FISHERIES TRAINING PROGRAMME

P.O.BOX 1390 SKULAGATA 4
121 REYKJAVIK, ICELAND

FINAL PROJECTS
1999

THE EFFECT OF HOOK SIZE AND BAIT TYPE ON THE FISHING SELECTIVITY OF LONGLINE GEAR

E.M.A.B. Ekanayake
National Institute of Fisheries Training
Sri Lanka
ftcn@sri.lanka.net

Supervisors: Mr. Magnús Freyr Ólafsson and Mr. Lárus Pálmason

ABSTRACT

A longline experiment was conducted in Icelandic waters in November 1999. The main objective was to study the effects of hook and bait type on catch efficiency. Three trials (different location) were conducted where two types of hooks (no 7, J hooks and no 12, EZ hooks) and three types of bait (squid, herring, and sand eel) were tested. Cod, haddock and redfish were the most common species in the study. Fishing area is the most important factor in terms of total catch and species composition of the catch. Redfish were only caught in substantial numbers in the depth set (80 m, trial 2), and the number of cod increased with increased distance from shore. In general, the size of fish within each species increased with depth. It was also observed that the mean length of cod and haddock was higher on hook no 12 than hook no 7. Within trials, no patterhn of change in mean length of cod, haddock and redfish was observed with the three types of bait tested. Bait retention however was much larger for squid than the other two bait types that become more important with increased soak time. The results in this study do not show any significant difference in terms of number of fish according to hook size.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

Longline fishing is one of the most common fish capture methods in the world. Longline is a passive fishing gear, which has developed from the ancient handline. The first reliable sources of the use of longlines go back to the middle of this millennium. Ever since, the longline has developed to increase the efficiency of the gear, adapting it to various habitats and fishing cultures. As for most other fishing gear the greatest improvements have come this century. Synthetic materials have replaced natural fibres used in the longline fisheries. The use of plastic and rubber floats have made it possible to use longlines in more hazardous habitats with regard to currents and depth, and the design of the hooks has improved. However, longlines were more or less limited to inshore fisheries until the 1960s when a large number of different mechanised longline systems were invented (Sainsbury 1996).

Today the structure and the design of longlines have become highly sophisticated. The use of new technology, including new materials and the use of microprocessors (sensors and display units) has eliminated many of the difficulties formerly associated with longlines. It is now possible to automate completely the baiting, setting and hauling process at sea, thus lessening the dependence on land based baiting. Different mechanical systems have been developed and introduced to improve the longline fishing method such as the autoline system (Bjørndal and Løkkeborg 1996).

In general, all longlines consist of four main components. The mainline (the line to which snoods and hooks are attached), the snood (the short line connecting the hook to the mainline), the hook and the bait. Longlines are divided in to three groups, according to their application; demersal, semipelagic and pelagic. Within these groups their composition and use can be very different, regarding the number of hooks, length of mainline and snood and the material used in each part of the gear. The factors that affect the choice of materials and construction the most are different fishing areas and target species (Sainsbury 1996).

In the last few years there has been an increasing debate about responsible and sustainable fisheries. In this regard the longline has many advantages. The longline has only a minor impact on the seabed and a low energy coefficient and therefore limited destruction and pollution effects. Many scientists and environmental organisations claim that towed fishing gear has a serious negative impact on the seabed, for example on corals. Another advantage of longlines is the good quality of the catch and low discard rate of under-sized fish and non-target species. In addition it is believed that fish escaping from longlines have a fairly good survival possibility compared to other fishing methods (INFOFISH International 1995). Many responsible governments, among them the government of Sri Lanka, encourage local fishermen to use longlines and other passive fishing gear.

2. FISHERIES IN SRI LANKA

The species composition of the catch from Sri Lankan waters varies much between areas and seasons but consist mainly of highly migratory pelagic species such as tunas, seerfish, billfish and sharks. The most common fishing gear used is drift gillnet (52%), followed by longlines (15%) and Beach seine (10%)(Figure 1). In the early

1980s the government of Sri Lanka banned all use of trawl in the Sri Lankan Exclusive Economic Zone (EEZ). In 1994 the government also banned all use of purse seines and the use of light attraction. Fisheries in the northern part of the EEZ are limited because of security problems. Sri Lankan fishermen options are therefore limited to gillnets, longlines, handlines and other passive fishing methods (MFARD 1999).

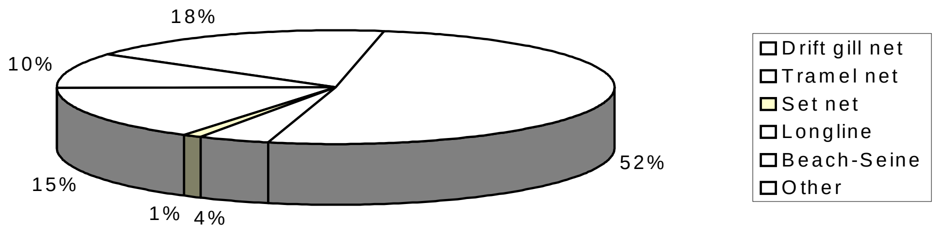


Figure 1: Gear composition used in marine fisheries off Sri Lanka (NARA 1997)

2.1 Longlining in Sri Lankan waters

The fish stocks in the inshore waters around Sri Lanka have been over-exploited (MFARD 1999). The catch per unit effort has declined and so has the profitability of the fishery. Because of these factors and increased fishing efficiency of bigger boats using new equipment, it is logical that exploitation of resources shifts from inshore to offshore in an effort to increase the profitability of the fisheries.

The fishery has expanded rapidly in recent years. Since 1997, about 50 small fishing companies have been established. These companies use well-equipped boats, suitable for deep-sea fisheries (MFARD 1999). In order to maximise the capacity of these vessels it is necessary to introduce modern longline fishing gear to replace the low-tech fishing gear used at present. The change of fishing area from coastal to off-shore over the past few years has also resulted in the use of a combination of gear, such has longline and handline together with the drift gillnets (Dayaratne 1992a).

The use of gillnets in only permitted in inshore areas, where the individual size of fish is relatively small. Small mesh size gillnets in off shore are not allowed. The government does not allow the use of this type of gear offshore, as gillnets catch a high proportion of small immature fishes (Figure 2). The average weight of yellowfin tuna, bigeye tuna and sharks caught by longline is much higher than the average size fish caught in gillnets (Figure 2).

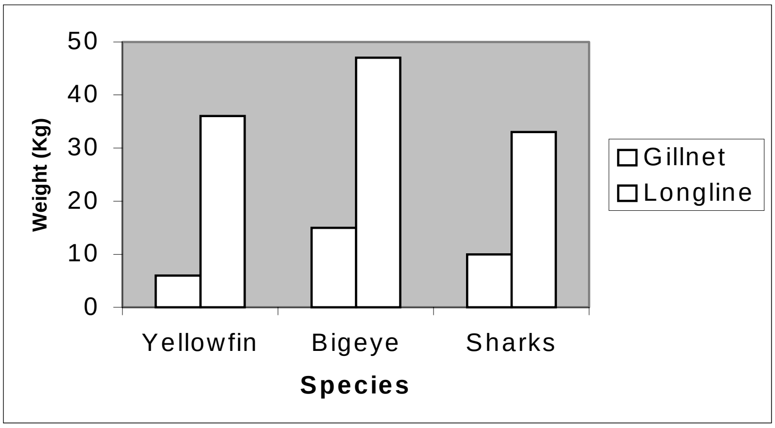


Figure 2: Average weight of common species in the Sri Lankan off shore fishery (NARA 1998).

2.2 Monthly CPUEs on tuna longlines

The offshore longline fishery targets highly migratory species, such as yellowfin tuna, bigeye tuna and billfish. Therefore there are distinct seasonal changes in the fishery. During the early period of the southwest monsoon in July to September, relatively high abundance was observed off the southwest coast. During the northeast monsoon, the abundance of these resources is higher off the east coast reaching a peak from March to May. These results agree with the experiences of fishermen throughout the last decades (NARA 1998).
In a survey of the offshore resources carried out in 1995-97, longline catches were generally found to be highest in July to September, but the pattern was different for different species (Figure 3).

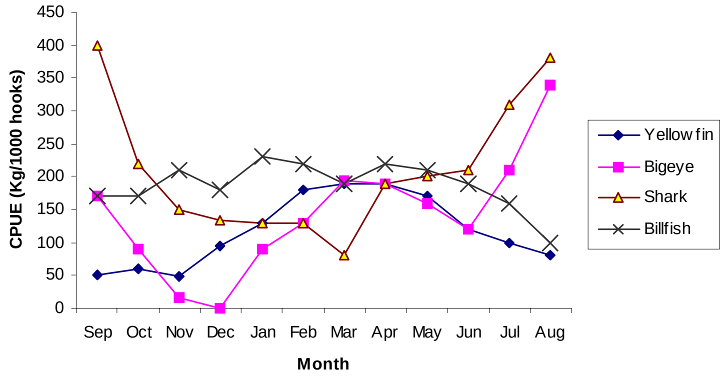


Figure 3: Average monthly CPUEs from off shore tuna longlines in Sri Lankan waters 1995 to 97 (NARA 1998).

2.3 Temperature profiles and tuna distribution

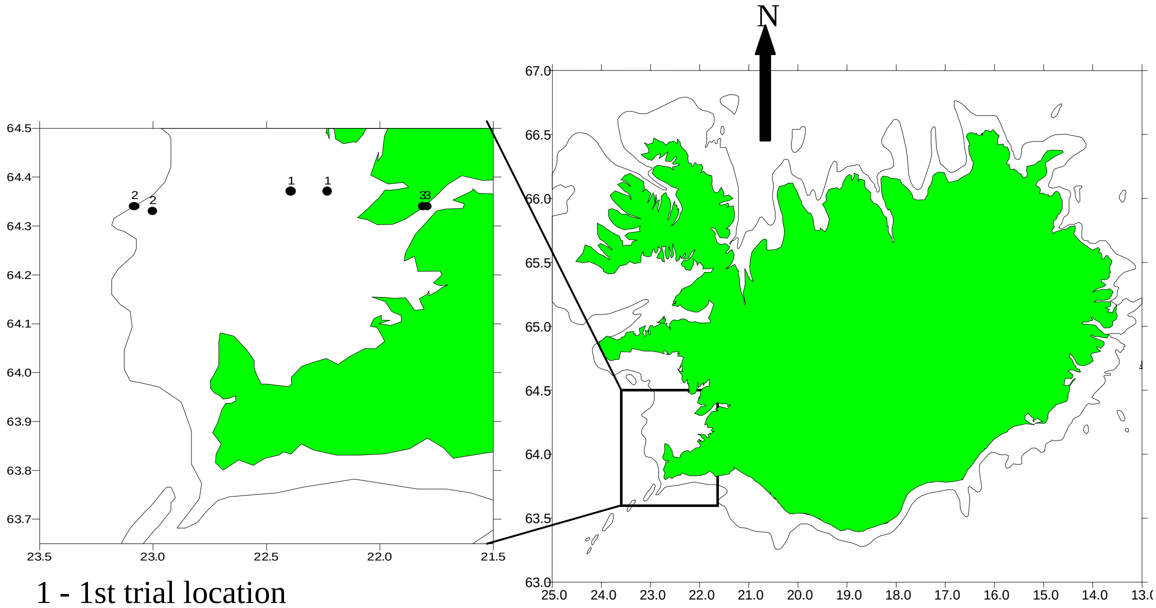
The distribution of tuna is closely linked to water temperatures. Yellowfin tuna prefer waters temperature between 18 – 21°C and is mainly in the uppermost 50 m with juveniles concentrated in the warmest surface layers. Bigeye tuna is found from the surface down to a depth of 250 m. Juveniles are in the upper most layers down to 100 m, and the large adults in deeper waters. They are found in water temperatures between 13 – 29°C, the most favoured temperature range being 17 – 22 °C (NARA 1998).

The National Institute of Fisheries Training is the only institute under the Ministry of Fisheries that educates fishermen. It is also the main link of the Ministry to fishermen. There are four regional fisheries centres conducting fisheries training programmes for fishermen to increase their knowledge about new technologies in fisheries. The fisheries training centre in Negombo is the most important of these four centres because of the number of fishermen in the surrounding area. The author of this paper is responsible for training fishermen in the use of new technologies, through the training institute.

Knowledge about longlines is poor among Sri Lankan fishermen. Therefore knowledge on longline research which can be applied in Sri Lanka is important, especially research into the efficiency and selectivity of longlines. It was therefore decided to conduct a research project, on the effects of hook and bait types in longline fisheries as a similar approach would be applicable to research in Sri Lankan waters.

3. MATERIALS AND METHODS

Three fishing trials were conducted from 4th to 12th of November 1999 on a 13 t, 11.7 m commercial coastal longliner. The fishing trials were conducted on known fishing grounds in Faxaflói Bay, SW Iceland (Figure 4). The first trial was carried out on the 4th of November at location 1 at a depth of 53 m on a sandy bottom. The second trial on the 5th on a sandy and muddy bottom at the depth of 80 m and the third trial on the 11th on a sandy bottom at 43 m depth. Weather conditions were similar during all trials, slow wind and air temperature just above 0°C. Efforts were made to minimise other factors which could effect catching efficiency for example differences in current, setting time and soak time. The bottom longlines were set in fleets of 6 lines in the mornings and the soak times for all trials were similar, 2-4 hours, which is a common soak time for the coastal fleet in Icelandic waters.



1 - 1st trial location
2 - 2nd trial location
3 - 3rd trial location

Figure 4: The experimental area showing the exact location of the three longlines trials.

Each line was divided into three sections. The sections were separated by 16.2 m of line without hooks. Each section lied 157 hooks with hooks no 7 and no 12 used alternatively. The bait used was squid, herring and sand eel, each used for one section on each line (Figure 5). Details of the lines are shown in Table 1.

Table 1: Gear parameters for the experimental longline.

Mainline	Material:	Danline (polypropylene/polyethylene) covered with tar.
	Dimensions:	Diameter, 5.0 mm; length per line 510 meter with 470 hooks.
Snood	Material:	Blue colour nylon.
	Dimension:	Diameter, 1.2 mm, length 40.6 cm, with even spacing of 1.08 m between each snood.
	Mounting:	Knotted to mainline.
Hooks	Type:	Mustad no 7 and 12. Quality no 2330bd J and Ez 39975 respectively.
	Number:	235 hooks of each type alternatively fixed on each line.
Bait	Species:	Herring, Squid and Sand eel.
	Numbers:	157 hooks on each line with each type of bait.

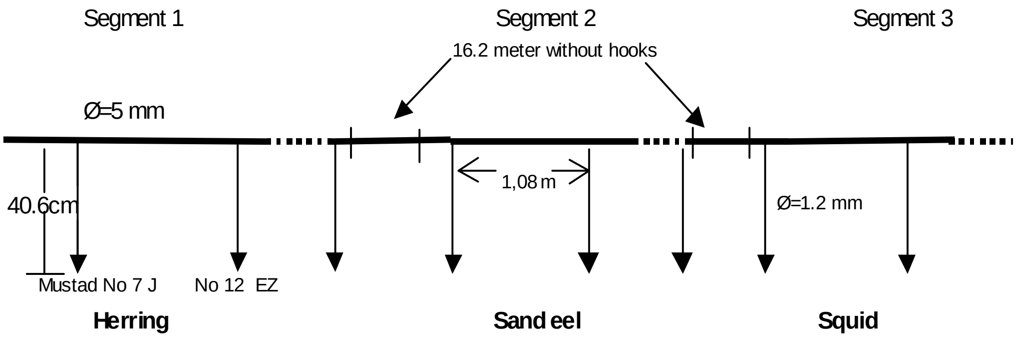


Figure 5: Gear parameter with experimental longline gear module.

Six lines were set in each trail for one experiment with all combinations. In trials 1 and 2 the lines were set perpendicular to known current direction, but in trial 3 the current direction were not known. Mechanised line hauler was used. For every hook catch, bait losses and bait return was recorded. All the fish were identified to species, their total length measured (+/- 0.5 cm) and their weight recorded (ungutted +/- 5 g) for each group separately.

4. RESULTS

4.1 Number of fish caught by hook, bait and trial

Fish were caught on 15.0% of the hooks. Of the total catch 27.3%, 44.5% and 28.2% was caught in trials 1, 2 and 3 respectively, and 49.1% was caught on hook no 7 and 50.9% on hook no 12 (Table 2). Of the total catch, 36.5% was caught on squid, 27.7% on herring and 35.9% on sand eel baited hooks (Table 3). The catch composition varied considerably among trials. Haddock was an important part of the catches in all trials, and contributed most both to number and weight in trials 1 and 3. Cod was the most important species in trial 2. Substantial number of redfish were also caught in trial 2, but their contribution to the total weight was relatively low (Table 4). Overall, haddock contributed most to the catch (50.6 % by number and 45.1% by weight), followed by cod (22.1% by numbers and 36.9% by weight) and redfish (14.15 by number, 3.7% by weight). The combined contribution of other species, such as saithe, ling, skate, tusk, whiting, catfish, and flat fish was smaller and they were therefore not included in the analysis for size selection.

Table 2: Number of fish caught and their total weight in all three trials, broken down according to species and hook type.

Species	Hook No 7		Hook No 12		Total number
	Number	Weight (kg)+	Number	Weight (kg)+	
Cod	126	450	155	570	281
Haddock	332	534	311	710	643
Redfish	81	53	100	49	181
Saithe	12	15	13	43	25
Skate	24	48	33	59	57
Other	49	120	36	110	85
Total	624	1220	648	1541	1272

+Weight of fish caught on line 5 and 6 trial 2 have a median weight.

Table 3: Summary of number of fish caught and their percentages in all three trials.

Species	Squid		Herring		Sand eel		Total number
	Number	%	Number	%	Number	%	
Cod	117	25	97	28	67	15	281
Haddock	201	43	172	49	270	59	643
Redfish	67	14	45	13	69	15	181
Saithe	22	5	02	-	01	-	25
Skate	27	6	12	3	18	4	57
Other	30	7	24	7	31	7	85
Total	464	100	352	100	456	100	1272

Table 4: Summary of number of fish caught and their total weight in all three trials, broken down according to species.

Species	Trial 1		Trial 2		Trial 3		Total number
	Number	Weight	Number	Weight	Number	Weight	
Cod	61	116	213	880	7	24	281
Haddock	243	297	80	204	320	743	643
Redfish	3	1	178	101	-	-	181
Saithe	-	-	25	58	-	-	25
Skate	17	29	37	78	3	-	57
Other	23	50	33	149	29	31	85
Total	347	493	566	1470	359	798	1272

The total numbers and proportions of fish caught by different hooks and bait types are shown for each trial in Table 5, 6 and 7. The three tables were tested together using chi^2 test for independence and found to be significantly different ($Chi^2 = 68.7$, $df = 4$, $p = 4.27e-14$).

Table 5: Contingency table (percentage value) of number of fish caught by hook and bait in trial 1.

Hook/Bait		Squid	Herring	Sand eel	Total Proportion
No 7	N	55 0.333 [a] 0.534 [b] 0.043 [c]	62 0.376 [a] 0.512 [b] 0.049 [c]	48 0.291 [a] 0.393 [b] 0.038 [c]	165 0.48
No 12	N	48 0.265 [a] 0.466 [b] 0.038 [c]	59 0.326 [a] 0.488 [b] 0.046 [c]	74 0.409 [a] 0.607 [b] 0.058 [c]	181 0.52
Total Proportion	N	103 0.30	121 0.35	122 0.35	346

The numbers in each cell correspond to
N= number of fish caught by bait and hook type.
[a] Number of fish (above) within cell / the total number of fish caught on hook no 7 or 12.
[b] Number of fish within cell / the total number of fish caught on bait type.
[c] Number of fish within cell / the total number of fish caught in all trials.

Table 6: Contingency table of number of fish caught by hook and bait in trial 2.

Hook/Bait	Squid	Herring	Sand eel	Total Proportion
No 7	104 0.390 0.418 0.082	78 0.292 0.506 0.016	85 0.318 0.518 0.067	267 0.47
No 12	145 0.483 0.582 0.114	76 0.253 0.494 0.060	79 0.263 0.482 0.062	300 0.53
Total Proportion	249 0.44	154 0.27	164 0.29	567

Table 7: Contingency table of number of fish caught by hook and bait in trial 3.

Hook/Bait	Squid	Herring	Sand eel	Total Proportion
No 7	54 0.281 0.486 0.042	39 0.203 0.506 0.031	99 0.516 0.579 0.078	192 0.53
No 12	57 0.341 0.514 0.045	38 0.228 0.494 0.030	72 0.431 0.421 0.057	167 0.47
Total Proportion	111 0.31	77 0.21	171 0.48	359

In the first trial there was no significant difference between the bait types ($p = 0.69$, Table 5). In the second trial there was significant difference between the bait types ($p = 0.02$, Table 6) with catches on the squid being higher than for herring and sand eel. In the third trial there was also a significant difference in the number of fish caught between the bait types ($p = 0.0002$, Table 7), with catch on sand eel being highest (Figure 6).

The proportion of fish caught by different size hook in all the trials (Table 8) was tested using chi^2 test for independence and found not to be significant ($Chi^2 = 3.95$, $df = 4$, $p = 0.14$) (Figure 7).

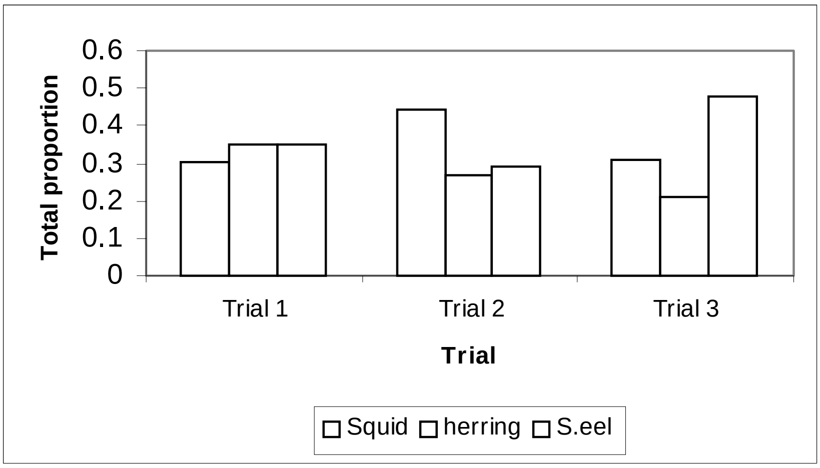


Figure 6: Total proportions of catch caught on different bait type in all trials.

Table 8: Contingency table of number of fish caught by hook for trials.

Hook/ trial	1	2	3	Total Proportion
No 7	165 0.26 0.48 0.13	267 0.43 0.47 0.21	192 0.31 0.53 0.15	624 0.49
No 12	181 0.28 0.52 0.14	300 0.46 0.53 0.24	167 0.26 0.47 0.13	648 0.51
Total Proportion	346 0.27	567 0.45	359 0.28	1272

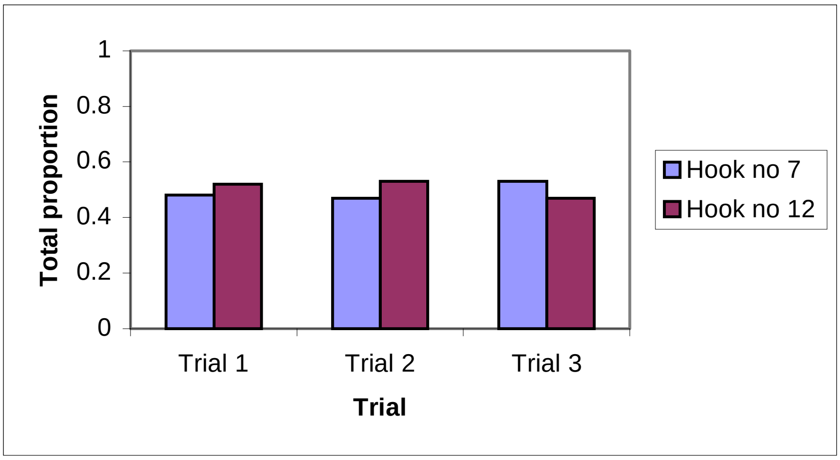


Figure 7: Total proportions of catch caught on different hook size in all trials.

The proportion of fish caught by different type of bait in all trials was tested using Chi^2 test for independence and found to be significantly different ($Chi^2 = 49.15$, df = 4, p = 5.42e-10). Squid and sand eel were similar, but the proportion of fish caught on herring was less (Table 9).

Table 9: Contingency table of number of fish caught by bait for all trials.

Bait type/Trial	1	2	3	Total proportion
Squid	103 0.222 0.298 0.081	249 0.538 0.439 0.196	111 0.240 0.309 0.087	463 0.36
Herring	121 0.344 0.350 0.095	154 0.438 0.272 0.121	77 0.219 0.214 0.061	352 0.28
Sand eel	122 0.267 0.353 0.096	164 0.359 0.289 0.129	171 0.374 0.476 0.134	457 0.36
Col. Total Proportion	346 0.27	567 0.45	359 0.28	1272

4.2 Analysis of mean length

The effect of hook size and bait type on the average length of the three major species caught was investigated for each trial separately. The results are summarised in tables 10, 11 and 12.

Analysis of variance was used to test whether observed differences were statistically significant.

4.2.1 Cod

Only a few cod were caught in trial 3 (Table 12). A test using analysis of variance on the length measurements was therefore only done on data from trials 1 and 2. With trials 1 and 2 combined, differences in length between hook sizes was significant with the substantially larger fish being caught on hook no 12 ($F = 7.56$, $df = 1$, $p = 0.00064$). Significantly larger cod were caught on herring than that of on other bait ($F = 7.24$, $df = 2$, $p = 0.0075$). The effect of trials on the size of cod caught was greater than hooks or baits ($p = 0.000 < p = 0.00064 < p = 0.0075$). (See Appendix Tables 19, 20 and 21 for full analysis).

Testing hooks within trials it was shown that no 12 hooks caught significantly larger cod than no 7 hooks ($F = 11.48$, $df = 2$, $p = 0.000$). Bait type within trials had less effect ($F = 2.24$, $df = 4$, $p = 0.065$) (table 13). By combining trials 1 and 2 no significant interaction in the length of cod was detected between hook and bait combined. By testing trial 2 alone significant difference in length between bait types was found ($F= 3.79$, $df= 2$, $p= 0.0241$) (Appendix Table 25 for full analysis).

Table 10: Mean length (cm) by species in trial 1, (the sample sizes are given in brackets).

Hook/ Bait	Species	Squid	Herring	Sand eel	Mean
7	cod	47.44 (9)	51.7 (10)	50.67 (6)	49.94 (25)
	haddock	46.37 (38)	46.87 (45)	48.79 (33)	47.34 (116)
	redfish	NA (0)	27.00 (1)	NA (0)	27.00 (1)
12	cod	49.57 (7)	51.6 (10)	53.16 (19)	51.44 (36)
	haddock	59.93 (34)	47.63 (43)	47.32 (50)	54.78 (127)
	redfish	44.00 (1)	58.00 (1)	NA (0)	51.00 (2)

Table 11: Mean length (cm) by species in trial 2, (the sample sizes are given in brackets).

Hook/ Bait	Species	Squid	Herring	Sand eel	Mean
7	cod	68.00 (39)	70.95 (37)	62.14 (22)	67.03 (98)
	haddock	50.71 (17)	56.38 (13)	55.07 (15)	54.05 (45)
	redfish	29.83 (30)	36.38 (16)	28.00 (34)	31.40 (80)
12	cod	73.81 (59)	76.13 (38)	74.22 (18)	74.72 (115)
	haddock	59.93 (15)	60.2 (5)	57.06 (15)	59.06 (35)
	redfish	32.39 (36)	30.74 (27)	28.31 (35)	30.48 (98)

Table 12: Mean length (cm) by species in trial 3, (the sample sizes are given in brackets).

Hook/ Bait	Species	Squid	Herring	Sand eel	Mean
7	cod	NA (0)	116 (1)	47.5 (2)	81.75 (3)
	haddock	45.48 (48)	46.67 (34)	46.17 (89)	46.14 (171)
	redfish	NA (0)	NA (0)	NA (0)	0 (0)
12	cod	57.67 (3)	54 (1)	NA (0)	55.84 (4)
	haddock	44.57 (49)	47.25 (32)	44.79 (68)	45.54 (149)
	redfish	NA (0)	NA (0)	NA (0)	0 (0)

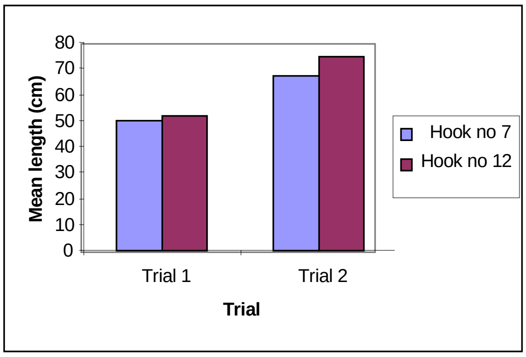


Figure 9: The mean length of cod caught on different hook size in trial 1 and 2.

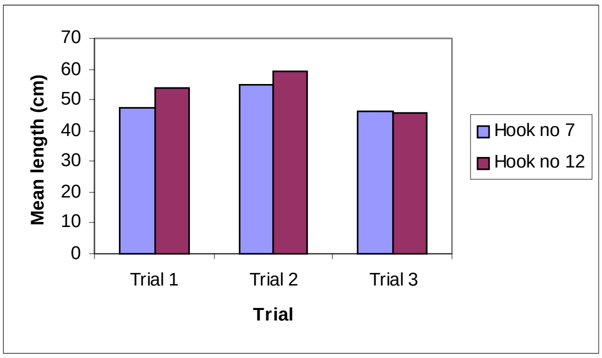


Figure 8: The mean length of haddock caught on different hook size in all trials.

Table 13: Analysis of variance of cod length with hook and bait within trial .

Source	Df	Sum of Sq.	Mean Sq.	F Value	P Value
Trial	1	19597.10	19597.10	176.65	0.000
Hook within trial	2	2546.49	1273.24	11.48	0.000
Bait within trial	4	992.89	248.22	2.24	0.065
(Hook within trial):					
(Bait within trial)	4	367.04	91.76	0.83	0.509
Residuals	262	29065.18	110.94		

4.2.2 Haddock

When all trials were combined there appeared to be no effect of hook size (p = 0.64) nor bait type (p = 0.59). There was however a significant difference in the mean length of haddock caught in different trials (p = 0.000) with the largest haddock being caught in trial 2 and the smallest in trial 3 (Table 11 and 12). (Appendix Table 22, 23, and 24 for full analysis).

Within trials, hook size was found to have a significant effect in the size of fish caught in trial 1 and 2 (F = 3.583, df = 3, p = 0.01) (Table 14 and Figure 9).

Table 14: Analysis of variance of haddock length according to hook size within trials.

Source	Df	Sum of Sq.	Mean Sq.	F Value	P Value
Trial	2	6762.60	3381.29	65.56	0.000
Hook within trial	3	554.40	184.80	3.583	0.01
Residuals	637	32853.44	51.575		

No significant difference between bait types was found.

Table 15: Analysis of variance of haddock length according to bait within trials.

Source	Df	Sum of Sq.	Mean Sq.	F Value	P Value
Trial	2	6762.6	3381.29	64.62	0
Bait in trial	6	39.20	248.22	0.749	0.610
Residuals	634	52.32	118.86		

4.2.3 Redfish

No redfish were caught in trial 3 and only three in trial 1. The statistical analysis was therefore only done on data from trial 2. The difference in length between hook sizes was not significant (Table 16). The difference in length between bait types was significant with the largest redfish being largest on herring and the smallest on sand eel (Table 11 and 17).

Table 16: Comparing the log length of redfish by hook size using analysis of variance.

Source	Df	Sum of Sq.	Mean Sq.	F Value	P Value
Hook	1	0.014	0.014	0.008	0.59551
Residuals	176	8.794	0.049		

Table 17: Comparing the log length of redfish by bait type using analysis of variance.

Source	Df	Sum of Sq.	Mean Sq.	F Value	P Value
Bait	2	0.249	5.233	0.515	0.00619
Residuals	175	8.311	0.047		

4.3 Bait retention

All hooks without fish were checked for bait retention. Bait return by hook type, bait type and trials (Table 18) was tested using chi^2 analysis for independence and was highly significant (Chi^2 = 51.39, df = 4, p = 1.85e-10). In all trials combined, no difference between bait loss according to hook size was found. On the other hand a strongly significant difference was found on number of bait returns in all to trials combined (p=0.0002). Of the returned baits more than 94% was squid in all the trials (Figure10).

Table 18: Contingency table of bait return by hook, bait and trial.

	Trial 1			Total prop´n	Trial 2			Total prop´n	Trial 3			Total prop´n
Hook/ Bait	Squid	Herring	Sand eel		Squid	Herring	Sand eel		Squid	Herring	Sand eel	
7	363 0.91[d] 0.46[e] 0.14[f]	31 0.08 0.70 0.01	6 0.02 0.67 0.00	400 0.47	434 0.93 0.06 0.15	27 0.06 0.77 0.01	4 0.01 1.00 0.01	465 0.51	418 0.97 0.49 0.16	14 0.03 0.64 0.01	0 0.0 NA 0.0	432 0.50
12	434 0.96[d] 0.54[e] 0.16[f]	13 0.03 0.30 0.01	3 0.01 0.33 0.00	450 0.53	447 0.98 0.50 0.17	8 0.02 0.23 0.00	0 0.00 0.00 0.00	455 0.49	429 0.98 0.51 0.16	8 0.02 0.36 0.00	0 0.0 NA 0.0	437 0.50
Total Pro.n	797 0.94	44 0.05	9 0.01	850	881 0.96	35 0.04	4 0.00	920	847 0.97	22 0.03	0 0.0	869

The numbers in each cell correspond to
N= number of bait return by hook, bait and trial.
[d] Number of bait (above) within cell / the total number bait return on hook no 7 or 12.
[e] Number of bait within cell / the total number bait return of that particular bait in indicated trial.
[f] Number of bait within cell / the total number bait returned for all bait type in all trials.

The proportion of bait retention for squid was the highest in all the trials (Figure10).

Figure 10: Proportion of bait retention for bait.

5. DISCUSSION

5.1 The effect of locality

Haddock, cod and redfish were the most abundant species in the catch by number and weight. Their relative abundance and size varied considerably between trials, and trial number explained more of the observed variation than any other factor. Other common species were saithe and skate (Tables 2, 3 and 4). Catch of cod increased with increasing distance from shore, with most cod caught in trial 2 and only a handful caught in trial 3. The reverse trend was observed for haddock. The largest fish were caught in trial 2, which was furthest away from the shore and in deepest water. (Tables 10, 11 and 12, Figure 4) This pattern is in good agreement with the known distribution of these species in Icelandic waters (Gunnarsson et al. 1998, Jónsson 1996). The difference in total number of fish and species composition of the catch between trials can possibly be explained by differences in physical and biological factors between the research areas. Pitcher (1993) mentions several factors that influences differential distribution or zonation of fish species, such as others the diversity of habitats, diversity and accessibility of prey and predator risk. Haddock preys mainly on benthic animals but also on small fish such as sand eel and juveniles of demersal species (Pálsson 1983). Most of the haddock main prey types are found in all the three trial areas. Cod on the other hand is known to be an aggressive fish predator attacking prey up to 1/3 of it owns size. One possible explanation for lower ratio of haddock in trial 2 could be the amount of cod in that area and the fact that the cod was of bigger size than in the other two areas. The mean length of haddock was considerably larger in trial 2 than in trials 1 and 3. It is therefore presumed that the haddock in trial 2 was not as vulnerable for predation of cod because of its size.

Most of the redfish was caught in trial 2, only three in trial 1 and none in trial 3. According to Jónsson (1992) the main distribution of these species of redfish is within 40 and 300 m depth so lower catches in trial 1 and 3 are not surprising. Red body colour is typical of fish inhabiting the middle layers of the oceans (Bond 1979), and the redfish is more common offshore (Jónsson 1992).

5.2 The effect of bait

It is common knowledge among longline fishermen in Faxaflói-Bay that squid is a good bait for cod, sand eel for haddock and herring is usable for both of these two main species. On the other hand Thorsteinsson and Björnsson (1996) documented that squid was more effective than mackerel but gave a similar catch in numbers of haddock and cod. Carr and Derby (1986) identified amino acids as a feeding attractants and stimulants for fish. No studies have been documented that support or explain the fishermen's sensation about selective baits for either cod or haddock. On the other hand there is a reason to believe that squid, herring and sand eel do not contain the same composition and amount of different amino acids. It is therefore possible that fish species are more attracted to one type of bait than another.

Significant differences were observed in the number of fish caught on different bait types in trials 2 and 3 (Figure6). Area 2 is known to be good fishing ground for cod (Eymar Einarsson, pers. comm.). Cod dominated the catch in trial 2 and was mainly caught on squid (Tables 3 and 11 for trial 2) which can indicate that the fishermen is right about squid being more efficient for fishing cod than the other two bait types.

In Trial 3 haddock was by far the most common species in terms of number of caught fish (Table 12). No redfish was caught in that trial and only seven cod. Because of low number of other species and highly significant results (p= 0.0002) in bait selectivity. It is logical to assume that sand eel is a better bait for haddock than herring or squid. On the other hand haddock did not seem to prefer sand eel to herring and squid in trial 1 and 2. The species compositions in these trials were more variable and that can interfere with on the selectivity of the bait. In addition the longlines in trial 1 and 2 were set later in the mornings than the lines in area 3. Løkkeborg et. al. (1989) reported that cod and haddock show diurnal rhythms in feeding activity. The response of cod and haddock to baited hooks was shown to increase at dawn and dusk. Limited feeding search behaviour was observed in night time and around and shortly after noon. It is therefore possible that the catch composition in trials 1 and 2 reflects the distribution of the fish species in low active feeding status in these areas rather than bait preference. The fish just took the bait that was closest in stead of searching for their favourites.

5.3 The effect of hook size

The two types of hooks used in this study differ in both size and shape. The no 12 hook is bigger, has a bigger gape opening (Table 1) and is more rounded (the point and barb bent more inwards) than the J hook. (no 7) Several researches indicate that the size but mainly the shape has an effect on the catch rate in longline fisheries (Løkkeborg and Bjorndal 1992, Huse and Fernö 1990). Bjorndal and Løkkeborg (1996) explain that the EZ hook is more efficient than the J hook as when the line is pulled (jerk of a fish or line when hauled to the surface) the inward bent EZ hook is more likely to penetrate into the flesh around the fish's mouth. The result in this study does not indicate that the EZ hook is more efficient in terms of number of fish. However when the mean length of cod and haddock is examined (Tables 13 and 14) there is a significant difference in favour of the EZ hook. This indicates that the EZ hook is more effective holding bigger fish that are stronger and therefore more likely to tear the hook out of its mouth. Other explanations for these results could be that bigger fish prefers bigger hooks but according to Fernö and Olsen (1994), the effect of hook size on size composition has not been clearly documented. Bjørndal and Løkkeborg (1996) state that generally smaller hooks give higher catch rates than larger ones. The results in this study does not show any significant difference in terms of number of fish according to hook size, but this may be a reflection of the size composition of the fish in the trial areas.

Of the three bait types used, squid gives a significantly greatest return of whole bait. The squid flesh is denser, so it may not be possible for the fish to eat it without getting caught (Bjørndal 1983). Sand eel and herring is soft flesh bait that comes off more easily.

ACKNOWLEDGEMENTS

My thanks to the project director of United Nation University- Fisheries Training Programme Dr. Tumi Tomasson and the Deputy Programme Director Mr. Thor Asgeirsson for giving me the opportunity to participate in this programme and for their guidance and assistance.

I am also thankful to my supervisors Mr. Magnus Freyr Olafsson and Mr. Larus Palmason. Dr. Lorna Taylor gave valuable assistance with my statistical analysis during this study. My thanks and appreciation go to the captain of the research vessel EBBI, Mr. Eymar Einarsson and his assistant Mr. Gunnar Kjartansson for their helpful co-operation in the fishing trials.

I am also thankful to the director and all the members of the Marine Research Institute.

REFERENCES

Bjørndal, A. 1983. Effect of different longline bait (mackerel, squid) on catch rates and selectivity for tusk and ling, Institute of Fishery Technology Research , Nordnes, Norway.

Bjørndal, Å & Løkkeborg. S. 1996. *Longlining*. Oxford: Fishing News Books. Osney Mead

Bond, C.E. 1979. *Biology of Fishes*. Saunders College, Philadelphia.

Dayaratna, P. 1992a. Observations on the species composition of the large pelagic fisheries in Sri Lanka. National Aquatic Resources Research and Development Agency, (NARA), Crow Island, Colombo 15.

Dayaratna, P.1992b. Tuna fisheries in Sri Lanka. National Aquatic Resources Research and Development Agency, (NARA), Crow Island, Colombo 15.

Fernö, A. and Olsen, S. 1994. *Marine fish behaviour in capture and abundance estimation*. Oxford: Fishing News Books 94-7919.

Gunnarsson, K., Jónsson, J., Palsson, O. K. 1998. Sjavarnytjar vid Iceland. Reykjavik, Iceland: Mál og Menning.

Huse, I. and Fernö, A. 1990*. Fish behaviour studies as an aid to improved longline hook design*. Fisheries research, 9:287-297.

INFOFISH International 1995.

Jónsson, J. 1996. Tagging of cod (gadus morhua) in Icelandic waters (1948-1986) and tagging of haddock in Icelandic water (1953-1965). Marine Research Institute, Iceland

Jónsson, G. 1992. *Icelandic fishes*. Reykjavik, Iceland: Fjolva-utgafa.

Løkkeborg, S. & Bjorndal, Å. 1992. Species and size selectivity in longline fishing: A review. Fish Res., Elsevier science publishers, 13, 311-322

Løkkeborg, S. Bjorndal, Å. and Fernö, A. 1989. Responses of cod (Gadus morhua) and haddock (Melanogrammus aeglefinus) to baited hooks in the natural environment. *Canadian Journal of Fisheries and Aquatic Sciences* 46:1478-1483.

Palsson, O. K. 1983. The feeding habits of demersal fish species in Icelandic waters, Rit fiskideildar, 7(1): 1-60

Pitcher, T.J. 1993. *Behaviour of teleost fishes.* London: Chapman & Hall.

Sainsbury, J.C. 1996. *Commercial fishing methods*. Oxford: Osney Mead. 3rd ed.

Sri Lanka. Ministry of Fisheries Aquatic Resources Development (MFARD)1999. *Six-year fisheries development programme (1999-2004)*. Colombo: Sri Lanka.

---. --- 1998. *Fish landing annual report*. Colombo: Sri Lanka.

---. National Aquatic Resources Research and Development Agency (NARA) 1998a. *Fisheries in Sri Lanka 1998*. Crow Island, Colombo: Sri Lanka.

---. --- 1998b. *Report on offshore large pelagic fish resources survey*. Crow Island, Colombo: Sri Lanka.

Thorsteinsson, G. and Björnsson, H. 1996. Longline experiments, ICES.

APPENDIX

Table 19: Analysis of variance of cod length with hook.

Source	Df	Sum of Sq	Mean Sq	F value	P value
Hooks	1	1483.16	1483.158	7.560062	0.00635733
Residuals	279	54735.15	196.183		

Table 20: Analysis of variance of cod length with bait.

Source	Df	Sum of Sq	Mean Sq	F value	P value
Bait	1	1422.69	1422.69	7.243856	0.00754405
Residuals	279	54795.61	196.40		

Table 21: Analysis of variance of cod length with all trials.

Source	Df	Sum of Sq	Mean Sq	F value	P value
Trial	1	19728.99	9864.496	75.15433	0.000
Residuals	272	36489.31	131.257		

Table 22: Analysis of variance of haddock length with hook.

Source	Df	Sum of Sq	Mean Sq	F value	P value
Hooks	1	13.19	13.18983	0.2105393	0.6465006
Residuals	641	40157.25	62.64782		

Table 23: Analysis of variance of haddock length with bait.

Source	Df	Sum of Sq	Mean Sq	F value	P value
Hooks	2	64.57	32.28380	0.5151772	0.5976422
Residuals	640	40105.87	62.66543		

Table 24: Analysis of variance of haddock length with all trials.

Source	Df	Sum of Sq	Mean Sq	F value	P value
Hooks	2	6762.60	3381.299	64.77615	0.000
Residuals	640	33407.84	52.20		

Table 25: Analysis of variance of cod mean length with trial 2.

Source	Df	Sum of Sq	Mean Sq	F value	P value
Hooks	2	938.62	469.3089	3.789898	0.2415887
Residuals	640	26004.62	123.8315		

Table 26: Analysis of variance of haddock mean length with trial 2.

Source	Df	Sum of Sq	Mean Sq	F value	P value
Hooks	2	67.61	33.8038	0.2599442	0.7717685
Residuals	77	10013.28	130.02426		