

# Design, Operation of Long lines for Resource and Energy Conservation

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## Introduction

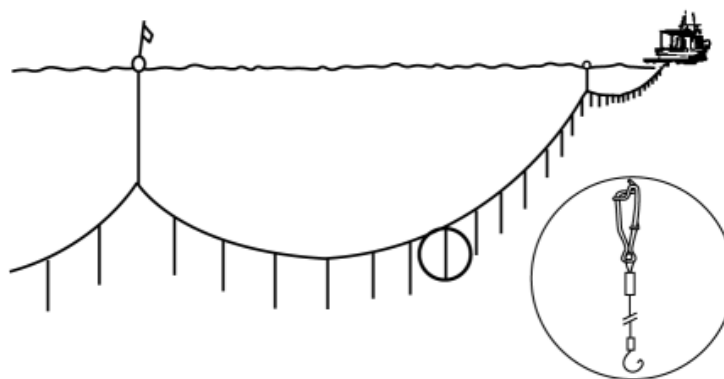
The name of “longline” comes from the length of the lines that are used. In broad terms, a longline consists of a mainline where many branch lines are attached. Each branch line has a baited hook at its end. Longlines are proven to be a good fishing method for catching large, high quality and high value 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. The high fuel consumption of large-scale fishing has made the fishermen adopt low energy fishing methods. 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. Most of the developing nations are trying 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 crafts engaged in long lining is increasing 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 120-400 HP engines and small vessels with 14-28 HP engines. The structure of the vessels has been altered for doing small-scale fishing like longline. Squid and herring are mostly used for bait to catch demersal and semi pelagic fish. The bait size used in bottom set longline is based on fishermen’s experience. Baiting is done by hand and hauling is mostly done by powered haulers. Longline fishing in Indian waters 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. 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.

## Classification of Longlines

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.

## What is long lining?

longline fishing uses a long mainline made of mostly nylon monofilament to which are attached hundreds or thousands of branchlines, each with a single baited hook. The line is suspended in the water by floatlines attached to floats, which may have flagpoles, lights, or radio beacons. Longlines are usually set and hauled once daily and are allowed to drift freely, or soak, for several hours while fishing. Longlines are set, either by hand or mechanically, while the boat steams away from the line and are usually hauled mechanically while the boat steams toward the line. The species targeted are tunas and some billfish.



**Structure of longline**

## A bit of history

longline fishing for oceanic species evolved in Japan during the nineteenth and early twentieth centuries. Sailboats equipped with hemp longlines would venture as far as 30 nm offshore from Japan in search of tuna and billfish. By 1912 there were over 100 registered sailboat tuna longliners in Japan. The first diesel powered steel longline vessels did not appear until the early 1920s. The longlines were hauled by hand until 1929 when the first mechanical Izui line hauler was developed. Improvements in fishing vessels, including the introduction of the internal combustion engine in the early 1900s, resulted in an expansion of the fishing grounds, enabling the Japanese to fish the Nojimasaki fishing grounds for albacore in the central Pacific by the early years of the Shōwa Era. The Japanese fleet had an operating radius of approximately 2000 miles eastward to the longitude of Midway Island (approximately 180° E) prior to World War II, although the vast majority of those vessels landed at their homeports in mainland Japan. Global expansion of longline fisheries began in the 1950s and 1960s, spreading throughout the Atlantic (North and South) and Mediterranean. This expansion was largely driven initially by the Japanese tuna market and supported by improved freezing technology and international transportation. Subsequently, liberalized trade regulations and emerging markets for swordfish and other species (e.g., shark fins for China) encouraged additional fleet expansion.

## Target Species

The main target species of oceanic longline fishing are tunas and billfish, while other species including sharks can also be an important component of the catch. The catches of long line

can be divided into three distinct categories: target, byproduct and by-catch. Tunas are by far the most important target species for longlining. The highest value species are bluefin tuna, followed by bigeye tuna, yellowfin tuna, and albacore tuna, in that order. Some billfish are also targeted, with broadbill swordfish being the most important, followed by striped marlin.

### **Bigeye tuna**

Bigeye tuna are the most valuable species caught in the longlines and are found throughout the tropical and temperate waters in Pacific, Atlantic and Indian oceans. Fishermen targeting bigeye tuna set their lines deep because bigeye are often associated with the thermocline, which is found between 100 and 350 m, depending on the area and time of year. Bigeye tuna can be caught all year round in equatorial waters but are more seasonal in higher latitudes. The best bigeye catches are usually in the winter months. The most marketable bigeye tuna are those weighing 40 kg or more. Bigeye tuna are usually marketed as fresh chilled fish for sashimi.

### **Yellowfin tuna**

Yellowfin tuna are also found throughout the tropical and temperate waters of Pacific, Atlantic and Indian oceans, but the stocks change as per the oceans. Although they can be caught in deeper water, longline caught yellowfin are usually taken in water from near the surface down to 250 m above the thermocline. This layer of water is called the mixed and intermediate layer. The preferred temperature range for yellowfin tuna is 18° to 28°C, which roughly corresponds to temperatures found in the mixed and intermediate layer. The best season for yellowfin tuna is in the spring and summer months. The most marketable yellowfin tuna are those that weigh 30 kg or more. Yellowfin are usually sold as fresh chilled fish for sashimi or to be used in cooking. Yellowfin is second to bigeye as a sashimi fish in quality and value.

### **Albacore tuna**

Albacore tuna are also found throughout the tropical and temperate waters of Pacific, Atlantic and Indian oceans. These fish are schooling fish and are caught seasonally, in the summer and autumn months, at the surface by troll boats, and are smaller than longline caught albacore. Larger fish are caught by longline in deep tropical and subtropical waters down to the depth of the thermocline. Depth and temperature ranges for longline caught albacore are similar to those for bigeye tuna. The season for longline albacore is not as apparent as for other tunas — autumn months in some locations, all year round with peaks in summer and in autumn and winter in other locations, and autumn and winter months in other areas. Longline caught albacore range from 15 to 20 kg and are sold frozen whole to canneries, fresh to export markets, or as frozen quarter-loins.

### **Striped marlin**

Striped marlins are found throughout the tropical and temperate of Pacific, Atlantic and Indian Oceans. They are usually found in the upper mixed layer or near the surface. In fact, longline caught striped marlin are most often caught on the branchlines nearest the floats, the shallowest branchlines. They are not usually the main target species of longliners, but are caught

in association with yellowfin tuna sets. The preferred surface temperature range for striped marlin is 20° to 23°C, although they can also be found in temperatures ranging from 15° to 26°C. The usual size range of striped marlin is 60 to 120 kg, although specimens up to 190 kg have been caught.

### **Byproducts and By-catch of longlining:**

Byproduct and bycatch are species that are caught incidentally (not targeted) during longline fishing, that have a commercial value and are retained for sale. These species include opah, black marlin, Indo-Pacific blue marlin, short bill spearfish, sailfish, skipjack tuna, mahi mahi, wahoo, pomfret, escolar and barracuda, amongst others. A range of shark species are also taken as byproduct, although they are mainly prized for their fins (finning is probably going to be phased out as more and more countries are adopting a policy where the entire shark must be retained). Black marlin, Indo-Pacific blue marlin, sailfish, skipjack tuna, mahi mahi and wahoo are distributed throughout the subtropical and tropical Pacific Ocean and are caught near the surface on the shallowest hooks in a set, near the floats. Conditions for catching these species are similar to conditions for catching yellowfin. Byproduct species such as pomfret, escolar and opah are usually found in deeper waters and are associated with bigeye catches. The most common species of shark taken by longlining include the blue shark, oceanic white tip shark, short-finned mako shark, silky shark, thresher shark and tiger shark. These are all pelagic or oceanic sharks. Sharks are mainly caught on the shallower set hooks during normal tuna longlining activity.

### **Bycatch**

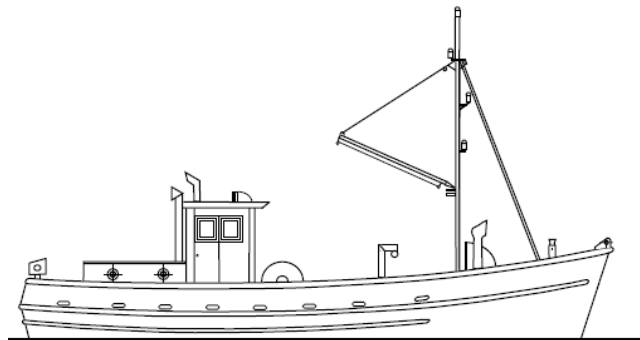
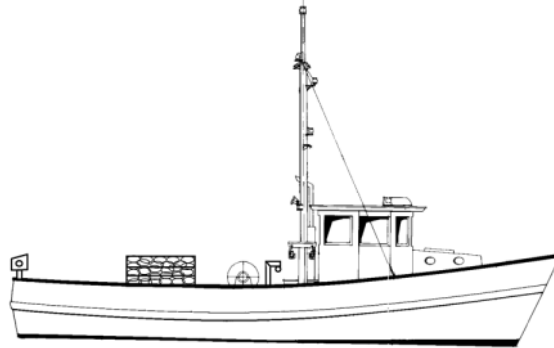
Bycatch are the unwanted species that are taken incidentally during longlining, and are discarded as they have no commercial value. These species include snake mackerel, lancetfish, pelagic rays, seabirds and sea turtles, amongst others. Snake mackerel, lancetfish and pelagic rays can be taken at various depths on a longline, and are not really associated with a particular type of longline set. The fish are generally small in size. Seabirds, such as albatross, and sea turtles are sometimes caught on longlines. The seabirds attack the baits on the gear as it is being set, while the sea turtles are taken on the shallow hooks, generally near the floatline. The catch of seabirds and sea turtles by longliners has become an environmental issue as the animals are protected. This is an area of concern to all longline fishermen. Another form of bycatch are fish, both target and byproduct species, that have been damaged by sharks or toothed whales. In some cases, shark damaged fish may be retained for crew consumption or sale if the damage is limited. However, when toothed whales take fish, they only leave the heads, and these are discarded.

### **Bait used in longline fishing**

Bait used for longline fishing is usually frozen whole finfish such as sardines, saury, or mackerel and scads. Frozen whole squid is often used for tuna longlining but is more important as bait for swordfish. Live milkfish is also used for tuna longlining. The average bait weighs about 80 to 100g. If the bait is much bigger than 120g it is likely that some target fish will be missed.

### **Longline vessels**

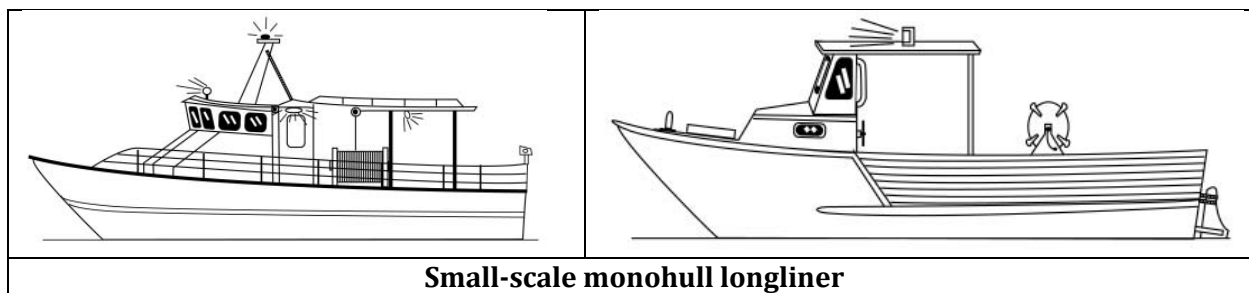
Specialised vessels for longline fishing, longline vessels, operate throughout the world. The vessels are characterised by the rail roller, the longline hauler or the setting chute. Longline vessels may be classified by size (LOA) into small (8-15 m), medium (15-25 m) and large (25-50 m) longliners. Some vessels have the cabin forward and the working area aft, while others have the opposite layout. Both work successfully, and it is up to the individual to choose the size, design and layout he prefers.



**Longline vessels with a forward and aft wheel house**

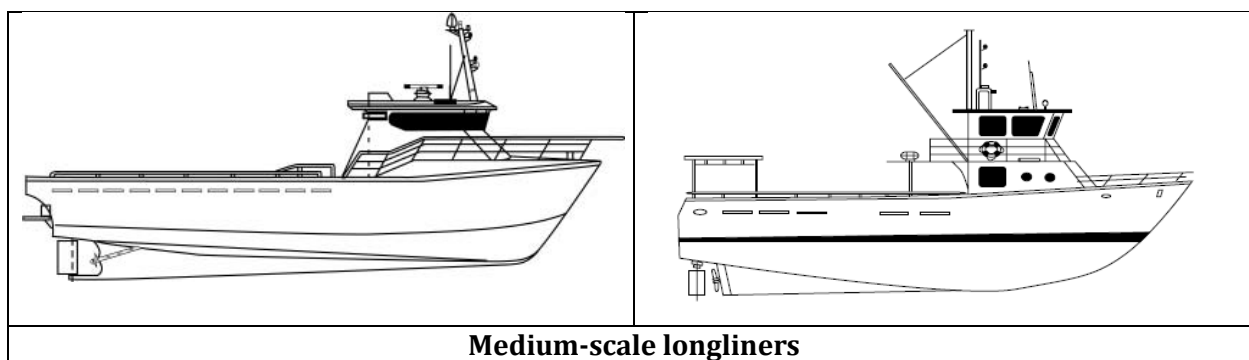
### **Small-scale longliners:**

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. Small-scale longline boats include artisanal vessels and catamarans that use either hydraulic or hand operated longline reels capable of setting and hauling 300 to 400 hooks per day. Most small-scale longliners use monofilament longline systems. These boats have limited operating range and limited fish holding capacity, but have been quite effective in some localities. What they lack in production capabilities is often made up for because they are inexpensive to purchase and operate. The traditional non mechanized and motorized traditional craft Catamarans and fiber catamarans of 21-36' LOA and 4' width with outboard engine of 8-21HP and usually went out on day or overnight trips, and made just one or two sets in coastal waters ranging from 10 to 50 nm offshore. The crews on these vessels are might be three to six fishermen. The size and limited capacity of small-scale vessels greatly restricts their movement, and they cannot follow fish like the medium-scale vessels.



### Medium-scale longliners

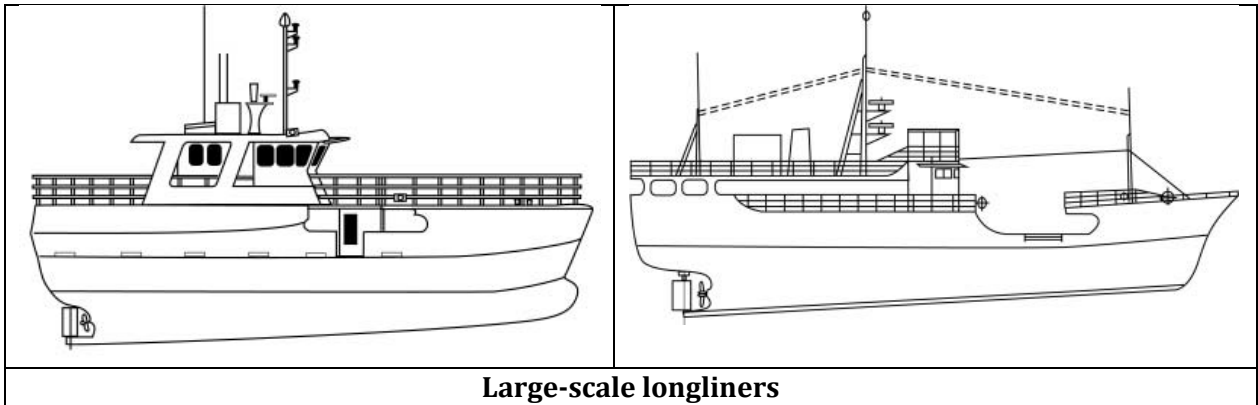
Medium size longliners catch fish in coastal or inshore waters. Fishing trips usually last from two to seven days and the number of fishermen is three to eight, depending on the fishing operation. A 20 m longliner may carry 90-100 sets of gear (30,000-40,000 hooks) during a two-day trip with four fishermen. Medium size longline vessels are normally equipped with engines of 250-600 HP, giving a maximum speed of 8-10 knots (4-5m/s). Medium-scale longliners have greater operating ranges and fish holding capacities than small-scale longliners and thus are able to fish within a country's entire EEZ and even outside the EEZ on the high seas. Trawlers, bottom fish boats, trollers, and even squid jiggers have all been successfully converted to longline boats. Longliners can have single or multiple fish holds, fish preservation can be by ice or CSW or RSW, and the hull material can be steel, fibreglass, aluminium, or wood. Most of longlinng fleet in India belongs to this category.



### Large-scale longliners

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). Large-scale longliners

include freezer albacore boats and freezer sashimi boats. Their operating range includes all of the world's oceans. They can stay at sea for several months at a time, conducting from 50 to 100 sets or more per trip and setting from 2500 to 3500 hooks each day. They are capable of holding up to 100 mt or more of frozen fish. There are also a few large-scale longliners that target fish for export to overseas markets as fresh chilled fish.



### **The longline: Basic Gear Configuration**

There are two basic types of longlines: traditional rope, also known as basket gear, and monofilament gear with some combinations and variations. Basket gear evolved during the late nineteenth century and is still in use today, particularly in the Asian fleet. Monofilament gear evolved in the 1980s and revolutionised longline fishing by offering a less labour intensive and more efficient method of catching fish. Fundamentally, however, the two systems are similar. A longline is made up of units or sections of line that are called baskets. A basket of longline gear is the amount of mainline and branchlines in between two floats. The term is used both for basket gear and for monofilament gear. The mainline is suspended in the water by a series of floats, or buoys, that are attached to the mainline by floatlines. The line is set and hauled once a day from a moving vessel. It is allowed to drift or soak on its own for four to eight hours in between setting and hauling. A typical longline set from a medium-scale longliner would be about 30 to 60 nm long and have about 1200 to 2500 hooks. A typical longline trip on a medium-scale longliner would last about one to three weeks and the line would be set about 6 to 12 times once each fishing day.

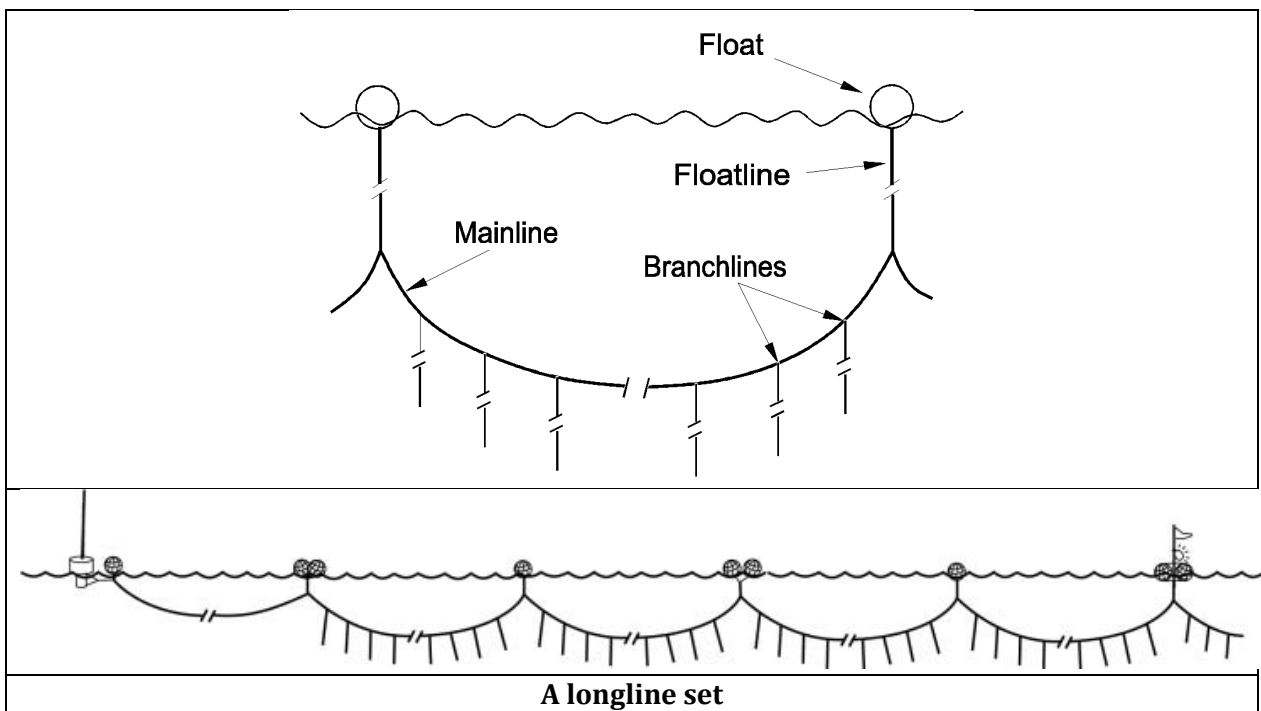
### **Description of Longline Gear**

Longline gear consists of three basic components: the mainline, the branch line, and the baited hook. All of these parts are adaptable for targeting specific species through changes in materials, lengths, and deployment strategies. For example, setting the mainline along the seafloor, a demersal set targets flatfish, cod, groupers and coastal sharks. Using small buoys and float lines to suspend the gear below the surface results in a pelagic longline set that targets pelagic tunas, swordfish, billfish and other free-swimming predators. In between these two extremes are a variety of different configurations that are adapted by local fisheries to target specific species.

## Gear construction

### 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 sea beds. 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).



### 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. Species which are distributed over a large area (as for tuna) the branch lines are usually 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.

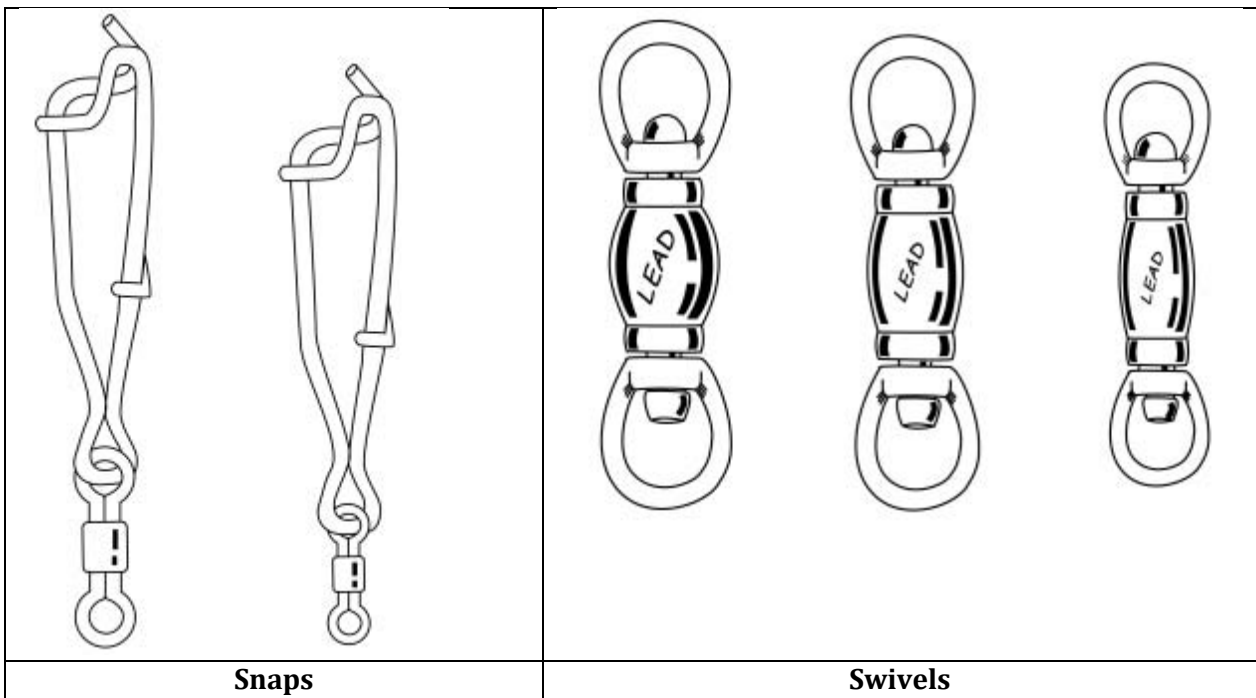
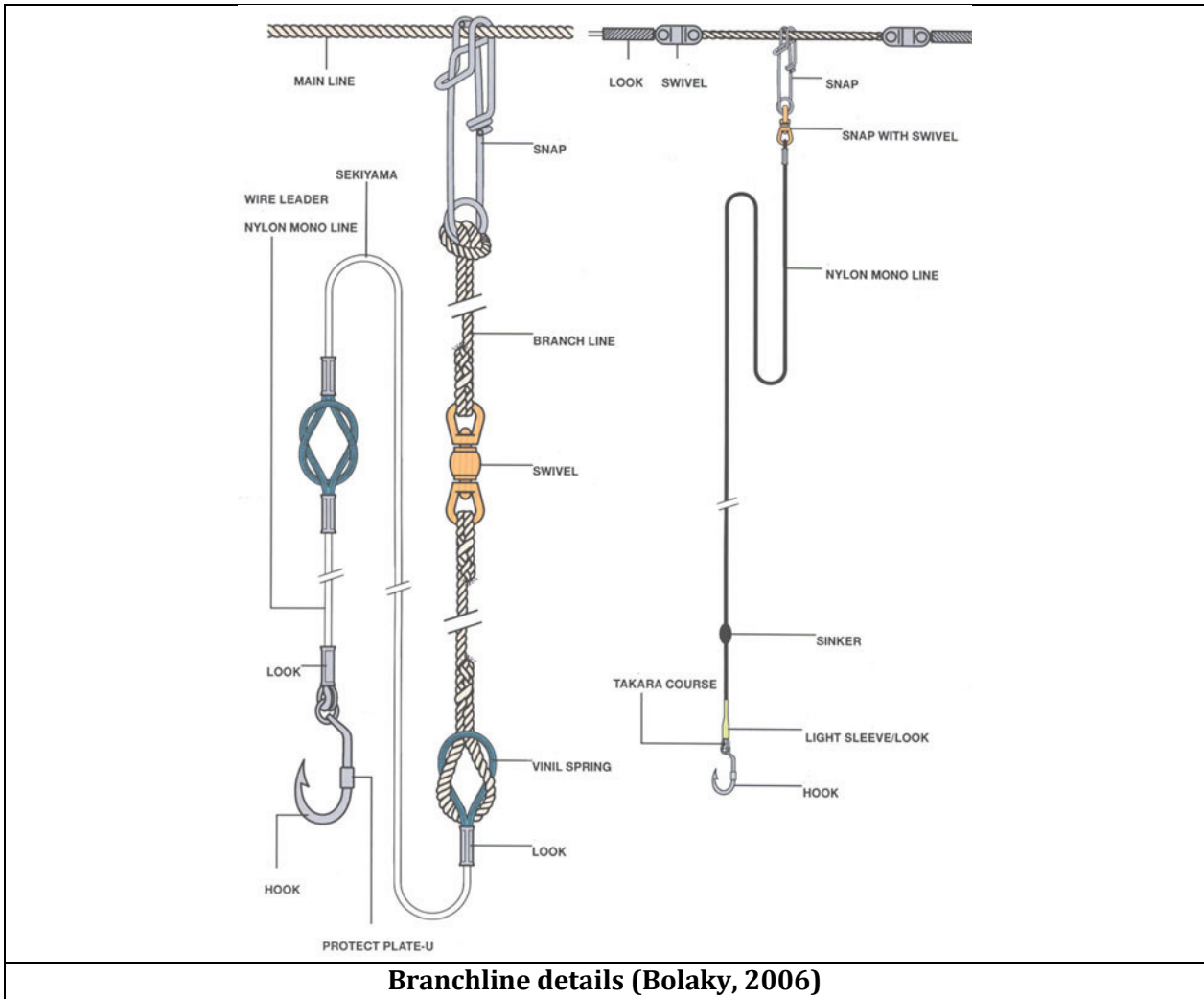
There are several pieces of hardware used in the construction of branchlines, including snaps, swivels, hooks and sleeves.

### ***Snaps***

The swivel snap often called a clip is a very important component of a branchline. There are different snaps for rope and monofilament gear, and they should not be interchanged, as they will not work properly. Snaps made for rope gear have a jaw that is too big to grip monofilament mainline. A suitable monofilament snap has a tight jaw that grips the monofilament mainline.

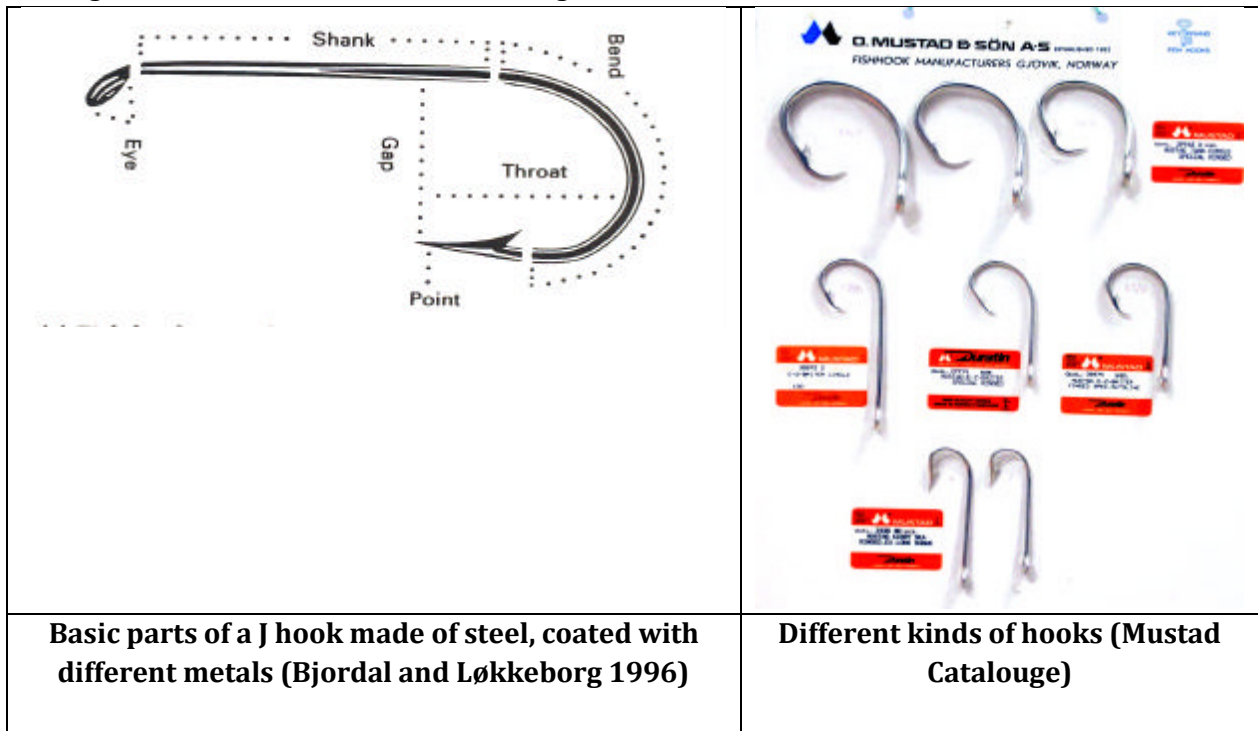
### ***Swivels***

The most common swivels used in branchline construction are the leaded types, which come in 38, 45, 60 and 75 g sizes. The leaded swivels are used to increase the sinking rate of the gear and baited hook, to add weight to keep the branchline deeper in the water, especially in rough weather, or to provide a connection point in the branchline between the main part and the leader. 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.



## 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. 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.

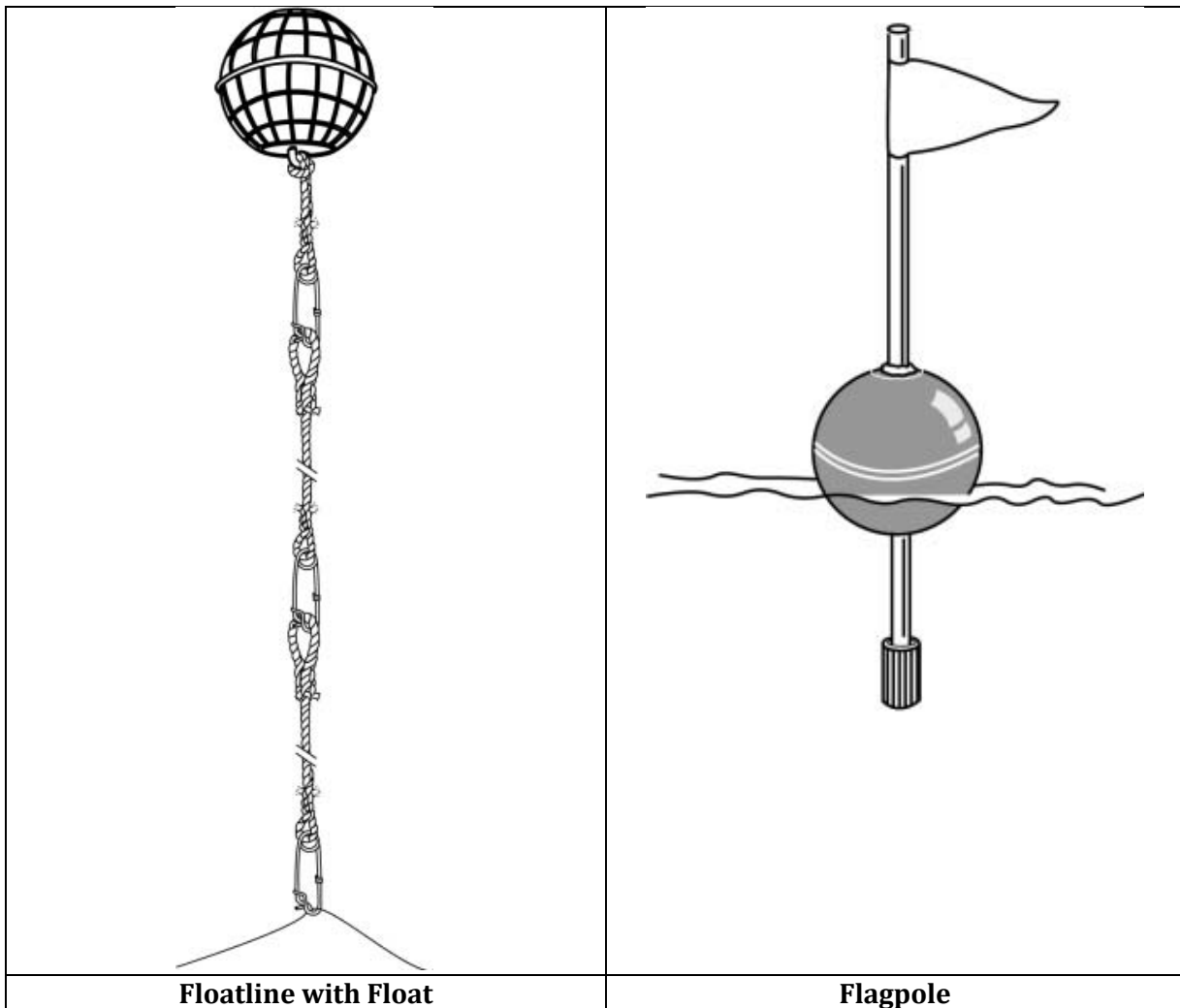
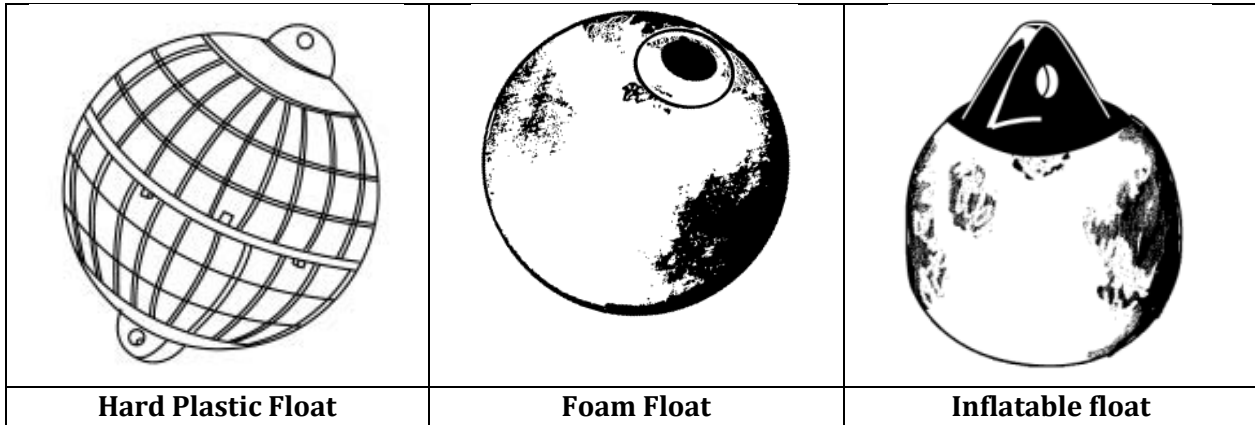


Circle hooks have shown that they have many advantages. The main advantage is the circular appearance of the hook with the barb of the hook pointing back towards the shank or the eye. The auto baiter type of hook is used in auto line systems. This kind of hook is a compromise between the circle hook 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 of 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.

## Floats, Flagpoles and Floatlines

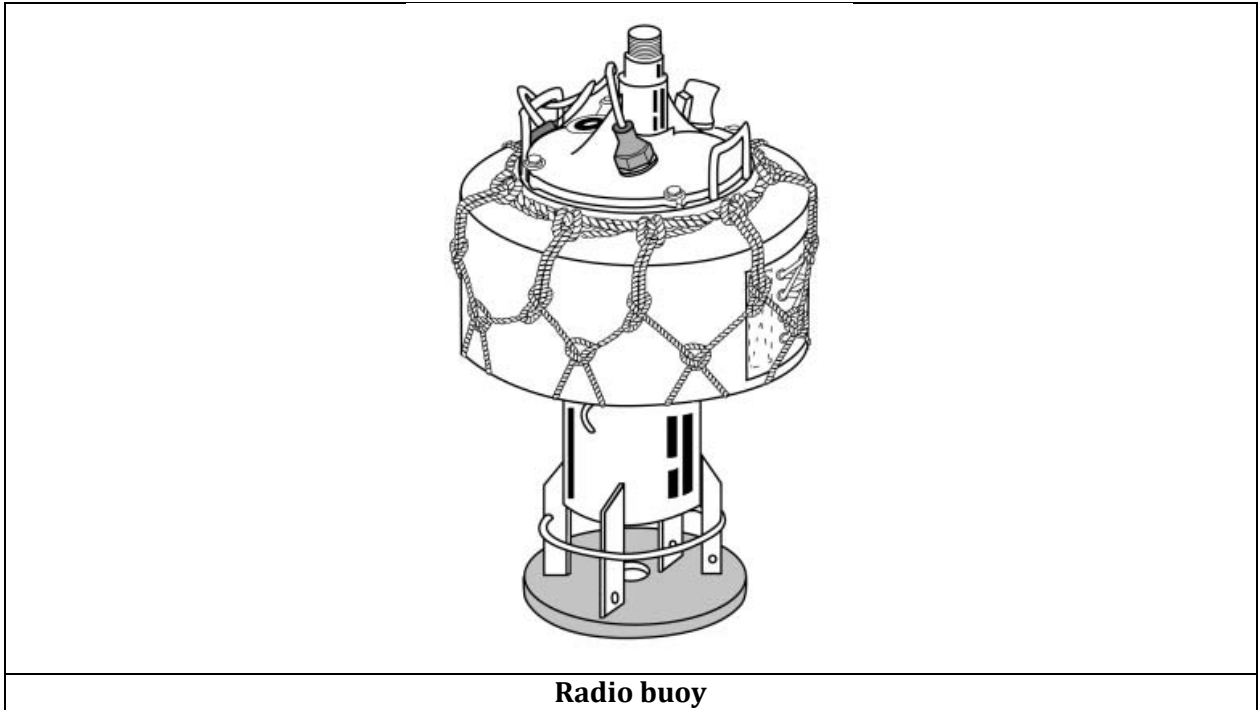
There are several different types of floats used in longline fishing including glass floats, hard plastic floats, inflatable buoys, bullet buoys, and solid foam floats. The most popular floats for monofilament longline fishing are hard plastic floats that range from 165 to 360 mm in diameter. These floats usually have one or two ears, eyes for attaching line and are ribbed on the

outside so they pull through the water easily. Glass floats were popular years ago with Japanese basket gear. Glass floats need to have a net made from tarred rope, as they do not have attachment ears and they are easily broken. Hard plastic floats often have tarred rope netting around them as well. Inflatable floats and foam floats are not very good for tuna longlines as they are compressible and could collapse if a fish drags them down deep. Foam floats and bullet buoys are often used on swordfish longlines, however. Plastic floats for tuna longlines should be pressure rated down to 200 to 300 m.



## Radio buoys

Radio buoys and radio direction finders (RDF) allow longline fishermen to have a more relaxed break while the line is soaking. Radio buoys give out signals that are picked up by the RDF on the fishing boat from as far away as 35 nm, so the fishermen can sleep while the line is soaking, knowing that they will be able to find the line later. Radio buoys require special rigging and special maintenance. Radio buoys usually come with a flotation collar made of canvas covered foam.

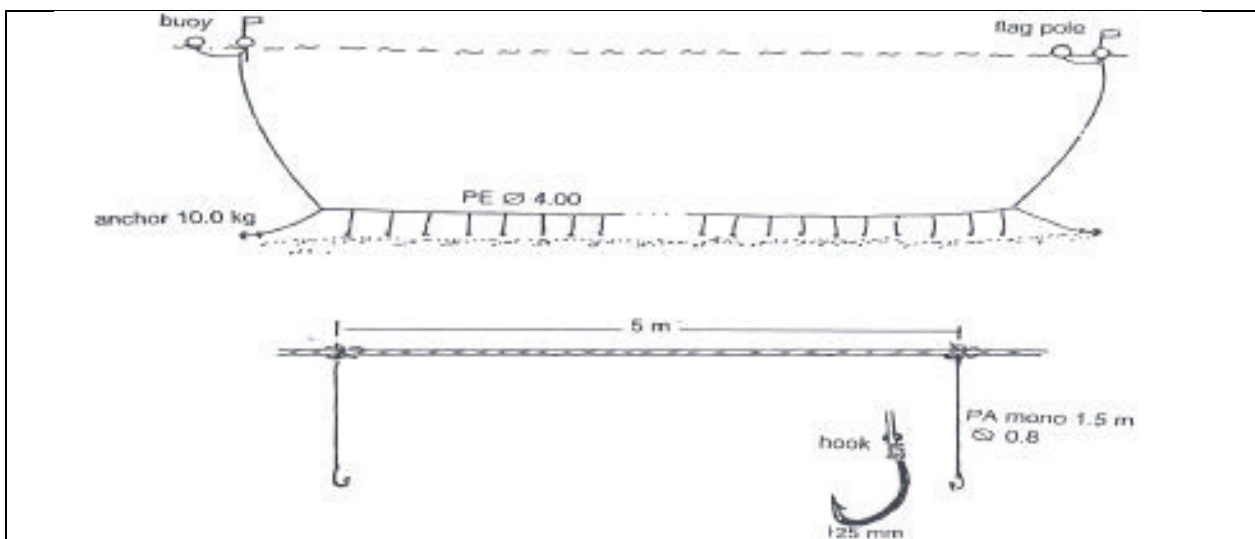


## Bait

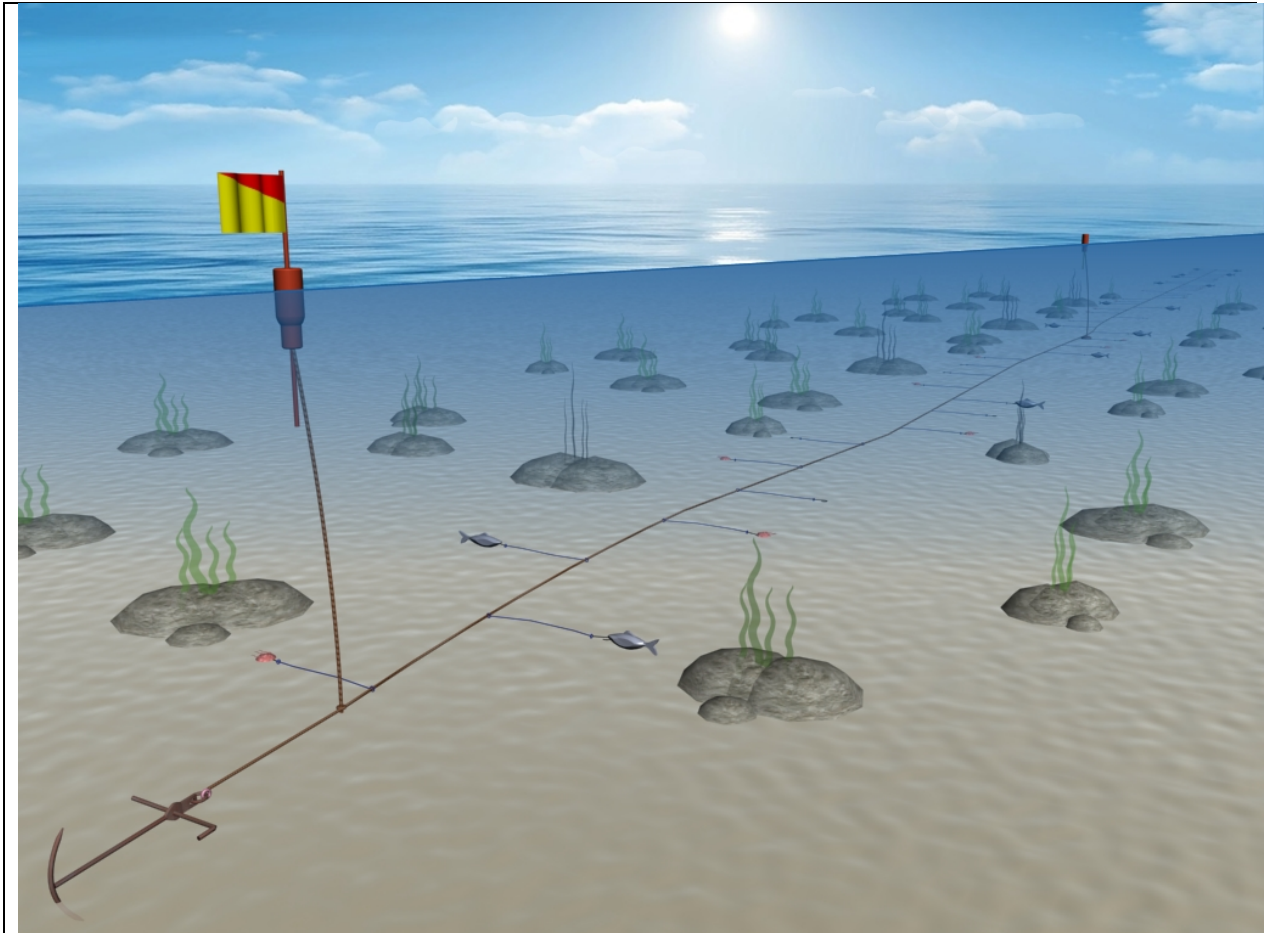
The principle of line fishing is to lure fish to bite the bait. Therefore, bait is one of the most important factors in line fishing. The catch rate depends to a large extent on bait type, quality and size (Bach *et al.* 2000). Fishermen use different types of bait from their experience accumulated over the years. The type of bait is chosen with regard to the target species. 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 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. The bait loss is more important for hooks on the bottom. Bait size is also an important factor affecting the fish size and catch rate. As 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.

## Bottom set longline

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



**The whole view of a bottom set longline and hooking space. A mainline with a branch line set on the bottom by buoy and anchors (Hameed and Boopendranath 2000).**

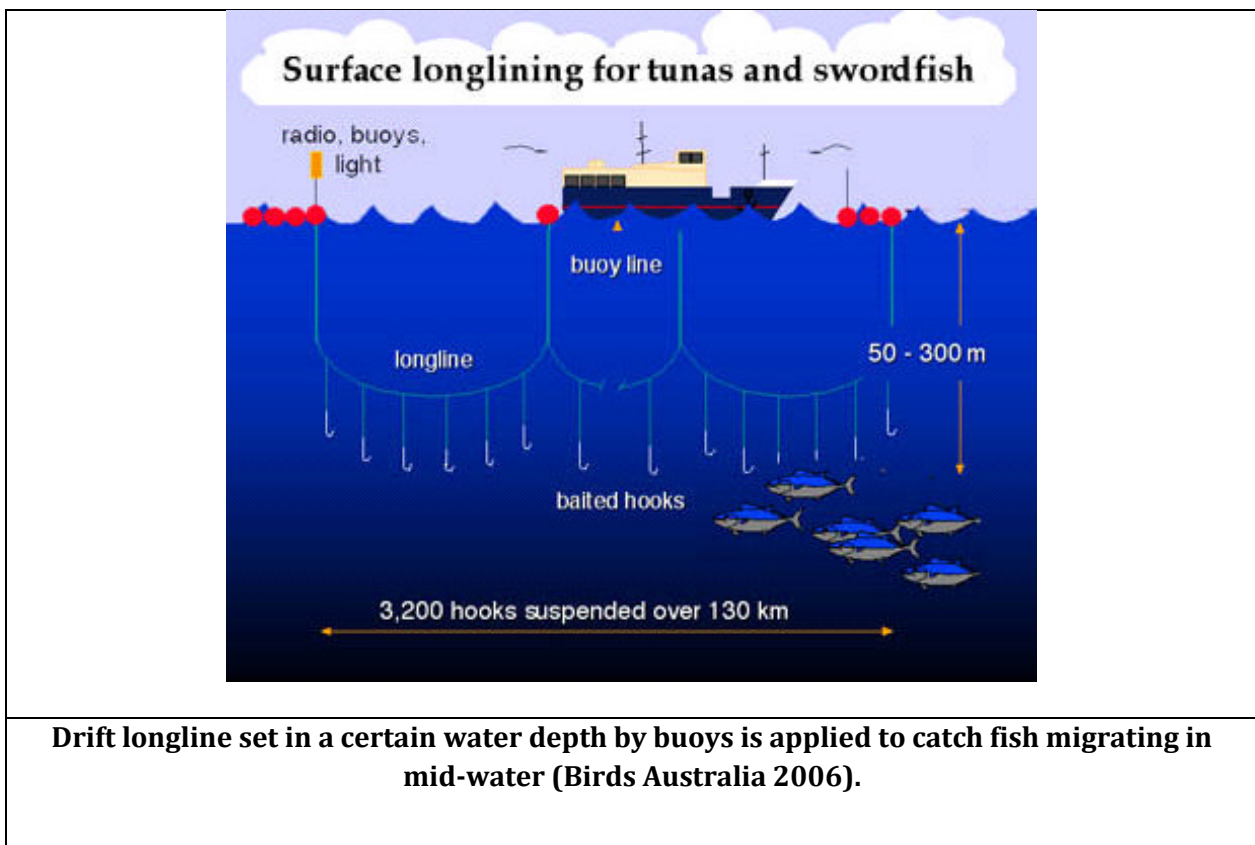


**Bottom set longline**

The anchor is made of stone, steel, lead or chain with a weight from 5-10 kg up to 80 kg. 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. 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.

## 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. 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.



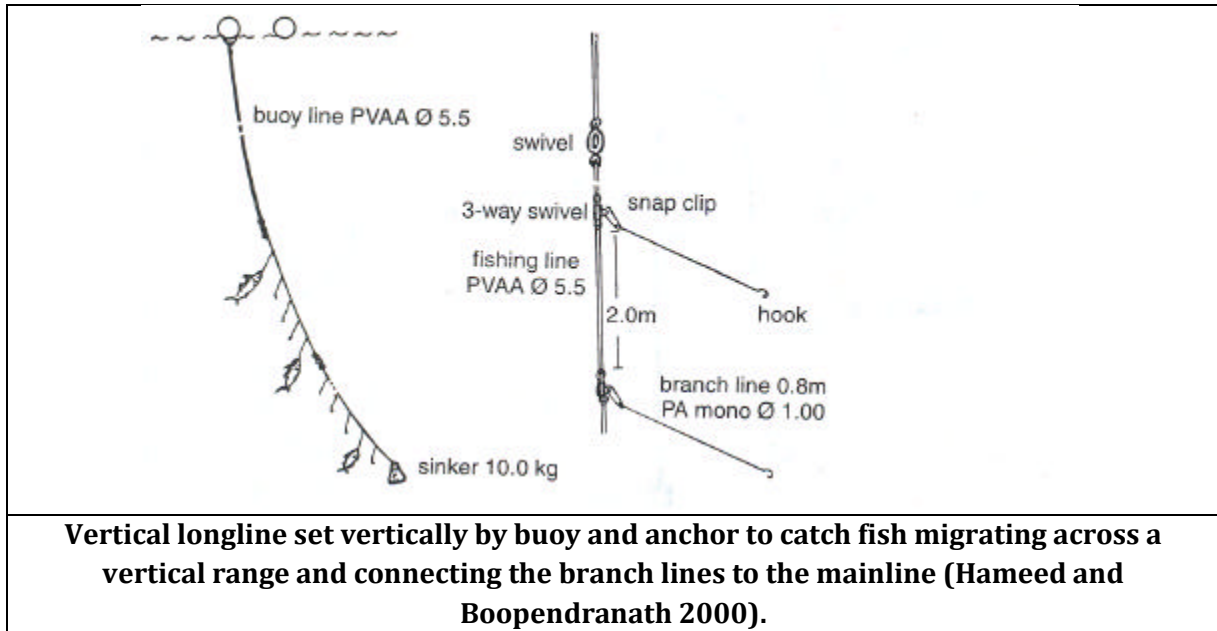
There are some cases that on hauling branch lines are removed from the mainline and kept separately. But nowadays lines with branch lines are usually kept on racks after hauling (Bjordal and Løkkeborg 1996). To locate the potential fishing ground and to position the line in deep seas, it is important 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).

### **Vertical longline**

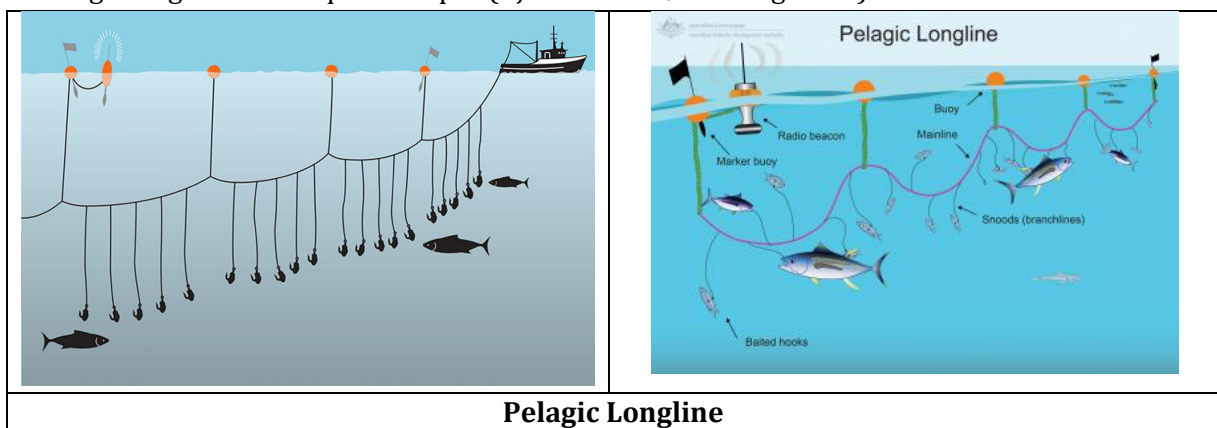
Vertical longline is used to catch fish with a wide vertical distribution. Vertical longline is effective on steep shelves. Vertical longline is used in deep waters up to 1,200 m and in shallow areas having rough bottom conditions or in areas where fish aggregating devices are deployed. Gear construction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

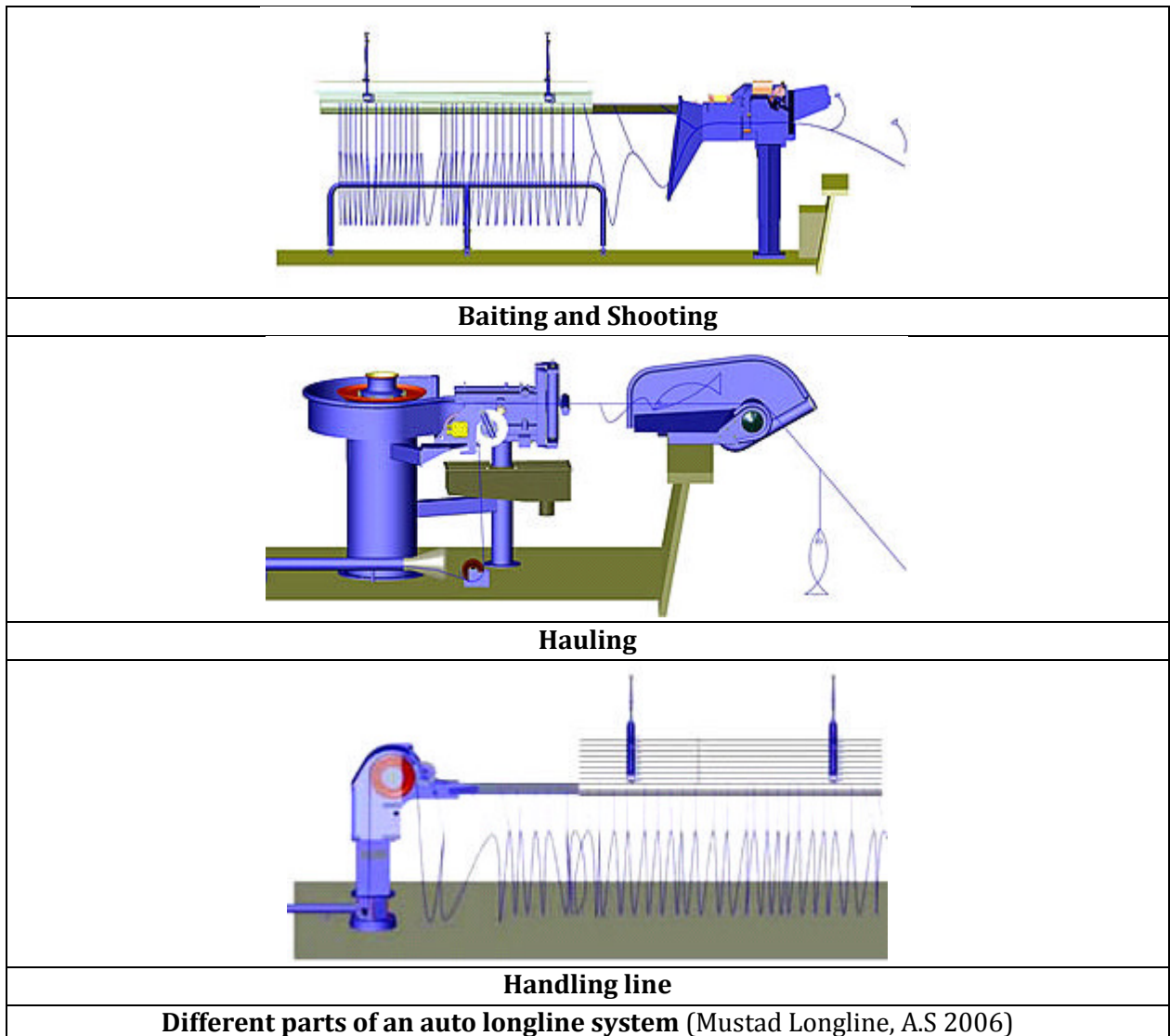
### Pelagic longline

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 (Bjorndal and Løkkeborg 1996).



## Mechanisation of longline

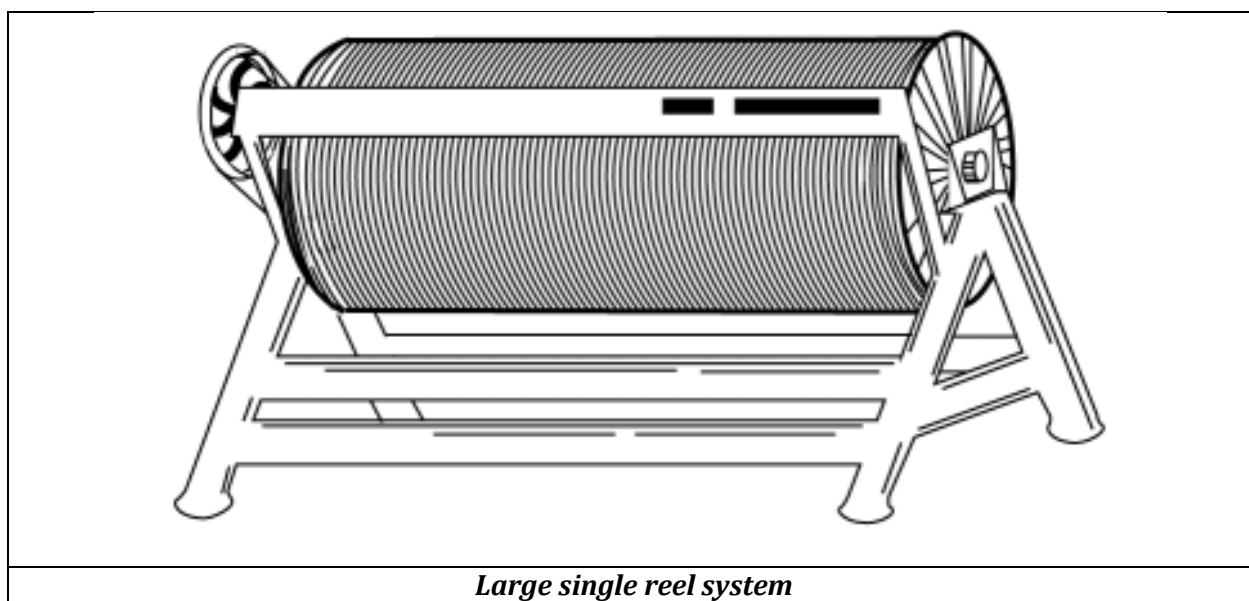
Many studies on longline mechanisation have been conducted since the early 1960s especially in Canada, the Faroe Islands, Germany, Iceland, Ireland, Japan, Norway, Sweden, UK and USA (Bjordal and Løkkeborg 1996). The main focus of this research has been on automated baiting, hauling operation systems and line handling systems. These three systems are operated in a whole system. 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. 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.

### **Monofilament reel system**

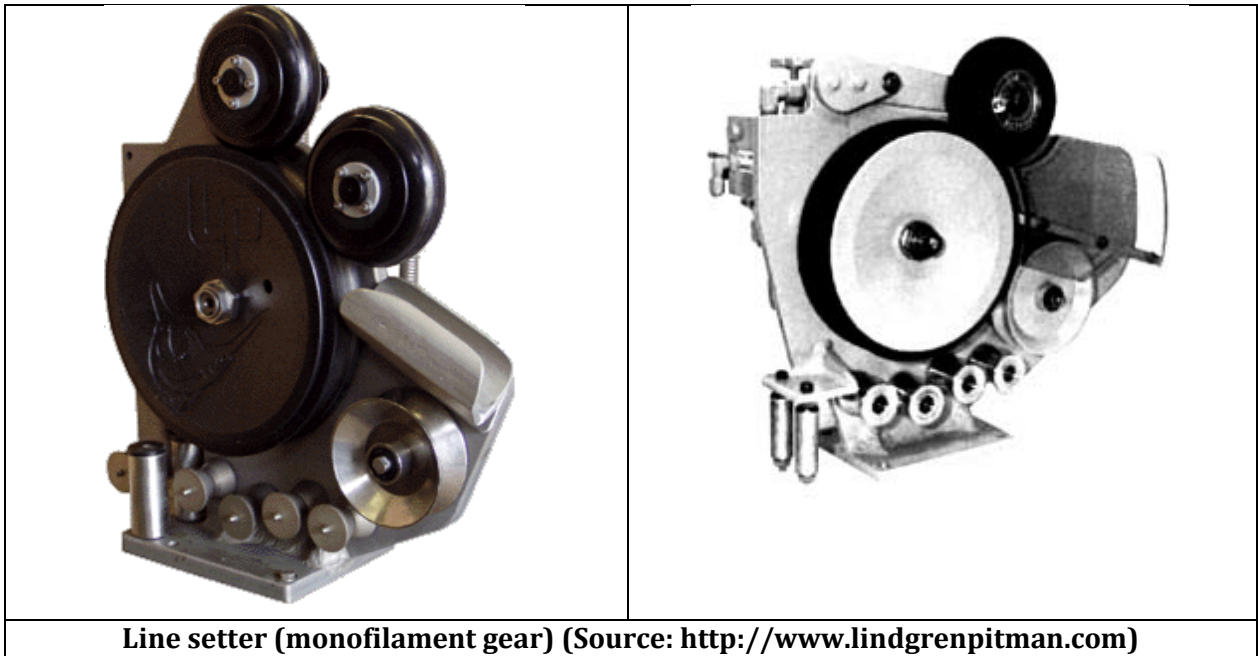
A monofilament reel system uses a hydraulic reel to haul and store the mainline. Blocks are used to guide the line to the reel. The reels come in sizes to suit different size boats. Small reels hold 5 to 10 nm of mainline, large single reels can hold up to 60 nm of mainline, while double reels can hold over 100 nm. Reel capacity is also governed by the diameter (3.0 to 4.5 mm) of the monofilament mainline.



*Large single reel system*

### **Line setters**

Line setters, or shooters, can be used for setting continuous rope or monofilament lines. The line setter deploys the mainline at a predetermined speed, which is faster than the vessel is travelling. This gives the fish master control over depth of the mainline. The branchlines, floats and floatlines are snapped onto the mainline at regular intervals. Line setters are slightly different for rope and monofilament gear, because of the type and size of the mainline.



### **Advantages of longlining over trawling**

Unlike trawlers, however, longliners are able to work in those areas not accessible to trawlers, particularly those which have complex sea bed topography, rough ground or are at significant depth. Longliners reduce quite considerably losses in fishing time due to weather conditions. This is because when trawling is impossible, a longliner is still able to fish. By-catch of undersized fish by longlining is fairly insignificant due to the selectivity of longlines. As for the longline, it is more selective because of its passivity. This is why those fishing grounds that are temporarily or permanently closed to trawlers because of overfishing of juveniles remain open to longliners. Longliners are more effective at scratching for scattered schools of fish, while trawlers are more productive with dense populations of fish.

### **Fuel consumption**

A significant advantage that longliners have over trawlers is the relatively low fuel consumption per unit of catch. For example, it was established that a trawler expends 0.6-1.5 tonnes of fuel per tonne of raw fish caught, while a longliner expends 0.1-0.3 tonnes (Karpenko, 1997; Makeev and Shentyakov, 1981; Pavlov and Makeev, 1987; Glukhov, 1994; Chumakov and Glukhov, 1994a, 1994b; Sorokin and Chumakov, 1995). With regards the amount of fuel used over time, the longliner spends 2.7 times less fuel every hour than a trawler (Zherebenkova and Makarova, 1990).

### **What are the problems in longline fishing?**

#### **Declining sea turtle stocks:**

Sea turtle populations are declining worldwide due to human activities including: destruction or disturbance of nesting beaches; hunting for food and sale; and incidental catches related to some fishing activities such as trawling, gillnetting, purse seining and tuna longlining.

### **Perceived overfishing:**

There is worldwide concern about the catch and use of pelagic sharks and, to a lesser extent, marlins and other pelagic fish species by longline vessels. Some concerns are related to a belief that these species are being overfished.

### **Seabird interactions:**

The incidental take of seabirds by longline vessels (both pelagic and demersal or bottom-set) has been widely publicised, although this mainly occurs with albatross in higher latitudes.

### **What can be done to make longline fishing sustainable?**

- Minimizing the incidental catch of unwanted bycatch species. Keeping good data in logbooks on all fishing activities, including the recording of byproduct and bycatch taken or interactions with protected species.
- Setting pelagic longline gear deeper than 100 m will reduce the incidental catch of many bycatch species (especially sea turtles).
- Setting deep, using a line setter, puts the bait in the zone where catches of albacore and bigeye (target species) will be maximised.
- Not using squid for bait on shallow-set hooks (those closest to the float and floatline) will lessen the chance of hooking sea turtles, as this is a favourite food of theirs.
- Not using a branchline under the float to target sharks.
- Setting pelagic longlines at least 12 nm from a reef or island, and ensuring they drift offshore, will minimise interactions with reef sharks (not pelagic sharks) and some turtle species, as they do not venture far from the reef.
- Using monofilament leaders (not wire) directly onto the hook will allow sharks to bite off the hook and escape.
- The bycatch of sea turtles by pelagic longlining is an issue of great concern. If a turtle is caught, steps should be taken to give it the best possible chance of survival.

### **Avoiding seabirds and bait loss**

The issue of tuna longline gear interacting with seabirds, causing incidental takes, is an issue in some regions in longline fishing. There is a problem though at times with bait loss through seabirds attacking baited hooks as they are set. In areas where seabird interactions have occurred, mitigation measures have been developed and introduced. These measures also work to reduce bait loss, by making it difficult for the seabirds to get to the baited hooks, or getting the baited hooks to sink faster. Setting tuna longline gear at night is by far the simplest and easiest way to avoid bait loss to seabirds, as most seabirds are day feeders. However, in some fisheries the setting time is dictated by the main feeding time of the target species and night setting of the gear may result in lower catch rates.

## Depredation by toothed whales

'Depredation' is the term used when unwanted species such as cetaceans or sharks consume hooked fish, while predation refers to one species preying on another. Toothed whales sometimes attack and eat tuna and swordfish that are caught on longlines. When a pod of these whales finds a longline with fish, they follow the line eating everything except the head of the hooked fish. Some dolphin species have been associated with the loss of bait from longline gear. Some whales have interacted with the longline gear itself and become caught, putting the whale at risk and damaging the gear. Given there are no foolproof mitigation measures available at present, the following measures can avoid or minimise the chance of interactions or depredation.

- Reducing vessel noise, possibly through vessel design.
- Managing gear noise through its operation (turn off echo sounders when not in use, reduce noise of deck machinery, propeller noise etc.).
- Considering changes to gear and setting and hauling practices.
- Considering changing fishing areas and fishing seasons.
- Avoiding areas where cetaceans are known to congregate.
- If cetaceans are sighted during the set, discontinue the set, haul the line, and move to another location.
- Use acoustic equipment to try to locate and subsequently avoid cetaceans.
- Avoiding discarding of offal and used bait in the vicinity of fishing locations.

## Conclusion

Longlining is one of the main fishing methods that holds potential for economic development in many countries and territories. The method targets the larger, deeper swimming tunas and other oceanic resources that command high prices in export markets if they are handled carefully and quality is maintained throughout the catching, processing and exporting processes. The costs for local operators to set up a longlining operation are high, but the potential returns are also great. While promoting longline fishing focus should be on sustainable and responsible fishing practices. longlining has 1.5 times more advantages than trawl and fewer drawbacks. However, it should be noted that longline fishing has the clear drawback of needing to use additional biological resources, ie. squid, fish, shellfish, etc, as bait for its hooks. This negative characteristic of longline fishing, however, is compensated for by the much more sparing fishing qualities it has in comparison with other fishing methods. Despite the few drawbacks of longline fishing, its advantages over other fishing methods are very clear. The large-scale development of the sustainable longline fishery is one of the means of optimizing the exploitation of tuna and other oceanic resources. At the same time, it is necessary to state that the development of the longline fishery must not only be aimed at increasing the size of the fleet, but also at increasing the working efficiency of existing vessels. Tunas and other oceanic resources can be caught very effectively using the longline, but remain inaccessible to the bottom trawl which is the most common fishing method. For promoting longline, it will be necessary to avoid shifting preference over to longlines entirely. It should be borne in mind that some stocks of fish, bottom resources such as shrimps are difficult for the longline to access and their exploitation is only possible using trawl fishing gears. Therefore it is essential to ensure that only the combined use of these fishing gears will allow for the optimal utilisation of the all the resources. There should be a rational

distribution of fishing efforts according to fishing areas and seasons and the taking into account the various biological peculiarities of the fish being exploited.

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