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LONGLINE FISHERIES WITH SPECIAL EMPHASIS ON BAIT SIZE AND FISHERIES IN DPR OF KOREA

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ABSTRACT

A longline experiment was carried out in Stakksfjordur on 8 and 27 January 2006. The aim of the experiment was to investigate the catch rate (number and weight) and length distribution according to different bait sizes. Three trials were conducted keeping certain experimental conditions. In each trial, a skate, which had three lines, was set. Each line had 500 hooks with different bait sizes (small bait 15 g, medium bait 25 g, big bait 35 g). The bait type was saury and the hook used in the experiment was EZ 12/0. The main species was haddock and a little cod, catfish, starry ray and whiting were caught. The medium size bait gave higher catch than the small and big bait in number and weight. The small bait gave a little higher catch than the big bait. The proportion of haddock was 92%. Therefore length analysis was applied only to haddock. The result of measuring the mean length of haddock shows that there is no significant difference in length according to bait sizes.

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1 INTRODUCTION

The Democratic Republic People's of Korea (DPRK) is located in the northern part of the Korean peninsula above the 38-parallel. It has seas on the east and west sides and borders China and Russia in the north (Figure 1).

The shelf area is 26,251 km^2 and the EEZ is about 73,000 km^2. Information on DPRK fisheries is not widely available. The following information is gained from FAO (1998).

DPRK is a mountainous country with several ranges extending in a northeasterly to southwesterly direction. Only 15% of its land area is used for agriculture, which is confined mainly to the west coast and to several broad river valleys in the west (Figure 1).

Figure 1: Map of the Democratic People's Repub lic of Korea.

With the limited land area suitable for agriculture, fisheries play an important role in the lives of the Korean people.

DPRK is a maritime country. The mixing of the cold and warm water currents and the enrichment of nutrients from rivers and streams create favourable conditions for developing marine fisheries in these waters.

The East Sea, which has a surface area of about 970,000km^2, has both cold and warm water species totalling approximately 650. The cold-water fish of commercial importance

caught by Korean vessels include Alaska Pollack, herring, flounder and silverfish. The warm water species include sardines, anchovies, mackerel and half beak.

The West Sea, which has a surface of about 430,00km^2, has a total of 250 cold and warm water species, including anchovies, Spanish mackerel, hairtail, herring and cod.

The fisheries industry of DPRK falls under a single organisation, the Ministry of Fisheries.

The fishing fleet structure of DPRK is neither sophisticated nor large. There are a total of 1,550 mechanised fishing vessels used in marine capture fisheries, eight of which are large vessels (more than 80 m in length and with 2,250 HP engines). The others are medium and small-sized vessels. More than 4,000 small none-motorised boats are used for collecting seaweeds. Only medium-sized vessels that have engines of more than 200 HP are equipped with trawl nets for bottom trawl. The majority of the smaller fishing boats with low-power engines are equipped with stationary fishing gear such as trap nets and longlines. Most vessels are made of steel but wooden vessels are also used (FAO 1998).

During the past 13 years the catch in DPRK waters has dropped dramatically. In 1993 and 1994, the fish catch was 397, 398 tons. However, since 1995, the fish catch has decreased and has been about 200,000 tons since 2000 (Figure 2).

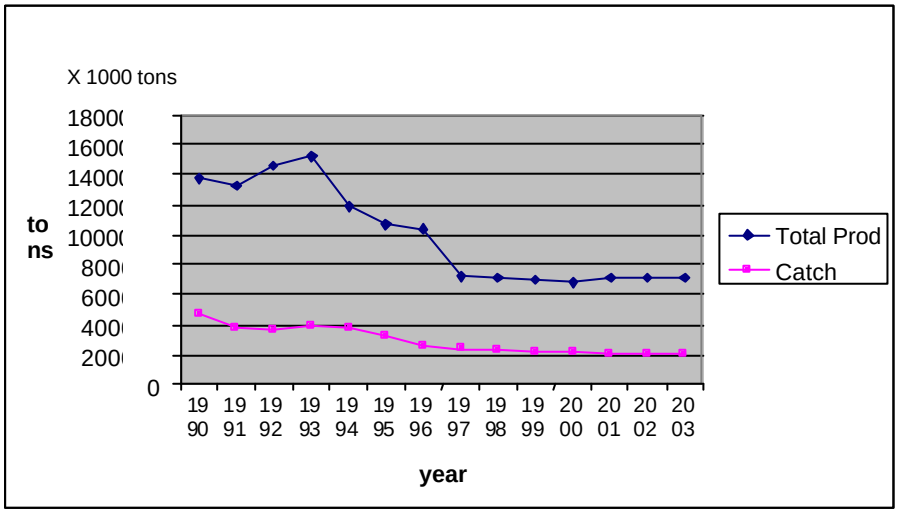

Figure 2: Total marine products and fish catch (FAO 2003).

The reasons for this are over exploitation by large-scale fishing and changes in seawater currents (FAO 1998). Changes in oceanographic conditions cause fluctuations in the abundance of marine fishes exploited, especially Alaska Pollack, sardines and herring.

The high fuel consumption of large-scale fishing has made the government apply more effective fishing methods because DPRK imports all of its oil. Trawl fishing is very

costly in terms of fuel and not environmentally friendly. Longline fishing, on the other hand, does not require much fuel and is environmentally friendly.

In order to protect fish resources, trawl and purse seine fishing are not permitted in inshore seas, only in offshore and in open seas, and small-scale fishing is widely practiced in inshore seas. The government tries to find solutions to increase the catch amount without using trawl and purse seine fishing in inshore waters. One solution is developing longline fishing because it secures sustainable catching with less fuel consumption in inshore areas and protects fish resources.

The proportion of catch by longline increases every year. In the past fishermen mostly used the hand line but nowadays longline fishing is increasing. The vessels used for longline are medium-sized with 200-400 HP engines and small vessels with 28 HP engines. The structure of the vessels has been altered for doing small-scale fishing like longline.

There are some difficulties in doing longline fishing because it has not been practiced widely in the past. Fishing gears, such as mainlines and branch lines and hooks, are provided by the Ministry of Fisheries. The main hook size provided by the Ministry is similar to EZ 8/0. Other types and sizes are not used widely in longline fishing. Squid and herring are mostly used for bait to catch demersal and semi pelagic fish. The bait size used in bottom set longline is 20 g based on fishermen's experience. Baiting is done by hand and hauling is mostly done by powered haulers.

Longline fishing in DPRK is in its initial stages and problems remain to be solved. The technical information on longline has not yet been widely introduced to the relevant people. Scientific fishing methods are not widely used and the mechanisation of longline is in its infancy. Fishermen use different sizes of bait according to their experience. This may be one of the reasons for the decreasing catch rate. Attempts to change the bait size have been made but the optimum bait size has not been found yet. A good understanding on how to study different bait sizes is therefore very important.

In longline fishing, several factors such as the hook, bait, branch line and mainline affect catch ability and selectivity. Many investigations into the effects of hook and bait type have been carried out, but in regard to bait size, little is known (Bach *et al.* 2000). Under conditions when hook and bait types are fixed, the size of the bait may have a great impact on the catch rate. Small fish generally prefer prey below a certain size because of their mouth size and their ability to capture and handle the prey. Therefore, there are possibilities to increase the catch rate by using various sizes of bait (Bjordal and Løkkeborg 1996).

Longline fisheries are the focus of this study with special consideration on how bait size affects the catch rate and composition. An attempt will be made to describe world trends in longline fisheries considering the longline fisheries in DPRK.

2 GLOBAL LONGLINE

The name of "longline" comes from the length of the lines that are used. In broad terms, a longline consists of a mainline where many branch lines are attached. Each branch line has a baited hook at its end.

Longlines are proven to be a good fishing method for catching large, high quality and high value fish. Therefore, it has become a popular method from 1980s. Longline gear is used all over the world, from small-scale fishing to modern mechanised longline operations. The longline is a very simple fishing gear, but there are many variations in gear construction, fishing method and fishing strategy.

Based on the structure and fishing method, longlines are classified into four categories: drift longline, bottom set longline, vertical longline and bottom vertical longline (Hameed and Boopendranath 2000). In some cases, longline is grouped into two categories: surface longline and bottom longline, but this categorisation is based on the same principles as the first.

2.1 Gear construction

2.1.1 Mainline

The mainline is the basic part of longline gear. Branch lines, buoy and sinker lines are attached to it. The mainline is characterised by the material, material construction and size.

The length of the mainline varies according to the fishing ground, scale of fishing operation and other conditions. In large-scale longline fishing, the length of the mainline can be up to 180 km. The thickness of the multifilament mainline generally ranges from 4 to 11 mm in diameter depending on the type of longline fishery.

The mainline is made of highly specific gravity materials such as hard twisted polyamide, polyvinyl chloride or polyvinyl alcohol. In the past, natural fibres were used but now synthetic materials are widely used because of their higher breaking strength and higher resistance to deterioration. Mainlines are made with either multifilament or monofilament. Multifilament mainlines are made from fibre filaments that are twisted to threads and strands to make rope. A multifilament mainline is usually a twisted rope with three strands. Braided rope may also be used. Multifilament mainlines are normally treated with coal tar or some other impregnating material to improve the handling properties and the lifetime of the line.

During the last 30 years, monofilament mainlines have been used in almost longline fishing because the catching performance of monofilament lines has been shown to be superior to that of multifilament lines. In contrast to multifilament lines, monofilament lines have one filament only, which is made from polyamide. Because of their low breaking strength and poor resistance to chafing, monofilament mainlines can seldom be

laid on the bottom except on smooth seabeds. Monofilament mainlines are usually used in pelagic or semi pelagic longline fishing. The monofilament is given a certain heat treatment in order to obtain good coiling and handling properties (Bjordal and Løkkeborg 1996).

2.1.2 Branch lines

Branch lines are connected to the mainline at appropriate intervals.

Branch lines affect the catch rate with regards to their material, length, thickness and the attachment.

Monofilament branch lines give 10-29% higher catch rates for cod and haddock as compared to multifilament branch lines. Thinner branch lines give better catch rates than thick ones (Bjordal and Løkkeborg 1996).

The branch line interval is determined by taking into consideration the biomass, the size of the fish and the convenience of operation. For species distributed over a large area (as for tuna), branch lines are widely spaced and where fish is more concentrated as in demersal waters, they are comparatively closely spaced.

The lower visibility of the monofilament branch lines results in higher catch rates. When the length of branch line is increased, the catch rate usually increases, but because longer branch lines tend to tangle easily, their length is limited to less than half the hook spacing.

The length of the branch line varies according to the fishing operation. Multifilament branch lines may be from 0.3 m to several meters long. The length of the branch line together with the length of the buoy line and the shape of the mainline catenary attained during operation determines the fishing depth of hooks. When fish is hauled, it tends to rotate around its own axis and around the mainline. Thus twisting and shortening of the branch line take place. So due to reduction in flexibility, the possibility of the fish breaking loose and getting lost is increased.

When branch lines made from monofilament material are attached to the mainline, there are some problems because they are slippery and stiff. To solve these problems, swivels are used to connect the branch lines to the mainline. Because swivels prevent twisting and tangling, monofilament lines with swivel give high catch rates. It has been proven that the swivel attachments improve the catch rate by about 15%, depending on the type of fishery, the target fish and the weather conditions (Bjordal and Løkkeborg 1996). Swivel connected branch lines make the de-twisting work of fisherman easy. Swivels also allow for the possibility of using a monofilament branch line with a multifilament mainline (Figure 3).

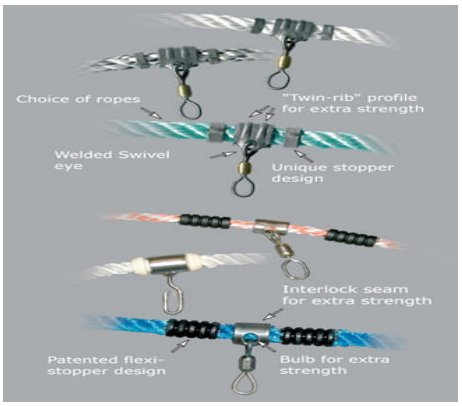

Figure 3: Different swivels which have different stoppers to prevent slipping on the mainline (Mustard Longline A.S. 2006).

2.1.3 Hook

The hook is the heart of the longline system. Everything else is just a means of getting the hook in front of the fish. The hook mainly consists of an eye, shank, bend, point, gap and throat (Figure 4).

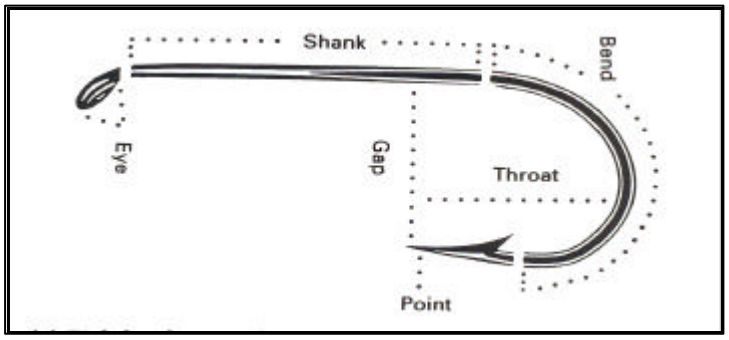

Figure 4: Basic parts of a J hook made of steel, coated with different metals (Bjordal and Løkkeborg 1996).

The hook types vary greatly and about 50,000 types of hooks have been designed. They can be classified into hooks for commercial and sport fishing. The hooks for longlines are chosen on experience, depending on the type of fish that one hopes to catch and its behaviour.

The main factors, which characterise the hook are shape, size and coating. The name of the hook indicates its basic shape, and the quality number identifies the varieties within this hook group. Hooks can be straight or with the point turned left or right. The shank may be forged, which makes the hook stronger and more resistant to forces acting in the hook.

Depending on the fishing operation, several types and sizes of hooks are used (Figure 5).

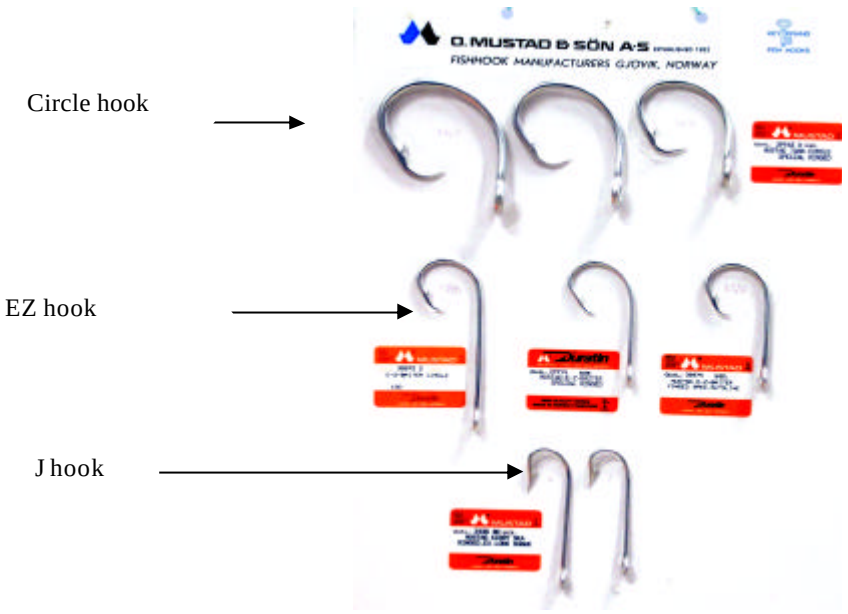

Figure 5: Different kinds of hooks. Circle hook (developed) for catching tuna, EZ hook for hand baiting, J hook used in the past.

Two kinds of hooks are mostly used in the North Pacific longline fisheries: circle hooks and auto baiters. Circle hooks have shown that they have many advantages. The main advantage is the circular appearance of the hook with the barb of the hook pointing back towards the shank or the eye. The auto baiter type of hook is used in auto line systems. The main producer is Mustad and Sons. This kind of hook is a compromise between the circle hook and the strait shank required by the automatic baiters of some systems.

In order to protect hooks from corrosion, they are coated with metals such as tin, nickel, cadmium or a combination or these metals, or other anti-corrosives. Hooks are used in various working conditions such as hooking and baiting. To fulfil the requirements of strength and elasticity in the working process, a hardening process is needed, which is critical to make the hooks neither too soft nor too brittle.

2.1.4 Bait

The principle of line fishing is to lure fish to bite the bait. Therefore, bait is one of the most important factors in line fishing.

The catch rate depends to a large extent on bait type, quality and size. (Bach *et al.* 2000). Fishermen use different types of bait from their experience accumulated over the years. The type of bait is chosen with regard to the target species. In the northeast Atlantic squid and mackerel are used as bait for catching cod and haddock, and saithe is used for demersal species.

When different types of bait are used in the same line, catch rates increase. Cod in the Barents Sea are most effectively caught on mackerel and squid bait (Løkkeborg 2000). In the Icelandic longline fishery, a combination of saury, squid and sausage made in Norway is mostly used for catching cod, ling and haddock (Figure 6).

Figure 6: Different kinds of bait. Saury, herring and squid are cut by hand to a certain size (30 g) and ready to bait on hook.

Bait quality is one of the important factors, which affect the catch rate. Bait must also be suitable to the target species. What attracts the fish is the odour from the bait. As the odour gets stronger, the more it attracts fish. The quality of bait is also measured by how well it remains on the hook.

In some longline fishing for tusk and ling, a combination of mackerel and squid baits is used. It has been shown that the catch rate for squid bait was 100% higher than the mackerel bait for ling but only 9% higher in catching tusk when the combination of mackerel and squid was 4:1 ratio. Another fishing experiment showed that mackerel and squid bait at 1:1 ratio caught 40% more tusk than longlines baited with mackerel alone (Bjordal and Løkkeborg 1996).

In addition to the attractiveness of the smell and taste stimuli, the efficiency of bait is determined by its physical strength and ability to remain on the hook throughout the soaking time. In catching cod and haddock, mackerel has given a higher catch rate than squid in pelagic longlining. However, squid stays better on the hook than mackerel, and when catching cod and haddock in bottom longline fishing, fishermen often use squid or a combination of squid and mackerel as bait. The bait loss is more important for hooks on the bottom, and squid may be more efficient for bottom longline fishing than mackerel even though mackerel may be more attractive for cod and haddock.

Bait size is also an important factor affecting the fish size and catch rate. The most pronounced effect of bait size on catch rate has been shown for haddock catching using

semi pelagic longline. Mackerel bait weighing 10 g was shown to catch more than twice as many haddock as 30 g mackerel bait. Because bait in mid-water is more easily seen than bait on the seabed, the effects of bait size are more pronounced for pelagic or semi pelagic longline than for bottom longline. The bait size also affects the size of the fish caught, as small fish prefer small size prey because of their mouth size and ability to bite and handle the prey.

In Icelandic waters, the most common bait size is 30 g/hook and the bait type used is herring, squid, mackerel and saury from Brim Company.

2.2 Bottom set longline

Bottom set longlines operate close to the sea bottom for demersal species such as shark, sea beams, sea bass, goupers, snapper, cod, haddock, halibut, hake and flat fish. Because the bottom longlines are set near the sea bottom, they are easily damaged by obstacles on the bottom.

Bottom set longline is widely used and has been known in Europe and in the Mediterranean area as well as in the Far East since early times. In Norway, longlines were known at least since the middle of the 16th century (Hameed and Boopendranath 2000). The total line can be more than 30 km long with 20,000 to 30,000 hooks. The hooks are baited and this can be a tedious task (350 hooks/hour) (Gabriel *et al.* 2005).

When using bottom longlines, the ground must be fairly regular since rocks or corals may entangle the lines and break them. Where muddy bottoms are found, the longlines are not set to remain on the bottom and are held off the seabed by floats. They can be set so that the bait is suspended at any desired distance from the bottom.

Many investigations (Bjordal 1981) have found that the efficiency of longlines is influenced not only by the design of the hook and the type, size and shape of the bait, but also by the material, length and spacing of the branch lines. In bottom longline fishing, the main concern is the selection of optimum branch lines because of the character of the fishing operation.

The bottom set longlines which have the branch lines set at wider spacing catch fish better than those with the branch lines set more closely together, and they also need less bait for the same area.

The length of the branch line must be selected correctly. The branch line cannot be too short because short branch lines are less effective than long branch lines. The length of the branch line is related to the hooking space and the free space of the vessel used in longline fishing.

The branch lines are knotted to the mainline. They can also be connected to the mainline by using removal clips or swivels. Using swivels has many advantages in handling. The branch lines can be easily changed and stored separately and also the distance between

branch lines on the mainline can be adjusted whenever it is needed. It also has the advantage in eliminating entanglements of the branch lines, thus reducing the labour of gear handling (Gabriel *et al*. 2005).

Branch lines are mostly made of monofilament and multifilament. In some longline fisheries, particularly for catching different sharks, branch lines made of steel wire or chain are used because fibre branch lines are easily cut by the sharp teeth.

Monofilament branch lines range from 0.3 mm to more than 1 mm (diameter) in thickness and from 0.5 mm to several meters in length according to the type of fishery.

Multifilament branch lines may be either twisted or braided with a thickness from 2 mm to 4 mm (diameter) and lengths from 0.3 m to several meters. In most parts of the world the branch lines are usually used in equal lengths (Bjordal and Løkkeborg 1996).

Bottom longline fishing is mostly carried out at depths from 100 to 800 m. The longline fleets are set on the bottom with anchors, buoy lines, buoys and/or marker buoys at either end (Figure 6).

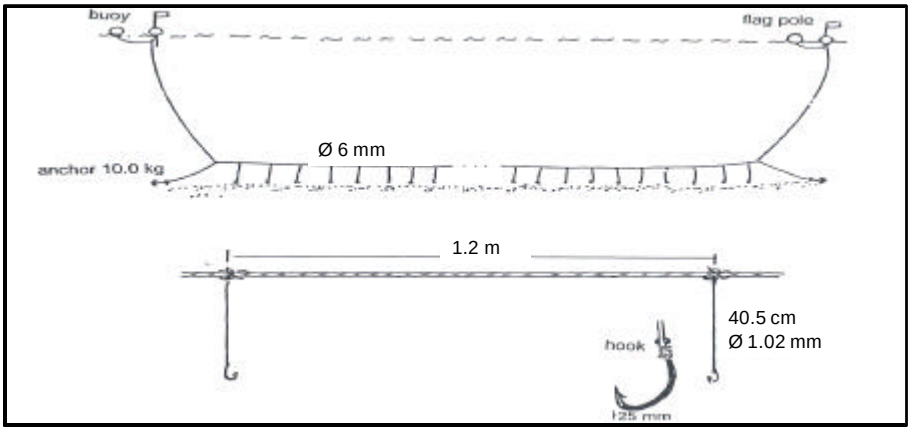

Figure 7: The whole view of a bottom set longline and hooking space. A mainline with a branch line carrying 500 hooks is set on the bottom by buoy and anchor (Hameed and Boopendranath 2000).

The anchor is made of stone, steel, lead or chain with a weight from 5-10 kg up to 80 kg. In auto longline in Iceland, stone and lead sinkers are often used for anchors. The anchor keeps the longline in a certain position with some claws which have a good grip on the bottom. It also makes the gear sink to the bottom quickly.

The purpose of buoys is to keep the gear in a certain position with anchor. It is made of synthetic fibre with different buoyancies. The buoy line is a rope somewhat stronger than the mainline, because it must have the high strain that is often needed to pull the anchor. In the middle, buoys with buoy lines and anchors are also used in order to save time and prevent the risk of losing gear if the mainline breaks during hauling. In case the line breaks, instead of moving to the end buoy, which might be far away, the middle buoy which is close to the vessel is picked up and the hauling is done continuously after short

time. The purpose of the marker buoy is to mark the ends of the longline fleet so that fishermen can easily find the longline from a distance. It consists of a pole (3-4 m long) and a weight at the bottom end to keep it floating in an upright position. Marker buoys usually carry one or two flags at the top end in order to make it more visible and a battery-light package or radar-light reflector in the marker buoy is used to identify the gear easily in darkness. In addition to the marker buoy, there are normally one or more surface floats, the main function of which is to keep the strain off the buoy line.

The amount of lines depends on the capacity of the vessel, topography of the bottom, and the distribution and density of fish. In the area with wide distribution and high density of fish, one line with about 15,000-30,000 hooks is set straight or in U-form. Also in the continental slope, lines are separated parallel into small fleets (lines) with 1,500 to 3,000 hooks (Bjordal and Løkkeborg 1996). In areas where little fish are found, lines are spread wide, 800-1,000 m apart. If the catch rate is high in an area, fishing is done several times.

Fishing is done by setting in stern, soaking, and hauling in starboard and handling gear. Before setting, baiting is done by auto baiting machines on boat or manually on land. Soaking times are different depending on the fishing operation, normally two to three hours. Hauling is done by powered machines in the starboard. Different methods are used for storing longlines. In auto longline fishing, hooks with the mainline and branch line hang on racks. Basket, tubes and wooden or plastics boxes are used for keeping hooks with branch lines.

2.3 Drift longline

Drift longline is operated close to the surface in middle water layers for pelagic fishes such as tuna, marlin, billfish, mackerel and shark (Figure 7).

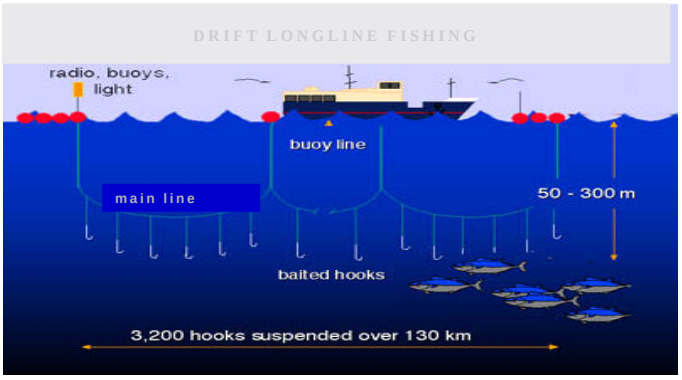

Figure 8: Drift longline set in a certain water depth by buoys is applied to catch fish migrating in mid-water (Birds Australia 2006).

The fishing method is similar to the bottom set longline. The setting work is done from the stern. The speed of the vessel in setting differs according to the fishing conditions, but is normally around 5-6 knots. At first, marker buoys with flags, radio buoys and light buoys are thrown in and the mainline is released. The marker buoy, light buoys and radio

buoys are connected at proper intervals. In case of auto line, hooks are baited when the mainline is released. After setting, the vessel stays for six hours near the line. In hauling, the line is hauled by a powered hauler and when the branch line comes onboard the fish is removed. For traditional drift longlines, the mainline carrying the branch lines is coiled and kept in a basket. In modern large-scale drift longline, mainline is continuously pulled and kept on a powered reel or rack with branch lines. There are some cases that on hauling branch lines are removed from the mainline and kept separately. But nowadays lines with branch lines are usually kept on racks after hauling (Bjordal and Løkkeborg 1996).

To locate the potential fishing ground and to position the line in deep seas, it is important to know the correlation between fish distribution and sea surface temperature or the thermocline. Distribution of fish is determined by temperature and feed organisms. Thermocline is the temperature continuity layer where temperature changes rapidly with depth, between mixed surface waters and cooler deeper waters. Fish like tuna are generally found in the thermocline layer. The swimming layer of the yellow fin tuna and albacore is in the mixed layer and thermocline. Big eye tuna occupies lower layers of the thermocline and the cooler waters below. Information on the swimming layer of target fishes and their association with the thermocline is used by fishermen for fishing the target species. Sea surface temperature and ocean colour charts are used to locate potential fishing grounds based on the temperature preference regimes of target species and the aggregation of feed organisms in the thermal front (Hameed and Boopendranath 2000).
The most common drift longline in fisheries is the tuna longline. The tuna longline was introduced by Japanese fishermen about 300 years ago and they have been a leading nation in terms of longline fisheries along with China and Taiwan. The tuna longline, like most of other longlines consists of many sets. Each set ranges from 150-400 m in length. Typical branch lines for tuna longline consist of three sections and each branch line is attached with a special snap-on metal clip to the mainline. Each set is stored in a basket. Japanese fishing boats, ranging from 200 to 800 gross tonnages in size, usually carry 350-400 baskets of longline. The tuna longline is not only an effective fishing method but also a very labour intensive one (Gabriel, *et al.*2005).

Mechanisation and automation for both bottom and drift longline are successfully under way. While setting, the hooks are baited by drawing them through an automatic machine. Mechanical hydraulic line haulers are now widely used in drift longline fishing. This system includes de-hooking of fish, twist removal of branch lines, hook cleaning and handling lines. This has decreased the manpower required dramatically (Hameed and Boopendranath 2000).

2.4 Vertical longline

Vertical longline is used to catch fish with a wide vertical distribution. Vertical longline is effective on steep shelves. Vertical longline is used in deep waters up to 1,200 m and in shallow areas having rough bottom conditions or in areas where fish aggregating devices are deployed. Gear construction has a little difference to drift longline (Figure 7).

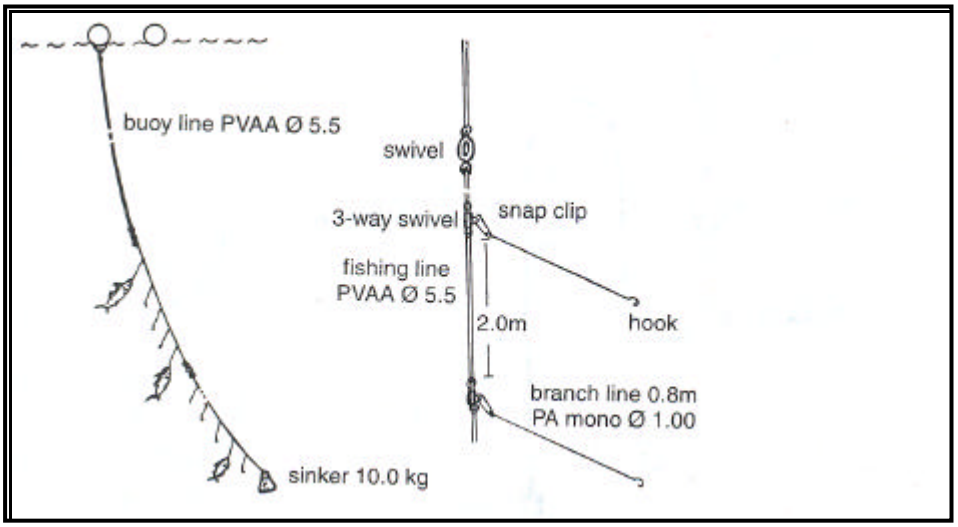

Figure 9: Vertical longline set vertically by buoy and anchor to catch fish migrating across a vertical range and connecting the branch lines to the mainline (Hameed and Boopendranath 2000).

It consists of a single line with a float at one end and a weight at the other. The mainline extending across the vertical range of the swimming layer of the target species is attached to the buoy line with a swivel. Branch lines are attached to the mainline through three-way swivels or snap clips, at intervals of around 2 m. The mainline is set vertically with the upper end joined to a large float and flagpoles, and the lower end is provided with a sinker. Branch lines are attached at approximate intervals to the mainline (Hameed and Boopendranath 2000).

The fishing operation is similar to drift longline. When the vessel arrives at the fishing ground, the anchor, marker buoy and radio buoy with the connected end mainline are thrown overboard. The line is set over the stern when the vessel moves ahead. The hooks are baited before setting the line. After soaking for a period, the lines are hauled up using a line hauler. The soaking time depends on fish distribution and density. Fishes are removed when the branch lines come up, mainlines and branch lines are arranged and stored, and accessories are removed and stored.

Bottom vertical longline combines the properties of the bottom set longline and vertical longline, using their advantages.

Many hooks are attached at suitable intervals less than 2 m by polyamide monofilament lines less than a meter in length to the branch lines. Branch lines are designed to be directed vertically during operation by adding floats at the top and sinkers at the bottom end. Branch lines are hung from the mainline by means of snap clips at interval of 20-25 m. The mainline is positioned at an appropriate height from the bottom by adjusting the buoyancy. When the mainline does not touch the ground the gear is particularly suitable for rough grounds (Hameed and Boopendranath 2000).

2.5 Pelagic longline

Pelagic longline is normally not anchored but drifts freely in the sea. Pelagic longlines are mainly used in high seas longline fisheries for pelagic species such as sword fish, tuna, shark and salmon, but are also in coastal waters for species such as haddock during periods when the fish are feeding on pelagic prey. The fishing operation is similar to drift longline. Between the ends (marker) buoys, the mainline is suspended in the sea by floats attached at intervals. Sometimes the branch lines are weighted, but this method usually relies on the mainline sinking under its own weight to get to the required depth (Bjordal and Løkkeborg 1996).

2.6 Longline vessels

Specialised vessels for longline fishing, longline vessels, operate throughout the world. The vessels are characterised by the rail roller, the longline hauler or the setting chute. Longline vessels may be classified by size (LOA) into small (8-15 m), medium (15-25 m) and large (25-50 m) longliners.

Small longline vessels are operated by one to three fishermen and the fishing trips are short (one or two days). The boats are mostly made of wood, fibreglass, steel or aluminium.

Medium size longliners catch fish in coastal or inshore waters. Fishing trips usually last from two to seven days and the number of fishermen is three to eight, depending on the fishing operation. A 20 m longliner may carry 90-100 sets of gear (30,000-40,000 hooks) during a two-day trip with four fishermen. Medium size longline vessels are normally equipped with engines of 250-600 HP, giving a maximum speed of 8-10 knots (4-5m/s).

Large longline vessels are built for deep-water fishing for more than three weeks at a time. The size and the structure differ according to the fishing operation. Some vessels are 40 to 60 m long and have 20-25 fishermen. Fishing trips are often 18 to 24 months. Some large longline vessels are used as combination vessels, gillnetting for herring and cod in winter and spring and longlining for tusk and ling on the coastal side and continental slop during summer and autumn, mainly based upon onboard baiting of the lines during one to two week trips. The latest development in large-scale longliners is a series of vessels built for fishing Patagonian toothfish at large depths (1,000-2,500 m) off Argentina (Bjordal and Løkkeborg 1996).

2.7 Mechanisation of longline

Many studies on longline mechanisation have been conducted since the early 1960s especially in Canada, the Faroe Islands, Germany, Iceland, Ireland, Japan, Norway, Sweden, UK and USA (Bjordal and Løkkeborg 1996).

The main focus of this research has been on automated baiting, hauling operation systems and line handling systems. These three systems are operated in a whole system (Figure 9).

Two main systems have been quite successful, one is automated baiting (precise or random baiting) and the other is storage of the gear (rack or drum storage).

The automated baiting is either precise baiting or random baiting. In precise baiting, a piece of bait is put on each individual hook by a baiting machine, which cuts the whole bait fish to a certain size. Precise bait size is guaranteed to be comparable to hand baited bait size.

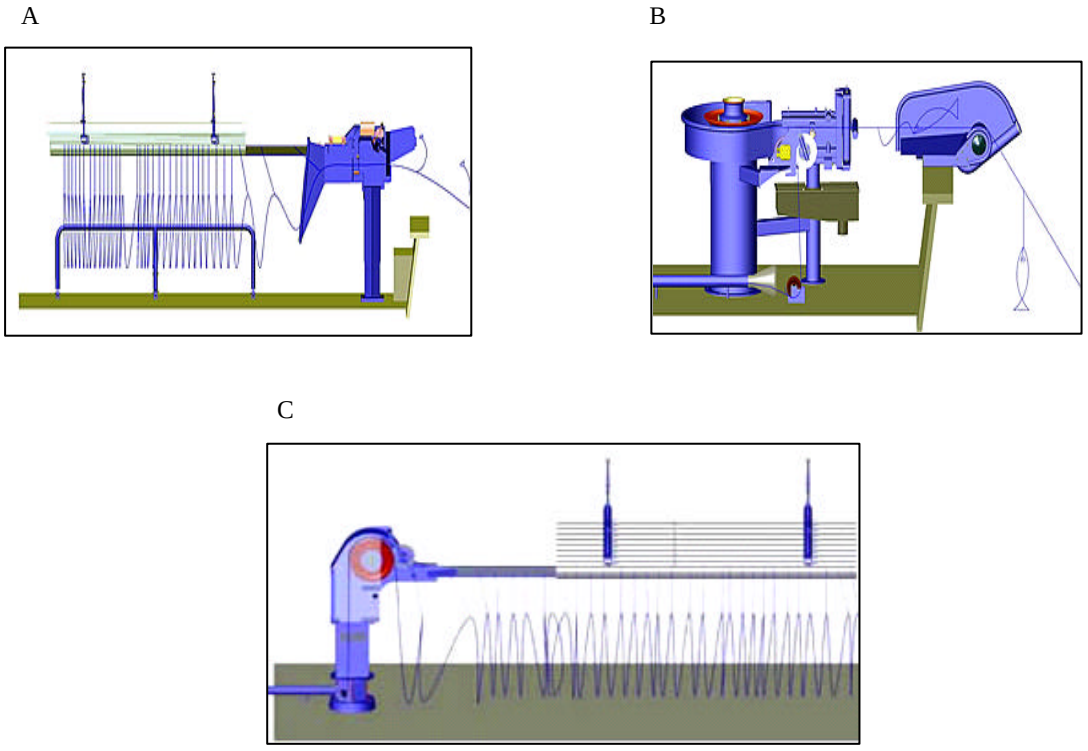

Figure 10: Different parts of an auto longline system. A) Baiting and Shooting, B) Hauling and C) Handling line (The three pictures are copied from Mustad Longline A.S 2006).

The auto longline system developed by O. Mustad and Sons Ltd of Norway is widely used in commercial fishing. The system is operated by three fishermen. When setting is

done, one fisherman feeds bait fish onto the conveyor belt and the other checks that the hooks run smoothly off the rack and replaces empty racks with loaded ones. Bait is put on hooks at a certain size and speed in auto baiters. When the hook penetrates the bait, a piece of bait is cut by a mechanically driven knife and the baited hook is pulled out of the machine. This work is done at the speed of up to six EZ baiter hooks per second with a hooking spacing (branch line spacing) of 1.3 m. The captain controls the vessel and fishing operation. The setting speed is usually from 6-10 knots depending on the model of baiting machine used and spacing between hooks. Hauling is done by a powered line hauler. It pulls the gear over a rail roller. When hauling, one fisherman gaffs and the other blades the fish. The line from the rail roller passes the de-hooker and the hook cleaner. Then it passes through the hauler to the twist remover and the hook separator. Twists in the branch lines are removed automatically by the twist remover by using water jet flushing. Also cleaning the lines is done at the same time as twist removal. The hook separator catches the hooks and guides them onto the rack. This is done by using magnets. When the hooks and line arrive on the rack, repair work is done.

In random baiting, the line is set through the container with the mixture of pre-cut bait and water. A piece of bait is snagged to a hook randomly, when the hook passes through the bait mixture. In this case, the bait is securely fastened.

Metal racks or rails are used for rack storage. The hooks are put onto the rack in sequence and branch lines and the mainline are suspended underneath. Also, drums are used either to store the mainline only by using detachable branch lines or to store the complete gear.

3 LONGLINE FISHERY OF DPRK

Very little has been documented about the longline fishery of DPRK and most of the information is based on the experience of fishermen and people in the fishery.

3.1 Fishing grounds and target species

Longline fishing is mostly done in the East Sea of Korea because it has a wide continental area and appropriate bottom type, and in some cases small longlines are also used in the West Sea of Korea. In the East Sea of Korea, there are good fishing grounds in the so-called Hollow where weather conditions and bottom conditions are good for line fishing. The bottom consists of smooth sand and mud. Thus most fishermen catch fish in these fishing grounds. Longline fishing is done all year round except during spawning season in May and November. The depth of longline fisheries grounds ranges from 30 m to 200 m in the East Sea of Korea and from 20 m to 100 m in the West Sea of Korea.

The target fishes are flounder, cod, Pollack and some other fishes migrating to the fishing ground. Mackerel, cod, squid and other fishes migrating in the mid water are fished with a drift longline.

3.2 Structure of vessels

Most of longliners are the alternatives of trawlers for small-scale fishing with 400 HP (32 m), 200 HP (28 m), 100 HP (16 m) engines and the small vessels with 28 HP (8 m) and 16 HP (6 m) engines.

Typical small longliners are made of wood but steel boats are also used. Medium size and large vessels are mostly made of steel. They carry 10 lines with 5,000 hooks and travel with a speed of 8-9 knots. The number of fishermen ranges from six in small boat and to 12 in medium and large-size vessels (large vessels are those with 400 HP engines).

The main structure of the vessels consists of a rack for branch lines and the mainline, a rail roller, a longline hauler and fish holds. Most of the work like baiting, storing lines, de-hooking, correcting and cleaning hooks is carried out by hand and hauling is done by powered haulers. Baskets are used for storing gears. Setting lines is done in the stern and hauling on the starboard. Fish holds are under the deck. Caught fish is either delivered to the processing mother ship or to the homeport.

Echo sounders are mostly used to record the desired depth and partly to evaluate adequate bottom substrate and configuration for setting the gear. An satellite information system is not yet used in longline fishing in DPRK.

3.3 Structure of longline gear

Longline gear in DPRK is similar to that used in other countries but with a few differences.

Several types of material are used in mainlines and branch lines. Synthetic fibre material called vinalon (breaking strength 8g/denier) is mostly used in ropes. They are twisted to form strand and rope in different sizes. Multifilament and monofilament are also used widely in longlines. To improve the handling properties and the lifetime of the multifilament and monofilament, it is treated with heat and coated with tar. It gives the effect on the structure of the material so that it improves the coiling properties after being exposed to stretching during hauling of the line.

Multifilament mainlines are made from fibre filaments that are twisted to threads and strands to make rope. The thickness ranges from 3 to 10 mm in diameter according to the fishery type. A multifilament mainline is normally twisted with three strands. Braided imported rope is seldom used. Nowadays the use of monofilament has increased because of higher catch rates compared to multifilament. The length of the mainline is different according to the fishing operation. In bottom set longline, it ranges from 300 to 500 m.

Branch lines are made of the same material as the mainline but in some cases different materials are used. The main materials are synthetic fibre vinalon, multifilament and monofilament. The length of branch lines is determined by the hook spacing. In bottom set longlines, the length is limited to less than half of the hook spacing; normally 40 cm.

Two main methods for connecting branch lines to the mainline are used. One is to fasten the branch lines to the mainline directly and knots are made on the mainline. The other is to use clips made of stainless steel spring. This method has the advantage in exchanging branch lines easily and storing them separately. The branch line spacing on the mainline can also be changed whenever it is needed. According to the wide use of monofilament, swivels are used in large longliners (with 400 HP engines) but in small and medium size longliners, both hand fastening and clips are often used.

Different methods for storing longlines are used depending on the vessel and fishing method. When the number of hooks is small, hooks are hung on wooden clamps. Baskets, tubes, and boxes are used for storing mainlines, branch lines, and hooks. Racks are not used in large vessels yet.

The types and sizes of hooks that are used vary a little according to target species and fishing methods, but not a great deal. In bottom set longlines for catching demersal fish, hooks made of stainless steel and similar to EZ 8/0 are mostly used by fishermen. In small longliners and drift longliners, hooks smaller than EZ 8/0 are mostly used. From the fishermen's experience, catch rates increased by using hooks smaller than EZ 8/0. The number of hooks in a line is different according to the fishing operation, but normally 200-300 hooks are used.

In the past, different types and sizes of bait were used based on fishermen's experience, but nowadays fixed types of bait are used because the Fisheries Ministry got a good result from the relevant enterprise on it. The main bait type used in bottom longline is squid and herring; saury is also used in small-scale longline fishing. The bait is pre-cut and put on hooks in a certain bait size (20 g) by hand. Before going to sea for fishing, prepared bait is kept frozen. Cork buoy markers (50 cm in diameter) and sinkers (made of steel, 8 kg) are used.

3.4 Fishing operation

The most used longline fishing method is bottom longline and drift longline. Pelagic longline is not widely used yet. The operation for fishing is similar to global longline fishing methods, but as with the structure of the gear, there are some differences in the operation.

Bottom longline is applied in certain fishing grounds less than 100 m in depth and sometimes at a maximum depth of 200 m. Fishing begins before dawn when fish migrate actively for feeding. On arrival at the fishing ground, the line is set perpendicular to the current. This work is done in the stern. At first, the anchor, buoy line and buoy are pulled off from the rail roller. The captain takes the course in relation to the fishing ground conditions at a slow speed of 2-5 knots. When the anchor and buoy are dropped, the pre-baited line is thrown off the roller at the vessel speed. To avoid tangling of lines, chute made of steel is used. This gives increased safety for the fishermen. The setting depth of the bottom longline is controlled by adjusting the length between the sinker and the mainline. At the end of setting, the marker buoy is set to identify the line. After setting

one line, the other lines are set in parallel in the same way when several lines are set. The soaking time depends on the fish density and weather conditions but three to five hours is common. Hauling begins by locating the marker buoy. The captain uses modern navigation devices or in darkness, powerful searchlights are used. Using a throwing hook or long pole with a treble hook, the marker buoy is picked up onto the vessel. Hauling work is usually done on the starboard by a powered hauler. The hauler consists of a rail roller, sheave and coiler. The rail roller protects the vessel and lines from chafing and makes the line pull into the sheave. The sheave squeezes the line to get good grip. The lines from the sheave are cleaned and de-hooked by hand and stored in baskets. One fisherman at the rail roller gaffes the fish by using a pole with a treble hook and clears the tangling. The other men de-hook and bleed the fish. When hauling, the captain takes care of the correct manoeuvring course of the vessel. The course is parallel or slightly to the left of the line and the speed of the vessel is adjusted according to the hauling speed.

In contrast to bottom longline, drift longline is not anchored and usually drifts freely in the sea. The mainline is suspended by floats and float lines in the sea. The depth of the drift longline is controlled by the length of float line. The number of floats are determined according to the fishing conditions like target fishes feeding in the middle and surface water depth. In drift longline, very thin monofilament lines for catching Pollack are used to keep them in a certain water depth. The lines are set in the certain depth with many attached surface floats. The drifting time depends on the fish density, normally six to eight hours. When hauling, all the floats are picked up at first and then the line is hauled.

In addition to these line fishing methods, vertical longline fishing for catching squid is widely used from May to October. The fishing method is a little similar to jigging. The length of the vertical lines ranges from 30-50 m according to the depth of squid migration. In a vertical line, 20-60 branch lines with flounder bait are connected to the mainline. Sometimes jigging is done by hand or automatic machine. The caught fish are delivered to the homeport daily or to the processing mother ship.

3.5 Comparisons of global longline with longline fisheries in DPRK

3.5.1 Application of fishing method, prominent fishing gear and auto longline in global longline fisheries

The water depth for longline fishing in global longline fishing ranges mainly from 30 m to 60 m, up to 2,500 m. The main fishing method is bottom set, pelagic and semi pelagic longline.

Special longliners and the combinations of trawl and longliner, gill-netter and longliner are used. The vessels are classified into small vessels with two to three crew members and one or two day fishing trips, medium size vessels with three to eight crew members and two to seven day fishing trips and large vessels with 20-25 crew members and more than three week fishing trips.

The fishing procedure is similar, namely, setting in the stern, hauling on the starboard and handling gears and fish, though small differences according to fishing method are found. Setting is done mostly before dawn with a setting velocity of 6 knots (in some cases 3 knots) and in the direction perpendicular to the current. Soaking time is different according to distribution and density of fish, but usually two to three hours

To increase the catch rate and for the easy handling of gear, much attention is paid to select rational material and the length of the lines. The standard length of a mainline in one line is 500 m and the total length ranges up to 180 km. Multifilament lines with a thickness of 4 mm-11 mm in diameter are widely used, but because of the advantages of monofilament, it is extensively used nowadays, especially in pelagic and semi pelagic longline fishing. The material of branch lines with the length of 20-50 cm is the same as that of the mainline but it may be different, such as monofilament or multifilament. Using branch lines of monofilament, catch rates are 10-29 % higher than using multifilament branch lines. Almost all lines are attached with swivels made by a specialised company but little lines without swivels are also used.

Various types and sizes of hooks are used according to the target fishes and fishing operation. Traditionally circle type hooks in hand baited longlines and baiter hooks (EZ) are used in global longline fisheries. The number of hooks normally amounts to 100-500 hooks and 20,000-30,000 hooks in total length.

The bait type is different according to the target fishes but selected bait types like saury, squid, herring and mackerel provided by specialised companies are mostly used. The standard size of bait is 30 g in an auto baited machine though it varies by fishing operation.

Automatisation of longline fishing is motivated through the world with the main point on baiting, hauling and handling gear.

3.5.2 Longline fishing operation and gear in DPRK compared to global longline fishing

Bottom set and drift longline are the main fishing methods in longline fishing in DPRK. Longline fishing is done at water depths of 20-300 m and in certain fishing grounds, the so-called Hallow, traditionally. Fishing begins mostly before dawn and in some cases during the daytime. Fishing operation is similar to global longline fishing but there are some differences in soaking time, handling of gear and mechanisation. Soaking time is longer than in global longline fisheries, normally three to five hours in bottom set longline and six to eight hours in drift longline.

There are no specialised longliners. Most of them are altered trawl and purse seiners for universal fishing. Combinations with trawl or purse seiners with 400 HP and 200 HP engines and small vessels with 28 HP and 16 HP engines are found popular.

Rope is made of synthetic fibre like vinalon and nowadays imported monofilament and multifilament ropes are also in use. In the mainline, multifilament ropes with a thickness

of 3-10 mm in diameter and 300-500 min length are used. The length of branch lines is normally 40 cm though some differences are found according to fishing operation. The use of swivels is found in imported ropes but most branch lines are connected to the mainline directly.

Handling lines is done basically by using baskets or tubes without using racks.

The hook provided by the Ministry of Fisheries is similar to EZ 8/0 and hooks made by artisans are also used.

The bait types in popular use with a standard bait size of 20 g are squid, sardine and herring. Sometimes clam is also used. Baiting, setting and handling are carried out by hand and hauling is done by powered haulers.

3.5.3 Main findings in comparison

Longline fishing has become one of the most important fishing methods throughout the world as it secures a friendly and profitable fishery for the future. Longline fishing gives:

- Large fish and excellent quality
- Little waste
- Very good prices
- Very good profitability

The catch amount by longlines ranges from about 15-90% of the total small-scale artisan fishing in the world catch (Løkkeborg 2000). From this, the significance to develop longline fishing is made.

Automatisation of longline fishing is the most important factor guaranteeing high catch and less labour throughout the world. Almost every fishing operation including baiting, setting and handling can now be done automatically.

Nowadays the main research point is focused on the study of factors which influence fishing gear and catch rates because the fishing method is almost completed and some successes in the use of monofilament, selection of hooks, bait type and soaking time etc. are made.

4 LONGLINE EXPERIMENT ON BAIT SIZE

4.1 Aim of experiment

Research on how to increase longline catch rates in DPRK is in its infancy. There are many problems to be studied. Especially the study on bait has not been carried out comprehensively yet. Fishermen use certain types of bait such as herring and squid with a bait size of 20 g, which is selected from the fishermen's experience. Sometimes fishermen change the bait sizes according to their fishing operation. This causes fluctuation in catch rates.

The catch rates (number and weight of fish) and length distribution according to different bait sizes (small bait 15 g, medium size bait 25 g and big bait-35 g) are shown in this experiment. The principle of this experiment is based on the fact that fish prefer certain sizes of prey according to their mouth sizes and ability to handle it.

4.2 Method and material

From 8-27 January 2006, three fishing trials were carried out by the hand baited longliner "RAN" SH 500 in the area between 63° 59´ 168-63° 49´090N, 22° 26´668-22° 28´ 002W (Figure 10). Three lines with different bait sizes were set in the direction parallel to the wind direction (Figure 11).

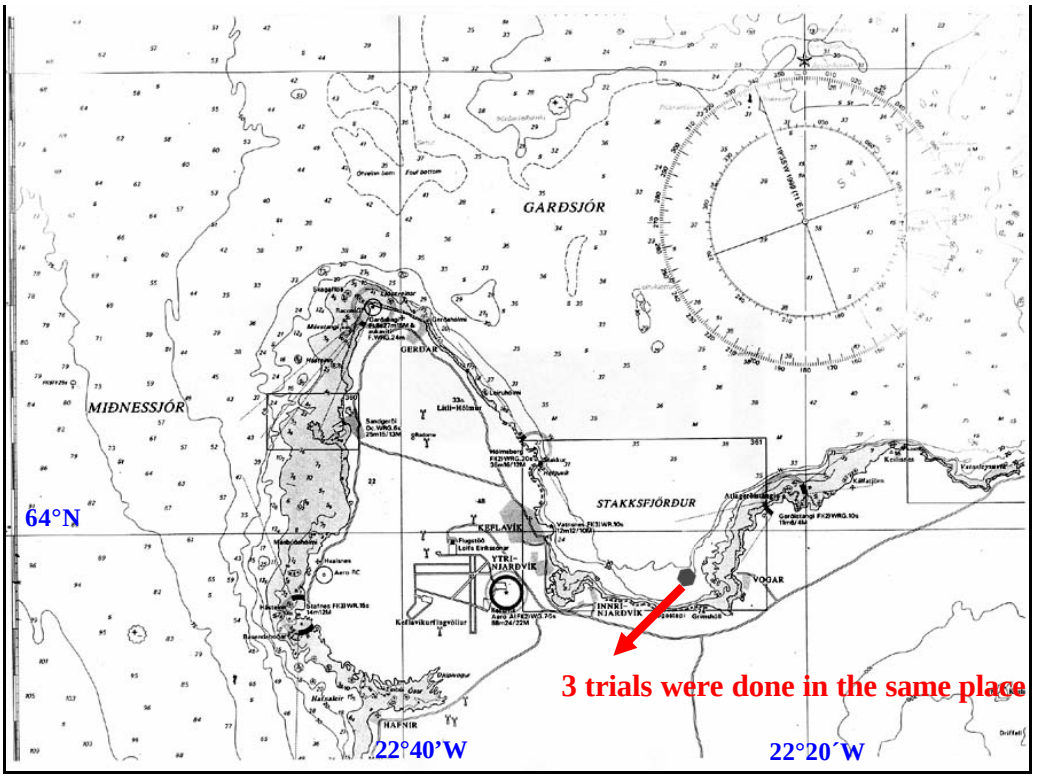

Figure 11: Fishing ground for the experiment.

Each line was hand baited with saury having the bait sizes small (15 g), medium (25 g) and big (35 g). The direction of the line was parallel to the wind direction. The bottom was mainly mud and the depth was around 20 m. The normal soaking time was 2.5 hours, which is the common soaking time in coastal longline fishing off Iceland. Water temperature was around 0°C during all the trials. Deep attention was made to keep all the experimental conditions constant in all three trials. One skate for the experiment that had three lines with three different bait sizes was set with setting a speed of 4.5 knots. The total length and weight (bladed) of all the fish were measured according to species and bait sizes separately.

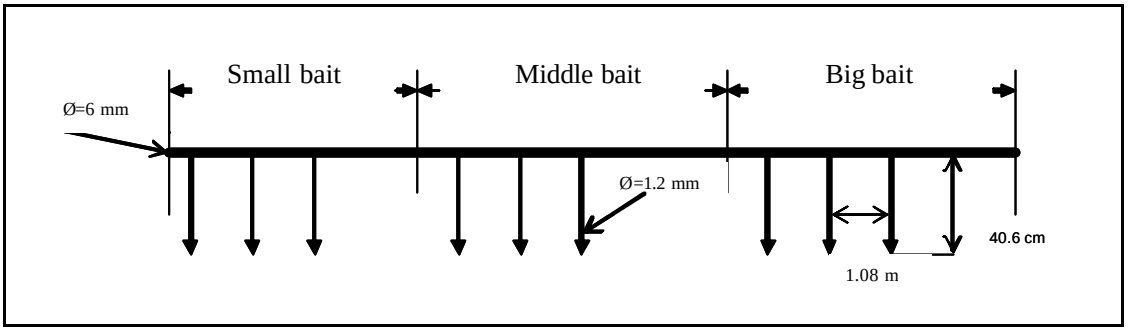

Figure 12: Longline arrangement for the experiment. Three lines with the bait sizes small (15 g), medium (25 g) and big were set in one skate.

The first trial with three lines was carried out on 8 January at 20 m water depth in daytime (from 12:00 to 14:00) on a mud bottom. The weather was bad with 4.5 m wave heights and heavy winds (6 m/s). Forty baited hooks were tangled and bait loose was caused because of bad weather. The second trial was carried out on 20 January at the same location as the first trial in the daytime (from 14:00 to 16:00). The weather was good with 2 m wave heights and still winds (2m/s). The third trial was carried out on 27 January in the daytime (from 15:00 to 17:00). The weather was good with 1 m wave heights and still winds. Little tangle was found (only eight hooks).

Table 1: Specifications of gear used in the experiment.

Gear	Specification
Mainline	
• Material	Multifilament polypropylene with tar
• Length	510 m
• Thickness	Ø=6 mm
• Colour	Black
Branch line	
• Material	Multifilament nylon
• Length	40.6 cm
• Colour	White
• Spacing between branch lines	1.08 m
• Thickness	Ø=1.02 mm
Hook	
• Type	EZ
• Size	12/0
• Number of hook per line	500
• Method of mounting	With swivel
Bait	Saury
• Type	15 g, 25 g, 35 g (small, medium and big bait)
• Size	
Boat	
• Name	RAN SH 500(registered number 2477)
• Width	2.57 m
• Length	8.67 m
• Horse power	350 HP
• Gross tonnage	6.4 t
• Depth	1.19 m

4.3 Results

In three trials, a total of 507 fishes were caught. The main species were haddock and little catfish, cod, starry ray, whiting and flat fish (Table 2).

Table 2: Total number of fish and percentages in all three trials.

Species	Number of fish	Percentage %
Haddock	480	94.67
Cat fish	8	1.58
Cod	8	1.58
Starry ray	4	0.78
Whiting	4	0.78
Flat fish	3	0.59

In every trial, the catch composition was similar and haddock was the main species (Table 3, 4, 5).

Table 3: Number of fish and percentages according to species in trial 1.

Bait	Small bait		Medium bait		Big bait	
Species	Number of fish	Percentage %	Number of fish	Percentage %	Number of fish	Percentage %
Cod	1	1.49	0	0	1	3.57
Haddock	62	92.53	33	91.66	26	92.86
Whiting	4	5.97	0	0	0	0
Cat fish	0	0	1	2.77	0	0
Starry ray	0	0	2	5.77	1	3.57

Table 4: Number of fish and percentages according to species in trial 2.

Bait	Small bait		Medium bait		Big bait	
Species	Number of fish	Percentage %	Number of fish	Percentage %	Number of fish	Percentage %
Cod	0	0	0	0	0	0
Haddock	71	97.26	91	95.79	47	94
Whiting	0	0	0	0	0	0
Cat fish	0	0	3	3.16	2	4
Starry ray	2	2.74	1	1.05	1	2

Total 110 kg of saury was used for bait in all trials.

Table 5: Number of fish and percentages according to species in trial 3.

Bait	Small bait		Medium bait		Big bait	
Species	Number of fish	Percentage %	Number of fish	Percentage %	Number of fish	Percentage %
Cat fish	0	0	0	0	2	3.85
Cod	0	0	2	2.90	0	0
Flat fish	0	0	1	1.44	2	3.85
Haddock	37	100	65	94.20	48	92.30
Whiting	0	0	0	0	0	0
Starry ray	0	0	1	1.45	0	0

The total numbers and percentages of fish in all trials caught using three different bait sizes are shown in Table 6 and Figure 11. Bait size appears to influence the number of fish caught as there are differences between bait sizes in all trials (Chi^2 =15, 65, DF=2, P=0, 0005345).

Table 6: Analysis of numbers and percentages of fish caught by three bait sizes in all trials.

Bait	Small bait	Medium bait	Big bait
Number of fish	177	200	130
Percentage %	34.85	39.40	25.74

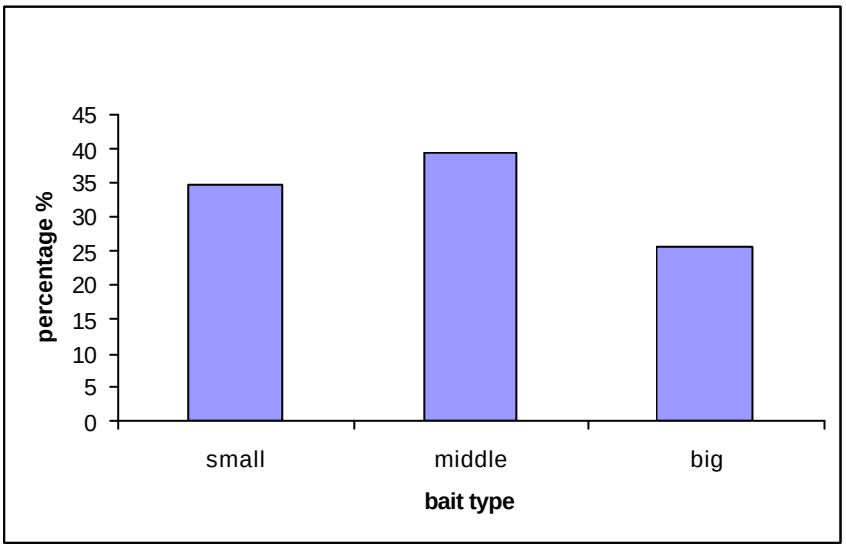

Figure 13: Analysis of numbers (%) of fish caught by three bait sizes in all trials.

In total 498 kg of fish was caught. The total weight in all trials according to bait sizes are summarised in Table 7 and Figure 12.

Table 7: Summary of weight (kg) of fish and percentages according to three bait sizes in all trials.

Bait	Small bait	Medium bait	Big bait	Total weight kg
1 trial	53.1	34.6	27	114.7
2 trial	72.7	106.9	49.3	228.9
3 trial	29.5	74.9	50.5	154.9
Total weight	155.3	216.4	126.8	498.5
Percentage %	31.2	43.4	25.4	100

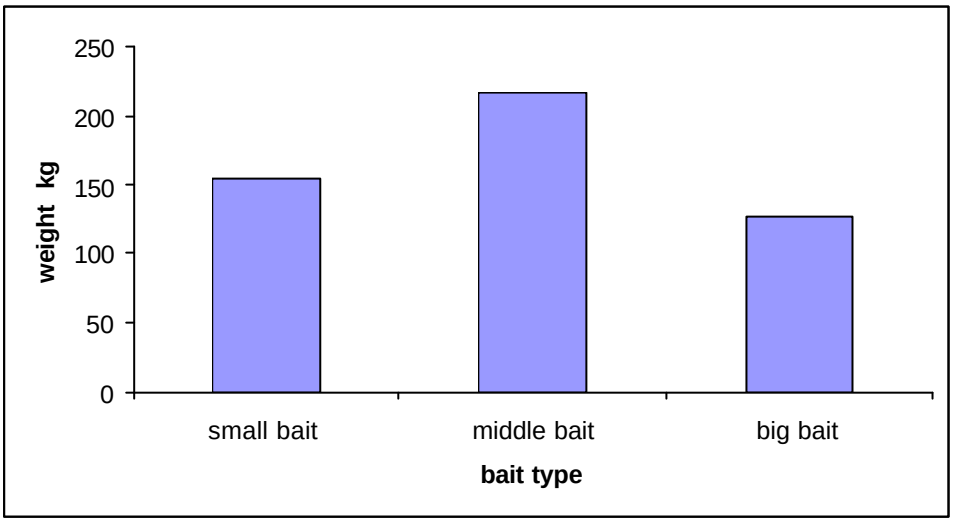

Figure 14: Analysis of weight of fish caught by three bait sizes in all trials.

Weight analysis was carried in all trials according to the three bait sizes and similar results to the number analysis were found (Chi^2 = 22, 5624, p= 1,261E-05).

In all trials, most of the catch was haddock and a few other species were caught in much smaller quantities. Therefore the length analysis was done on the length of haddock. Figure 13 shows relations between mean lengths. In Figure 13, the fish are aggregated into 5 cm length groups.

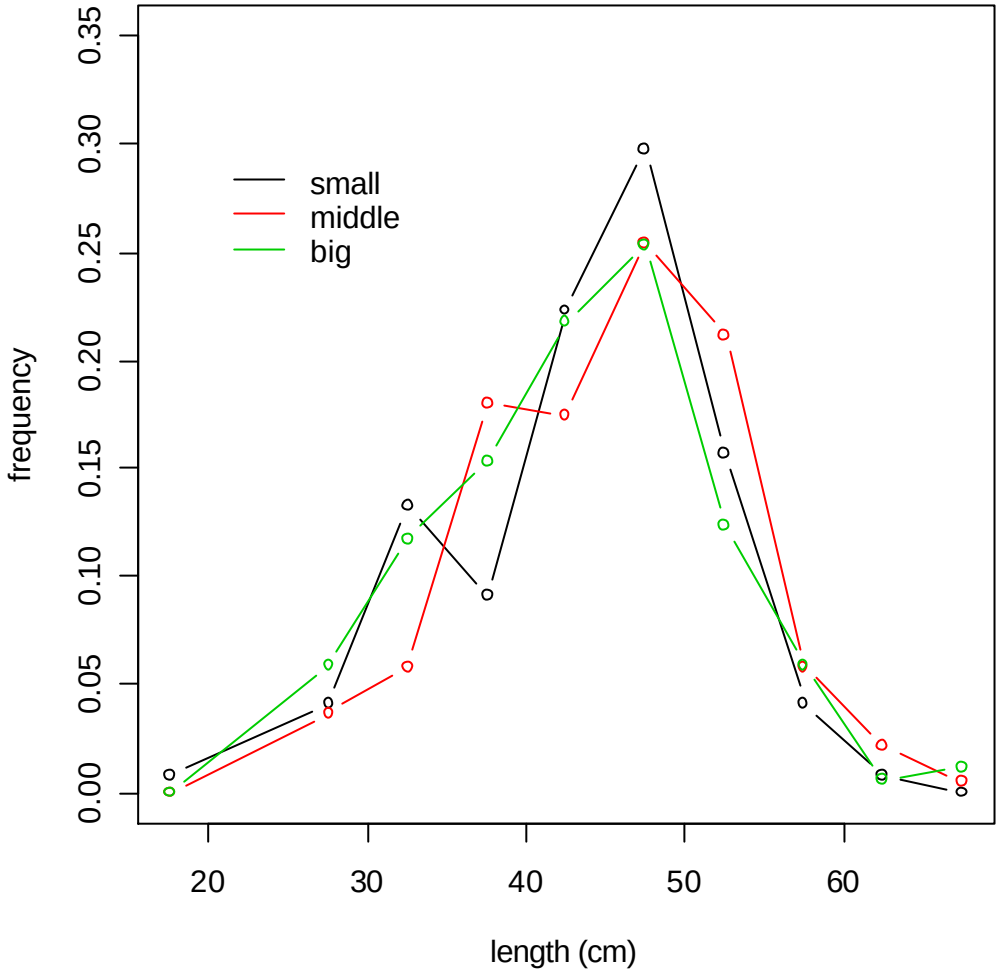

Figure 15: Relative frequency of fish length between different bait sizes (5 cm length classes).

From the ANOVA test, there is a significant difference in mean length among the trials ($F=11.71$, $DF=2$, $p<0.05$), but within trials there is no significant difference in mean length by bait size ($F=1.276$, $DF=2$, $P=0.279$).

5 DISCUSSION

Longline fishing is one of the most traditional and widespread fishing methods all over the world from small-scale artisanal fishing to modern mechanised longline operations (Bjordal and Løkkeborg 1996). It is an environmentally friendly fishing method and gives excellent quality and very good profitability. The catch amount by longline is more than 15% of the total small-scale artisan fishing (Løkkeborg 2000). Specialised large longliners and small longliners are widely used. The catch by a small longliners is about 1000 kg per day. Multifilament is normally used for mainlines and branch lines, but monofilament is also widely used. In hand baited longline fishing, circular and EZ types of hook are used and EZ types of hook are used in auto baiting longline. All the lines, hooks, baits and accessories are provided by specialised companies. Mechanisation of longline is at a high level throughout the world.

DPRK pays attention to developing small-scale fishing and one important method. All the fishery enterprises have small-scale fishing workshops and longline fishing is widely used under the control of these workshops. However there is a lack of information on longline. Gear structure and mechanisation of longline are still in their infancy.

Haddock was the main species in the catch by number and weight in this experiment. Bait types common in bottom longline in Iceland are saury, herring and squid. In auto longliners, 30 g of bait is cut by a baiter and put on a hook automatically. In hand baited longliners, 25 g -30 g of bait is cut manually.

In this experiment, bait sizes affected both the number and weight of fish caught in all trials. Medium bait size (25 g) gave a higher catch (4.55%) than small bait (15 g) in number and also higher catch (13.56%) than big bait (35 g). In weight, medium bait also gave higher catch (12.2%, 18.1%) than small and big bait.

Previous studies have shown that bait size may affect catch efficiency. Johanessen *et al.* (1993) demonstrated that bait affected the catch rate and baits of 10 g caught more than twice as many haddock as 30 g baits. Fish prefer the prey suitable to their mouth size and ability to handle it (Løkkeborg 2000). Therefore, the optimum bait size increases the probability for fish to hook and catch.

In this experiment, bait sizes do not have a great effect on the length of haddock caught. Several factors such as gear, catching strategy and biotic factors influence the species and size distribution of catches by longline (Huse and Soldal 2000). Small bait gave a little more influence on length than big and medium size bait. On the other hand, Astrid *et al.* (2001) documented that big fish prefer big prey because of its big shape, size and odour. But this experiment has supported their findings according to the length and size of fish caught. The data collected in the first trial was not satisfied to the normal experimental conditions because of bad weather. Setting is normally done before dawn and it gives high catch rates because of fish behaviour (Bjordal and Løkkeborg 1996), but all the trials were carried out in the daytime, which could have influenced the data.

6 CONCLUSIONS

The longline fishery in DPRK, which is in its initial stages, needs comprehensive information on it. In this situation, the study of this project will help DPRK in developing its longline fishery.

Some possibilities to improve the longline fishery can be gathered from the study:

- Construction of gear (selection of line material and size, boat, hook, buoy and auxiliary equipment)
- Good organisation of the work on board
- Mechanisation of longline fishing
- Suitable fishing operation

The results from the experiment on bait size gives incentive to the relevant people in DPRK to change the bait size in order to catch more fish.

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APPENDIX: MATERIALS NEEDED TO MAKE A LONGLINE

Appendix 1: Characteristics of nylon monofilament cord

Diameter (mm)	Length per kg (m)	Mass (g/1000 m)	Breaking strength (kg)	
			Dry line, unknoted	Wet line, knotted
0,1	90,9000	11	0,65	0,4
0,2	22,700	44	2,3	1,4
0,3	11,100	90	4,7	2,7
0,5	4,170	240	12	6,5
0,7	2,080	480	24	12,5
1,0	1,090	920	42	22
1,3	650	1,540	65	35
1,6	430	2,330	98	52
1,9	300	3,290	132	72

Appendix 2: Characteristics of synthetic fibre cord

Diameter (mm)	Polyamide		Polyethylene		Polyester		Polypropylene	
	Mass (kg/100 m)	Dry-line breaking strength (kg)	Mass (kg/100 m)	Dry-line breaking strength (kg)	Mass (kg/100 m)	Dry-line breaking strength (kg)	Mass (kg/100 m)	Dry-line breaking strength (kg)
4	1,1	320			1,4	295		
6	2,4	750	1,7	400	3	565	1,7	550
8	4,2	1 350	3	685	5,1	1 020	3	960
10	6,5	2 080	4,7	1 010	8,1	1 590	4,5	1 425
12	9,4	3 000	6,7	1 450	11,6	2 270	6,5	2 030
14	12,8	4 100	9,1	1 950	15,7	3 180	9	2 790
16	16,6	5 300	12	2 520	20,5	4 060	11,5	3 500
18	21	6 700	15	3 020	26	5 080	14,8	4 450
20	26	8 300	18,6	3 720	32	6 350	18	5 370
22	31,5	10 000	22,5	4 500	38,4	7 620	22	6 500
24	37,5	12 000	27	5 250	46	9 140	26	7 600

Appendix 3: principle hook characteristics

Ordinary hooks			Hammered hooks		
Number	Opening (mm)	Diameter (mm)	number	Opening (mm)	Diameter (mm)
12	9,5	1	2	10	1
11	10	1	1	11	1
10	11	1	1/0	12	1
9	12,5	1,5	2/0	13	1,5
8	14	1,5	3/0	14,5	1,5
7	15	2	4/0	16,5	2
6	16	2	5/0	20	2,5
5	18	2,5	6/0	27	3
4	20	3	8/0	29	3,5
3	23	3	10/0	31	4
2	26,5	3,5	12/0	39	5
1	31	4	14/0	50	6
1/0	35	4,5			

Appendix 4: Buoy characteristics

mm	Diameter Ø=mm	Height H=mm	Buoyancy (kg)
510	160	185	2
760	240	350	8
1015	320	440	17
1270	405	585	34
1525	480	670	60
1905	610	785	110
2540	810	1000	310