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Selectivity in Shrimp Trawl

by

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ABSTRACT

The selectivity of a 43 mm shrimp trawl is described by comparing catches to an alternating 18 mm mesh size. A total of 44 hauls were made with four different haul durations (0.5, 1, 2 and 4 hours). The selectivity factor was found to be 0.36, and not dependent on haul duration.

INTRODUCTION

Shrimp (Pandalus borealis) in Greenland waters has since 1988 been surveyed each year in July in areas where commercial shrimp fishery are practiced. The results are presented to NAFO Scientific Council as "Swept-Area" biomass estimates. The interpretation of these swept area estimates is strongly influenced by the selectivity of the trawl as only shrimp above some minimum size are present in the catches.

This paper presents an estimate of the selectivity of the survey trawl and investigates this selectivity as a function of haul duration.

DATA AND MATERIAL

44 hauls were made between the 31th of August to the 10th of September 1990, by the shrimp trawler "Qavaq" in a fishing area located between 71°04' N, 71°05' N, 53°37' W and 56°16' W (NAFO 1A) west of Uummannak fjord in West Greenland (fig.1). The gear was a 1800 meshes "BASTARD" trawl and the codend was altered every second day between using 43 mm and 18 mm mesh sizes. The trawling speed was approximately 2 knots. The fishing depth was about 400 m. Four different hauls were applied: 0.5 hr, 1 hr, 2 hrs and 4 hrs in order to investigate the influence of haul duration on selectivity of the gear.

To avoid bias caused by a possible length dependent vertical migration of the shrimps, the fishing period were restricted to between 7 am. and 5 pm. Hauls of each duration were scattered throughout the whole fishing period. The haul schedule for one day using 43 mm mesh in codend was repeated the next day using 18 mm mesh size in codend. The haul schedule and the number of hauls of each duration are shown in table 1 and 2.

The catch was sampled directly from the codend. A sample was approximately 4 kg (about 500 individuals). Carapace length of all shrimp were measured with 0.1 mm accuracy using a sliding gauge connected to a computer.

The total catch of shrimps per haul was assessed by counting the number of frozen shrimp blocks reaching the freezer. To this count was then applied the average fresh weight of the shrimps in one block as obtained by a separate sampling.

THE SELECTIVITY MODEL AND PARAMETER ESTIMATION

The selectivity is described by a logistic function, (Sparre et al. 1989):

$$R_L = \frac{N_{43,L/N43}}{N_{18,L/N18}} = \frac{1}{1 + EXP(-S*(L - L_{50}))}$$

where R_L is the retention (= the probability that a shrimp of length L, if caught in the 18 mm codend, is also retained in the 43 mm codend). ($1-R_L$ = the probability that a shrimp of length class L is only retained in the 18 mm codend and not in the 43 mm codend)). $N_{43,L}$ and $N_{18,L}$ are the number of shrimps of length L caught in the 43 mm and 18 mm mesh size in codend respectively. S determines the slope at the inflexion point and L_{50} is the length at which 50% of the shrimps retained in the 18 mm codend are retained in the 43 mm codend too.

A logistic function define a symmetric curve around the L_{50}. The selectivity function is not always symmetric, but a symmetrical curve is usually a reasonable approximation (Pauly 1984).

The catch was pooled in 0.5 mm classes for each gear and each haul duration resulting in 8 length distributions.

S and L_{50} were estimated by using non-linear regression.

In a few cases outliers were removed in order to obtain a satisfactory fit. These outliers were in all cases based on no more than two observations and are found in either the very small size length groups or among the large shrimp.

Table 2 shows, for each duration of haul, the average catch per haul of shrimps and by-catch, the average CPUE (kg/h) for shrimps and by-catch and the average carapace length of the shrimps together with the variance of these averages. The average CPUE's are 147.3 kg shrimp/hr (std.err. = 21.7 kg/hr) for 18 mm mesh size and 128.7 kg shrimp/hr (std.err. = 14.1 kg/hr) for 43 mm mesh size.

The estimation is done by non linear least square fit applied to the model as specified above.

RESULTS

Fig.2 to 5 show the observed retention points R_L together with the fitted selectivity curves. Fig.2 gives the results for the 0.5 hr duration hauls, Fig.3 for 1 hr, fig.4 for 2 hr and fig. 5 for 4 hr. Further fig. 2 to 5 give the estimated parameter values and the corresponding analysis of variance. The estimated selection parameters are given in table 3 together with L_{25}, L_{75} and the selection range. The selection range ($L_{75} - L_{25}$) is calculated as: Selection range = 2 * ln 3/S (Sparre et al. 1989). The average selection factor for <u>Pandalus borealis</u> (S.F. = L_{50}/mesh size) is calculated to be: 0.356 (std. dev. $9.778*10^{-4}$). Fig. 8 shows the four selectivity curves for each haul duration plotted together.

The duration of the haul do not seem to have any influence on the L_{50} i.e. the selectivity factor. To test whether the selection range changes with the haul duration two models were fitted.

A change in the selection range is equivalent to a change in the S parameter. The first model is a simple one with no effect of the haul duration (model 1) while the second model (model 2) allows a separate slope for each haul duration to be fitted.
Only data in the selection range from L_{25} to L_{75} were included in the analysis. The relationship between retention and length is close to being linear in the selection range and the problem is therefore reduced to comparing several slopes in a linear regression model. A F-test testing whether the complicated model 2 has any merit over model 1 is

$$F_{P2-P1,n-P2} = \frac{(S_1^2 - S_2^2)/(P2-P1)}{S_2^2/(n-P2)}$$

where P1 = number of parameters estimated in the simple model, P2 = number of parameters estimated in the complicated model, n = number of observations, S_1^2 = Sum of squares for the error term in the simple model and S_2^2 = Sum of squares for the error term in the complicated model. This gives:

$$F_{3,19} = \frac{(0.959282 - 0.915442)/(5-2)}{0.915442/(19-5)} = 0.22$$

This shows that the simple model 1 accounts just as well for the observations as do the more complicated model 2. By Occam's razor the simple model 1 should be chosen as working hypotese for the time being. Inspection of the estimated parameters, table 3, shows that there is obviously no difference between 0.5 hr and 1.0 hr, while for 2 hr and 4 hr duration the estimated selection range is significantly smaller (S is larger) than for shorter hauls. However these ranges are very poorly estimated. Fig.6 shows the four fitted selection ogives.

The total catch (including by-catch) for 18 mm and 43 mm codend mesh size respectively is plotted vs. the haul duration in fig. 7 and fig. 8 respectively. A correlation (Corr. coeff.= 0.856 and 0.691 for 18 mm and 43 mm. codend mesh sizes) is apparent.

DISCUSSION AND CONCLUSION.

Fishing was restricted to a rather narrow area (51.6 nm^2) in which the depth is almost the same (= 400 m +/- 50 m) to ensure that all hauls were made on the same shrimp length distribution (= same population). The average carapace length of shrimps varies very little with hauls duration and mesh size (table 2). Shrimps are inhomogeneous distributed in the area, as the variance of the catch of shrimps is big. The effect of this inhomogeneity was eliminated by distributing the hauls randomly in the area.

Mean CPUE of shrimp do not seem to vary with haul duration (table 2), although the figures here suffer of big variances as well. Using the 43 mm mesh size in codend instead of 18 mm only lower the total catch of shrimps with 13 %.

The average selection factor was estimated to be 0.356, which is in agreement with what Waldemarsen and Makalsen (1991) found (0.357 using 35 mm and 14 mm diamond mesh sizes).

L_{50} is found to be around 15.5 mm stretched independent of haul duration. Christensen and Lassen (1989) found, based on a very limited data material, 12.5 mm for the same mesh size. This observation were based on a significantly larger trawl (Skjervoy 3300) than that used in this study.

L_{50} is found to be almost constant with increased haul duration. This is surprising, as it is normal accepted (Sparre et al. 1989) that the meshes in the codend block with increasing catch and hence with increased haul duration, fig. 7 and fig. 8. Such blocking would cause the L_{50} to decrease with increased haul duration. The catch accumulates in the very back part of the codend, causing an enlargement of the circumference of that part of the codend. This open the meshes in this part and in the area just in front of the catch bolus. Opening up the meshes will cause an increased water flow to the area just in front of the catch bolus, making this area in the codend the most prominent area for the selection process and in the same time allow bigger shrimps to escape. This may counteract the increased blocking of the meshes resulting in a more or less stable L_{50} independent of haul duration (and catch).

The selection ogive becomes more knife-edged as haul duration increases (fig.6). This could be a side effect of the opening up of the meshes in the area in front of the catch bolus. As long as the meshes are prolonged a certain amount of smaller shrimps will be retained by the net if they are caught in a position crosswise to the length axis of the mesh. As the meshes become more and more quadratic the mesh openings will be selecting more and more precise as the selected size will become more or less independent of the orientation of the shrimp. This could result in a knife-edged selection curve as observed in the present data material.

REFERENCES

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Pauly, D. (1984). Fish population dynamics in tropical waters. A manual for use with programmable calculators. ICLARM. Studies and reviews 8. 325 p.

Sparre, P.; Ursin, E.; Venema, S.C. (1989). Introduction to tropical fish stock assessment. Part 1. Manual. FAO Fisheries Technical Paper. No. 306.1. Rome, FAO. 337 p.

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DATE	31/8	1/9	2/9	5/9	4/9	6/9	7/9	8/9	9/9	10/9
MESH SIZE	40	18	40	18	40	18	40	18	40	18
TIME	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
7⁰⁰	$	$	$	$	*	*	%	%	#	#
	$	$	$	$	*	*	%	%	#	#
	$	$	$	$	*	*	%	%	#	#
8⁰⁰	$	$	$	$	*	*	%	%	#	#
	$	$	$	$	*	*	%	%	#	#
	#	#	#	#	*	*	%	%	#	#
9⁰⁰	#	#	#	#	*	*	%	%	#	#
	#	#	#	#	*	*	%	%	$	$
	#	#	#	#	*	*	%	%	$	$
10⁰⁰	#	#	#	#	*	*	%	%	$	$
	#	#	#	#	$	$	%	%	$	$
	%	%	*	*	$	$	%	%	#	#
11⁰⁰	%	%	*	*	$	$	%	%	#	#
	%	%	*	*	$	$	%	%	#	#
	%	%	*	*	#	#	%	%	#	#
12⁰⁰	%	%	*	*	#	#	%	%	#	#
	%	%	*	*	#	#	$	$	#	#
	%	%	*	*	#	#	$	$	%	%
13⁰⁰	%	%	*	*	#	#	$	$	%	%
	%	%	*	*	#	#	$	$	%	%
	%	%	#	#	#	#	$	$	%	%
14⁰⁰	%	%	#	#	#	#	$	$	%	%
	%	%	#	#	#	#	$	$	%	%
	%	%	#	#	#	#	$	$	%	%
15⁰⁰	%	%	#	#	#	#	$	$	%	%
	%	%	#	#	#	#	*	*	%	%
	#	#	$	$	$	$	*	*	%	%
16⁰⁰	#	#	$	$	$	$	*	*	%	%
	#	#	$	$	$	$	*	*	%	%
	#	#	$	$	$	$	*	*	%	%
17⁰⁰	#	#	$	$	$	$	*	*	%	%
	#	#					*	*	%	%
							*	*		
18⁰⁰							*	*		

Table 1. Haul schedule. $ = 0.5 hour haul. # = 1.0 hour haul. * = 2 hours haul. % = 4 hours haul. Totaly one hour for setting and hauling are included in the indications.

Haul. dura.	Mesh size	Numb. of hauls	SHRIMPS						BYCATCH			
			Catch /haul		CPUE		Carapace mean lgth		Catch /haul		CPUE	
Hours	mm		Kg	VAR	Kg/h	VAR	mm	VAR	Kg	VAR	Kg/h	VAR
0.5	18	8	68.1	4212.1	136.3	16848.5	23.0	0.61	14.8	44.6	29.6	178.3
	43	8	65.6	980.4	131.1	3921.6	23.3	0.67	35.9	930.6	71.9	3722.4
1.0	18	8	157.5	8850.0	157.5	8850.0	23.3	0.53	56.4	2509.6	56.4	2509.6
	43	8	157.5	11307.1	157.5	11307.1	23.5	0.57	47.8	384.2	47.8	384.2
2.0	18	3	260.0	22800.0	130.0	5700.0	23.7	0.14	192.4	4491.3	96.2	1122.8
	43	3	240.0	24300.0	120.0	6075.0	24.0	0.89	60.1	819.8	30.1	205.0
4.0	18	3	666.7	173333.	166.7	10833.3	23.9	1.36	324.7	41674.2	812.0	2604.6
	43	3	425.0	58125.0	106.3	3632.8	23.3	0.64	190.3	65044.0	47.6	4065.3

Table 2. The number of hauls, catchweight, catch per unith effort and carapace meanweight for shrimp and bycatch for each haul.length and meshsize.

Haul duration	L_{50}	s	L_{25}	L_{75}	Selection range
Hours	mm		mm	mm	mm
0.5	15.33	0.5567	13.36	17.31	3.95
1.0	15.28	0.5550	13.30	17.26	3.96
2.0	15.37	2.4904	14.94	15.82	0.88
4.0	15.31	5.5443	15.11	15.51	0.40

Table 3. The selection parameters estimated by non-liniar regression.

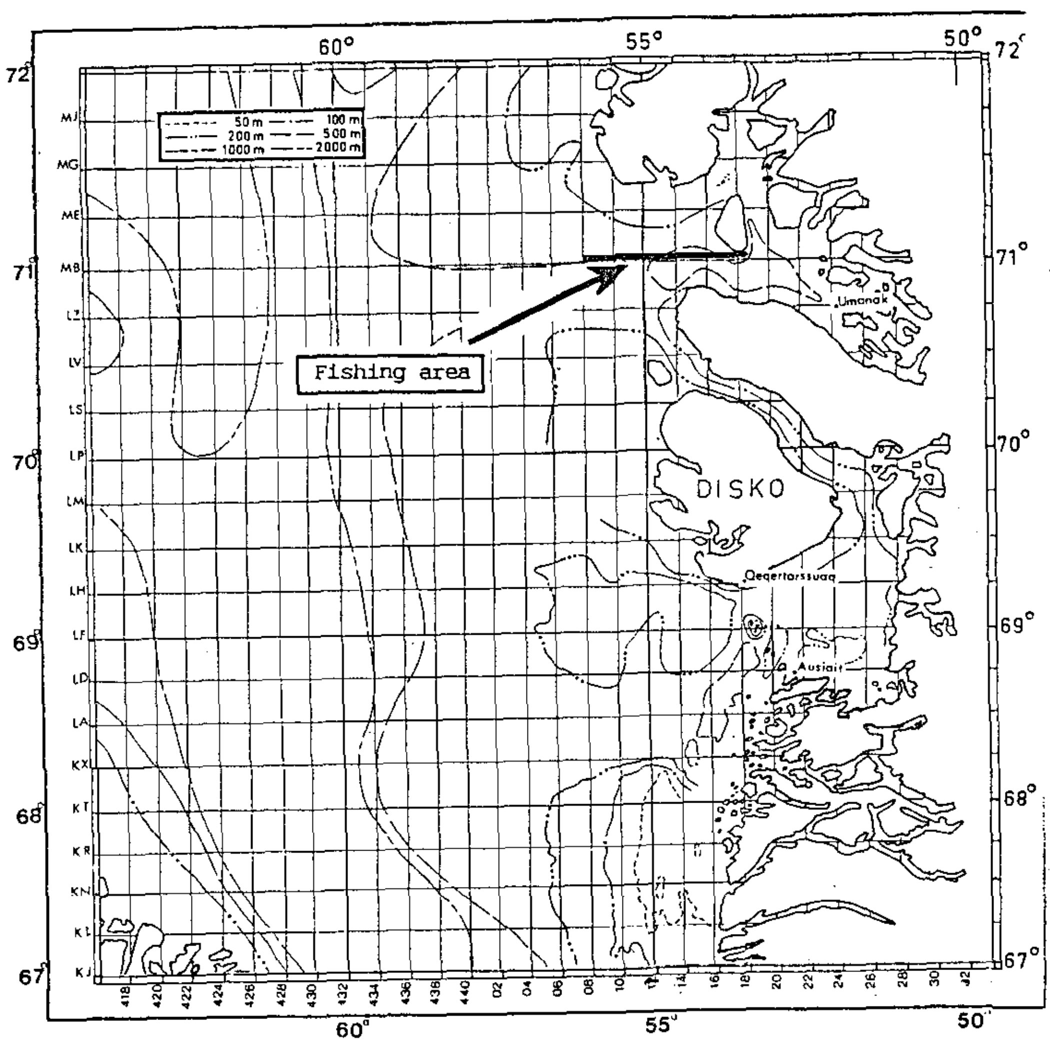
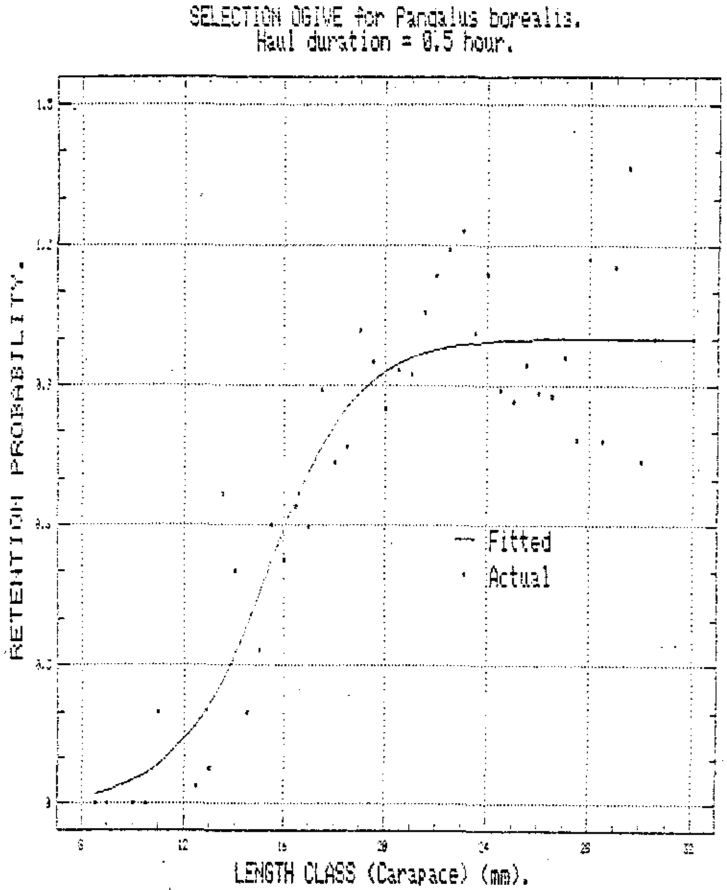


Figure 1. Fishing area. The area is aproximately 51 nm^2 with an average depth of 400 m.



Model Fitting Results

	estimate	stnd.error	ratio
Coefficient 1	-.5566724	.10591340	-5.2559
Coefficient 2	15.3341366	.36084574	42.4950

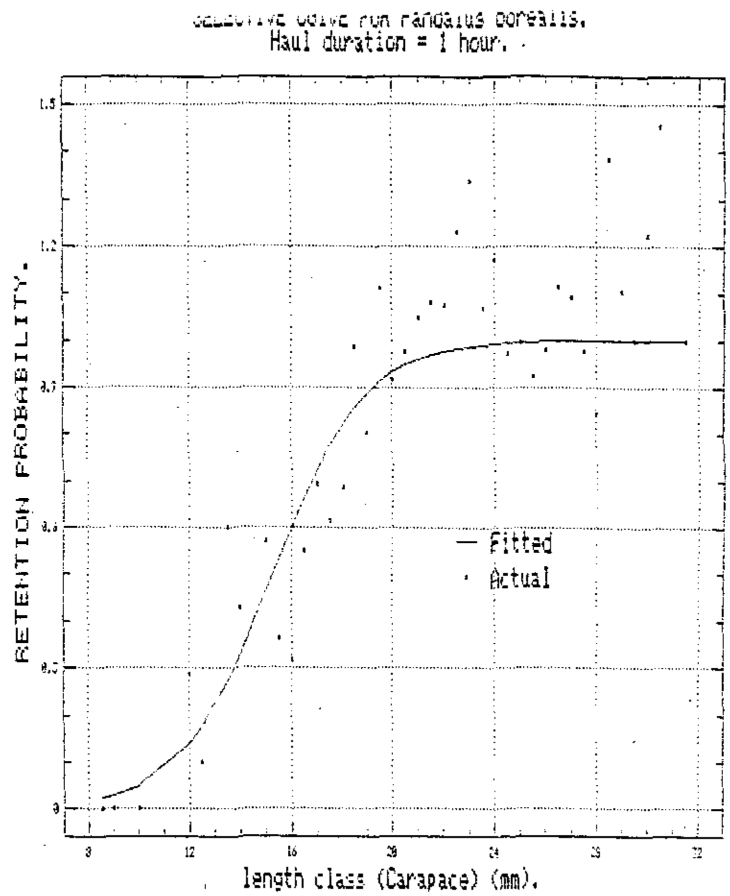
Total iterations = 4 Total function evaluations = 15

Analysis of Variance for the Full Regression

source	sum of squares	df	mean square	ratio
Model	28.51564	2	14.25782	620.10456
Error	.942697	41	.022993	
Total	29.458332	43		
Total (corr.)	6.235421	42		

R-squared = 0.848816

Figure 2. Selection ogive for Pandalus borealis for a haul duration of 0.5 hour.



Model Fitting Results	estimate	stnd.error	ratio
Coefficient 1	-.5549680	.12893139	-4.3045
Coefficient 2	15.2772392	.44918670	34.0109

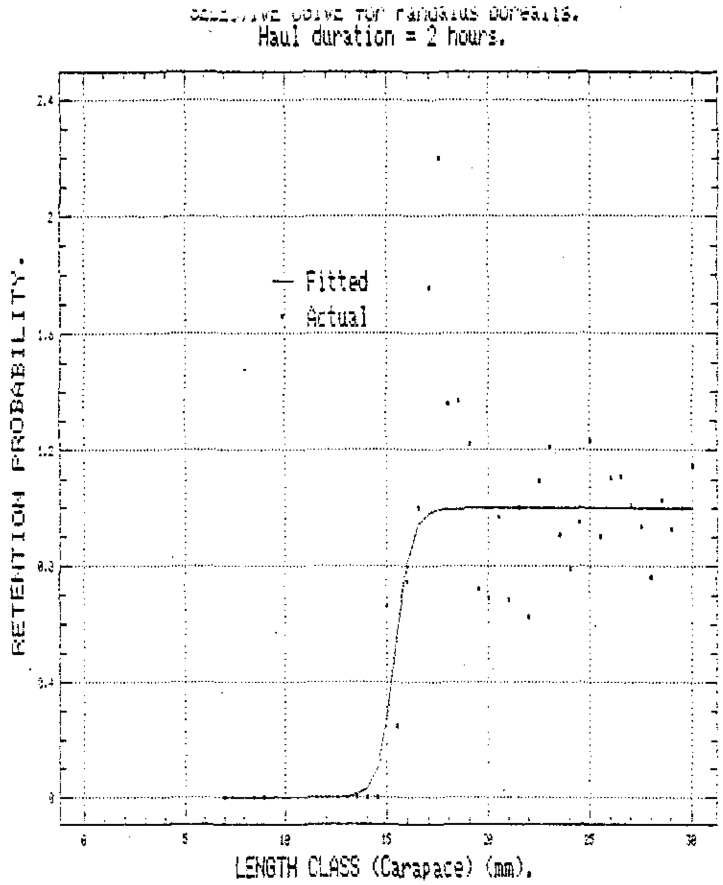
Total iterations = 5 Total function evaluations = 19

Analysis of Variance for the Full Regression

source	sum of squares	df	mean square	ratio
Model	32.17579	2	16.08790	550.35584
Error	1.110809	38	.029232	
Total	33.286601	40		
Total (corr.)	5.945651	39		

R-squared = 0.813179

Figure 3. Selection ogive for Pandalus borealis for a haul duration of 1.0 hour.



Model Fitting Results

	estimate	stnd.error	ratio
Coefficient 1	-2.4904080	1.75889759	-1.4159
Coefficient 2	15.3764897	.32146236	47.8329

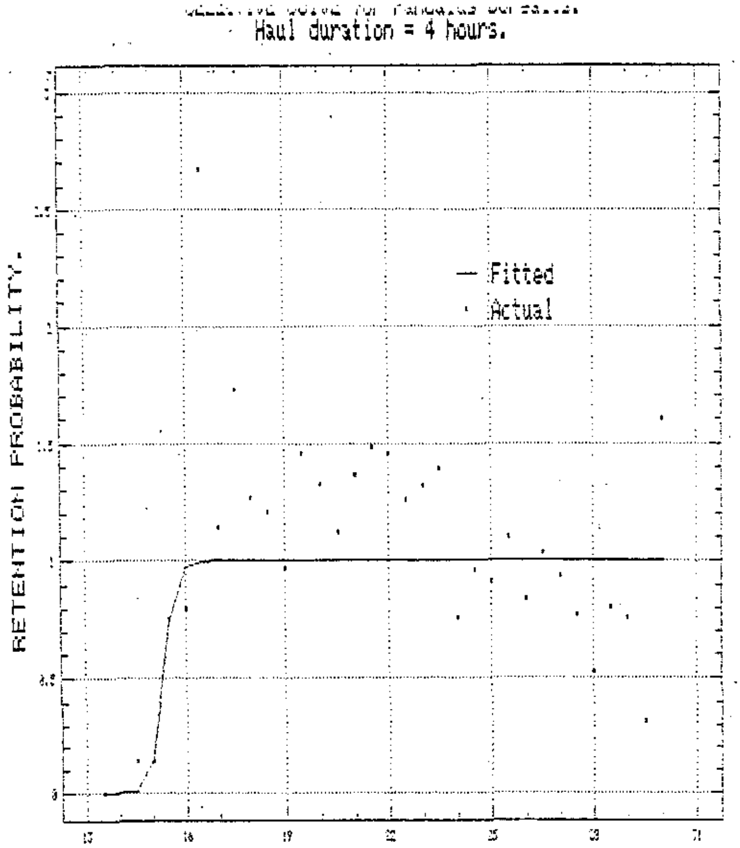
Total iterations = 8 Total function evaluations = 33

Analysis of Variance for the Full Regression

source	sum of squares	df	mean square	ratio
Model	32.17779	2	16.08889	189.23349
Error	3.315834	39	.085021	
Total	35.493622	41		
Total (corr.)	11.479107	40		

R-squared = 0.711142

Figur 4. Selection ogive for Pandalus borealis for a haul duration of 2.0 hours.



Model Fitting Results			
	estimate	stnd.error	ratio
Coefficient 1	-5.5443080	8.25677758	-.6715
Coefficient 2	15.3079133	.34465969	44.4146

Total iterations = 5 Total function evaluations = 16

Analysis of Variance for the Full Regression				
source	sum of squares	df	mean square	ratio
Model	38.194623	2	19.097311	98.028805
Error	6.039211	31	.194813	
Total	44.233834	33		
Total (corr.)	8.502810	32		

R-squared = 0.289739

Figure 5. Selection ogive for Pandalus borealis for a haul duration of 4.0 hours.

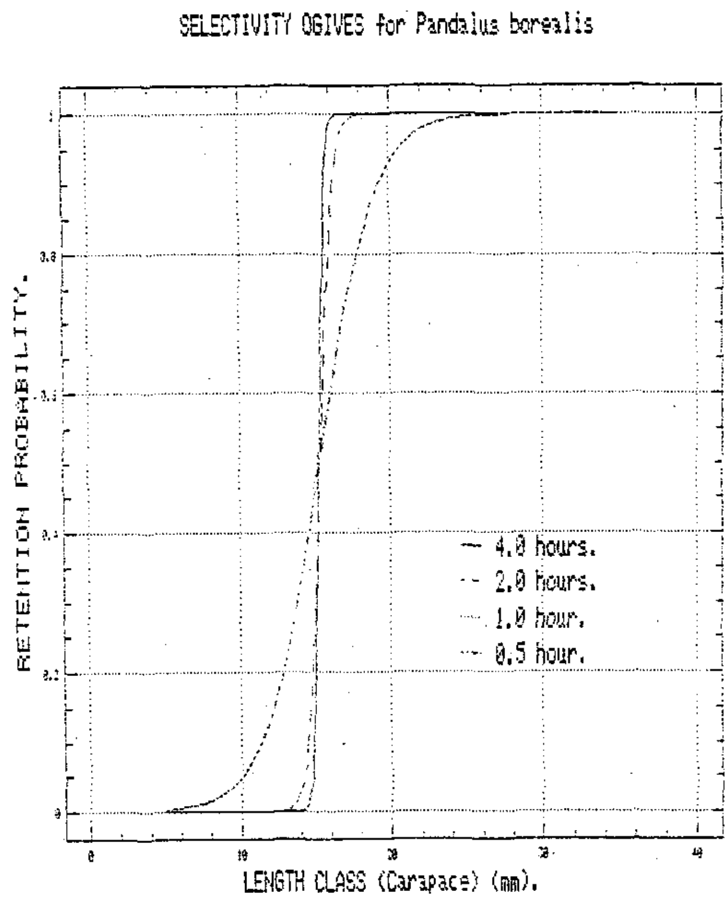
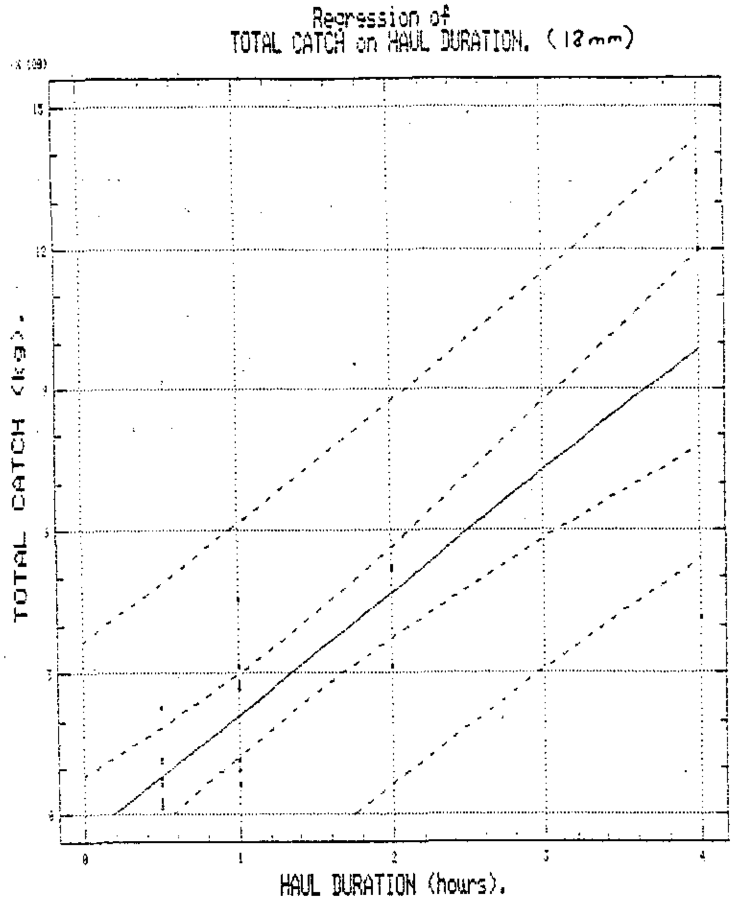


Figure6. Selection ogive for all haul durations. The ogives for 0.5 and 1.0 hour haul duration are identical.



Regression Analysis - Linear model: Y = a+bX

Dependent variable: catchtot   Independent variable: albtid

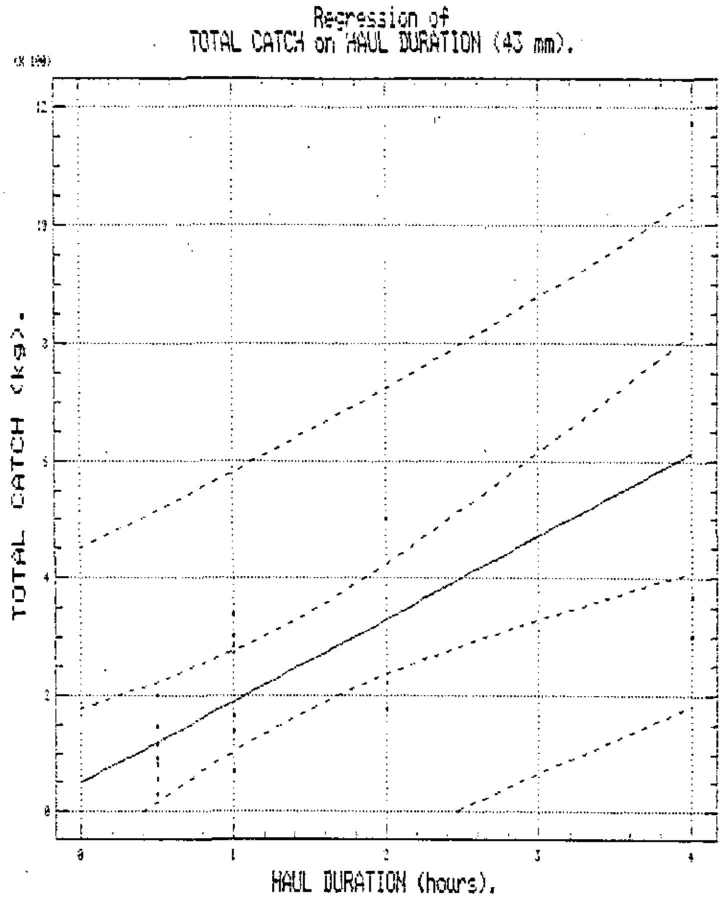
Parameter	Estimate	Standard Error	T Value	Prob. Level
Intercept	-47.1875	62.197	-0.7585	.45832
Slope	253.127	34.3823	7.40411	.00000

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	Prob. Level
Model	1938321.6	1	1938321.6	55	.00000
Error	707148.51	20	35357.43		
Total (Corr.)	2645470.2	21			

Correlation Coefficient = 0.855976   R-squared = 73.27 percent
Stnd. Error of Est. = 188.036

Figur 7. Results of total catch per haul using 18 mm meshsize versus haul duration.



Regression Analysis - Linear model: Y = a+bX

Dependent variable: CPUEA.catchtot   Independent variable: CPUEA.sibtid

Parameter	Estimate	Standard Error	T Value	Prob. Level
Intercept	50.6288	61.1736	0.827625	.41821
Slope	140.877	33.7598	4.16811	.00052

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	Prob. Level
Model	572969.26	1	572969.23	17.4	.00052
Error	626622.19	19	32980.17		
Total (Corr.)	1199592.5	20			

Correlation Coefficient = 0.691113   R-squared = 47.76 percent
Stnd. Error of Est. = 181.504

Figur 8. Results of total catch per haul using 43 mm meshsize versus haul duration.