 50% sexual maturity problematic. The model could not fit the sexual maturity data for the males in 2008 (Table 4; Figure 4). That fact is also reflected by a larger confidence interval in the estimate of $x_{50\%}$ (Table 4). However, a fairly clear progression was generally observed in the proportion of mature fish relative to size.

The estimates of the $x_{50\%}$ values for each species varied considerably from year to year and were outside the biological norms. For example, a 6-cm decrease was observed in the estimate of the $x_{50\%}$ values in the male and female yellowtail flounder between 2006 and 2007.

For the winter flounder, similar results were observed, with wide variation in the proportion of immature fish. In 2006, the number of immature males was more than two times the number of mature males, but the proportion was reversed in 2008 (Table 5). It was possible to fit the logistic model to the data in each case (Figure 5), but the estimates exhibited significant interannual variability and some large confidence intervals (Table 5). These variations are not biologically realistic. In general, the 2007 and 2008 estimates are more alike, even though significant interannual differences are still observed in certain cases.

Despite the interannual variability observed for each species, we pooled the data for each species for illustration purposes (Tables 4 and 5; Figure 6). Pooling the years resulted in an estimate for $x_{50\%}$ of 18 cm for female yellowtail flounder. The values obtained for female yellowtail in this study, regardless of the year, are significantly lower than the minimum size of 25 cm established for this fishery. The Grand Banks of Newfoundland (Northwest Atlantic Fisheries Organization division 3LNO) is the subject of two annual surveys, with the data from the spring survey used to determine the size at sexual maturity of yellowtail flounder. From 1984 to 2007, the value of $x_{50\%}$ was estimated at 33 cm on average (Maddock Parsons et al. 2008). It is possible that 3LNO yellowtail flounder grow more quickly or reach a larger size than yellowtail in the southern Gulf. In the annual September survey in the southern Gulf, few yellowtail longer than 30 cm are observed (Hurlbut et al. 2008), which is not the case on the Grand Banks.

Pooling the data for winter flounder, regardless of the level of interannual variation, resulted in an estimate for $x_{50\%}$ of 24 cm for females and 21 cm for males (Table 5). The estimated $x_{50\%}$ values for female winter flounder in this study are close to the minimum size of 25 cm for this species in the southern Gulf. Those estimates are also within the range of values obtained previously for female winter flounder during the spring surveys in the southern Gulf (24 cm in 1987 and 26 cm in 1991; Morin and Forest-Gallant 1997).

For the estimation of the size frequency distributions, the annual catches were separated by the type of fishing gear and, in the case of the trawl fishery, by the source of the catch, i.e. whether they were commercial or non-commercial (Figures 7 and 8). These distributions were weighted by catch to estimate the number of fish caught by the sampled vessels. For each type of gear, the frequency of each length was then expressed by its proportion relative to all the catches. The cumulative catch curves are presented in Figures 9 and 10.

It is not possible to use the length frequency data to determine the effect of mesh and type of fishing gear on size composition. The types of gear were generally not set in the same locations at the same time. Non-commercial fishing by trawlers in 2006 (done with smaller-mesh gear) caught smaller yellowtail than did fishing with the other types of gear in the same year (Figures 7 and 9). In 2007 and 2008, however, seines caught a proportionately higher number of small yellowtail. A similar but less marked effect is present in winter flounder. Non-commercial fishing by trawlers caught smaller winter flounder in 2006 compared to fishing with the other types of gear (Figures 8 and 10), but seines or trawls used for commercial fishing had the same effect in 2007 and 2008. Each year, gillnets caught the largest winter flounder of all the types of gear. At present, we cannot separate the effects of mesh size, type of fishing gear or physical factors such as depth on size composition.

Overall, it can be seen that the proportions below the minimum size of 25 cm for yellowtail flounder were significant, namely 40 to 70% for seines and trawls and about 30% for gillnets (Figure 9). For winter flounder, these proportions were 20 to 30% in the seine and trawl fisheries and less than 10% for gillnets (Figure 10).

Sources of Uncertainty

The proportions of immature fish in the sampling program and the estimated sizes at maturity varied from year to year during this study. The fact that the samples came from various types of fishing gear and various fleets could have contributed to that variability. The distribution of the samples varied depending on the year and the fishing vessel, and the majority of the samples came from catches made close to shore. A major source of uncertainty in this study is therefore the possibility that the sampling of a fishery with a limited spatial distribution does not correspond to the distribution range of the mature and immature fish in the population.

Conclusions

The reliability of the estimates of size at maturity for the two species is called into doubt by interannual variations that do not correspond to the biological norms. These variations could be explained by bias due to a targeted fishery that harvests spawning aggregations. The samples from this fishery contained many fewer immature yellowtail and winter flounder than mature fish. If the true abundance of immature fish is not represented in the fished areas, the estimates of size at sexual maturity could be biased. This potential spatial heterogeneity requires a sampling plan that is random, or at least independent of fish concentrations, and that covers the distribution of mature and immature fish. That does not seem to be the case for the Magdalen Islands coastal fisheries at present. Size at sexual maturity, estimated using this study, is not considered representative of the population around the Islands. As a result, the development of new management measures should not be based on the values presented here.

However, the size frequency distributions demonstrate that a large proportion of the yellowtail flounder catches are currently below the minimum size of 25 cm. These proportions range from 40 to 70% depending on the year and the type of fishing gear used. In winter flounder, these proportions are 20 to 30%.

Some recommendations come out of this study. It is important to continue monitoring of the coastal yellowtail and winter flounder fishery around the Magdalen Islands because there are significant proportions of fish smaller than 25 cm in the catches of this fishery. Size at sexual maturity should be estimated using methods other than the local fishery, such as a spring survey with an appropriate sampling plan. In addition, the potential for using the data from the annual September survey in the southern Gulf to determine the size at sexual maturity of these fish should be explored.

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Sources of information

Hurlbut, T., T. Surette, D.P. Swain, R. Morin, G. Chouinard, H.P. Benoît, and C. LeBlanc. 2008. Preliminary Results from the September 2007 Bottom-trawl Survey of the Southern Gulf of St. Lawrence. DFO Can. Sci. Adv. Secr. Res. Doc. 2008/019. 49 p.

Ihaka, R. and R. Gentleman. 1996. R : a language for data analysis and graphics. Journal of Computational and Graphical Statistics 5: 299-314.

Maddock Parsons, D., W.B. Brodie, M.J. Morgan and D. Power. 2008. The 2008 assessment of the Grand Bank yellowtail flounder stock, NAFO Divisions 3LNO. Northwest Atlantic Fisheries Organization SCR Doc. 08/45. 50 p.

Morin, R. and I. Forest-Gallant. 1996. An update on winter flounder and yellowtail flounder in NAFO Division 4T, 1995. DFO Can. Sci. Adv. Secr. Res. Doc. 96/72. 25 p.

Morin, R. and I. Forest-Gallant. 1997. Assessment of NAFO Division 4T winter flounder in 1996. DFO Can. Sci. Adv. Secr. Res Doc. 97/69. 24 p.

Appendix: Tables and Figures

Table 1. Annual landings (tonnes) of yellowtail and winter flounder in the Magdalen Islands by the non-commercial bait fishery (Bait) and the commercial fishery (Comm.). The vessels that engage in non-commercial bait fishing were identified from a list of authorized vessels (DFO Cap-aux-Meules). The last column (% Bait) indicates the percentage of catches from the non-commercial fishery.

	Yellowtail Flounder				Winter Flounder			
Year	Bait	Comm.	Total	% Bait	Bait	Comm.	Total	% Bait
2001	5	280	285	2%	11	167	178	6%
2002	4	188	192	2%	6	95	100	6%
2003	3	133	135	2%	9	128	137	7%
2004	8	177	185	4%	18	136	153	12%
2005	8	161	169	5%	17	163	180	9%
2006	11	170	181	6%	17	150	167	10%
2007	18	124	142	12%	28	95	122	23%
2008	16	75	91	17%	31	80	112	28%

Table 2. Source of the samples from the Magdalen Islands, namely the coastal non-commercial bait fishery (Bait) or the commercial fishery (Comm.). The number of samples is indicated, followed in parentheses by the number of fish examined for length and for stage of sexual maturity.

			Yellowtail Flounder		Winter Flounder	
Year	Type	Number of Samples	Length	Maturity	Length	Maturity
2006	Bait		26 (3,422)	0	34 (3,761)	0
	Comm.		12 (2,756)	12 (258)	7 (1,040)	7 (230)
	Total	**82**	**38 (6,178)**	**12 (258)**	**41 (4,801)**	**7 (230)**
2007	Bait		21 (2,583)	16 (357)	30 (3,673)	23 (825)
	Comm.		41 (5,830)	41 (1,135)	26 (3,185)	26 (840)
	Total	**117**	**62 (8,413)**	**57 (1,492)**	**56 (6,858)**	**49 (1,665)**
2008	Bait		24 (3,289)	24 (643)	25 (2,699)	24 (805)
	Comm.		21 (3,321)	21 (637)	12 (1,287)	12 (362)
	Total	**63**	**45 (6,610)**	**45 (1,280)**	**37 (3,986)**	**36 (1,167)**

Table 3. Description of the appearance of yellowtail and winter flounder gonads in the spring at each of the three stages of sexual maturity.

Stage	Female	Male
1. Immature, juvenile	• Gonad small; light in colour, cream or yellow, wine red in winter flounder • Eggs barely visible and not separated	• Gonad small in very young fish • Little sperm
2. Spawning condition	• Gonad enormous, swollen • Eggs very visible, numerous	• Gonad large • Sperm abundant, very visible
3. Post-spawning	• Gonad like a deflated sac, red in colour • A few eggs visible • Membrane thick	• Gonad small, yellowish-white in colour • Sperm still visible

Table 4. Summary of the results of the logistic regression adjustments for yellowtail flounder.

Year	Sex	$\ln L(m, x_{50\%})$	n_{imm}	n_{mat}	$x_{50\%}$	$x_{50\%}$ (95% C.I.)	m
2006	male	-42.80	40	48	22.76	(21.75 - 23.76)	0.133
2006	female	-82.74	70	96	23.94	(23.11 - 24.76)	0.117
2007	male	-185.20	79	364	16.22	(14.37 - 18.06)	0.066
2007	female	-197.53	105	933	18.07	(17.46 - 18.67)	0.140
2008	male	-111.18	31	396	-	-	-
2008	female	-352.92	144	706	15.77	(13.89 - 17.64)	0.053
2006-2008	male	-397.71	150	808	11.37	(8.12 - 14.61)	0.041
2006-2008	female	-726.02	319	1,735	17.70	(17.02 - 18.38)	0.079

Table 5. Summary of the results of the logistic regression adjustments for winter flounder.

Year	Sex	$\ln L(m, x_{50\%})$	n_{imm}	n_{mat}	$x_{50\%}$	$x_{50\%}$ (95% C.I.)	m
2006	male	-53.22	68	28	29.66	(27.92 - 31.40)	0.090
2006	female	-56.92	56	56	26.77	(25.98 - 27.55)	0.147
2007	male	-246.91	137	541	21.20	(20.52 - 20.89)	0.108
2007	female	-269.47	204	603	23.26	(22.88 - 23.65)	0.157
2008	male	-171.12	81	370	19.01	(17.63 - 20.38)	0.073
2008	female	-228.47	195	365	24.57	(24.07 - 25.06)	0.132
2006-2008	male	-563.51	286	939	20.66	(19.92 - 21.41)	0.072
2006-2008	female	-593.57	455	1,024	23.96	(23.65 - 24.26)	0.134

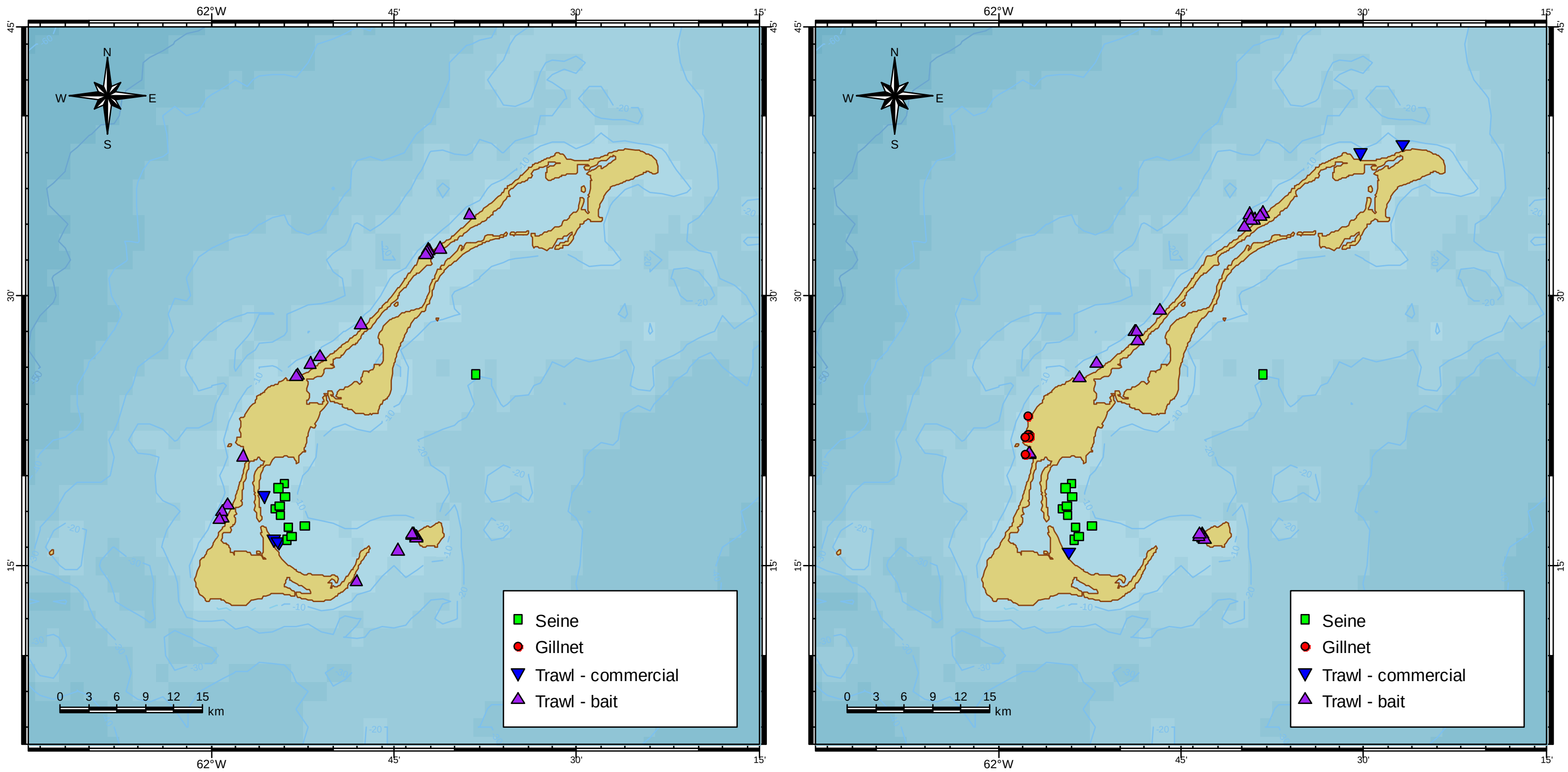

Figure 1. Spatial distribution of the catches sampled for length by type of fishing gear for yellowtail flounder (left) and winter flounder (right) around the Magdalen Islands in 2006.

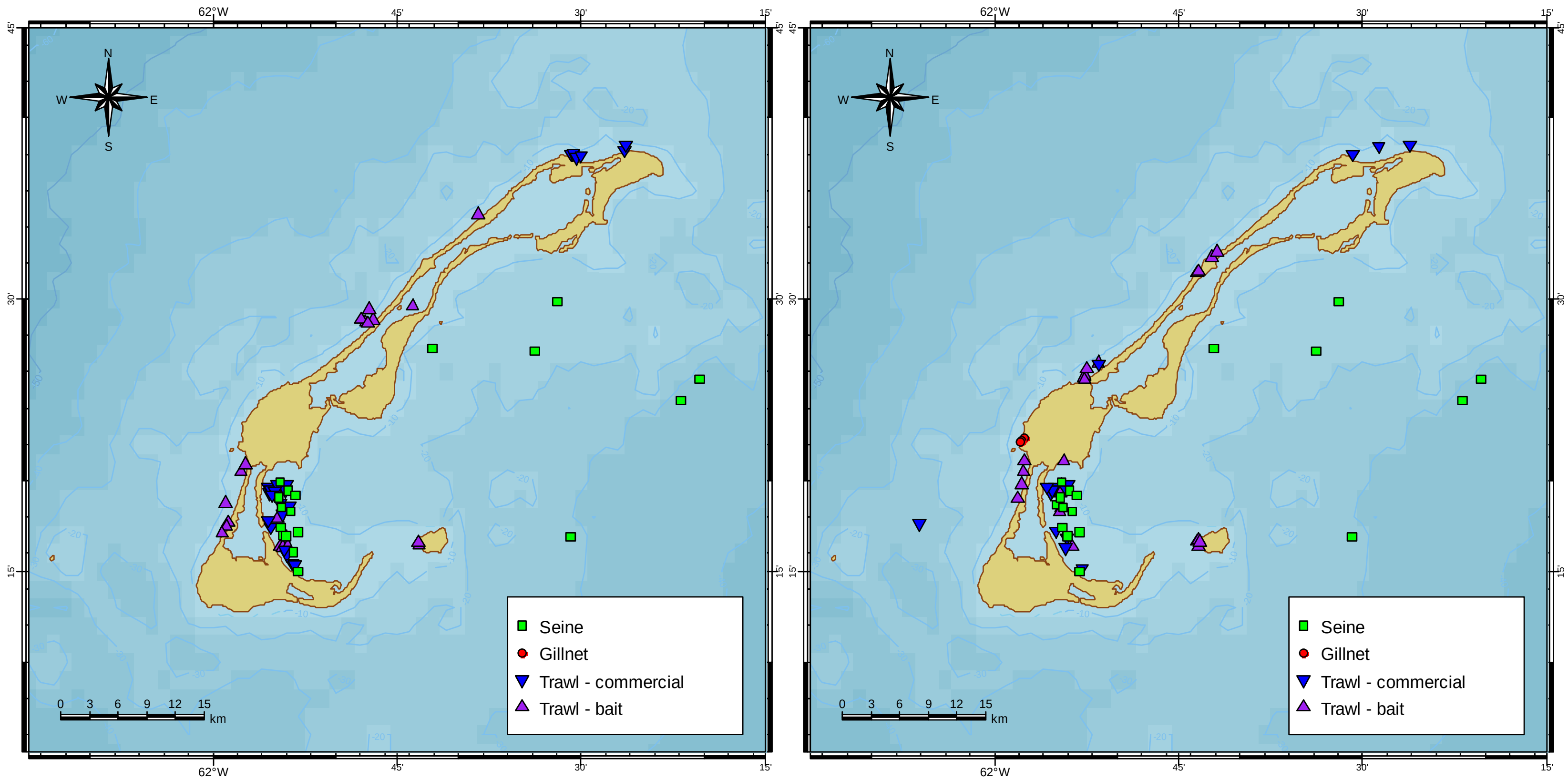

Figure 2. Spatial distribution of the catches sampled for length by type of fishing gear for yellowtail flounder (left) and winter flounder (right) around the Magdalen Islands in 2007.

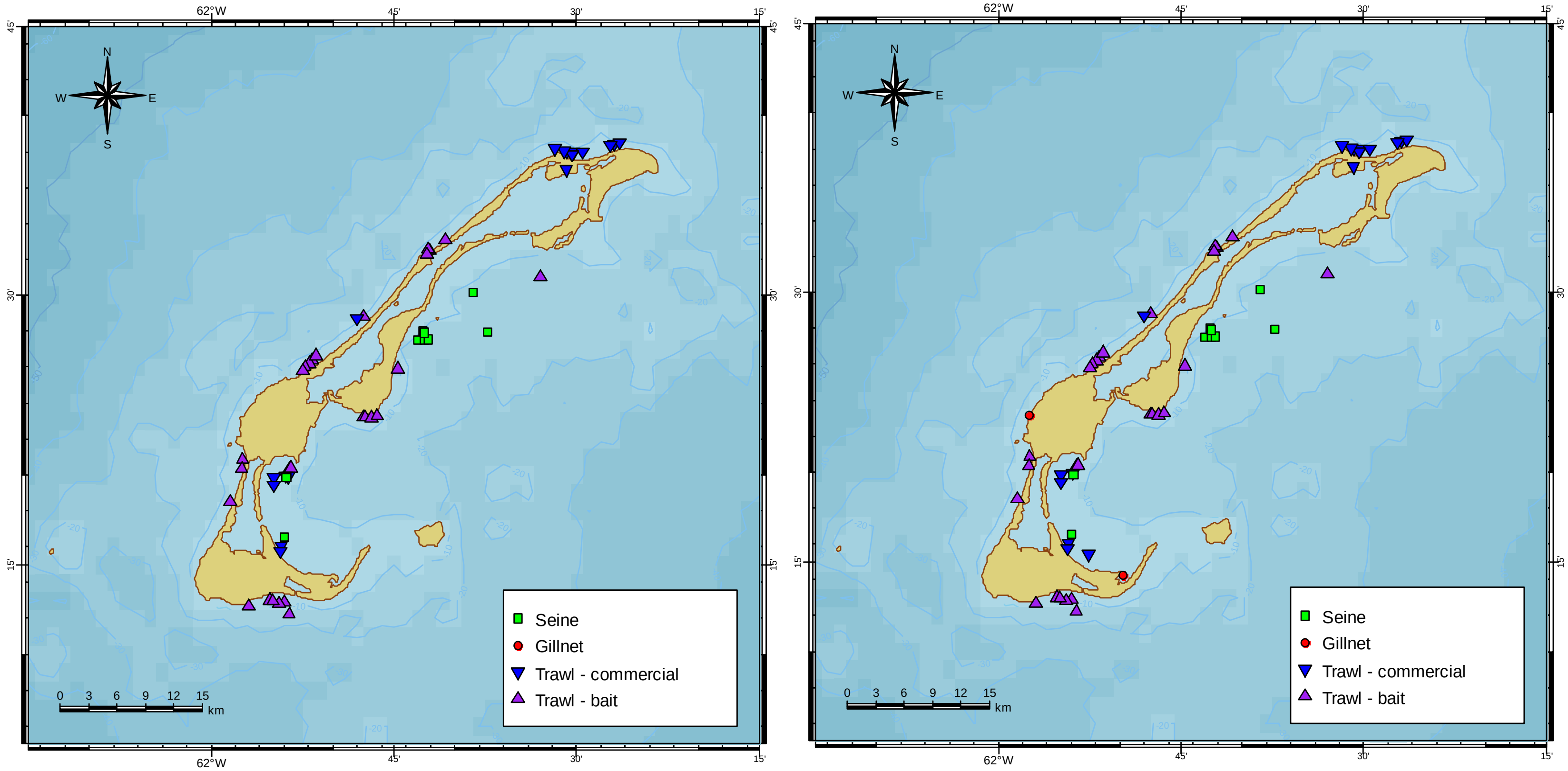

Figure 3. Spatial distribution of the catches sampled for length by type of fishing gear for yellowtail flounder (left) and winter flounder (right) around the Magdalen Islands in 2008.

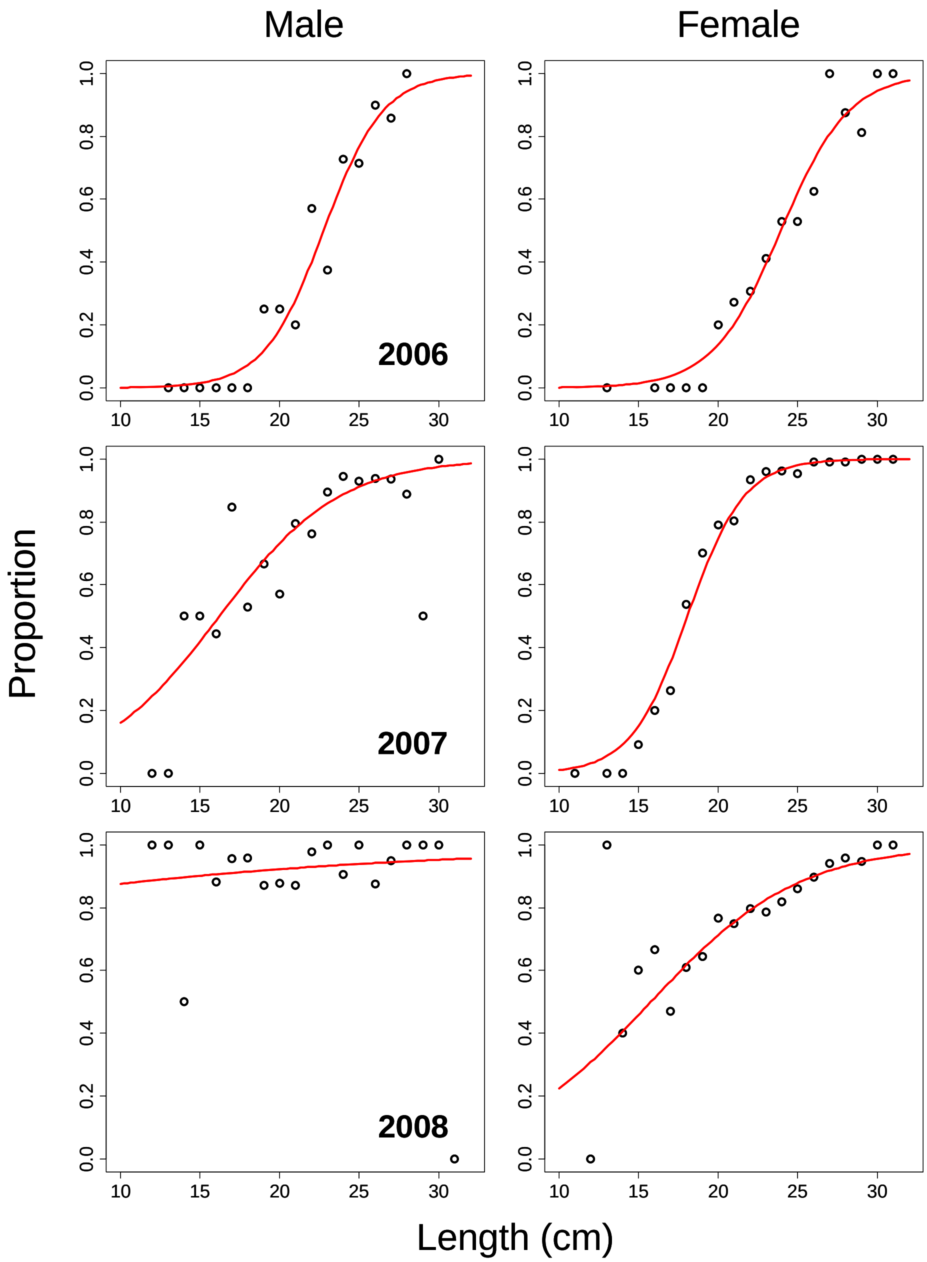

Figure 4. Average logistic curves of the proportions of mature yellowtail flounders in the males (left) and females (right) for 2006 (top), 2007 (middle) and 2008 (bottom). The points are the empirical proportions estimated from the data.

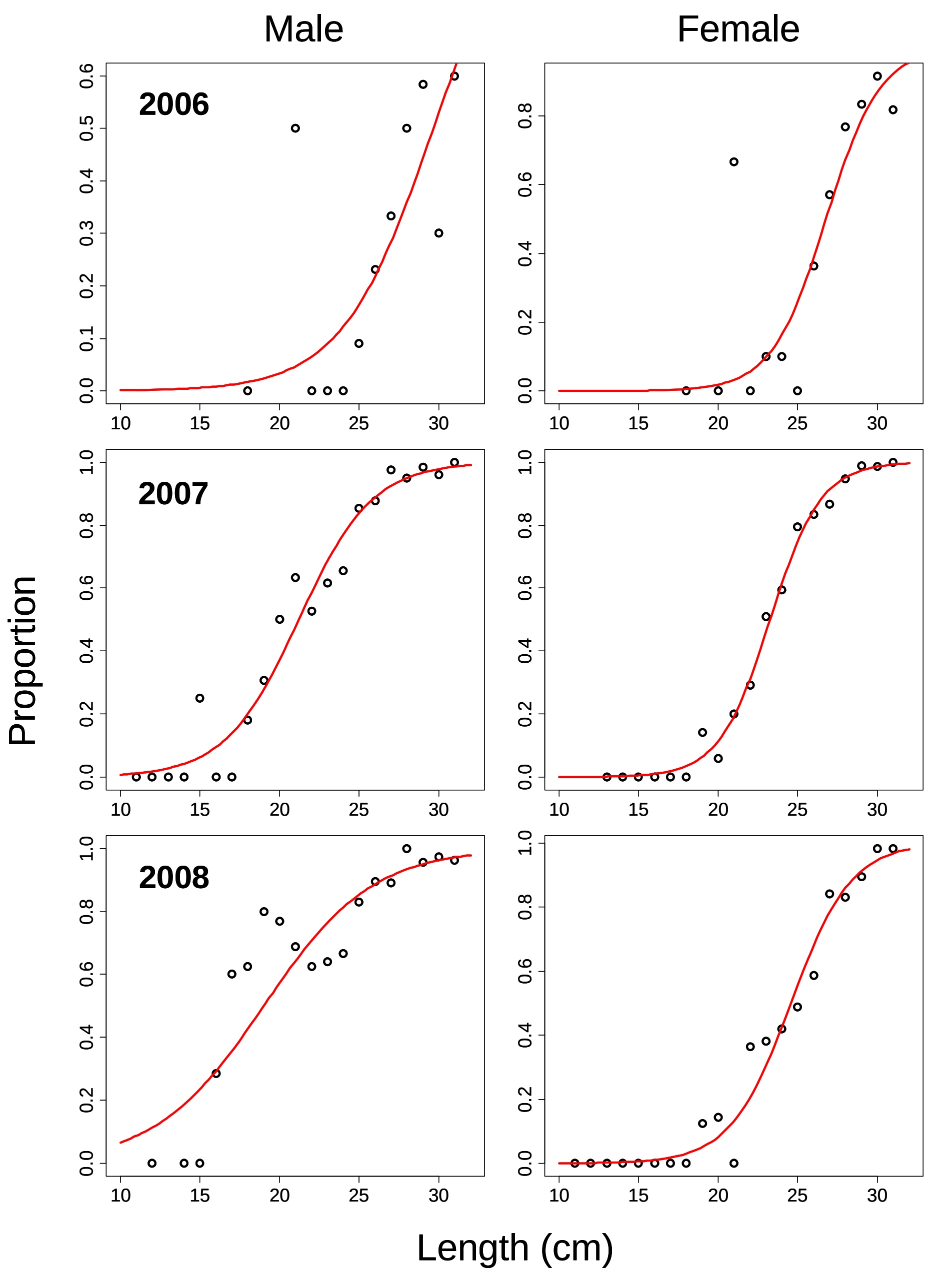

Figure 5. Average logistic curves of the proportions of mature winter flounders in the males (left) and females (right) for 2006 (top), 2007 (middle) and 2008 (bottom). The points are the empirical proportions estimated from the data.

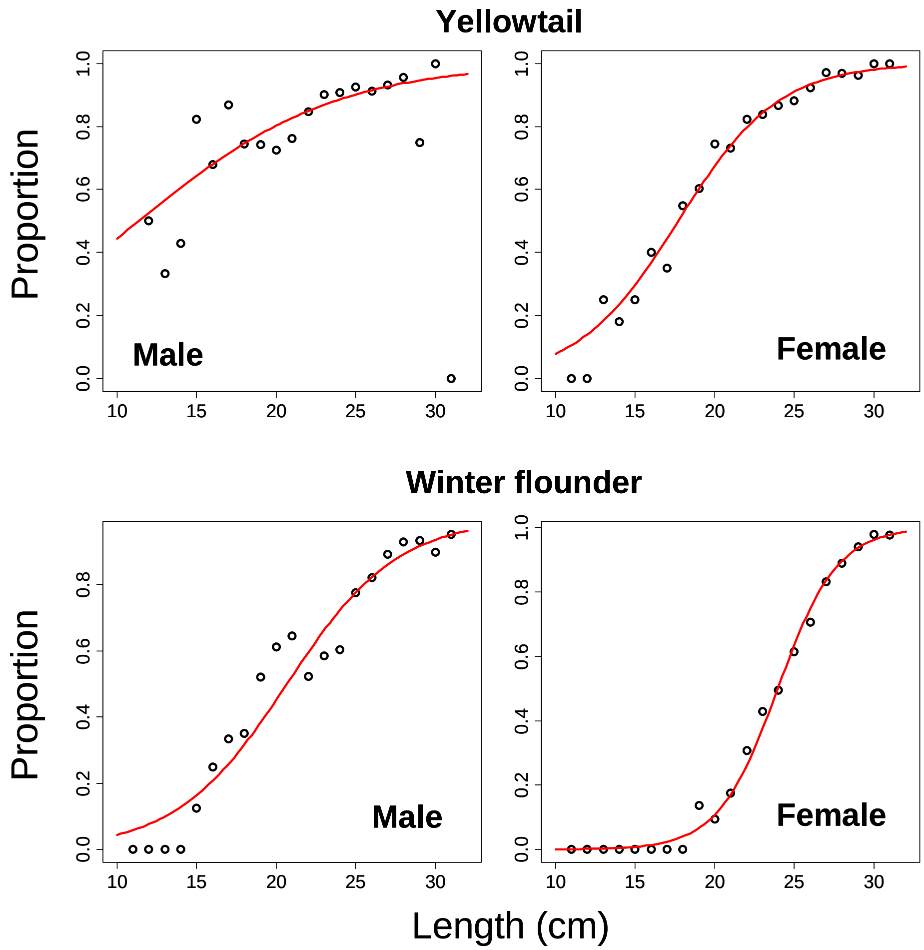

Figure 6. Average logistic curves of the proportions of mature fish in yellowtail flounder (top) and winter flounder (bottom) for males (left) and females (right) using combined data from 2006 to 2008. The points are the empirical proportions estimated from the data.

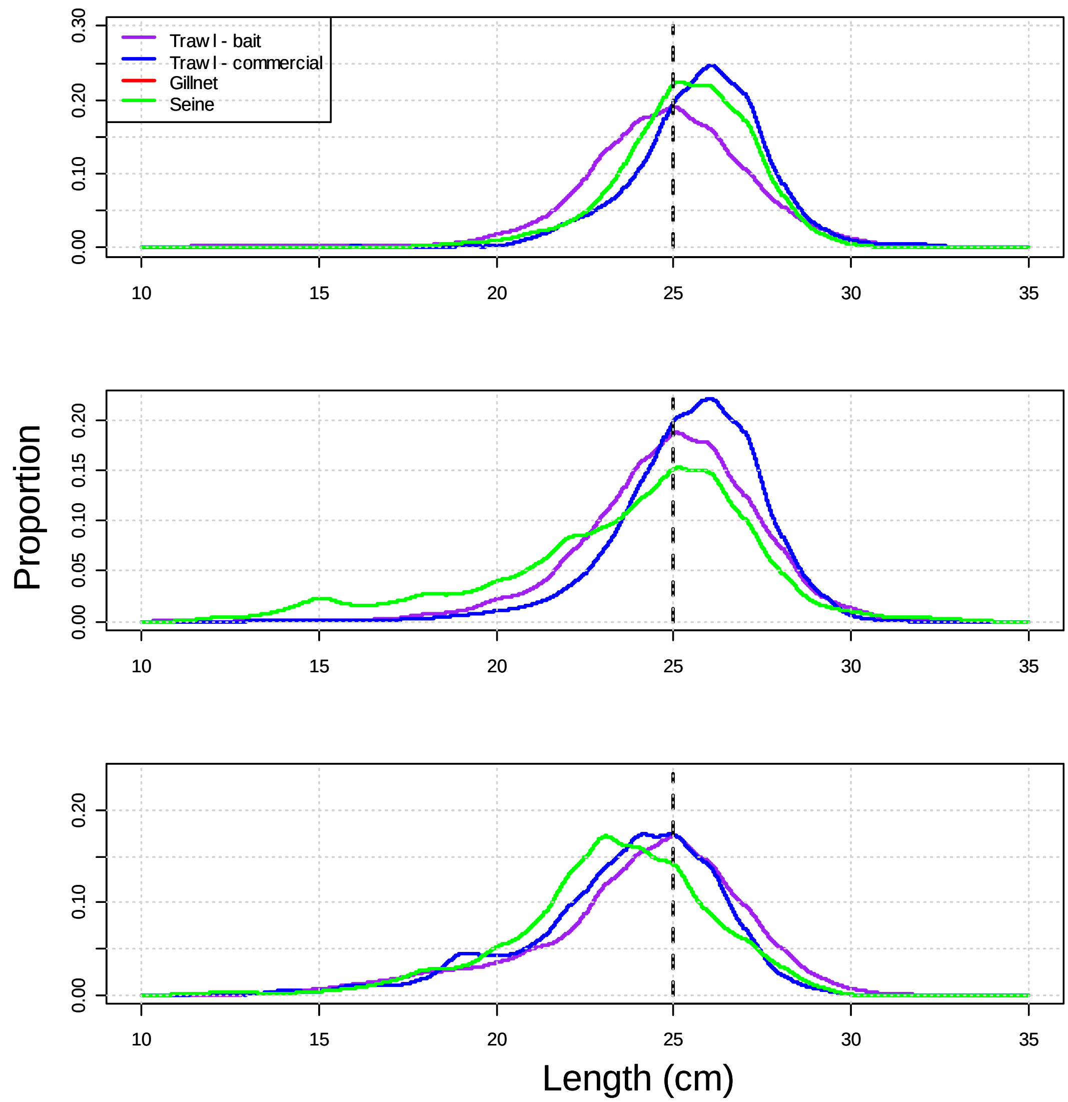

Figure 7. Distributions of proportion relative to length for yellowtail flounder according to type of fishing gear for 2006 (top), 2007 (middle) and 2008 (bottom). The curves were smoothed non-parametrically.

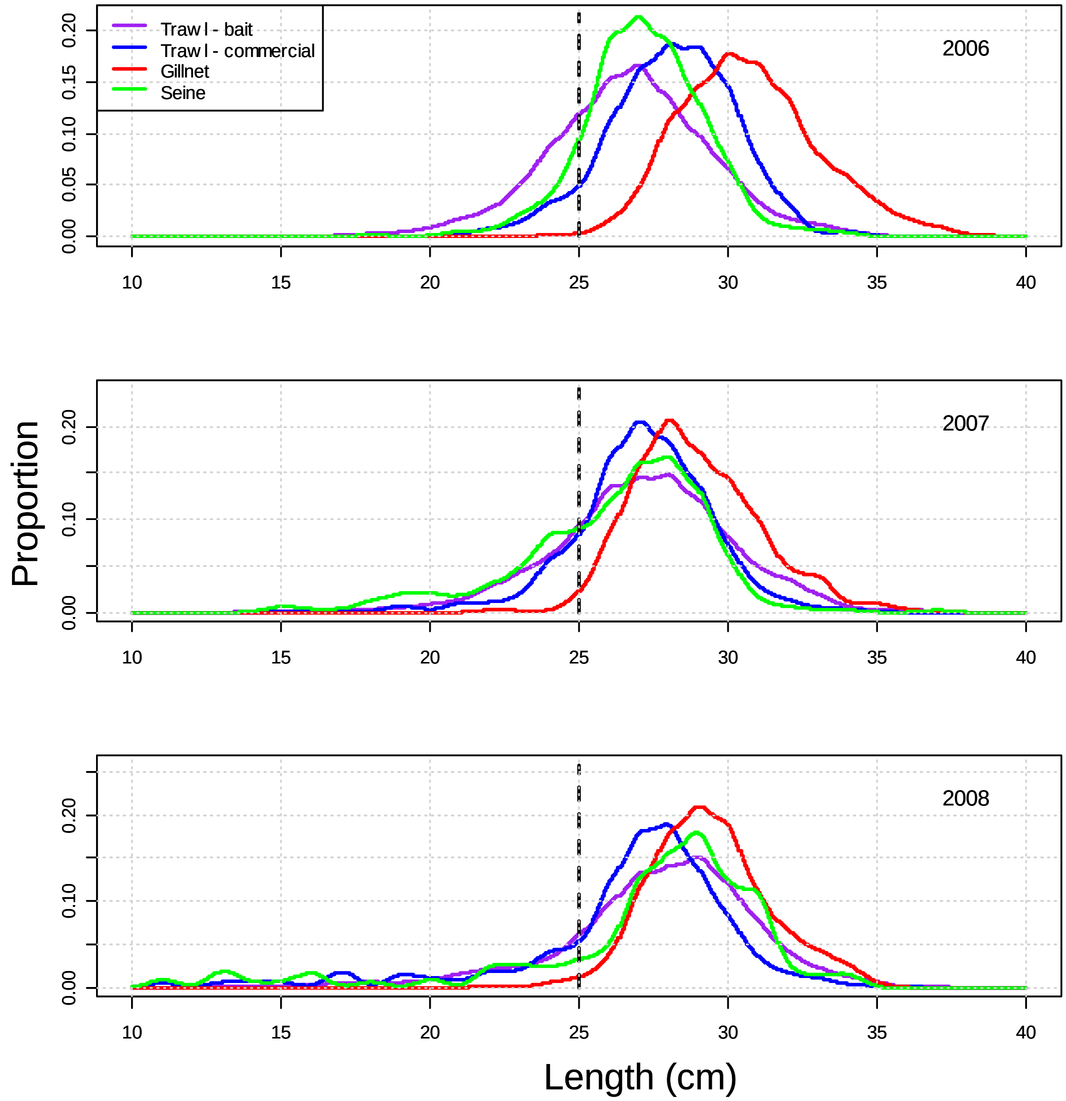

Figure 8. Distributions of proportion relative to length for winter flounder according to type of fishing gear for 2006 (top), 2007 (middle) and 2008 (bottom). The curves were smoothed non-parametrically.

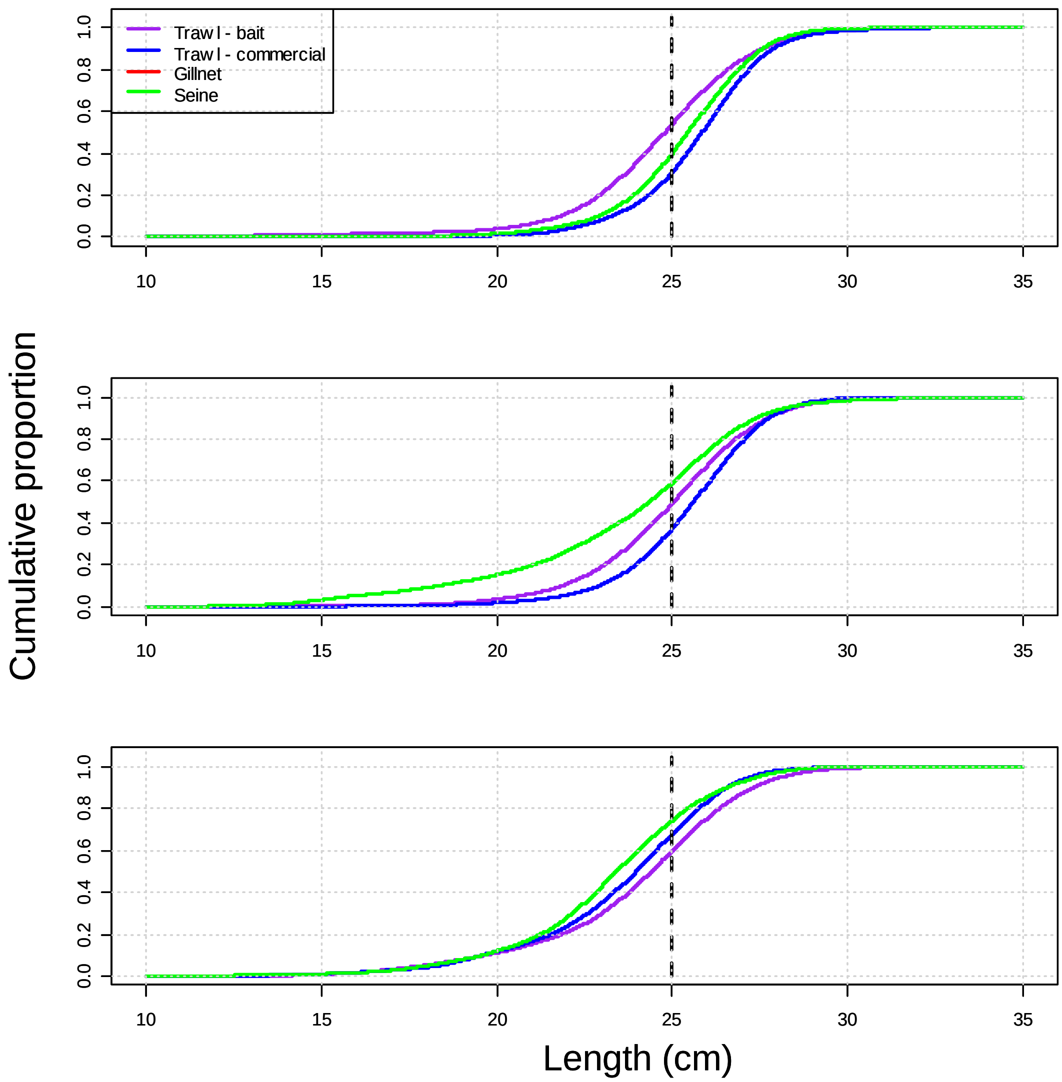

Figure 9. Cumulative size frequency distributions for yellowtail flounder according to type of fishing gear for 2006 (top), 2007 (middle) and 2008 (bottom). The curves were smoothed non-parametrically.

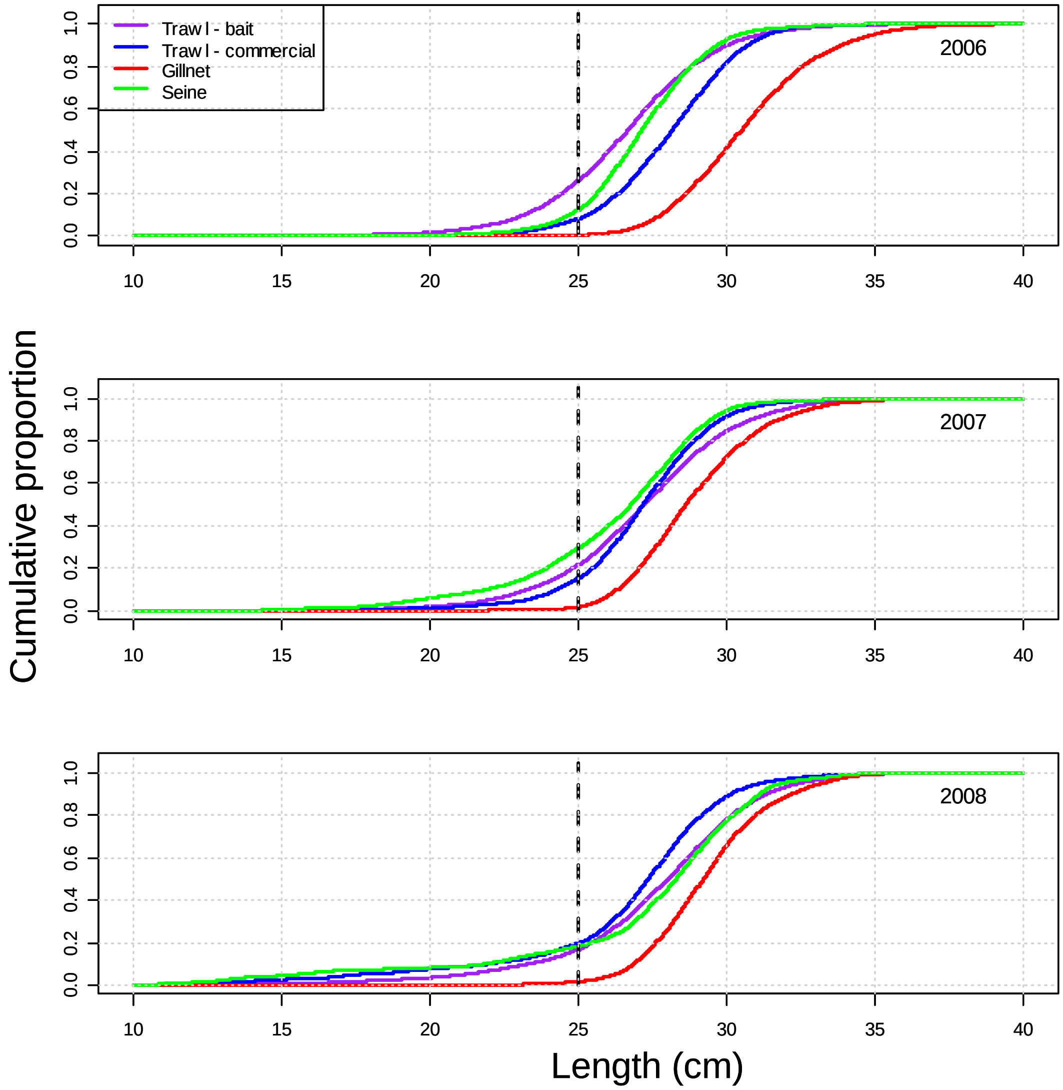

Figure 10. Cumulative size frequency distributions for winter flounder according to type of fishing gear for 2006 (top), 2007 (middle) and 2008 (bottom). The curves were smoothed non-parametrically.

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