FISHERIES TRAINING PROGRAMME
P.O. Box 1390, Skulagata 4
120 Reykjavik, Iceland

Final Project 2005

THE EFFECTS OF THE COLOUR OF THE MAINLINE AND DIFFERENT SNOOD ATTACHMENTS ON THE CATCHING EFFICIENCY OF LONGLINE

Weragama Arachchige Shyamantha
National Institute of Fisheries and Nautical Engineering
Crow Island, Mattakkuliya
Colombo-15
Sri Lanka
Shyamantha.w@gmail.com

Supervisor
Mr. Lárus Þór Pálmason
larus@fss.is

ABSTRACT

Longline is widely used in the world and it is believed to be an environmentally friendly method, relative to some other gears. The catching efficiency of longline may be affected by several technical, biological and environmental factors. To find out how mainline materials (multifilament with tar and multifilament green) and various kinds of snood attachment systems (using swivel and without swivel) affect the catching efficiency of longline, an experiment was carried out in Icelandic waters from December 2005 to February 2006. This experiment showed that longlines where branch lines are attached to the mainline using knots, give higher catch rates (higher than 35%) than longlines which have branch lines attached to the mainline using a swivel. And the same time it has been shown that longlines, which have a multifilament mainline with tar, can take more catch (24%) than longlines where the mainline consists of multifilament with green colour.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

The longline is commonly believed to be an environmentally friendly method. It has less impact on natural habitats, discards of undersize and unwanted fish tend to be low and fish catch is high quality (Løkkeborg 2000). Furthermore, there is no evidence of ghost fishing by lost lines, which in the case of gill net is a serious ecological problem (Shahul and Boopendranath 2000). Therefore, it is very important to increase longline fishery. As an environmentally friendly method, the use of longline is encouraged by the Sri Lankan government. If longlines can be introduced with high efficiency, most of fishermen may begin using this gear instead of gill nets.

Longlining in Sri Lanka is still not well developed because of lack of knowledge about longline gears and the new technology, which is used in longlining throughout the world. Very high prices and unavailability of suitable baits can see as barriers to developing the usage of longline in the country. According to research there is potential to increase the tuna longline fishery in offshore areas around Sri Lanka's exclusive economic zone (EEZ) (Maldeniya and Amarasooriya 1998).

To develop longlining in the country, new technology should be introduced to the fishermen and they should be aware and encouraged in this matter. The development of longline is not only valuable to Sri Lanka but also to the whole world. Therefore, this project was selected to knowledge about the use of longline gear.

Catching efficiency of longlines may be affected by several technical, biological and environmental factors such as the mainline and snoods material, the hook design and size, rigging, and the type and size of the bait (Løkkeborg and Pina 1997). The objective of this study is to examine the effects of the material used to make the mainline (multifilament with tar and multifilament with green colour) and the different kinds of snood attachment systems to the mainline (attach using swivels and tying directly to the mainline).

2 FISHERIES IN SRI LANKA

Sri Lanka is an Island 65,610 km^2 and centrally located in the Indian Ocean. It has a 1,760 km coastline. The EEZ is about 7.8 times the total area of the country. The area, which is covered by the continental shelf is 30,000 km^2, i.e. 5.8 % of the total the EEZ (Central Bank 2000).

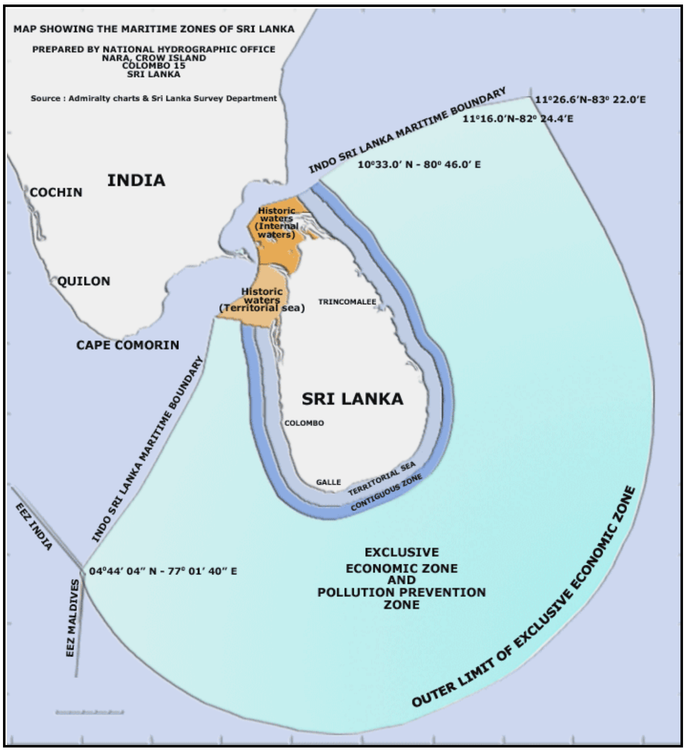


Figure 1: Map showing the maritime zone of Sri Lanka (Ministry of Fisheries and Aquatic Resources in Sri Lanka 2005.

The marine fishery of Sri Lanka can be divided into two major categories: costal fisheries and offshore fisheries (Wijayaratna 2001). National marine fishery production was 284,960 tonnes in 2004. The coastal fishery plays a major role in the fishing industry in Sri Lanka and this contribution was around 57% (163,850 tonnes) while the offshore fishery contributed about 32% (90,830 tonnes) during the year 2004 (Information Centre NARA 2005) .

The total catch realised according to the gear and other basic operational parameters are given in Figure 2. Drift gill nets are the most common fishing gears used in Sri Lanka followed by the longline. The gill net is one of the predominant and most effective fishing gears. There are two types of gill nets: the stationary and drift gill net. However, the drift gill net (driftnet), which has been used primarily for pelagic species, is used more frequently. In early 1980s, the government of Sri Lanka banned all use of trawl in the Sri Lankan Exclusive Economic Zone (EEZ). Further, in 1994, the use of purse seines and the use of light attraction were also banned. Fishermen then had very limited options for fishing gears such as gill nets longline, hand line and other passive fishing gears (Ministry of Fisheries and Aquatic Resources (MFARD) 1999) .

Figure 2: The total catch realised according to the fishing gear used in the marine fisheries of Sri Lanka (Information Centre NARA Sri Lanka 2005).

2.1 Active fishing boats used in Sri Lanka

An active fishing boat is defined as any vessel currently or regularly used in eligible fishing activities and includes vessels, which might be temporarily unserviceable or only used for seasonal fishing activities. On the other hand, unserviceable vessels, which are not expected to be used in future seasons, are routinely excluded from the scope.

Table 1: Age of fleet (year of manufacture) and active fishing boats by type (DFAR 1998).

Boat Type	Before 1970 (%)	1970-74 (%)	1975-79 (%)	1980-84 (%)	1985-89 (%)	1990-94 (%)	1995 or Later (%)
17-23 ft FRP	0.0	0.2	0.8	8.7	25.0	57.2	8.1
3.5 tonne	1.0	3.0	16.2	31.2	27.6	20.0	1.0
Multi-day boat	0.0	0.0	0.5	3.3	13.8	73.4	8.9

Possession of modern and newly constructed active fishing boats is a favourable condition for the advancement of the industry and Table 1 contains information on the age structure of the Sri Lankan modern motorised active fishing boats. It shows that most of the fishing vessels were recruited over the period 1985-1994. Most of the 17-23 ft FRP boats were added over the period 1990-94 while the 3.5 tonne vessels were recruited over the period 1980-84.Also, 73.4% of the multi-day boats joined the fleet over the period 1990-94. However, after 1994, the rate of expansion has decelerated and undoubtedly this is a favourable move in order to promote a sustainable industry. There is over exploitation in the costal area (Maldeniya and Suraweera 1991) and the surface fishery in the offshore area has reached its economical maximum limit (Maldeniya and Amarasooriya 1998). However, a resource survey concluded that there are about 6700 tonnes of potential yield at a depth of 50- 150 m to develop the tuna longline fishery (Maldeniya and Amarasooriya 1998). Table 2 illustrates the fishing fleet in Sri Lanka before the tsunami disaster on 26 December 2004. There were 1493 one day vessels with inboard engines and 1581 multi day vessels involved in the fisheries sector. But 490 of the one day vessels were destroyed and 328 boats were damaged by the tsunami disaster. Furthermore, 195 multi day boats were destroyed and 402 boats were damaged by the tsunami (MFAR/FAO 2005. Post Tsunami Reconstruction and Development Programme Situation Report-2005). Nevertheless, there is still a sufficient number of boats to develop longlining in the country.

Table 2: Fishing fleet in Sri Lanka (Ministry of Fisheries and Aquatic Resources, Sri Lanka 2005)..

Type of fishing fleet	No of fleet
Non mechanised traditional crafts	15260
Mechanised traditional crafts	675
Fibreglass crafts with outboard motors	11559
One day vessels with inboard engines	1493
Multi day vessels	1581
Beach seines	1052
Total	**30567**

2.2 Longline fishing in Sri Lanka

Longline fishing in Sri Lanka began in the late 1950s when the nine metre, 3.5 tonne motorised boats were introduced in 1957 with longlines with 100 hooks (Maldeniya 1995). These boats mainly targeted large tuna. In line with declining hook rates and the high price and unavailability of suitable bait as well as physical difficulties with manual hauling and too little knowledge about this fishing method (Pajot and Weerasooriya 1980) it soon began to wane. In these years longlining for sharks was being increased instead of longlining for the tuna (Maldeniya 1995). In the early 1980s, the Sri Lankan government introduced a fleet of 34 ft long, 11 tonne boats, which help fishermen to conduct multi day boat trips, in offshore waters (Dayaratna and Maldeniya 1995). In recent years chilled large tuna export has become an attractive venture. As a result, longlining for tuna has regained popularity in the country (Maldeniya 1995). Therefore most of the 3.5 tonne motorised boats, which at the numbered about 3000, were modified to conduct multi day fishing (Dayaratna and Maldeniya 1995). Furthermore, in order to develop the of tuna fishing industry in the country, the government has issued permits to several foreign vessels and several companies which conduct business jointly with Sri Lankan companies, to land tuna caught by their longliners outside of the Exclusive Economic Zone of Sri Lanka (Maldeniya and Amarasooriya 1998). At present, 1581 multi day vessels (Table 2) are engaged in the offshore waters fishery and longlines are used in combination with gill nets (Dayaratna and Maldeniya 1995) especially in the South, Southeast and East of the country (Maldeniya and Amarasooriya 1998).

3 LONGLINE AS A PASSIVE AND SIMPLE GEAR

In early days, in order to obtain fish, humans had to use their hands. But when their needs grew they had to find other methods to catch fish. Therefore, simple tools were invented to make fishing and processing of fish easier. Sometimes people want to catch more fish than is sufficient for their daily needs. Extra products can be preserved and stored by drying, smoking, salting or by simple processes of fermentation. To catch more fish required not only more time, but also bigger fishing gears as well as increased gear efficiency. Fishing for single fish or small quantities, as in subsistence fishing, was replaced by an artisan commercial fishery, sometimes related to special markets. This gave new impetus to improving fishing methods (Bjordal and Lokkeborg 1996).

Fishing gears can be divided into passive and active equipment. As a passive fishing gear, the longline is stationary and the encounter between the gear and the fish is the result of fish moving towards the gear. Therefore, to construct the gear much experience is needed and in this manner the fish should accept the gear and should not be frightened of its construction, colour, visibility, or anything else. Furthermore knowledge of fish behaviour is necessary to develop an effective fishing gear (Bjordal and Løkkeborg 1996). The longline is a very simple fishing gear, but there are great variations in the gear construction, mode of operation and fishing strategy. As for most other fishing gears, natural materials are replaced by synthetic fibres in the making of longlines. The major benefits of synthetic materials are that they are stronger and have higher resistance to deterioration (Bjordal and Løkkeborg 1996). The capture principles of longline are based on the feeding and hunting behaviour of target species (Shahul and Boopendranath 2000).

3.1 The structure of the longline

The longline consists of four main parts: the mainline, branch lines (which are also called snoods), hooks and bait. Other accessories are floats, the float line, sinker and weight, swivels and connectors, flagpoles, light buoys, radio boys and radar reflectors. In traditional operations, the longline is dived into convenient units known as baskets, with the accompanying branch line and float lines which are coiled and kept as discrete sets to ease handling and storage (Shahul and Boopendranath 2000)

There are numerous ways of rigging longlines according to target species and fishing conditions. The traditional bottom longline for species such as cod, haddock, ling and tusk has a multifilament mainline and snoods, and in recent years it has become common for it to be rigged with swivels and EZ- baiter hooks (Figure 3a) with a hook spacing of 1.2-1.8 m. Semi pelagic longline for cod and haddock have a monofilament mainline and snoods with swivels and J-hooks (Figure 3c) or a wide gap hook spacing with 2-3 m hook spacing. Tuna longlines typically have a multifilament mainline to which the snoods are attached with a metal snap at a wide hook spacing of about 50 m (Bjordal and Løkkeborg 1996).

The mainline is characterised by the materials, the material construction and the dimension or thickness, normally given as the diameter (mm). Mainlines are made of monofilament or multifilament materials. Most mainlines are made of multifilament, normally ranging from four to 11 mm in diameter according to the type of fishery. (Bjordal and Løkkeborg 1996).

Monofilament lines are commonly made from Polyamide material. The longline with a monofilament mainline has a superior catching performance to the multifilament mainline. However, because of the lower braking strength and poor resistance to chafing of monofilament materials, which are important properties of the mainline, monofilament mainlines are mainly used in pelagic and semi pelagic longlining (Bjordal and Løkkeborg 1996).

Multifilament mainlines are sometimes treated with coal tar or some other impregnating material, to improve both the handling properties and the lifetime of the line (Bjordal and Løkkeborg 1996).

The mainline is made of highly specific gravity material such as hard twisted polyamide, polyvinyl chloride, or polyvinyl alcohol. The total length of mainlines varies according to fishing grounds, the scale of operations and other considerations. In large-scale operations they are very long, extending up to 180 km where each unit of mainline has five or more branch lines (Shahul and Boopendranath 2000).

Snoods (branch lines) are made of either monofilament or multifilament materials. When monofilament material is used for branch lines it is usually made by polyimide and is between 0.3 and 1 mm in diameter. Multifilament snoods are made as twisted or braided lines with a thickness from 1 to 4 mm. However, in some longline fisheries (e.g. some shark longline) snoods are made of steel wires or chains. Monofilament snoods range from 0.3 to 1 mm in thickness and from 0.5 to several m in length according to the type of fishery (Bjordal and Løkkeborg 1996).

Various shapes and sizes of hooks can be found in longlines. They are manufactured using galvanised iron, brass and stainless steel (Shahul and Boopendranath 2000). When we consider the shape of the hooks, the 'J' type hook was dominant in longline fisheries until the mid 1980s (Bjordal and Løkkeborg 1996). To increase catching efficiency by developing probability of hooking a fish and preventing escape, new shapes of hooks have been developed. The superiority of these new types depends on the several factors such as how the hook point is bent. When the hook point is bent towards the shank or eye of the hook like EZ or Circle-hooks (Figures 3a and b), it is more efficient than J type hooks (Figure 3c) which point away from the shank or eye (Løkkeborg 2000).

(a) (b) (c)

Figure 3: Types of hooks (a) EZ-hook (b) Circle-hook (c) J-hook.

The other important factor is the size of the hook: smaller hooks generally catch more fish than large hooks (Løkkeborg 2000).However, using larger hooks enables larger fish to be caught.

Various materials have been used for making hooks throughout history such as stone, bone, horn, seashells, wood and metal. Until man learned the art of working with metal, the properties of the material used restricted the shape of the hooks (Bjordal and Løkkeborg 1996).

There is an immense number of fish hook varieties available from hook manufactures. The main variables of the fish hooks are the size, shape and coating, which give an indefinite number of possible combinations. Fish hook terminology is a somewhat confusing subject, since there is no strict international standard of definition of hooks. One widely used hook terminology is the system used by hook manufacturers O. Mustad and Son Ltd. In this system there is a numbering system for hooks according to their size. According to this system, with increasing ordinary numbers (1, 2, 3…) the size of the hooks decreases and when '/0' numbers increase the size of hooks also increases. According to this system, several names are used to indicate the basic shape of the hooks such as Circle, EZ Baiter, Kirby, O'Shaughnessy and Wide Gap (Bjordal and Løkkeborg 1996). Tin, nickel, cadmium or some other anti- corrosives materials are used to make coated hooks for resistance to corrosion. (Bjordal and Løkkeborg 1996). The distance between hooks varies depending on the type of longlining. In cod fishing the distance between the longline is commonly 1-2 m but in tuna longlining it may be as much as 50 m(Bjordal and Løkkeborg 1996). It is not clear when man started to utilise bait for fishing, but it most probably originated from the observation that fish were attracted to discarded offal (Bjordal and Løkkeborg 1996). Large varieties of bait types are used in longline fishing, for example herring, mackerel, anchovy, sardine, sprat, saury, saithe, capelin, shrimp, crab, etc. These fishes are used either whole fish or in adequate cutting pieces. The choice of bait in different longline fisheries depends not only on its catching efficiency for the target species but also on its availability, cost and handling properties.

The catching efficiency of the bait is affected by several properties (Løkkeborg 2000). The first one is the chemical composition with feeding attractants of the bait. Different fish species are attracted to different feeding attractants. Therefore, different types of bait should be used according to fish species and it can be said that this parameter effects the species selectivity. Secondly, the rate of release of the feeding attractants is also important. If the bait odour spreads to large areas of relevant fish species (which respond to that special odour), it can attract fish from a large area. Thirdly, the appearance (shape and size, taste and texture) of the baits must be considered. These features should affect the ingestion of the baited hooks once the fish have located the fishing gear. The size of the bait is very important to size selectivity (Løkkeborg 2000). Fish generally prefer to prey below a certain size, which is determined by factors such as their mouth size and ability to capture and handle the prey. Large baits were shown to catch fewer cod below 60 cm than small baits whereas the cod larger than 60 cm were caught in equal amount by both small and large baits. Although the same tendency can be demonstrated for haddock, their behavioural responses towards baited hooks are different from the cod. Haddock gives a higher catch rate for large fish to small baits , which is different to the cod. This is because cod most often suck the whole bait into their mouth, but haddock typically nibbles small pieces of bait and hooks are outside the mouth. Therefore smaller haddock also attacks larger baits but not small cod. In this way haddock attacks the same bait several times and the baits become smaller and smaller until finally the fish bite the hooks and are caught (Bjordal and Løkkeborg 1996). The fourth factor is the ability of the bait to stay on the hook. When the bait holds for a long time on the hooks, the fishing gear can remain effective for a long time. The physical strength of the bait is therefore an important feature. Therefore, bait loss directly affects the efficiency of the gear (Bjordal and Løkkeborg 1996). When fishing gear lines are set, sea birds can also bite the bait immediately when the gear reaches the seabed. For this reason baits can be lost which results in a reduction in fishing gear efficiency.

3.2 Types of longline used in the world

Longlines are set different ways and based on the setting method as well as the structure of the line; longlines can be divided into a few main categories. The three main kinds of longline are demersal, semi pelagic and pelagic (Bjordal and Løkkeborg 1996).

Demersal longline is traditional and is commonly used for demersal fish species such as cod, halibut, hake and ling in depths from 100 to 800 m (Figure 4). Accessories such as the anchor, buoys and buoy lines, intermediate buoys, marker buoys, poles and flags are used with the line. The anchor is used to keep fishing gear in a fixed fishing position as well as to make the gear sink faster to the bottom. In small-scale longlining, some metal, stone or some other material is used instead of an anchor.

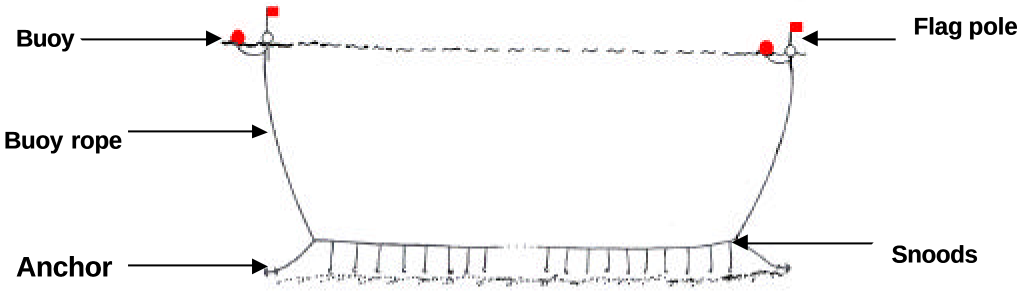


Figure 4: Demersal longline

Semi pelagic longlines are set in the same position using an anchor and mainlines are always set pelagically at variable fishing depths. An echo sounder is used to decide suitable depths. After that the mainline is set to match the fish depth and the gear depth as closely as possible, using sinkers and floats.

Pelagic longlines are used mainly in the offshore fishery for pelagic species such as tuna, swordfish, shark, and salmon. As well as costal water fish species such as haddock during periods when these fish are feeding on pelagic prey. These lines drift freely in the sea.

In addition to the main methods above, there are other longline setting methods such as vertical longline and bottom vertical longline (Shahul and Boopendranath 2000) and monofilament longline for Pollock (Bjordal and Løkkeborg 1996). In the vertical longline the mainline is set nearly in a vertical position. One end of the line is held on the sea bottom using an anchor or some weight and the other end is held on the surface of the water using a float. Vertical longline is a combination of the vertical longline and the bottom set longline. As bottom set longline mainlines are setting horizontally at an appropriate level in the water and branch lines are hung to the mainline with appropriate intervals of 20-25 m. Few numbers of hooks are attached to each branch lines.

Monofilament longlines for Pollock are used in South Korea in the small-scale fishery. Here the mainline is set semipelagically and frequently attached to surface floats. When hauling the normal way this may tangle and break. Therefore, normally this gear is discarded after use. Bjordal and Løkkeborg refer to this as "thro-away longline".

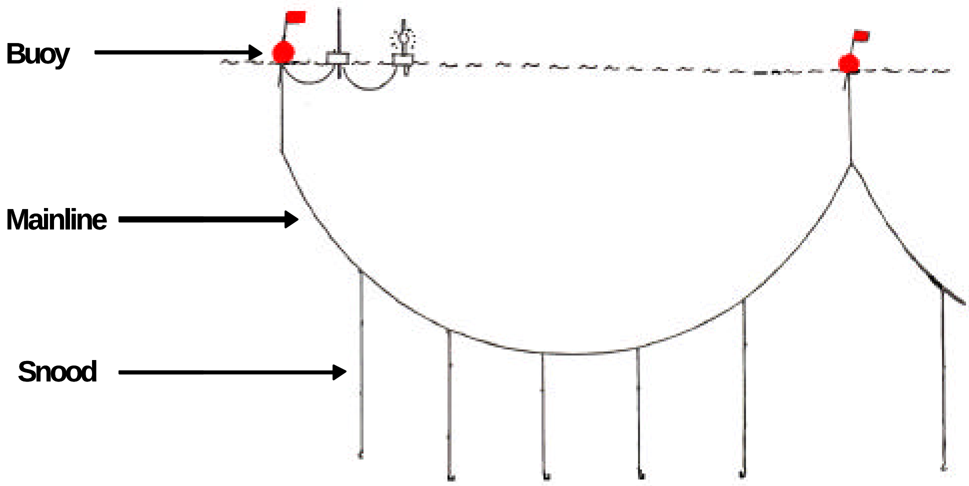


Figure 5: Pelagic longline.

3.3 Disadvantages of the longline

Although longline is thought to be an environmentally friendly method there are some disadvantages to this method, mainly the by catch of turtles and sea birds. Sea turtles are a global resource and several anthropogenic activities have been identified to cause declines in sea turtle populations. In some areas, some species of turtle are caught incidentally in the longline fishery. Pelagic stage loggerheads are sometimes hooked in the mouth or digestive tract and can also become entangled in the longlines (Wang *et al.* 2004). For an example, 20,000 loggerhead turtles are captured every year by the Spanish longline fishery in the Mediterranean Sea (Sea Shepherd Conservation Society 2005).

Albatrosses and large petrels mortality is the other global scale problem in longline fisheries. Primarily while fishing gear is being set, seabirds are hooked or entangled and dragged into the water, and drown as the gear sinks. Hundreds and thousands of seabirds, including tens of thousands of albatrosses, are caught annually in longline fisheries worldwide For the examples, during the 1980s Japanese pelagic tuna longline vessels took 44,000 albatrosses per year and the Hawaiian tuna and swordfish longline fishery, in the North Pacific, caused an annual mortality rate of nearly 3,000 albatrosses. In Peru it is estimated that about 2370-5610 albatrosses are taken annually as well as around 15,430, from the demersal longline fishery in Alaska (Gilman 2004a).

Over the past five years, various national governments and some regional organisations have developed numerous seabirds' mitigation methods to minimise the mortality of seabirds. It is necessary not only to minimise bird capture but also to make the measures convenient and provide crews with incentives to employ them consistently and effectively (Gilman 2004b).

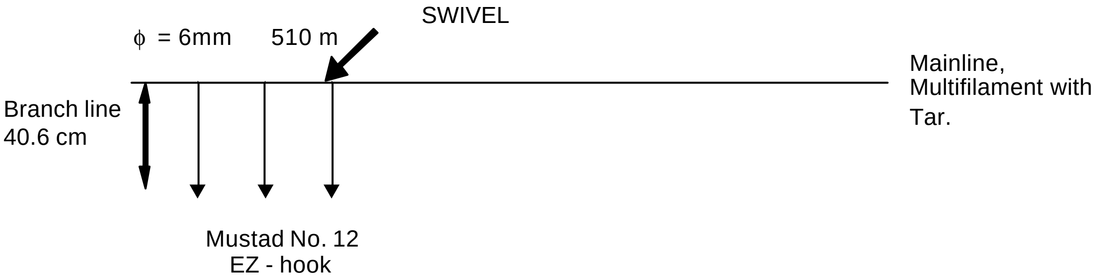
4 METHODS

For the experiment, three fishing lines were used. The arrangement of fishing gears can be seen in Figure 6 and Table 3. Each line consisted of a mainline 6 mm in diameter and 510 m in length. The mainline was lined by 500 (Mustad 12, EZ- type) hooks by snoods (ø=1.2 mm, 40.6 cm in length and with a spacing of 1.02 m). All these lines were used in three separate trails with all combinations as one fleet. In line number one, the mainline was made of multifilament with tar, snoods were rigged using swivels and in the other two lines snoods were attached to the mainline by tying and the second mainline was made of multifilament without tar and the third line was made of multifilament with blue colour. The previously frozen saury was used as bait in all trials with a standard size around 25 g.

In each trial, the total length and weight of every fish was measured separately using a ruler and electronic scale. Information related to the bait (bait losses, bait return) was also collected.

The three comparative fishing trials were conducted from 8 January to 27 January 2006, on board the commercial longliner (NT, 1.78 and length 8.67 m) in Icelandic waters. Every fishing trial was carried out in Reykjanes (southwest Iceland) as shown in Figure 7. The first trial was carried out on 8 January, the second trial was on 20 January and the third trial was on 27 January 2006. Setting times, in the trials were 12.30 pm, 2.33 pm and 2.50 pm respectively. During all trials, the wind direction was southwest and the air temperature was below 0°C. Intensity of light was also the same and low because of cloudy skies. The soaking time of the first trial was nearly two days, because of the bad weather conditions, lines had to keep in the sea nearly two days but in the other trials the soaking times were from 2 to 3 hours, which is the normal range in commercial longlining not only in Iceland but also worldwide (Bjordal and Løkkeborg 1996). Here, the bottom longlines were used in fleets of three lines and they were set at around 20 m depth in the all trials.

Line 01.



Line 02.

Line 03.

Figure 6: Gear parameters with the experimental longline gear module.

Table 3: Arrangements of the longline in relation to the experimental parameters.

Line No.	Mainline	Snood	Type of hooks	Type of baits
01	Multifilament 6mm, PP/PES Covered by tar.	White colour nylon, connected to the mainline using swivels.	Mustad no 12, EZ-hooks	Saury
02	Multifilament 6mm, PP/PES Covered by tar	White colour nylon, connected to the mainline without swivels.	Mustad no 12, EZ-hooks	Saury
03	Multifilament Green colour	White colour nylon, connected to the mainline without swivels.	Mustad no 12, EZ-hooks	Saury

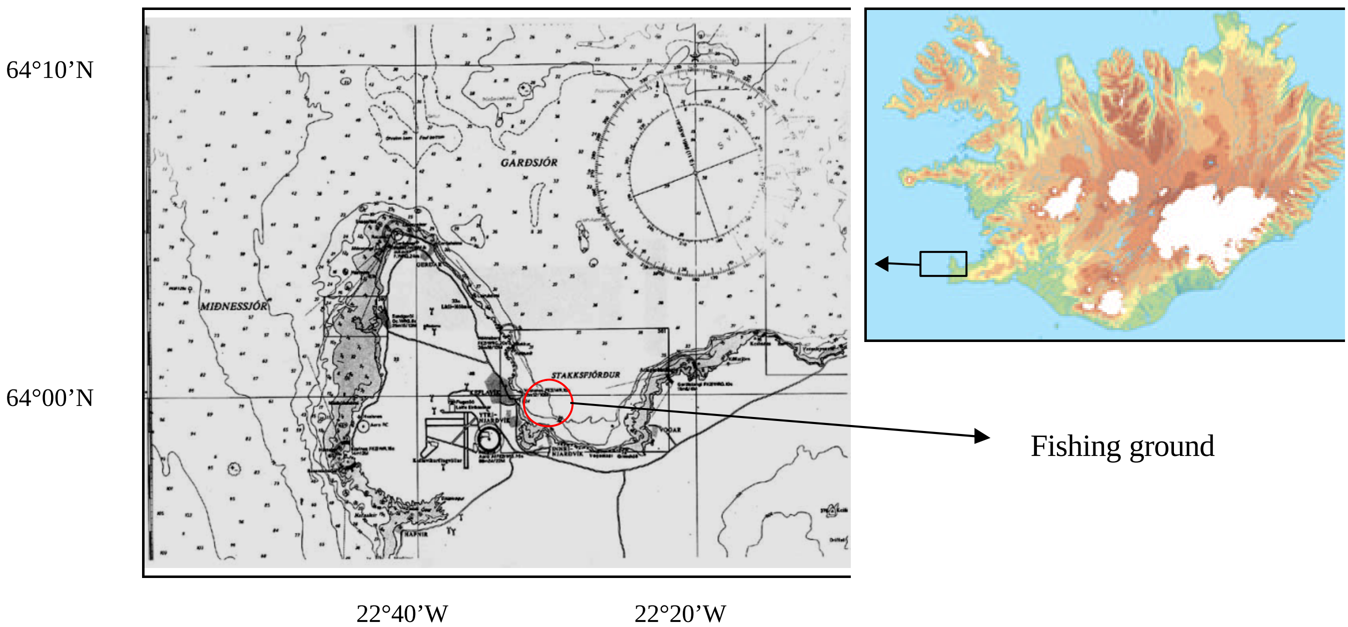


Figure 7: The areas where the three trials were conducted.

5 RESULTS

The total weight of 530.42 kg of fish was caught in the three trials. While haddock was the major fish species in the catch, cod, starry ray, whiting, flat fish and catfish were also found in fewer number. The number of each fish species is shown in Table 4.

Table 4: No. of fish according to fish species in each trial.

Fish species	Number of fish					
	Trip 1		Trip 2		Trip 3	
Haddock	126	(95.45%)	155	(95.69%)	173	(93.01%)
Cod	2	(01.51%)	2	(01.23%)	2	(01.07%)
Starry ray	3	(02.27%)	3	(01.85%)	2	(01.07%)
Whiting	_	_	_	_	8	(04.30%)
Flat fish	_	_	_	_	1	(00.01%)
Cat fish	1	(00.76%)	2	(01.23%)	_	_

Haddock was caught in all trials and made up over 93% of the total catch, starry ray was 2.27% of the total catch in the first trial and 1.85% and 1.07% in the second and third trials respectively. Two cods were caught in all trials which was around 1% of the total catch. Whiting, flat fish and catfish were not caught in every trial but were caught in small numbers, such as eight whitings (4.3%) and one flat fish (0.01%) in the third trial. In the first trial one catfish (0.76%) was caught and two (1.23%) in the second trial.

Table 5 illustrates the number of fish that were caught by each line in the separate trips. In the three trials, 25.05% of the total catch was caught by line 1 and line 2 and line 3 caught 42.79% and 32.15% respectively.

Table 5: No. of fish that were caught by each line in the three trials.

No. of fish	Line 1	Line2	Line3
Trip 1	44	55	32
Trip 2	28	90	44
Trip 3	48	60	78
Total	**120 (25.05%)**	**205 (42.79%)**	**154 (32.15%)**

To find out the relationship between snood attachment systems and caching efficiency, lines 1 and 2 can be considered (Figure 4). In line 2, snoods were attached without swivels and caching efficiency was shown to be significantly higher than for line number 1, which had snoods attached to the mainline using swivels (?2=67.335, P=0.000005 df = 10).

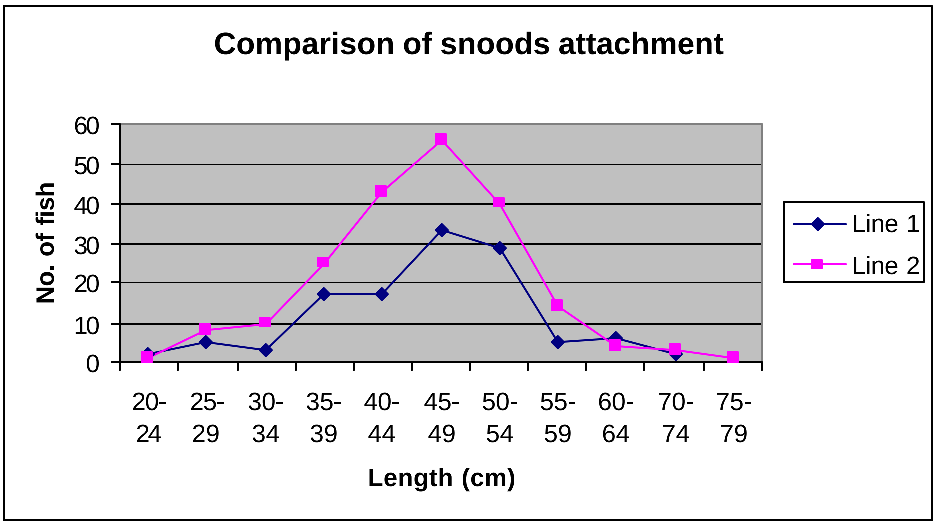


Figure 8: No. of fish that were caught by line 1 and line 2 according to the length of the fish.

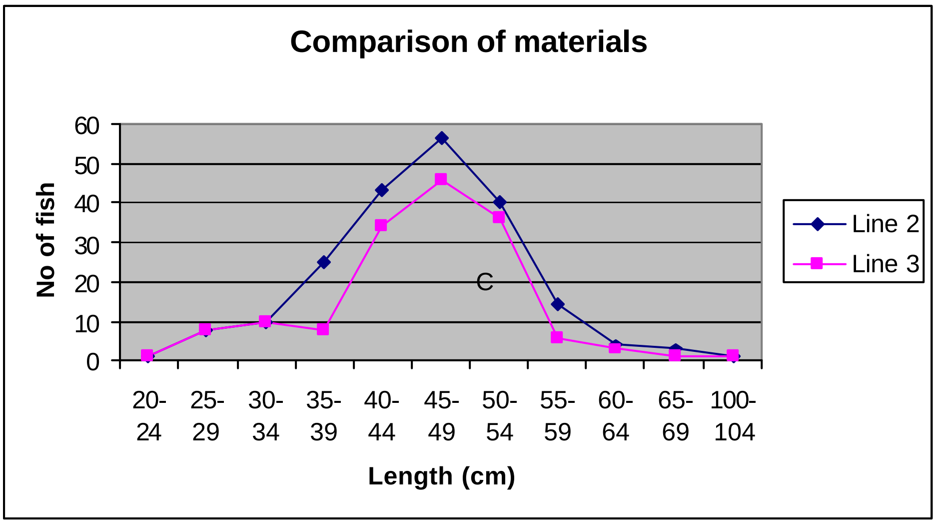


Figure 9: No. of fish that were caught by line 2 and line 3 according to the length of the fish.

To find out catching efficiency, when using different materials for the mainline, lines number 2 and 3 can be compared (Figure 5). The catching efficiency of line 2 is higher than line 3 and there are significant differences in catch rates between these two lines (?2 = 7.25, p= 0.000173).

6 DISCUSSION

Haddock was the main fish species caught in all trials. It made up 93% of the total number of fish caught and each fish weighed up to 3.8 kg. Haddock is usually caught at depths of 10-200 m and at the age of 4-6 years, 1-2 kg in weight. Cod is normally caught at the depth of 100-250 m and ocean temperature of 4-7°C. The most common age of cod is 4-7 years and the weight is most commonly 2-5 kg. Ocean catfish is caught at depths of 40-180 m (The Icelandic Ministry of Fishery 2006). The experimental fishing ground depth was around 20 m. Therefore, according to depth of the fishing ground, although cod, catfish, starry ray and whiting were caught in few numbers, haddock were caught in large numbers. When comparing line 1 (snoods attached to mainline using swivels) with line number 2 (snoods attached to mainline by knots), line number 2 showed higher catch rates than line 1 (Figure 8).

By a series of improvements, multifilament mainlines with swivels were developed. Therefore according to the type of fishery, target species and weather conditions during hauling of the gear, catch rates of the longline increased by using swivels about 15% (Bjordal and Løkkeborg 1996). When the longline is hauled under the bad weather conditions, fish may be lost because of snoods tangling and twisting on the mainline in the line without swivels, but the swivels prevent twisting of snoods so that their flexibility is maintained and loss of fish during hauling is reduced. During this experiment weather conditions were favourable and twisting of the snoods was minimised, therefore the lost fish during hauling was low. Line 2 (without swivels) showed higher catch rates than line 1 (with swivels). But if the line is used under different conditions, e.g. different fishing grounds and for different fish species, the results may change. Therefore, the experiment should be carried out in different fishing grounds as well as on different fish species.

In the Norwegian longline fishery and in some other parts of the world, swivel gear replaced traditional multifilament gear during the late 1980s (Bjordal and Løkkeborg 1996). The swivel was more convenient for fishermen and reduced the work of de-twisting snoods, and so reduced the manpower required for maintaining the fishing gear. When using longlines under good light conditions, the visibility of the lines (mainline and branch lines) may affect the catching efficiency (Løkkeborg, 2000). In this experiment, three trials were carried out during the day (between 12:30-14:30). Line 2 (Figure 5) with the mainline tarred, showed catch rates higher than line 3 (green mainline). Experimental features suggest some fish eyes to be an important sensory organ for both feeding and predator avoidance. It has been recognised that fish behaviour-control techniques using visual stimuli need to be developed (Gabriel and Dahm 2005.and Khem et al 1999 has done experiments with mackerel using various coloured lures and he found that mackerel was attracted more to colours with high contrast to the ocean (background) colour, such as red. This depends on the visuality; if they can see better they are usually attracted to the hook. In shallow seawater, coloured lures are more visible to pelagic fish, particularly species with good colour vision.

When comparing the appearance of different coloured monofilament, red, black, dark green and dark blue were seen as a dark silhouettes in the undersea green lighting and clear un-dyed monofilament is found to be invisible (Hsieh *et al.* 2001). Using this explanation it is easy to explain why fishermen use red and yellow lures in Japan and the same time we can explain the same results of this experiment that, why line 2 (multifilament mainline with tar) gives higher catch rates than line 2 (multifilament mainline with green colour). The experiment was carried out in the shallow water at 20 m depth. At that depth against the green background the visibility of the black coloured mainline (line 2) may be higher than line 3 , which is light green. On the other hand, line 2 with tar also has some special odour, therefore the fish can be attracted to that line more than to the other lines without tar.

6.1 Development of longlining in Sri Lanka

Longline is considered an environmentally fiendly method (Chapter 1). Therefore to increase longlining is a favourable condition in the world. At the same time there is potential to improve longlining in Sri Lanka. Therefore, we can identify the several most important factors to fulfil, on behalf of the increasing of usage of longline gears in the country. Fishermen's knowledge about the gear, skills in longlining and their knowledge about new technology, which is practiced in longlining around the world, should be increased. Increasing catching efficiency in the longline fishery is also important.

Using as a base of the knowledge and experience, which has been gained from this project, further steps can be suggested to carry out more experiments related to longlines in Sri Lanka. By a series of suitable experiments we may able to find relevant information to increase the efficiency of longlines in Sri Lanka to help Sri Lankan fishermen.

As described in Chapter 2.3, longlines have some disadvantages. The most important factor is the by catch of sea birds and turtles. To reduce turtle by catch, food colour and physical deterrents can be used. These help to prevent the turtles from the swallowing the baits. Some experiments have shown that the catching probability of turtles can be reduced by using blue-dyed bait (Kleiber and Christofer 1999). Furthermore, by using large (18/0, 5.7 cm) wide circle hooks, catching and entangling of the turtles can be reduced. To prevent mortality of seabirds in the longline fishery, side setting is one method that has been practiced. In this method the longline gear is set from the side of the vessel rather than the conventional position at the stern. Baited hooks are set close to the side of the vessel hull where seabirds are unable or unwilling to pursue them and by the time hooks pass the stern they have sunk and therefore seabirds cannot reach them.

Another method is blue-dyed bait. In the Hawaiian, Brazilian and Japanese longline fisheries this is done to reduce by catch of seabirds. The hypothesis is that it is difficulty for birds to detect the hook because the contrast between the bait colour and seawater colour is reduced. The baits is thawed, separated and soaked in a mixture of blue food colouring and seawater.

ACKNOWLEDGEMENTS

I am very grateful to the Director of the United Nations University – Fisheries Training Programme, Dr. Tumi Tomasson, Deputy Director Mr. Thor Asgeirsson, Mrs. Sigridur Kr. Ingvarsdottir and my supervisor Mr. Larus Palmason for their assistance and guidance. I would also like to thanks Mr. Hordur Oskarsson, the Captain of the boat, which we used for our experiment. In addition, I would like to thank the Chairman, Director General and other officers at my home institute (NIFNE).

REFERENCES

Bjordal, Å. and Løkkeborg, S. 1996. *Longlining.* Fishing news books

Central Bank (2000). *Annual report 2000*. Central Bank of Sri Lanka, Colombo Sri Lanka. Colombo: CBSL.

Dayaratna, P. and Maldeniya, R. 1995. Resent trends in tuna fisheries of Sri Lanka. *IOTC* [February 2006] <www.org/files/procedings/1995/ec/IOTC-1995-EC602-05 pdf

DFAR 1998. Department of Fisheries and Aquatic Resources in Sri Lanka. http://www.fisheriesdept.gov.lk/divisions/quality.htm

Ekanayaka, E.M.A.B.1999. *The effect of hook size and bait type on the fishing selectivity of longline gear.* Final Project UNU-FTP. Iceland.

Gilman E. 2004a. References on Seabird By catch in Longline Fisheries *Western Pacific Regional Fishery Management Council* 2004

Gilman E. 2004b. Assessment of Strategies to Reduce Seabird By catch Employed by Hawaii Pelagic Longline Tuna Vessels and of Observer Program Data Collection Protocols *Prepared for the Western Pacific Regional Fishery Management Council*. November 2004

Gabriel,O.,Lange,K. and Dahm, E. 2005. (Von Brandt's) *Fish catching methods of the world, Blackwell publishing.* Blackwell Publishing

Halliday, R.G., 2001. A combination of size selection of Atlantic cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*) by bottom longlines and otter trawls. *Fisheries Research* 57 (2002) 63-73

Hsieh, K.Y., Huang, B.Q. Wu, R.L. and Chen, C.T. 2001. Colour effect of lures on the hooking rates of mackerel longline fishing. *Fisheries Science* 2001; 67:408-414

Information Centre NARA Sri Lanka [Desember 2005] <http://www.nara.ac.lk/>

Khem, R., Sharma, Pingsun Leung, 1999. Technical efficiency of the Longling Fishery in Hawaii: An Application of a Stochastic Production Frontier. *U.S.A. Marine Resource Economics,* volume 13, pp. 259-274

Kleiber, P.and Christofer B, 1999. Work shop on reducing sea turtle takes in longline fisheries. *South-West Fisheries Science Centre* Administrative Report H-00-09

Løkkeborg, S. and Pina, T. 1997. Effect of setting time, setting direction and soak time on longline catch rates. *Fisheries Research* 32(1997)213-222

Løkkeborg, S. 2000. Fish behaviour and gear improvement in longlining. *Fishing gear system 2000* Scottish Exhibition and Conference Centre, Glasgow, Scotland.

Løkkeborg, S. 2004. A review of existing and potential longline gear modifications to reduce sea turtle mortality *FAO Fisheries Reports* - R738, Suppl.2004 246pg

Maldeniya, R. 1995. Small boat tuna longline fishery north-west Cost of Sri Lanka. [February 2006] <www.org/files/procedings/1995/ec/IOTC-1995-EC602-04.pdf>

Maldeniya, R.and Amarasooriya, D. 1998, Tuna fisheries in Sri Lanka: update. *IOTC* [desember 2005] < http://www.iotc.org/files/proceedings/1998/ec/IOTC-1998-EC7-04.pdf>

Maldemniya, R, and Suraweera, S.L., 1991.Exploratory fishing for large pelagic species in Sri Lanka.Main report, NARA, Sri Lanka. *BOBP*/REF/47

Ministry of Fisheries and Aquatic Resources in Sri Lanka (MFARD) 1999. http://www.priu.gov.lk/Ministries_2007/Min_fisheries_aquatic_resources.html

Ministry of Fisheries and Aquatic Resources in Sri Lanka 2005. http://www.priu.gov.lk/Ministries_2007/Min_fisheries_aquatic_resources.html

MFAR/FAO 2005. Post Tsunami Reconstruction and Development Programme. Situation report 2005.

Pajot, G and Weerasooriya, K.T, 1980. Fishing trials with bottom set longlines in Sri Lanka, *BOBP*/WP/6

Sea Shepherd Conservation Society 2005. http://www.seashepherd.org/seals/

Shahul, H.M, and Boopendranath, M.R., 2000. *Modern Fishing Gear Technology*, Daya publishing house, Delhi.

Svein Løkkeborg, and Teresa Pina, 1997, Effects of setting time, setting direction and soak time on longline catch rates, *Fisheries Research* 32(1997)213-222

The Icelandic Ministry of Fishery 2006. http://www.fisheries.is/stocks/whales.htm

Wang, J.H., Lohmann, K.J. Boles, L.C, and Irwin, W.P. 2004 .Responses of pelagic-stage loggerhead sea turtles to light sticks used in longline fisheries. [January 2006]<http://www.unc.edu/depts/geomag/NMFS-Poster/>

Wijayaratna B, 2001.*Costal Fisheries in Sri Lanka*. Final Project UNU-Fisheries Training Program-Iceland.