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Field of study: Fisheries Technology

NORWEGIAN HOOK DESIGNS IMPROVE CATCH EFFICIENCY IN THE ADRIATIC BOTTOM LONGLINE FISHERY

by

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Abstract

The present study reports the results of investigations conducted during 2006-2007 of the bottom longline fishery in the Southern Adriatic Sea. The study investigated the rigging of the line and the material used. These investigations specifically compared the catch efficiency of the traditionally used J-shaped hook to hooks with innovative design that are commonly used in the Norwegian costal longline fishery. Fishing trials were conducted using a commercial fishing boat operating in areas with two different bottom morphologies (rocky and muddy bottom). Species abundance of the catches in the two areas were compared. The working hypothesis was that the innovative hooks, characterized by a point toward the line of pull (i.e., Mustad: EZ-Baiter, Wide Gap, Wide Gap Eyed), perform better than the traditional hook whose point is parallel to the line of pull (i.e., Mustad: Round Bend Sea). A variant of the traditional J-shaped hook, characterized by an offset-angle (Mustad: Kirby) was also tested. The elasmobranch species (*Squalus acanthias* 26 % and *Raja clavata* 13 %) were the most abundant species on rocky bottom, followed by *Pagrus pagrus* (13 %). These species were hardly present on muddy bottoms where *Merluccius merluccius* dominated (48 %). The EZ-Baiter and Wide Gap hooks had the highest catch efficiency in terms of biomass of fish caught. They also gave the highest income. The Wide Gap Eyed hook performed the worst as it was not suitable for the baiting operations. The EZ-Baiter and Wide Gap hook were more efficient than the Round Bend Sea hook on both bottom morphologies. The results suggest that the EZ-Baiter hook performed better than Wide Gap hook on rocky bottom, while the Wide Gap performed better on muddy bottom. The Kirby hook did not improve the catch efficiency compared to the Round Bend Sea. It was concluded that introduction of the Norwegian hook designs could improve the efficiency and income of the Italian bottom longline fishery without large investments.

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1. INTRODUCTION

It is generally accepted that hook and line are more selective than trawl and thereby a more conservation-oriented fishing technique. Furthermore this method allows capture of fish of better quality. (Brandt 1984; Bjordal 1989; Løkkeborg and Bjordal 1992). Being less energy-demanding in terms of fuel, a transition from trawl to longline will make the fishery less vulnerable to the increase in fuel price (Bjordal 1989). The main fishing gear used in the Adriatic Sea today, however, is trawl. The use of trawl has traditionally generated a higher income and the working conditions have been better compared to those of longlining. The bottom longline fishery in Southern Adriatic has been suffering from a general lack of scientific knowledge regarding the state of the art as well as available technology. This study aims to improve the cost-efficiency ratio of the bottom longline through the study of new hook designs and rigging of the line. The species specific selectivity of the hooks is also considered. By changing hook design and the way of rigging the Italian longline could improve its efficiency without large investments.

The longline fishery is one of the most traditional and common fishing methods in the world. It is a passive fishing method that is based on fish attraction by means of bait. Longline can be used by a wide range of vessel from small-scale artisanal fishing boats to modern mechanised vessels. In the past, prior to the use of boats, the longlines were set from the shore, particularly on tidal shorelines (George 1993). The use of longline gear may have originated in the Mediterranean region and later spread to other countries. In Norway the use of longline gear dates back to the early 1700s (Bjordal and Løkkeborg 1996). The utilization of hooks is much older and goes back to the Stone Age when wood and bone were the materials used for their construction. Around 200 BC, bronze began to be used as hook material and new development originated in the hook design according to geographic areas. Two major developments can be identified in different regions: the Pacific-type hook and the Atlantic-type hook. The original Pacific hook did not have a barb (see Appendix 1). The point, bent towards the shank, filled the barb function. In the Atlantic type the point was parallel to the shank and the barb was present. At that time the production of hooks was labour intensive and expensive. Large scale usage of hooks become more common as production became more industrialized. Nowadays several thousand of hook types are available on the market. Definitions related to the longline fishery and hook anatomy are given in Appendix 1, 2 and 3.

The traditional J-shaped hook (Figure 1) is commonly used in Italy and has previously dominated the bottom longline fishery in many countries, including in Norway. In the middle of the 1980s Norwegian investigations on different hook designs produced a revolution in the longline sector. The fishing trials with new hook designs showed considerable increases in catch rates as well as a difference in how the fish were hooked (Huse and Fernö 1990). After some earlier scepticism among the fishermen, the new hook designs prevailed over the traditional J-shape hooks (Bjordal and Løkkeborg 1996). These are now widely used in fisheries for different species all over the Norwegian coast as well as in some other countries.

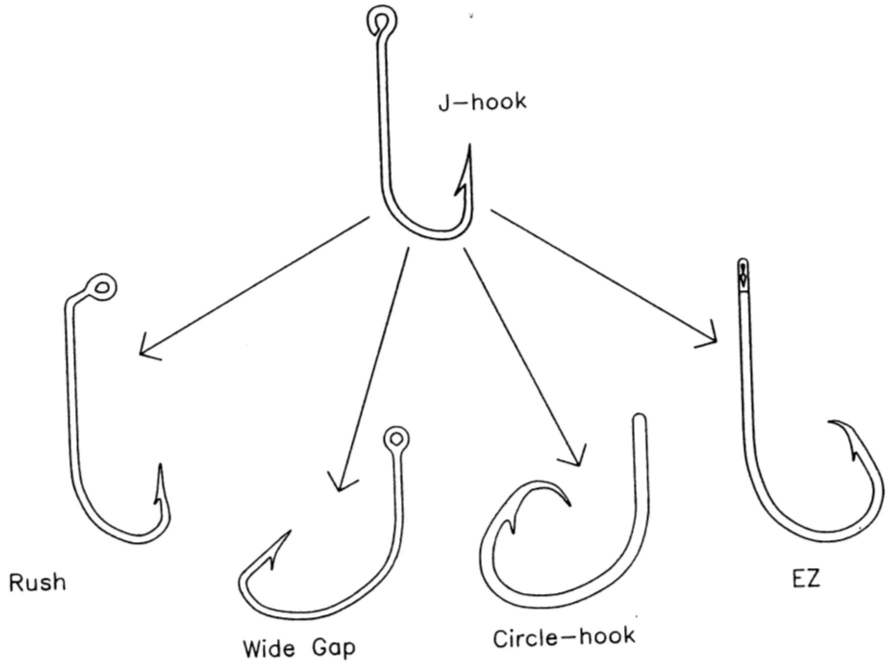

Fig. 1: Developing of new hook designs. (Source: Bjordal and Løkkeborg 1996).

The common feature of the new hook types is that the point of the hook is bended toward the shank or the eye rather than being parallel (Figure 1). The new hooks can be considered evolutions and hybrids between the ancient Pacific and European hook designs (Huse and Fernö 1990). The mechanical principle of the new hooks is that a hook with the point towards the line of pull ensures that the tension placed on the snood is more effectively transferred to the point of the hook. For the traditional J-hook there is an angle between the line of pull of the snood and the force generated on the hook point with a consequent reduction of the penetration forces (Bjordal and Løkkeborg 1996). The improved catch rate of the new hook design is explained by a combination of better hooking efficiency and lower probability of escapement after hooking. The narrower gap of these hooks compared to the J-shape hook could make escapement of the fish more difficult. This is supported by the fact that higher catches have been reported under bad weather conditions (Bjordal 1989).

1.1 The longline fishery in the Southern Adriatic

The Italian longline fishery is not evenly distributed around the peninsula but it is localized around some fishing harbours. The nature of the fisheries in the different regions is distinct both with respect to target species and the rigging of the line. In some fishing communities the operations are still done by hand as practiced hundred years ago and even the hauling is done manually (Ferretti, Tarulli et al. 2002). The only modernization of the fishery is introduction of synthetic fibres for the constructions of the bottom long line.

In Italy there are no data available on the exact number of fishing boats using longlines. The Italian fishery is characterized by a large number of fishing boats generally of small dimensions, i.e. most of them have a tonnage below 11 tons, operating with many different fishing methods. Often the same fishing boat uses different fishing gears during different periods of the year (Vacchi, Mesa et al. 1992). According to the statistical data given in the 2006 by the Italian Ministry of Agricultural and Environmental Politics, the fishing fleet was composed by 14 129 units. 69 % of the fishing fleet were allowed to operate with multiple fishing gear (this number includes both vessels operating with polyvalent licenses and boats registered in the small scale fishery). To what exact extent longline is used is unknown as boats operating with polyvalent licenses switch between gears depending on the season. Only the 2.3 % (330 units) of the entire Italian fleet are registered and operates exclusively as longline boats (Repubblica Italiana 2007). Details on the Italian longline fishery regulations are provided in Appendix 4.

The boats with polyvalent fishing licenses have in the past 30 years given priority to the bottom trawl fishery for many months of the year. The bottom trawl fishery secured a better income and the working conditions were less exhausting compared to the use of longline. The bottom longline fishery is labour intensive due to a lack of mechanization. This increases the cost of the fishery making it unprofitable in most part of the country. In recent years in some areas the bottom longline has been used mostly by older fishermen operating from fishing boats of modest dimensions. The situation has been better for boats operating with pelagic long lines. This is mainly due to the high price of their target species on the Italian market, mainly represented by swordfish (*Xiphias gladius*) albacore (*Thunnus alalunga*) and occasionally bluefin tuna (*Thunnus thynnus*) (Pietrucci and Antolini 1992).

One of the most important Italian harbours for the bottom long line fishery is Monopoli (Bari) located in the Southern Adriatic Sea (Figure2).

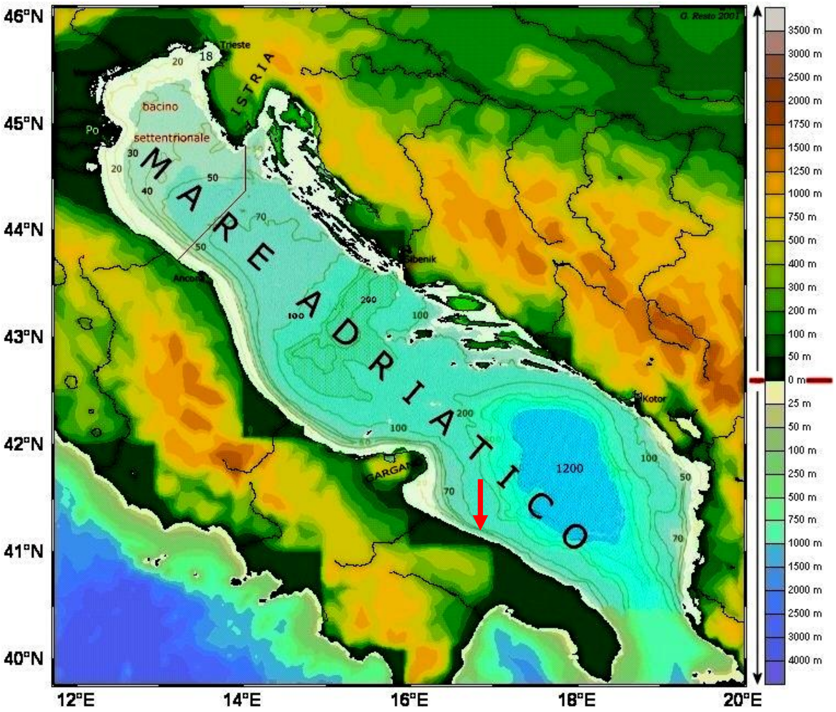

Fig. 2: Adriatic Sea map; the arrow indicates the location of Monopoli harbour.

In Monopoli the bottom longline fishery has an old tradition and has survived during the boom of the small-scale trawl fishery. In the course of the years the fishing community of Monopoli has continuously developed. Innovations have been made regarding the material used for the rigging of the longline as well as the execution of the fishing operations itself. The fishing boats in this area are considerably longer than in other areas in Italy. The boats operate year round using bottom longline and occasionally pelagic longline during some months of the year, usually between August and September, while mainly targeting swordfish. In Monopoli there are also boats with polyvalent licences operating with trawl or bottom longline according to the time of the year. Most of the boats operating with longline spend 3 to 4 days at sea sailing a distance between 70 and 90 nautical miles to reach the fishing grounds. In order to avoid direct conflict with boats using bottom trawl, the longlines are often deployed on fishing grounds with uneven or rocky bottom morphology that are not suitable for trawling. Furthermore this practice enables longliners to explore new and less exploited areas (Marano, Ungaro et al. 1989). This also explains why the longline activities takes place only in some specific areas of the Adriatic Sea.

The mechanization of the bottom longline is mainly limited to the utilization of automatic haulers. The improvement in fishing techniques and the availability of young and very skilled crew members makes this fishery as profitable as the trawl fishery. The most recent research on bottom longline rigging and fishing operations in the area was done in 1990 (Pietrucci and Antolini 1990). Back then the fishing operations were much more laborious than today with fewer hooks deployed and hauled per day per crewmember. The number of hooks deployed was strongly related to the morphology of the bottom and the depth. The number of hooks hauled per minutes was less on rocky bottom than on muddy bottom. This is due to the higher tension applied on the main line and the higher possibility of breakage during the operations on the rocky bottom. As consequence a lower speed of the hydraulic winch is required with a consequent lower number of hooks for minute hauled. The average number of hooks deployed per day per crewmember has increased from 1 100 in 1990 (Pietrucci and Antolini 1990), to 1 600 hooks today (Fishing trials 2007). On average, the number of crewmembers has decreased from 7 to 6 workers giving even harder working conditions, i.e. working days can be up to 16-17 hours / day.

1.1.1 The target species

The last investigation on the catches of the commercial bottom long line in the Southern Adriatic was conducted in 1998 and involved four longline fishing boats delivering their catches in the Monopoli harbour (DeZio, Ungaro et al. 1998). These boats were mainly operating on muddy bottom on a depth between 200 and 400 m. The most abundant species in the catch was hake (*Merluccius merluccius)* representing 76.4 % of the total catch. This was followed by conger (*Conger conger*) (10.7 %) and blackbelly rosefish (*Helicolenus dactylopterus*) (3.56 %). Other species caught included *Pagellus bogaraveo, Phycis blennoides*, and *Raja* sp (DeZio, Ungaro et al. 1998).

1.2 Objectives

This master thesis aims at contributing to improve the efficiency of the bottom longline fishery in the Adriatic Sea by investigating the use of special hooks and technologies that have already been successfully tested and employed in the Norwegian longline fishery.

The bottom longline fishery in Italy is suffering from a general lack of scientific knowledge regarding the state of the art and available technology. This may be due to the secondary importance of the Italian bottom longline fishery in the last decades (see section 1.1). The increasing oil price has created a strong rationale for switching from trawl to the less fuel intensive longline. From an economical point of view, the level of automation in the modern longline fisheries makes them an excellent alternative to the trawl (Pietrucci and Antolini 1990). A clear example of this is represented by the coastal and offshore longline fishery in Norway. The development of the longline fishery is fundamentally linked to the increase of its efficiency.

This thesis reports on the first fishing trial conducted in the Adriatic Sea using a commercial longline boat. Different hook designs were evaluated with respect to their efficiency and suitability in relation to how the Italian longline is rigged. Species specific selectivity of the hooks was also investigated.

1.2.1 Research approach

This research continues and extends previous investigations carried out in Norway regarding the usefulness of technical innovation in the costal bottom longline fishery. The catch power and selectivity of the classical hooks used in Italy were compared to three selected hooks used in the Norwegian longline fishery. A detailed description of the fishing operations, the target species, the material and the technology applied in the Italian bottom long line fishery is also given.

1.2.2 Working hypotheses

Experiments and practical use of the traditional Round Bend Sea (J-shaped hook) in Norway suggests that this hook has the lowest catch efficiency when compared to hooks with innovative designs (Skeide, Bjordal et al. 1986; Huse and Fernö 1990; Bjordal and Løkkeborg 1996).

The **main hypothesis** of this thesis is that the new types of hooks (made in Norway and not commercialized in Italy) are more catch-efficient than the J-shaped hook commonly used in Italy. The hooks are tested on fishing grounds with muddy and rocky bottom morphology. The main anatomic characteristic believed responsible of the greater catch efficiency is that the hook point is directed along the tension made on the snood.

For each new type of hook a sub-hypothesis has been formulated related to its anatomy and to the characteristics of the Southern Adriatic longline fishery.

1. The **EZ-baiter hook** can be hypothesised to work better towards larger fish species that have a powerful reaction. The largest and best paid fish are mainly represented by the Sparidae family, characterized by living in a rocky bottom habitat. Consequently it is expected to have the best catch efficiency on rocky fishing grounds.

2. The **Wide Gap hook** should represents a versatile hook with good catch efficiency on both bottom morphologies. It is expected to work better toward medium size fish (mainly found on muddy bottom), but at the same time give a good catch efficiency of rocky-bottom species (mainly big-size fish).

3. The **Wide Gap Eyed hook** is expected to have a similar performance as the Wide Gap hook due to its similar anatomy.

The Kirby hook is commercialized in Italy but rarely used in the commercial fishery. It represents a variant of the Round Bend Sea, i.e. a J-shaped hook (hook point not directed along the tension made on the snood). Its only anatomic difference to the J-shaped hook is that the hook point is bent toward the right (18-20° offset angle). This should give an idea of the importance of the off-set angle compared to the angle of pull. The forth sub-hypothesis formulated to this regard is the following.

4. The **Kirby hook** is expected to perform better than the Round Bend Sea due to its offset angle. This is believed to give an increased catch power of small and medium sized fish species (in particular hake).

2. TECHNICAL DETAILS OF THE ITALIAN AND NORWEGIAN BOTTOM LONGLINE FISHERY

Fishing with longline is a well-known technique all over the world and it is regarded as one the most fuel efficient, environment friendly and cleanest catching methods (Sainsbury 1996). Despite many similarities, there are large local variations in the design of the gear and fisheries tactics. A brief description of the Southern Adriatic and the Norwegian longline fishery will therefore follow.

The description of the fishing operations is largely based on own observations or information from the fishermen.

2.1 The Southern Adriatic bottom longline

In the last 15 years in this part of the Adriatic Sea, the longline rigging and fishing operation have been improved and speeded up when compared to other fishing districts in the peninsula, with the consequences of a better efficiency and remunerability.

2.1.1 Rigging of the longline

The longlines are entirely built and repaired by the crewmembers during the bad weather days that force the boats to be at the port. The first operation is to connect the hooks to the snoods. Thereafter 4 fishermen in coordination attach their snoods to the longline. The longline is stored in robust plastic baskets (tubs).

<u>The main line</u>

In the last ten years the material used for the main line has changed from polypropylene multifilament to polyamide monofilament. Due to the low specific weight (0.91 kg / m^3) of polypropylene a snood with 70-80 gr weight had to be attached every 4-5 snoods to ensure contact of the line to the bottom. For the snoods a nylon monofilament with a thickness of 5-6 mm was used and every longline unit (tub) consisted of about 250 hooks. The catch of pelagic fish was extremely rare since the fish could easily see the multifilament. Nowadays polyamide monofilament is commonly used for the construction of commercial longlines, both for the main line and for the snoods. The use of nylon has made it possible to catch highly valuable pelagic species. Nylon monofilament also guarantees bottom contact of the line due to its high specific weight (1.14 kg / m^3).

The Snood

All the snoods have equal length and are connected to the main line by a swivel joint, a quite recent introduction and that was developed in Monopoli in the 1990's. The introduction of swivels has improved and made the hauling operation faster. Tangling and twisting of the snoods around the main line has decreased compared to the traditional design where the snood was connected directly to the main line with a knot.

Two metal clamps limit the movement of the "two plane swivel" on the long line (Figure 3). It has been noticed that this rigging can cause some problems since the metal clamp entering the shave pulley may squeeze the main line. After many hauls a consistent damage of the main line in the metal clamp area has been noticed. Often the breakages of the main line are localized there (personal observation). Some boats have recently started to test another connection method of the snoods to the main line. With this method two fluorescent small balls are fastened to their extremity with a knot (Figure 4). The knot is made up of a nylon thread and it requires experience, strength and time to tie it properly. It takes 5 fishermen about 1 hour to rig 100 hooks using the traditional metal clamp, while the use of fluorescent balls required 3 hours.

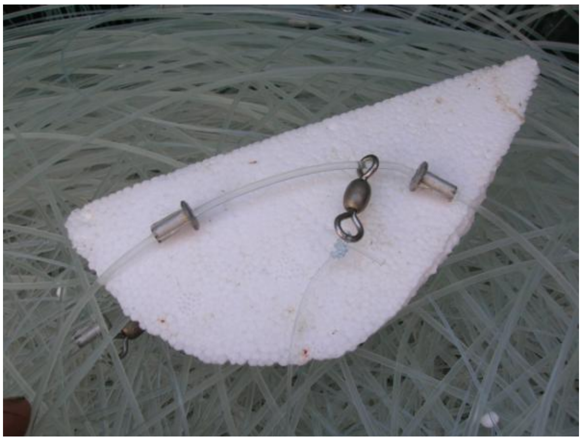

Fig. 3: Traditional swivel attachment using metal clamps.

Fig. 4: Innovative swivel attachment using nylon knots and plastic balls.

Hook spacing

The boats operating with bottom longline use a fix distance between the snoods of 5 m.

The tub

The tub is made of plastic whose edge is covered by a strip of cork were the hooks are attached.

In the past the number of hooks per tub was 250 and the hooks were baited prior to deployment.

Nowadays every bottom longline has around 1000 hooks per tub and the hooks are baited during deployment. Placement of the hooks on the cork has to be done in a special way. The two neighbouring hooks have to be placed on a different angle to each other. This is imperative for successful deployment of the longline (Figure 5).

The bait

Frozen sardine (*Sardina pilchardus*) is bought and used as bait. Sardine represents a good balance between attractive propriety, size of the bait and price. In the Italian bottom longline fishery the sardines are used whole and are hooked from the eyes (Figure 6). This way of baiting ensures a good grip of the bait on the hooks and at the same time it guarantees a fast baiting operation.

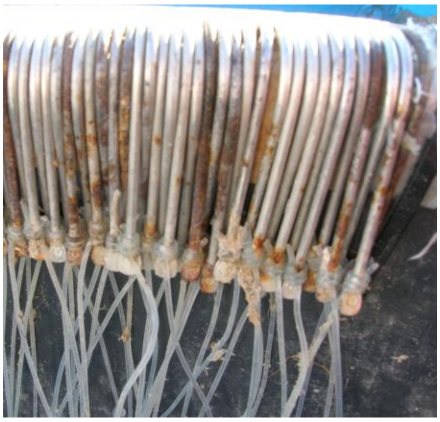

Fig. 5: Cork edged tub with typical hooks disposition.

Fig. 6: Sardine hooked from the eyes.

Previously, when the longline was baited on land the sardines were baited from the backside and all the hooks were hidden, but this operation was too laborious and not possible at sea. Sometimes two sardines were baited on one hook in order to produce a propeller movement of the bait when it was sinking. Based on experience the fishermen believe that this movement is particularly attractive for the pelagic fish species. In order to have a better grip on the hooks the bait has to be only partly defrosted. The largest sardines are discarded as the fishermen believe them to have poor catch efficiency (C. Centomani, personal communication)[1].

[1] Clemente Centomani, captain of the fishing boat “Angelo Padre”. Monopoli.

Setting design

The longline setting design can vary considerably from place to place. This appears to be primarily based on the captain's knowledge and intuitions about the fishing ground. For example if the fishing ground is muddy with no big difference in depth, all the tubs are connected and deployed after each other. On rocky bottoms, and especially if the fishery is done above shoals, the lines are often deployed parallel and fairly close to each other. The setting design is strictly decided according to the fish concentration in the area and by the presence of strong currents.

Soaking time

The soaking time varies from the first tubs deployed to the last ones. Soaking time can be 5 hours for the first tub and up to 13 hours for the last one. After deployment the boat sails towards the first tubs deployed. The crew takes about one hour break before hauling starts. Based on personal observations, as well as fishermen's conviction, the first tubs deployed have on average caught less fish than the tubs deployed later.

2.1.2 Fishing operations

Deployment of the line

The longline are placed on the stern of the boat where they are deployed. This operation requires a minimum of 5 crew members. One fisherman navigates the vessel, regulating the direction and the speed of the boat (around 5 knots). The other four are on the stern of the boat deploying the longline(Figure 7).

Fig. 7: Disposition of the four fishermen during the deployment of the line.

Two are baiting the hooks and throwing them over board. This is very dangerous work since the two fishermen have to be well timed and coordinate in order to throw the baited hooks in alternating movements. This operation also has to be strictly timed with respect to the deployment speed of the main line. If they wait too long the hook will be pulled away from their hands with high probability of injuring the crew seriously. If they throw the hook too early it will get entangled with the hook thrown by the other fisherman. A third fisherman is seated on the side of the long line and is giving the hooks directly in the hands of the two fishermen that are baiting them (Figure 8).

A fourth fisherman checks that the main line is coming out without tangles or other kinds of problems. If there is a problem he will have to quickly hold the main line and stop it in order to give the others three fishermen time to solve the problem. During these emergency situations the fisherman who is steering the boat must immediately decrease its speed. This fourth fisherman also has the responsibility to connect the lines of the tubs and to attach weights and marker buoys (Figure 9). The extremities of the longline are connected to a weight in order to hold the longline close to the bottom. The weight is also connected with a rope to a floating signal buoy with reflectors for them to be visible at night.As a general precaution, more buoys are connected to the longline when there’s a larger risk for breakage of the main line, for example on rocky bottom.

Fig. 8: The third fisherman (on the right) giving the hooks to the two “baiters”.

Fig. 9: The fourth fisherman connecting weight and marker buoy.

The deployment of the longline starts early in the morning (around 4 a.m.). It takes 6 fishermen around 5 hours to deploy 10 000 hooks (C. Centomani, personal communication)[2]. Using the old way of baiting the hooks it took 6 fishermen around 7 hours to deploy the 7 000 hooks (Pietrucci and Antolini 1990).

Hauling the longline

This operation occupies the majority of the working day and requires the presence of all the crew members. The time needed for hauling can drastically increase if the line breaks. The important parameters influencing the hauling speed are depth, current, sea conditions, setting design, number of hooked fish and capture of big fishes. An average calculation shows that it takes about 1 h 15 min to haul 1 000 hooks (personal observation).

A hydraulic winch, a so-called line hauler winch, is used for the hauling operations. It has three specially designed sheaves for holding and pulling the line on board. This is hydraulically driven by the main engine of the boat and is located to the aft, starboard side. Hauling the line normally starts with the end that was the first deployed.

One of the fishermen is operating the hydraulic line hauler winch. He grabs the marker buoy and places the buoy rope on the line hauler winch. The buoy rope is disconnected and the hauling of the main line begins. He also has to untangle the snoods around the main line before it enters the winch. If there is no fish, the snood is given to a fisherman seated on the left of the winch. This fisherman has to remove the remaining bait from the hook and at the same time make sure that the main line is stored without tangling. The clean hook is given directly to the third fisherman sitting to his left, which places the hooks on the cork edge of the tub(Figure 10). If the snood has fish, the crewmember operating the winch gives the snood to another fisherman on his right hand side (the forth fisherman). This forth fisherman cuts the snoods nearby close to the swivel or alternatively he unhooks the fish (Figure 11). If the snood is damaged, or if the fish is not hooked in the mouth cavity, the snood is cut. This happens often. The snood is replaced with a new one by the fifth fisherman operating around the tub.

The fifth fisherman (often the captain) also has the responsibility to steer the boat operating the manual commands which is situated in proximity of the hydraulic winch. Particular attention has to be given to avoid that the main line touches the keel of the boat causing breakage of the line. The sixth fisherman operates at the stern of the boat and his task is to gut

[2]Clemente Centomani, captain of the fishing boat “Angelo Padre”. Monopoli.

and store the fish in cases. Unlike the Norwegian longline fisheries, a gaff is not used to bring the fish on board. When the fish is of a modest dimension it is just pulled on board. If it is large fish or if it's a valuable species, a landing net is used to secure the catch. Sometimes, as the fish leaves the water, the increased weight strain can lead to loss of fish from the hook. In this case a long-hook 3-4 m long is used to pick it up from the sea surface. The same long-hook is used to take on board big pelagic species.

Fig. 10: The first fisherman operating with the winch (right) gives the snoods to the the second and third fisherman (left).

Fig. 11: The fourth fisherman taking on board the snood with the fish.

Handling of the catch

All types of elasmobranches, congers and the big pelagic fish were gutted at sea, while all the other species were landed round. Particular attention is required during the handling of some species of sharks with poisonous spikes as well as congers. These species are killed with a wooden club (Figure 12). The fish were washed and handled with care during storage. The fish were sorted by species and stored in one layer in polystyrene or wood cases (Figure 13).In order to preserve the quality of the fish a plastic foil is placed on top of the fish separating the fish from the ice that is used to keep the fish cool. The cases are stored in a refrigerated room in the boat.

On delivery the boxes are immediately weighted and transferred to a refrigerated trailer. The fish reaches the market the very same day. The same trailers deliver the frozen bait, the crushed ice and the empty cases to the fishing boat.

Fig. 12: The sixth fisherman handling a big conger.

Fig.13: Hake stored in polystyrene boxes.

2.2 The Norwegian bottom longline

In Norway many different kinds of mechanizations have been tested and some coastal and off-shore longliners have applied these new innovations.

The first fully automatized longline system to be used in the off-shore commercial fishery was the Autoline system manufactured by Mustad & Son Ltd of Norway in the 1970s (Bjordal and Løkkeborg 1996). This system is now the world leader in the off-shore longline fishery and has made all the fishing operations fully authomatized. Mustad has also produced a mechanized system that can be used by small longline vessels. This system, called the Mustad Miniline system, is based on snoods that are detachable and the line is spooled on to a drum. The snoods are automatically detached during hauling and the line and the snoods are stored in two different racks. The hooks are automatically baited upon deployment. In this system the main line can be monofilament polyamide (PA) or multifilament polyester (PES) and the fishermen can choose the distance between the hooks. Despite several promising fishing trials there are still problems that have to be solved before this system can be commonly used in the coastal longline fishery. To date only a few boats are operating with the Miniline system along the Norwegian coast.

Another system that has been produced and tested in Norway for the small and medium scale longline fishery is the Turboline System developed by Bjørshol International. This system is based on detachable hooks with a special arrowhead termination of the shank. The fishing trial related to the original method has showed several problems. New fishing trials are planned using a new arrangement of the original systems with land based mechanized baiting (L. Karlsen, personal communication)[3].

2.2.1 Small scale, coastal longline fishery

The coastal Norwegian long line fishing fleet is still using landed hand baiting and tub units since the efficiency of this method has not been achieved by any of the mechanized long line systems so far. Due to the above mentioned challenges in automation of the logline, the coastal Norwegian longline fishing fleet is still baiting on land and the line is deployed from tubs.

The Norwegian coastal fleets is using pelagic, semi pelagic and bottom longline rigging according to the target species and the period of the year. The use of monofilament or multifilament and the number of hooks for a standard, which equals 540 m main line, is also related to the kind of fishery and to the fishing district.

It is common to use a PES multifilament of 4.5 - 5.5 mm as main line and PA monofilament of 0.8 mm for the snoods. The length of the snoods is around 80 cm, much smaller than the length of the snoods used in Mediterranean waters. The longline is baited on land and the snoods with baited hooks are coiled inside the tube. The coiling and how the baited hooks are placed in the tub is imperative in order to avoid tangling during the deploying of the gear. When baiting thick multifilament it is common to lay the baited hooks along the rim of the tub and cover them with new coils of the main line. This is done to avoid tangling between hooks at different depths on the tubs. Coiling monofilament is more difficult due to its rigidity. Paper sheets are therefore laid over the coils of baited gear for every 10-20 hooks. This prevents the hooks from falling down and get entangled with the hooks placed in the lower layer (Bjordal and Løkkeborg 1996).

For vessels that are relevant to compare to the Adriatic Sea longliners, 2 to 3 crewmembers are needed for the operations at sea and the total number of hooks deployed seldom exceeds 15 000 each trip. The longline fishermen usually do not bait the line themselves. There are workers employed on land (men and women) that repair, bait and coil the longline. They are paid for tub baited and the most skilled baiters can bait up to 100-150 hooks per hour (including substituting missed/damaged hooks or snoods) (Personal investigation). The shape of EZ-Baiter and Circle hooks, that were introduced to the fishery, causes problems when

[3] Prof. Ludvig karlsen. NTNU Trondheim.

baiting with mackerel (*Scomber scombrus*) due to the small space between the point and the shank of the hook. In some fishing districts these kinds of hooks, have been replaced by the Wide Gap hook. The Wide Gap hook has become frequently used in the Norwegian coastal bottom longline fishery.

The tubs are deployed from the stern of the boat using a so-called line setter or line chute. This is an aluminium construction that enables the hooks to run smoothly overboard without the help of fishermen. This has greatly improved the safety of the fishermen that only have to replace the empty tubs with a full one thereby avoiding any dangerous contact with the hooks. Most of the line chutes utilized nowadays are double which increase the safety for the fishermen as they no longer have to remove the empty tub in front of the running hooks (Figure 14). The deploying speed is around 5 knots with an average of 80 hooks deployed per minute. This arrangement permits deployment of the longline also in bad weather without extra safety risk for the crew members.

Fig. 14: Double line chutes utilized by Norwegian costal longline boats.

3. MATERIAL AND METHODS

3.1 Area and period of investigation

The fishing trials were conducted with the 18 m long fishing boat, "Angelo Padre" (see specifications in Appendix 7) between the Italian coast and the Albanian/Croatian territorial waters in the Southern Adriatic Sea4. The investigation collected and utilized information in connection with the fishing harbour of Monopoli, which is located in the Puglia region (Figure 2).

Since the skills of the crew are particularly important in this type of low technology fishery, it was crucial to conduct the project in cooperation with an experienced crew. The fishing in Monopoli is traditionally organized in family enterprises, in which fishing practices are passed down through generations and have a long history. The captain and the two crewmembers (his younger brothers) were selected for this research project because they are members of a well-known longlining family in Monopoli, which is indicative of a high level fishing expertise.

During January 2007 (11.1 to 31.1) three fishing trips were carried out which lasted for 4, 3 and 2 effective fishing days respectively. The boat operated as a commercial fishing boat in all aspects including the choice of area, type of sea bottom substrate and line setting design. Experimental longline tubs were used in addition to commercial longline tubs.

The fishery was conducted in areas with two different bottom morphologies (rocky and muddy bottom), which were also characterized by different depth ranges. Ideally, the experimental longlines were supposed to be equally distributed on both rocky and muddy bottoms. However, this was not always possible due to constraints given by the commercial priorities of the operation and accidental damage of the equipment. Overall, six hauls were conducted on rocky bottom and eight on muddy bottom (see Appendix 6).

3.2 Pre-study of bottom longline rigging

In order to become familiarized with the gear, fishing practices, etc. used in the study area, visits were made during summer 2006 and January 2007 to the Monopoli fishing district. In

[4] Details about Adriatic Sea, its morphology, bathymetry, water circulation and chemical characteristics are given in Appendix 5

addition, several longline boat captains, a local research institution (Laboratorio Provinciale di Biologia Marina di Bari) and a fishing gear dealer (Barracuda s.a.s) were interviewed. Particular importance was given to the materials used for the rigging of the longline and the preferences of the fishermen in these matters. Due to the lack of related investigations carried out in Italy, scientific information and knowledge from studies carried out in Norway were used.

3.3 Fishing gears

The longlines used for the fishing trials were rigged and built using the same types of material (except for the experimental hooks[5]) as those used in commercial longlining. The longlines were rigged as follows:

- Main line: monofilament, 2.3 mm.
- Snoods: monofilament, 1.0 mm.
- Swivel: inox, 3/1.
- Hook spacing: 5 m.
- Tubs: plastic with corked edge.
- Hooks (Mustad): Round Bend Sea, Wide Gape Eyed, Wide Gap, EZ-Baiter, Kirby (Figure 15).

In order to facilitate their identification during the trials, a character was assigned to each hook type (see Table 1).

Fig. 15: The hooks tested. From the left EZ-baiter (B), Kirby (Z), Round Bend Sea (D), Wide Gap (C), Wide Gap Eyed (A).

[5] The hooks Wide Gap Eyed, Wide Gap, EZ-Baiter, used in these experiments were kindly supplied free of charge by O. Mustad & Son A.S., Norway.

Table 1: The hooks tested. Name, assigned character, size and identification code (given by Mustad).

Hook's name	Assigned character	Size	Identification Code
Wide Gap Eyed	**A**	4/0	72940 D
Wide Gap	**C**	5/0	72950 D
EZ-Baiter	**B**	11/0	39971 D
Kirby	**Z**	7	2310 DT
Round Bend Sea	**D**	7	2315 DT

3.3.1 Hook sizes and shapes

The most widely used commercial hook for the bottom longline fishery in Monopoli is the Mustad Round Bend Sea in size 7. This hook was therefore used as a reference and the other hook designs used in the trials were compared to this one.

Since hook size can influence catch efficiency, the comparison of different hook designs should ideally be based on hooks of similar size. However, the manufacturers do not use equivalent numbers on the different hook designs. Hooks with different designs, but identified with the same size number, can therefore differ considerable in size. This had to be taken into consideration during the experimental design. Hooks of similar sizes were chosen based on measurements of the anatomy of the hook (total length, gap, shank and throat) (see Table 2). Due to the big differences in the shape of the different hook designs (Figure 16), the selection of the hooks was a compromise between the measurements of the different parts of the hooks and subjective evaluation.

Measuring the shank length is difficult when comparing straight and curved hooks. It was therefore decided to measure it as the length between the eye and the horizontal projection of the point to the shank.

Table 2: Comparison of the different hook types based on measurements of their parts.

	Wide Gap Eyed	Wide Gap	EZ-Baiter	Kirby	Round Bend Sea
Tot. Lenght (mm)	44	45	54	44	45
Gap (mm)	17	17	13	14	16
Shank (mm)	32	25	27	22	23
Throat (mm)	12	17	19	16	18

Fig. 16: The offset angle of: from the left EZ-baiter (**B**), Round Bend Sea (**D**), Kirby (**Z**), Wide Gap (**C**), Wide Gap Eyed (**A**).

3.3.2 Experimental longlines

In total three experimental longlines were rigged. The total number of hooks and the types of hooks tested differed and changed during the fishing trips. The decisions on these changes were made on the background of discussions between the researcher and the crewmembers in response to observed practical problems of some of the innovative hook designs (Table 3).

Table 3: Hook types used in the rigging of the three experimental longlines.

	Longline 1	Longline 2	Longline 3
Hook types utilized	Wide Gap Eyed EZ-Baiter Wide Gap Round Bend Sea	Kirby EZ-Baiter Wide Gap Round Bend Sea	Kirby EZ-Baiter Wide Gap
Total Nr. of hooks	604	824	690

Since the Wide Gape Eyed hooks in longline 1 caused problems during the baiting operations they were replaced by Kirby hooks. Longline 2 was built using the same number of each hook designs as longline 1 (without the Wide Gape Eyed hooks). Both longlines were used during the second fishing trip. The good catch efficiency results of the experimental hooks motivated the captain to rig a third longline (longline 3) at his own expens. The traditional hook (Round Bend Sea) was not mounted on this last longline. All three longline riggings were used in the third fishing trip. An important statistical consequence of these changes is that the number of observations comparing hook A and Z is lower than the number of observations comparing hooks B, C and D. This will be discussed further in the analysis of the results.

3.4 Experimental design

The fishing area is characterized by a highly patchy distribution of fish, which represents a potential source of bias when comparing the catch efficiency of different hook designs. This problem was taken into consideration when deciding on the sequence of hooks in the experimental longlines. The hooks were organized in repeated series in which a batch of 15 hooks of one type was followed by a batch of 15 hooks of another type. The sequence of these different batches was kept consistent.

The choice of a batch-size of 15 hooks was made on the basis of statistical requirements (R. Primicerio, personal communication[6]), previous trials on hook design (L. Karlsen, personal communication [7]) and practical limitations (C. Centomani, personal communication[8]).

3.5 Categorization of the data set

For each setting of the longline, the position, depth, time of deployment, hauling, and weather conditions were recorded. The catches by each hook type were kept separate and identified to species level[9] (Tortonese 1970; Whitehead, Bauchot et al. 1986; Fisher, Bauchot et al. 1987).

The total length of each specimen was measured to the nearest cm. The total weight of each species caught on the different hooks was recorded.

Since the three different longlines did not contain the same number of hooks, the catch was standardized to 100 hooks (Nr. fish / 100 hooks). The weight was standardized (kg / 100 hooks) in order to get values of catch per unit effort (CPUE). The income was standardized in € / 100 hooks. The market prices for the catches, as used in income calculations, were obtained from the captains of the longline boats during 2007. (see Appendix 8). These prices represent the payment from the wholesaler. The prices fluctuate during the year and differ across wholesalers. The species caught were organized into price groups (Table 4). For each hook type the total income was calculated as the product of the species-specific price times the total weight of the species caught by that hook.

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[6] Dr. Raul Primicerio, NCFS, UIT,Tromsø.
[7] Prof. Ludvig Karlsen, NTNU Trondheim.
[8] Clemente Centomani, captain of the fishing boat "Angelo Padre", Monopoli.
[9] Concerning the Rajidae family, all species (except the *Raja clavata*) were only specified to the genus level.

Table 4: Price groups and price / kg for the different species caught.

PRICE GROUP	SPECIES	Price/kg (€)
1	*C. conger* *L. caudatus* *S. japanicus* *T. trachurus*	1
2	*R. clavata* *S.acanthias*	3
3	*E. alletteratus*	3,5
4	*M. merluccius* *Phycis sp.*	6
5	*S. scrofa* *T. lucerna* *D. sargus*	10
6	*P. pagrus* *D.dentex*	18

3.6 Data sets and statistical analyses

The three main variables analyzed were; 1) the mean weight of total catch (kg / 100 hooks), 2) mean number of fish caught (Nr. Fish / 100 hooks) and 3) mean income (€ / 100 hooks).

Two types of data analyses were performed. First an Exploratory Data Analyses (EDA) in which raw data from the three hook morphologies (B, C and D) were used because of the large and balanced data sets. Secondly an Inferential Statistical Analysis (ISA) was carried out. In this case all the data sets (hook A, B, C, D and Z) was used when analysis were made independently from bottom morphologies, whereas only B,C and D hooks were used with regards to bottom morphology (rocky and muddy). In the latter case, A and Z hooks were discarded because of the limited and unbalanced data sets.

The EDA was performed in order to check the data distribution and the presence of outliers. Since the EDA showed that the distributions of the dependent variables were skewed, the data were normalized before the ISA analysis. To normalize the data a logarithmic transformation was applied.

The catch data were analyzed by paired samples ANOVA. The advantage of a paired samples ANOVA, justified by the sampling design, is the reduction of within group variance, which increases the power of the test. A diagnostic check of the residuals after fitting the ANOVA model confirmed that the logarithmic transformation was successful.

Post hoc paired t-tests were used to identify differences in mean catch between hooks. Data were tested with a significance level of $p=0.05$. The ANOVA and t-tests were performed with the statistical software R®. Statview® and Microsoft Excel® were used to produce the figures.

The species-specific catching power of the hooks were also investigated. The results of this investigation are based on data collected for three species (*M. merluccius*, *P. pagrus*, *S. acanthias*). The species were chosen based on their economical importance and high abundance in the catch. As these analyses are only descriptive the complete hook data sets (A, B, C, D and Z) was used.

The design of the hooks determines its most likely location in the mouth/throat of the captured fish (Atlantic States Marine Fisheries Commision 2003) influencing the final quality of the catch. A preliminary and descriptive analysis on this matter was performed based on pictures of some individuals in the catch, i.e. some of the largest and. most valuable specimens. These species were *P. pagrus,* the most profitable species and *E. alletteratus*, the species characterized by the biggest size in the catch.

4. RESULTS

4.1 Species and biomass percentage

The list of teleosts and elasmobranchs caught with the experimental longlines are reported in Table 5.

Table 5: Species caught with experimental longlines during the trials.

SPECIES CAUGHT	
Teleosts	**Elasmobranchs**
Conger conger	*Squalus acanthias*
Dentex dentex	*Raja clavata*
Diplodus puntazo	*Raja sp.*
Euthynnus alletteratus	
Lepidopus caudatus	
Merluccius merluccius	
Pagrus pagrus	
Phycis blennoides	
Phycis phycis	
Scomber japanicus	
Scorpaena scrofa	
Trachurus trachurus	
Trigla lucerna	

The number and the abundance of species varied greatly between the two bottom morphologies. The percentage of species abundance was calculated separately for rocky (Figure 17) and muddy (Figure 18) bottoms.

C. conger was the most important species in term of biomass on the rocky bottom (29%) and the third most abundant on muddy bottom (6 %). On the rocky bottom the elasmobranchs (*R. clavata* and *S. acanthias*) represented 40 % of the biomass. The elasmobranch species made up only 1 % of the total catch on muddy bottom. *P. pagrus* was totally absent on the muddy bottom, but accounted for 13 % of the biomass on rocky bottom. *M. merluccius* was the most important species on muddy bottom (48 %), but only made up 5 % of the biomass on the rocky bottom. Percentage abundance was similar on muddy and rocky bottom for *T. lucerna* (3 % and 4 % respectively).

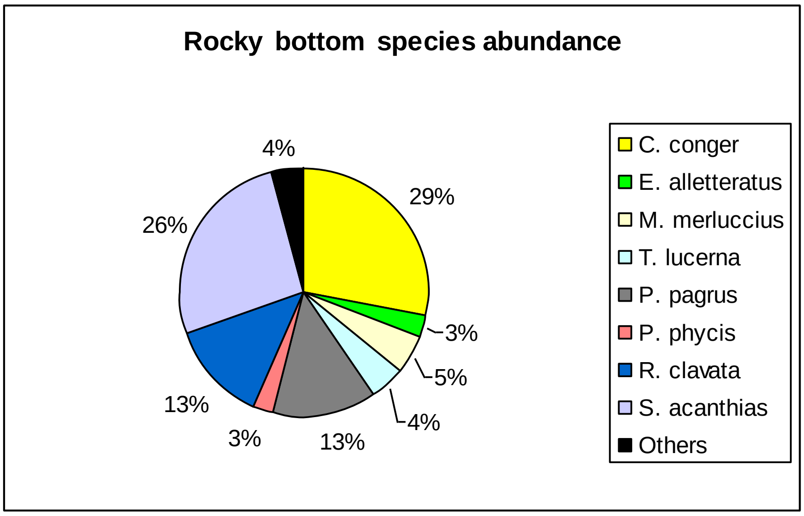

Fig 17: Percentages of species abundance in terms of biomass on rocky bottom.

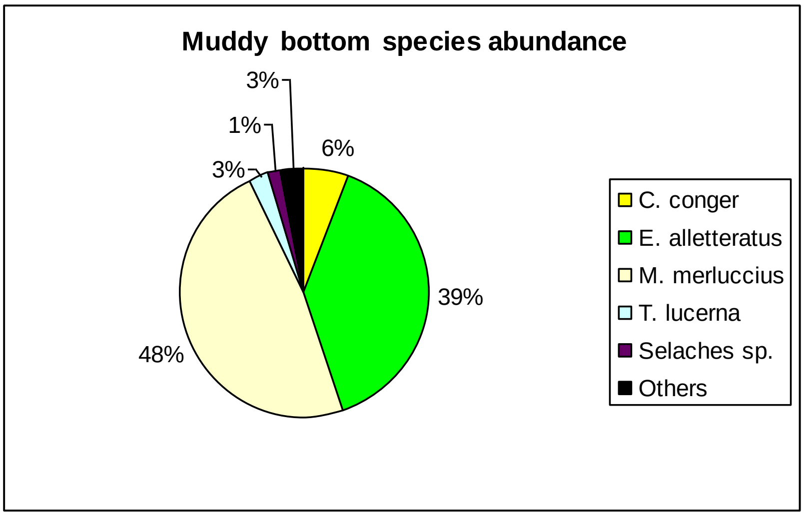

Fig. 18: Percentages of species abundance in terms of biomass on muddy bottom.

4.2 Exploratory Data Analysis (EDA) and Transformation

The EDA analysis describing the data (Figure 19), suggests a higher catch efficiency of hook B and C compared to hook D with respect to number of fish caught, total weight of the catch and income.

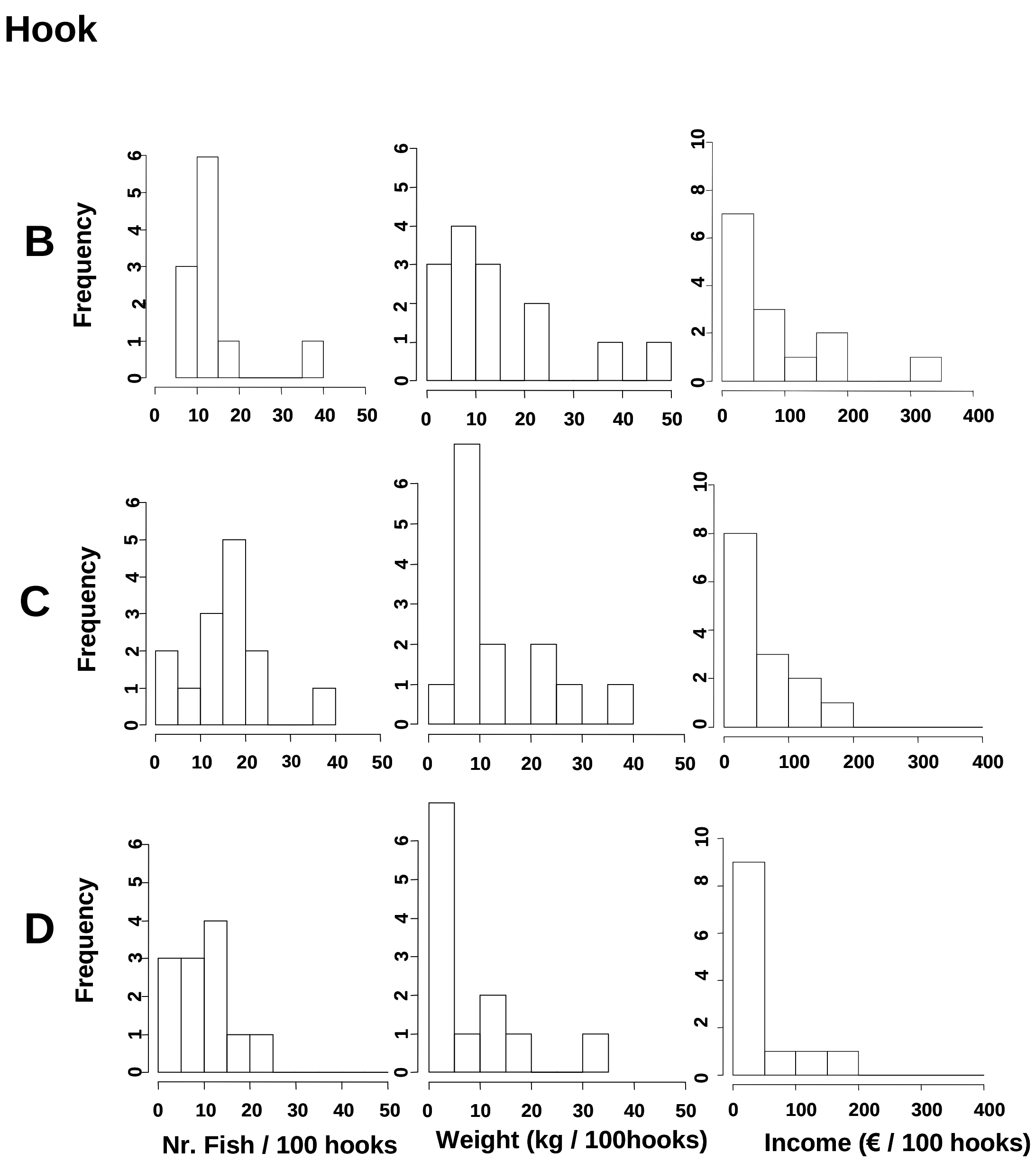

Fig 19: Frequency distribution for number of fish (Nr. Fish / 100 hooks), weight (kg / 100hooks) and income (€ / 100 hooks) for hook **B** (EZ-baiter),**C** (Wide Gap), **D** (Round Bend Sea).

4.3 Inferential Statistical Analyses (ISA)

4.3.1 Hook performances independent from bottom morphology

Hook B and C seem to have a greater catch power than hooks A and D in terms of weight of total catch. Hook Z does not show any clear difference from the other hooks (Figure 20). Hook Z seems to have the highest catch power with respect to the number of fish, followed by hook B and C. Hook A and D caught the lowest number of fish (Figure 20).Hooks B and C appear to generate a higher income than the other hooks (Figure 20).

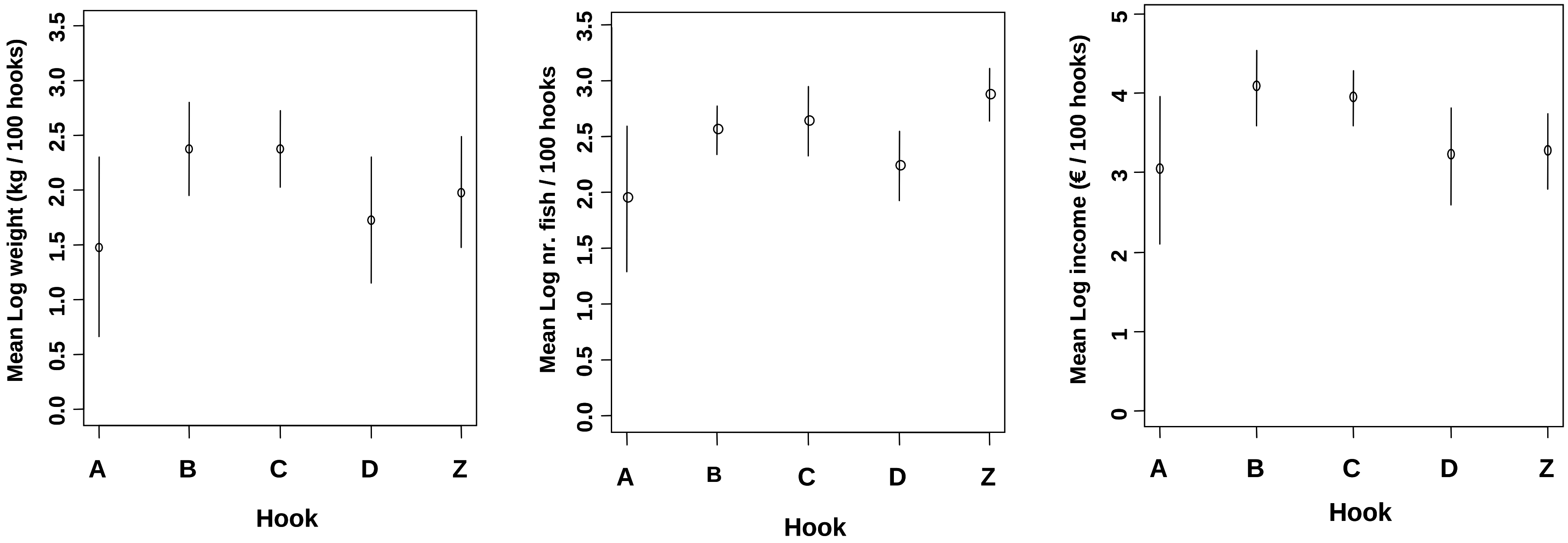

Fig. 20: Means of Log weight (kg / 100 hooks), Log number of fish (nr. fish / 100 hooks), Log income (€ / 100 hooks) of total catch for each of the Hooks: **A** (Wide Gap Eyed), **B** (EZ-baiter),**C** (Wide Gap), **D** (Round Bend Sea), **Z** (Kirby) hooks. Bars indicate 95 % Confidence Intervals.

4.3.2 Hook performances taking into account bottom morphology

Figure 21 and 23 describe the non-transformed data for the means of weight of total catch (Figure 21) and the means of number of fish (Figure 23)for the different types of bottoms and hooks.

The biomass caught seems to be greater on rocky than muddy bottom. Hook D appears to be the least efficient, particularly on muddy bottom (Figure 21).

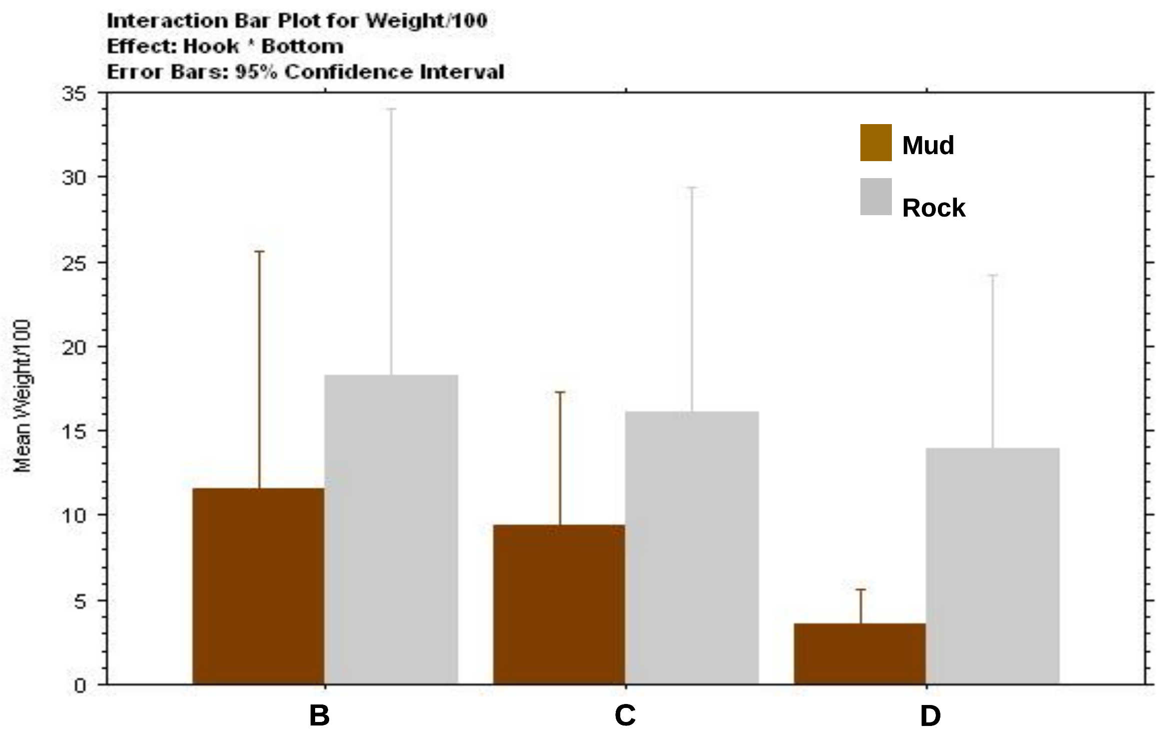

Fig 21: Means of weight (kg / 100 hooks) of total catch for each of the Hooks: B (EZ-Baiter), C (Wide Gap), and D (Round Bend Sea) Hooks) in each type of Bottom(Mud, Rock). Bars indicate 95% Confidence Intervals.

A repeated measure ANOVA with Bottom morphology (muddy, rocky) and Hook type (B, C, D) as the independent variables confirmed that weight differed significantly among types of bottom morphology ($F_{1,10}$=5.75; **p=0.04**) (Figure 22). The factor of Hook type approached significance ($F_{2,22}$=2.72; **p=0.09**). However, there was no significant interactive effect of the two factors ($F_{2,22}$=0.45, **p=0.64**). A paired-sample t-test comparing hook pairs revealed a trend indicating that B>D, t_{11}=2.00, **p=0.07**.

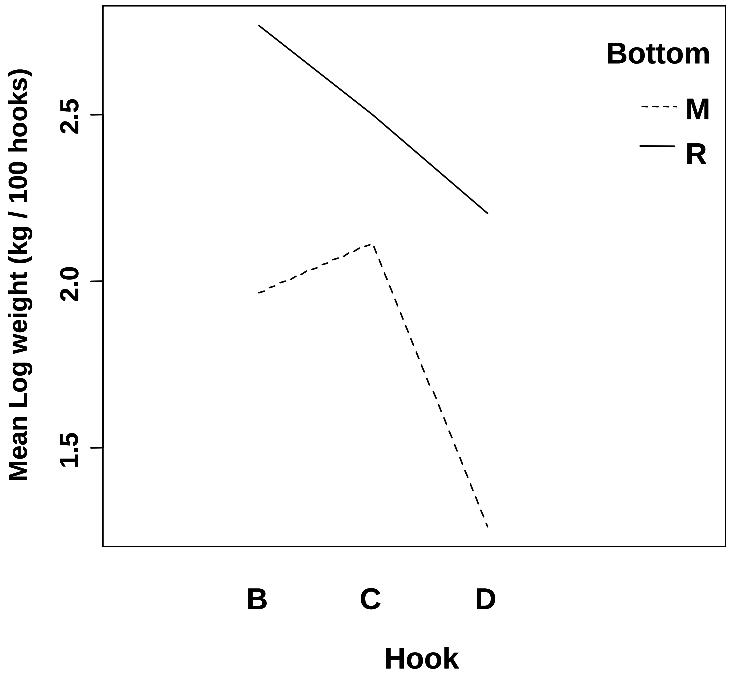

Fig. 22: Means of Log weight (kg / 100 hooks) of total catch for each of the Hooks: **B** (EZ-Baiter), **C** (Wide Gap), and **D** (Round Bend Sea) Hooks) in each type of Bottom (Mud, Rock).

A consistent difference in number of fish caught between the different hooks is not apparent from Figure 23. However, there seems to be an interactive effect between Hooks and Bottom morphology. Hook C seems to be more effective than hooks B and D on muddy bottom.

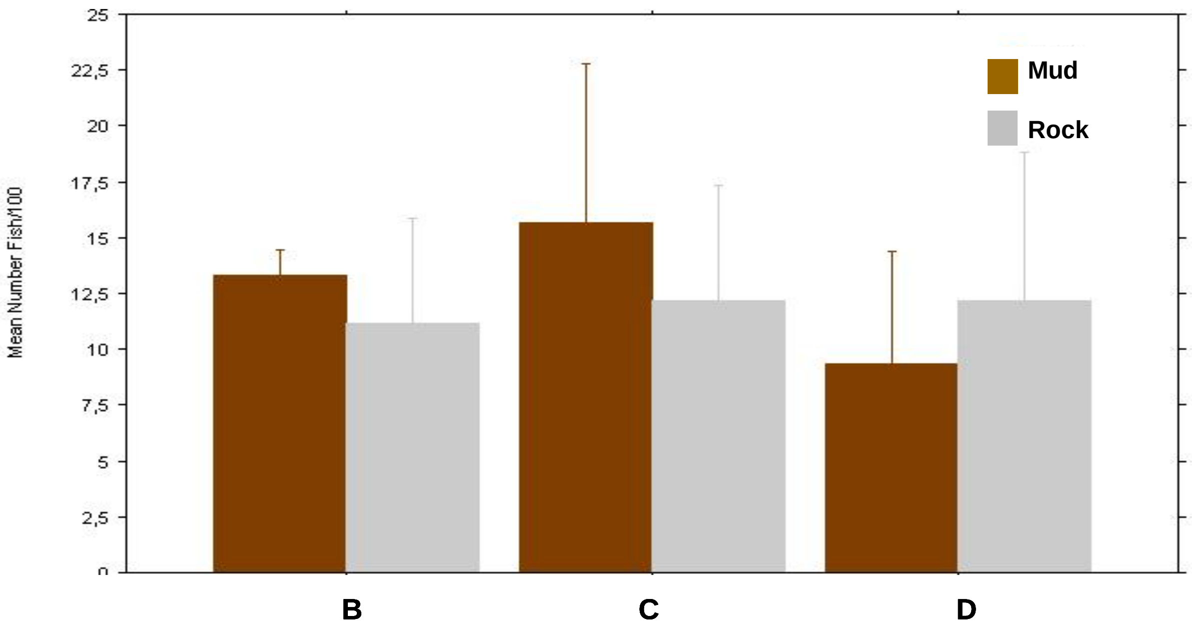

Fig 23: Means of number of fish (Nr. / 100 hooks) of total catch for each of the Hooks: **B** (EZ-Baiter), **C** (Wide Gap), and **D** (Round Bend Sea) hooks in each type of Bottom(Mud, Rock). Bars indicate 95% Confidence Intervals.

A repeated measures ANOVA with Bottom (muddy, rocky) and Hook (B, C, D) as the factors and the Log transformed values (Nr. fish) as the dependent variable, revealed that the interaction between Hook and Bottom Morphology was strong, but not significant, $F_{2,20}=2.89$ **p=0.07** (Figure 24). Number of fish caught did not statistically differ among hook types ($F_{2,20}=1.79$; **p=0.19**).

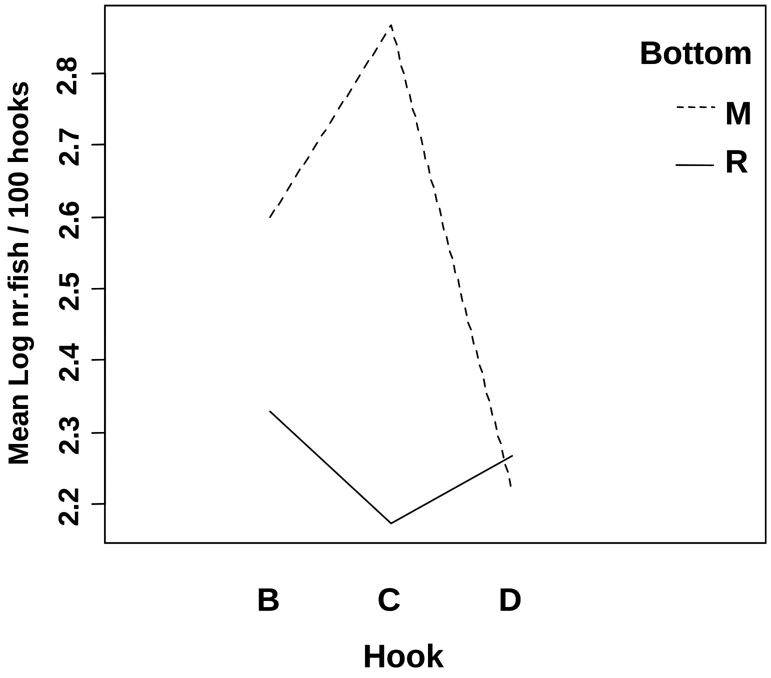

Fig. 24: Means of Log number of fish (Nr.fish / 100 hooks) of total catch for each of the Hooks: **B** (EZ-Baiter), **C** (Wide Gap), and **D** (Round Bend Sea) Hooks) in each type of Bottom (Mud, Rock).

A repeated measure ANOVA confirmed that Incomes differed significantly among hook type (B, C, D - $F_{2,24}=4.40$; **p=0.02**) and this was possibly related to bottom morphology (B, C, D - $F_{1,11} = 3.8$; **p=0.09**) (Figure 25). The paired-sample t-test comparing hook pairs showed that hook B performed better than hook D (B>D, $t_{11}=2.66$, **p=0.02**), but only a statistical trend indicating that hook C performed better than D (C>D, $t_{11}=1,94$, **p=0.08).**

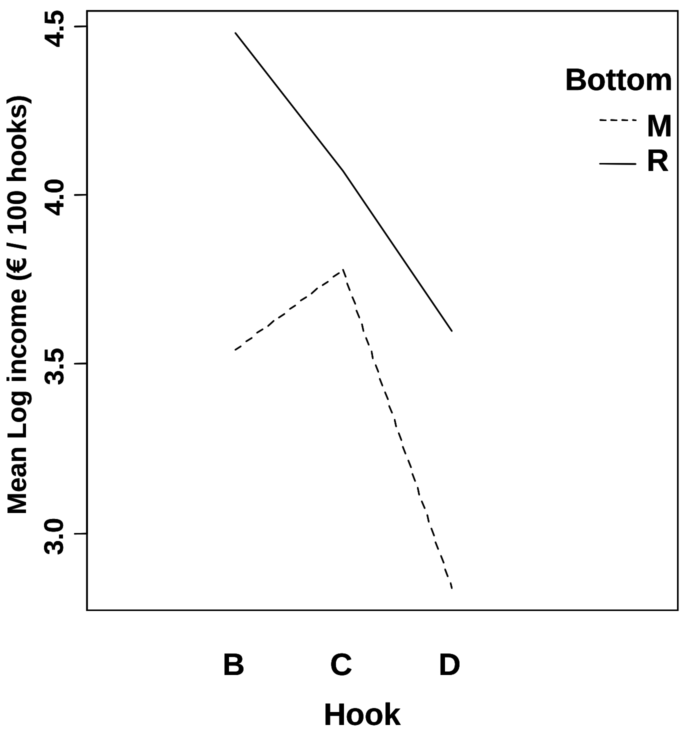

Fig. 25: Means of Log income (€ / 100 hooks) of total catch for each of the Hooks: **B** (EZ-Baiter), **C** (Wide Gap), and **D** (Round Bend Sea) Hooks) in each type of Bottom (Mud, Rock).

4.4 Species-specific catch power

The abundance of fish species captured during this study varied substantially between bottom substrates. The low presence of typically rocky bottom species on muddy bottom and vice versa created a very poor data set. The data set was therefore not of a quality that could be statistically analyzed.

Hook B followed by hook C seems to have a greater catch power to hook A, D an Z with respect to. *S. acanthias* (Figure 26). Hook C seems to be the most effective in catching *M. merluccius*, followed by B, Z, D and A. For *P. pagrus,* hook B shows the greatest catch power followed by A, D, C that show similar performance. The lowest catch power is registered for hook Z (Figure 26).

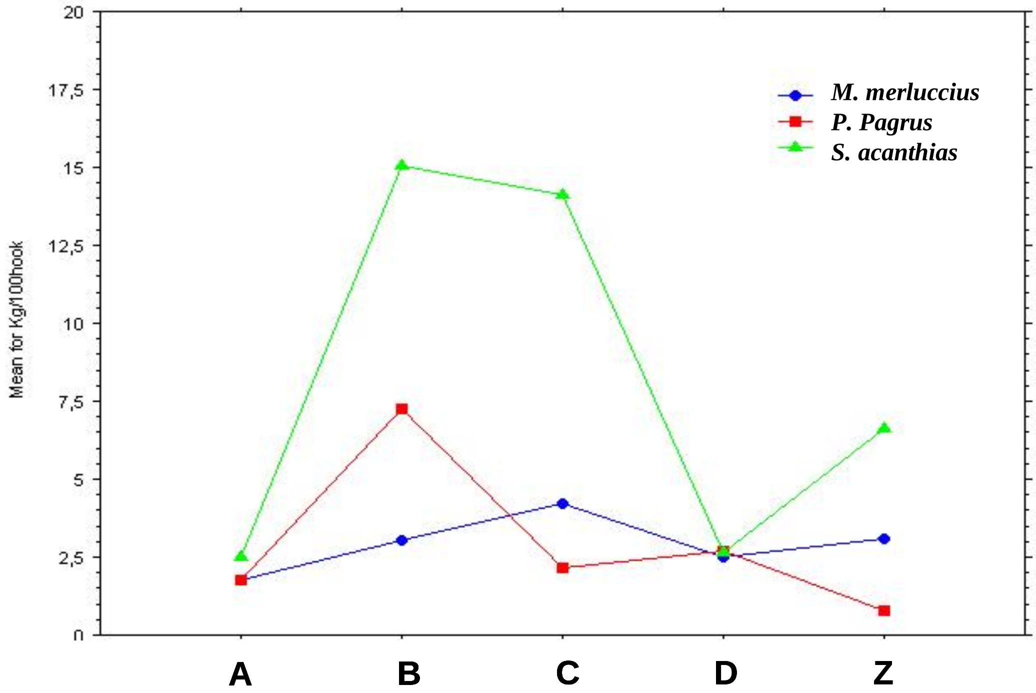

Fig. 26: Means of weight (kg / 100 hooks) in relation to three selected species (*M. merluccius, P. pagrus, S. acanthias*) and the hooks **A** (Wide Gap), **B** (EZ-baiter),**C** (Wide Gap), **D** (Round Bend Sea) hooks.

4.5 The location of the hooks in two of the species caught

This analysis only has a descriptive value since the observations were based on a sample of only two selected species (*E. alletteratus* and *P. pagrus*). Hook A, B and C typically hooked the fish in the jaw region, while hook D was most commonly swallowed by the fish (as illustrated in Figure 27).

An example of the efficiency of hook B towards large species is that 6 specimens of *E. alletteratus*, all hooked in the jaw area, were caught with this hook. 2 specimens were caught on hook type A, both of them hooked in the corner of the mouth. Hook C caught 2 specimens, one of them hooked in the mouth cavity and the other in the esophagus. Hook D caught 1 specimen and the hook was found in the stomach (Appendix 9).

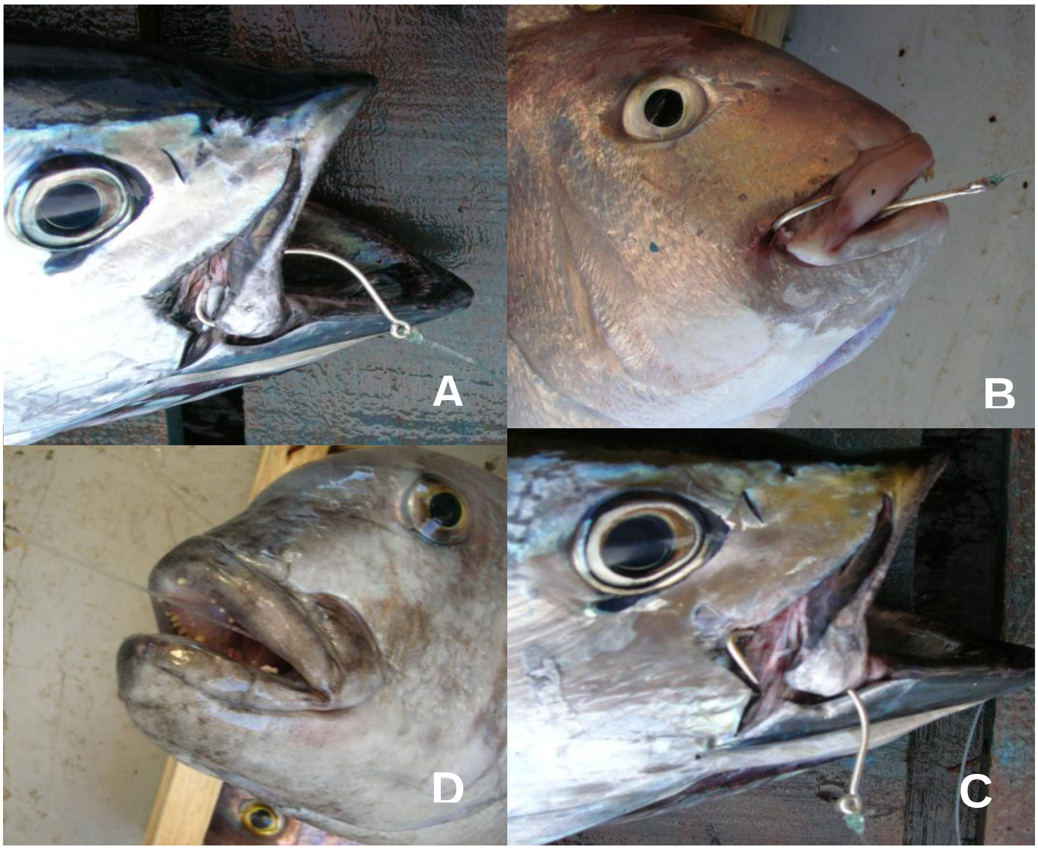

Fig. 27: Clock wise, starting from the top-left: *E. alletteratus* hooked by Wide Gap Eyed (**A**), *P. Pagrus* hooked by EZ-baiter (**B**), *E. alletteratus* hooked by Wide Gap (**C**), *P.pagrus* hooked by Round Bend Sea (**D**).

5. DISCUSSIONS

5.1 Species caught and biomass proportions

The study confirmed several aspects of previous bottom longline investigations (Pietrucci and Antolini 1990; DeZio, Ungaro et al. 1998; Romanelli and Tarulli 2001). The species composition of the catches were similar in areas of comparable bottom morphology. However, in this study we also caught pelagic species . Catches of pelagic species have not been reported in previous studies (DeZio, Ungaro et al. 1998; Ferretti, Tarulli et al. 2002). This could be explained by the different rigging of the longline. Previous investigations used polypropylene as the main line. In the present fishing trial the longlines were entirely built from the less visible polyamide monofilament. This might explain the catch of the high value pelagic species (*E. alletteratus*). (see Table 5). While previous fishing trials caught *Polyprion americanum*, this species was not caught in our study areas (DeZio, Ungaro et al. 1998; Romanelli and Tarulli 2001). This local depletion could be due to overexploitation by longline boats that have been operating in rocky areas. The life-history characteristics (large size and older age at first maturity associated with low fecundity) of such species (Fisher, Bauchot et al. 1987) make it particularly vulnerable to over fishing. Even though *P. americanum* inhabits rocky ground (Tortonese 1970) the nature of the bottom longline fishery may have caused depletion.

The hake (*M. merluccius*) constituted the smaller part of the catch in our studies (48 % of the biomass) compared to the study of DeZio et al. 1988 (77% of the biomass). Their study was conducted over a longer period of time, while our studies were conducted during the least profitable time of year for the hake fishery (DeZio, Ungaro et al. 1998). It is therefore difficult to conclude that there has been a decrease in the related hake catch. Previous investigations have shown that larger hake individuals are distributed at deeper depths than their smaller counterparts (Erzini, Goncalves et al. 2001; Romanelli and Tarulli 2001). This suggests that not only the bottom morphology but also depth has a significant relevance for the yield in the longline fishery.

5.2 The efficiency and selectivity of the different hooks

The present findings showed that the catch efficiency of hooks whit the point directed towards the line of pull (Norwegian hooks) is higher than that of hooks commonly used in the Adriatic longline fishery (J-shaped). This is in accordance with the main hypothesis of the thesis.

These innovative hooks also increased the income of the fishery (see Figure 25). The Wide Gap Eyed hook, however seems to perform the worst with respect to catch efficiency and income (see Figure 20). This was due to problems during the baiting operation for this type of hook (discussed later).

The Wide Gap and EZ-baiter hooks seemed to have the highest catch rate in terms of biomass and income on both types of substrate (see Figures 22 and 25). There was a clear difference between these two hooks and the traditionally used Round Bend Sea. This could be due to its J-shape which makes it less likely to successfully hook the fish (Huse and Fernö 1990; Løkkeborg, Bjordal et al. 1993). Despite an "offset angle" compared to the Round Bend Sea, the Kirby hook did not seem to have higher catch efficiency. Thus sub-hypothesis 4, that the Kirby hook performs better than the Round Bend Sea, is rejected. This suggests that the line of pull in relation to the point of the hook is the most important factor determining the success of the hook.

Interestingly, no significant difference between the catch efficiency of the Wide Gap and EZ-Baiter hooks were observed. In Norway the EZ-Baiter hook replaced the J-shaped hook in the longline fishery in the 1990s. The small gap space of the EZ-Baiter hook made manual baiting difficult and lead to increasing use of the Wide Gap hook in the costal Norwegian longline fishery. The Wide Gap hook is less bent and has a wider gap making baiting more efficient and therefore less time consuming (personal investigation). In Italy the use of sardine as bait does not lead to the same problem with respect to baiting. Both the Wide Gap and EZ-Baiter could therefore be used in the Southern Adriatic longline fishery.

The Wide Gap Eyed hook represents an extreme design with a very wide gap. It was originally produced as a variant of the Wide Gap but it is no longer produced for the Norwegian market (G. Liaklev, personal communication)[10]. The Wide Gap Eyed hooks that were used for the fishing trials in the study were custom-issued from Mustad. There were a number of problems with the use of this type of hook. The baiting operation took longer and therefore increased the chance of injury for the crew during the deploying operations. Furthermore, the hook easily fell off the cork lining the tub. The difficulty in baiting caused few replications for this type of hook. This can explain the large variants observed in the results (see Figure 20).

[10] Geir Liaklev, Mustad Ålesund.

The Kirby hooks appeared to have the highest catch rate in terms of the number of fish (see Figure 20). However, this result should be interpreted with caution as a lower number of experiments were conducted using the Kirby hook (see section 3.3.2). Even if the Kirby hook should turn out to be more catch efficient with respect to the number of fish, the Kirby hook seems to catch smaller individuals compared to the innovative hooks. This would be a concern both with respect to income and sustainable harvesting due to high catches of immature individuals.

5.2.1 Hook performance on different bottom morphology

The type of bottom morphology (muddy and rocky) played a clear role in terms of the weight of the fish caught .The highest biomasses were caught over rocky bottom (see Figure 22). This was expected as the large-sized species (Sparidae and Squalidae families) are often present in this type of habitat (Tortonese 1970). Although the number of fish caught was higher in muddy bottom areas than in rocky bottom areas (see Figure 24), the biomass was lower. Thus the fish in muddy bottom areas seems to be in average smaller and hence yield less income.

Although the differences in performance of the different hooks in relation to the bottom morphology were not significant due to low catches (reflected in high confidence intervals, see Figure 23 and 21) the data show some trends. The trends seem to support the hypothesis that the innovative hooks perform better than the traditional J-shaped hook on both type of substrates. This has also been shown in research done on hook performance in Norway where innovative hook designs have performed up to 34 % better, i.e. Wide Gap hook performances with respect to cod (*G. morhua*)(Huse and Fernö 1990) and 20 % to 40 % better. i.e. EZ-Baiter performances with respect to tusk (*Brosme brosme*), ling (*Molva molva*), cod and haddock (*Melanogrammus aeglefinus*) (Skeide, Bjordal et al. 1986). The success of the new hook designs is confirmed by the sale statistics of Mustad showing that the innovative designs have almost completely replaced the traditional hook (Bjordal and Løkkeborg 1996).

The EZ-Baiter hook seems to perform best in terms of biomass and number of fish in rocky areas followed by the Wide Gap hook. However, in muddy bottom areas the Wide Gap hook seems to catch the highest biomass and number of fish (see Figure 22 and 24). This is in accordance with sub-hypothesis 1, that the EZ-Baiter hook is better at catching larger species that dominate in rocky areas, and sub-hypothesis 2 that the Wide Gap hook performs better on muddy substrate. When analyzing the species-specific catch efficiency of the different hooks (see Figure 26), the EZ-Baiter hook seemed to be better at catching *P. pagrus* and *S. acanthias*. These species are the largest and are most abundant on rocky bottoms. The Wide Gap hook seems to perform better in muddy bottom areas that are dominated by medium size fish according to sub-hypothesis 2. This was exemplified by the higher catch of the medium sized fish *M. merluccius* that inhabits muddy bottom areas (see figure 26). Only descriptive information can be taken from the species-specific catch power of the hooks due to the lack of statistical tests applied (see section 4.4). The Round Bend Sea shows a lack of species-specific catch power with respect to the three species analysed There appears to be no difference in the hake-specific catch power of the Round Bend Sea and Kirby hooks(see figure 26). This observation also rejects the fourth sub-hypothesis. A Norwegian study shows that hook performance is species specific (Løkkeborg, Bjordal et al. 1993). However, the studies referred to in this article are not strictly comparable to this study as the species are different and the sizes of the fish caught by bottom longline are generally much smaller in the Adriatic Sea than in Norwegian waters.

5.3 Income

The income was significantly higher when using the EZ-Baiter hook compared to the Round Bend Sea hook (traditional J-shaped hook) on both types of substrate. Although not strictly statistically significant the results shows that the Wide Gap hook also gave a higher income. (see Figure 25). This can be explained by the higher biomass caught by the innovative designed hooks. Furthermore, the trend discussed above regarding the species specificity suggests that these types of hooks are more efficient than the J-shaped hook in catching the best paid fish. Due to large price variations between the different species caught in this fishery, further investigations regarding the species selectivity of the hooks are recommended.

Since the innovative hooks are not commercialized in Italy estimates of increased hook cost are not available. In the Norwegian longline fishery the cost of changing to the innovative hooks were low compared to the total cost of the fishery. The increased income resulting from using these hooks more than compensated for the slightly higher price of the innovative hooks. It is expected that this will be the case for the Italian longline fishery too.

J-shaped hooks have a higher tendency to get swallowed than Circle hooks, the type of hook that the EZ-Baiter and the Wide Gap hooks belong to (Prince, Ortiz et al. 2002; Bacheler and Buckel 2004; Kerstetter and Graves 2006). Swallowing of the hook causes the fish to die earlier which reduces the quality of the fish since it is attacked by other organisms prior to hauling of the longline (personal observations). Fish caught in the jaw region are more likely to be alive when hauled on board than fish that have swallowed the hook. This gives better quality of the fish and therefore a better price. Also this study found that fish caught on the innovative hooks were caught in the jaw region, while those caught on the J-shaped hook had swallowed the hook (see Figure 27). Use of innovative hooks could therefore improve the quality of the landed fish in the Italian longline fishery.

5.4 Comparison of longlining versus trawl fishery

Studies in the Southern Adriatic Sea found that the bottom longline fishery is more selective with respect to both size and species compared to the trawl (DeZio, Ungaro et al. 1998; Tatone 2004). Generally targeting the larger individuals that have been allowed to spawn promotes sustainable harvesting of the resource. However, it can be argued that this could lead to the removal of a large part of the spawning stock (Romanelli and Tarulli 2001).

The difference in size selectivity between trawl and longline is also important for stock assessment and thereby regulation. Knowledge of fishing gear selectivity is fundamentally important for making recommendations for harvest strategy (Huse, Løkkeborg et al. 2000). One example can be taken from the hake fishery within the investigated area (DeZio, Ungaro et al. 1998). When analysing the demographical structure of the hake stock based on trawl catch (over a long time) only 10 % of the catch was longer than 40 cm (Lt). It was extremely rare to find specimens longer than 60 cm. However, the median catch size of individuals caught by bottom longline in the same area was 70 cm (bottom longline landing data). Current stock assessments in the Adriatic Sea are based on trawl surveys. The selectivity of the trawl should be considered in stock assessment since population models can be sensitive to the population structure assumed by given data (Kvamme and Frøysa 2004). Only taking into account the data from trawl catches may give incorrect estimates in the stock assessment (DeZio, Ungaro et al. 1998). Similar differences in size selectivity have been also demonstrated in the hake fisheries of Southern Africa (Bjordal and Løkkeborg 1996).

In our fishing trials no hake under the legal size of 20 cm were caught regardless the type of hook. In contrast, the trawl fishery in the area is known to catch undersized hake (DeZio, Ungaro et al. 1998). Due to the high proportion of small hake in the Adriatic trawl fishery the EU allowed by derogation for the catch to contain 15% of hake between 15 and 20cm (Lt) in terms of weight until 31/12/2008 (Comunità Europea 2006). From a conservation point of view the use of longline in the hake fishery is therefore preferred.

In the Southern Adriatic bottom longline fishery the elasmobranchs are an important part of the catch. In contrast, they are rather marginal in the trawl fishery (DeZio, Ungaro et al. 1998; Tatone 2004). Longline selectivity towards elasmobranchs has been observed also in other areas (Connoly, Hareide et al. 1996; Erzini, Goncalves et al. 2001). This can be due to the fact that the elasmobranchs are voracious predators thereby attacking the baited hook (Romanelli and Tarulli 2001).Due to the specific selectivity of the longline toward Elasmobranches, an intensive bottom longline fishery in the Southern Adriatic could threaten the elasmobranch stocks due to their high age of first maturity (Romanelli and Tarulli 2001; Tatone 2004).

5.5 Selectivity in the longline fishery

The selective properties of the longline depend on several factors related both to the gear characteristics and to the species-specific fish behaviour toward the baited hooks. It is documented that small fish are excluded from the catch only when large specimens are present in the area . Thus, if the longline is set in areas populated by small fish only, there will be no exclusion of small fish as long as the bait and the hook are suitable for these fish (Huse, Løkkeborg et al. 2000).

5.5.1 Hook selectivity

There was a small difference in the size of the hooks tested in this experiment (see section 3.3.1). The size of the hook could affect the selectivity of longline (Løkkeborg and Bjordal 1992; Bacheler and Buckel 2004). Selectivity depends on the mouth dimension. Larger hooks demand a stronger force to penetrate the mouth tissue. Larger hooks are more resistant to breaking or straightening and therefore prevent the largest fish from escaping (Erzini, Goncalves et al. 1996). Nowadays the high quality hook manufactures ensure a high breaking strength also for hooks of small dimensions. Therefore, small differences in hook size do not lead to big differences in mechanical strength. Several studies have shown that small differences in hook size do not influence the size distribution of the fish caught (Løkkeborg and Bjordal 1992; Erzini, Goncalves et al. 1996; Erzini, Goncalves et al. 2001). Due to the small variations in the size of the hooks used, the size selectivity issues are therefore not expected to have influenced the results of this study.

5.5.2 Bait size selectivity

In the longline fishery, both the size and the number of fish caught are affected by the size of the bait (Huse and Soldal 2000). Prey selectivity is determined by factors such as mouth size and the ability to capture and handle the prey (Bjordal and Løkkeborg 1996). Furthermore, larger baits tend to have a higher release rate of attractants with a correspondingly larger field of smell distribution (Hart 1986). The baiting-behaviour of the fish also influence bait selectivity (Huse and Fernö 1990). Some species takes the entire bait in the mouth, while others nibble the bait piece by piece thereby allowing consumption of larger bait. Thus the selectivity of the hooks can be affected by the size of the bait. In this study differences in bait size has not been corrected for. The fishermen in the study area seem to be aware of bait size selectivity and do not use the larger sardines as bait due to assumed low catch efficiency.

5.6 Norwegian and Southern Adriatic bottom longline rigging comparisons

5.6.1 Main line

The past 20 years the monofilament main line (polyamide) has gained popularity in Italy. This is mainly due to its superior catch performance to that of multifilament lines (polypropylene). Investigations in Norwegian waters showed the same results (Karlsen 1976). The introduction of the polyamide main line also led big pelagic fish species to get caught during sinking of the gear (Tatone 2004). The disadvantages of the monofilament are lower breaking strength and breaking elongation of the monofilament compared to the multifilament. The coiling properties of the polyamide can sometimes be problematic when operating the longline (Bjordal and Løkkeborg 1996).

5.6.2 Swivel

Norwegian investigations in different fisheries (cod, haddock, tusk and ling) have shown that attaching the snoods to the main line using swivels gives a minimum 15 % increase in catch (Bjordal 1985). The swivels also give the possibility of using monofilament snoods with a multifilament mainline. This rigging is common in the Norwegian coastal fishery for cod and haddock. Monofilament mainlines are also widely used in the longline coastal fishery. Nowadays, the longlines are built using several different types of swivels, but the most effective for avoiding twisting around the snood's axis and around the main line is the "two plane swivel" (Bjordal 1989). The fact that the same type of swivel is used in the Italian longline fishery suggests that the fishermen in Monopoli have succeeded in modernising the rigging of the line using intuition and experience.

5.6.3 Swivel attachment

The main advantage of attaching the swivel to the main line using small plastic balls instead of metal clamps is that weakening of the line is avoided when the clamps enter the shave pulley. The disadvantages are that it takes longer to complete the knots and that the price of the fluorescent balls is high. In Norway the swivel has traditionally been attached using a knot. In the past years some longliners have started using metal clamps which have weakened the breaking strength of the line. One might expect that in the long run the use of the plastic balls could increase the lifetime of the longline and thereby save time and money due to lesser breakages of the main line.

5.6.4 Hook-spacing

The hook-spacing varies greatly between bottom longline fisheries in different countries. For example, in Norway the common hook-spacing is between 1 and 2m while in Mediterranean waters it is usually 2 to 6 m (Pietrucci and Antolini 1990). In the Southern Adriatic this distance has been the same for the past thirty years despite the fact that many parameters have changed during this time. The abundance of the fish stocks, the fishing operations and the fishing areas have all changed. Fishers referred to old traditions when asked why they did not experiment with the hook-spacing. However, some of the young and more innovative fishermen were willing to try out alternative hook-spacing as they have noticed that the standard length of 5 m is not giving the same catch per unit effort as it did ten years ago. This is particularly true when fishing in muddy bottom areas were the fish are less densely distributed. Longline researches have shown that hook-spacing is of high importance for the catch power as well as the species caught. Intra- and inter-specific competition may occur among fish that are attracted by the baited hooks (Hamley and Skud 1978; Milinsky 1986; Løkkeborg, Bjordal et al. 1993). When hook-spacing increases the larger fish wins the competition for the bait thereby decreasing the relative number of small fish caught (Løkkeborg and Bjordal 1992). In addition, increased hook-spacing allows for longer snood lengths. Thus the fish can make more rotations around the main line before the snood loses its elasticity, reducing the chance of escapement (Karlsen 1976). However the snoods lengths used in the Mediterranean are not expected to increase escapement due to fish rotation. Due to the relatively long distance between the hooks used today one could experiment with both longer and shorter hook-spacing. In order to compensate for the decreased abundance of fish experienced by the fishermen the past thirty years in the investigated area, increased hook-spacing could be tried.

5.6.5 Baits

There is a lack of scientific information on bait properties in the Southern Adriatic bottom longline. It is a common notion throughout the Italian fishing districts that sardine is the best bait. The fishermen have learned from experience that different types of bait gives different species specific catch efficiencies. In Norway, many fishing trials have been done to determine the different catch efficiencies and selectivity of various baits. Different prey types release different mixtures of chemical identities (Løkkeborg 1990; Bjordal and Løkkeborg 1996). In addition to the attractiveness of the smell, the efficiency of the bait is determined by its strength and ability to remain on the hook throughout the soaking period. The size of the bait is also of relevance as discussed in section 5.5.2. Experiments made in longline fishery for hake showed that a combination of mackerel and sardine was significantly more effective as bait than just sardine or mackerel (Franco, Bjørdal et al. 1987). These findings could be relevant for the Southern Adriatic Sea fishery where hake is one of the main target species.

5.6.6 Setting design

While the importance of setting design for catch efficiency has been widely investigated in Norway there have been no such investigations in Italy. However, the Italian fishers do base their setting design on experience. Research on setting design have been done with respect to odour spread in the water in relation to the direction and strength of currents (Løkkeborg and Pina 1997). The sensitivity of a fish to bait odour can vary widely between species, but a general tendency to swim upstream towards the baits has been demonstrated (Pawson 1977; Vabø, Huse et al. 2004). The longline fishers in the Adriatic did not seem to be aware of these mechanisms but at the same time different setting design were applied according to bottom morphologies (C. Centomani, personal communication[11]).

[11] Clemente Centomani, captain of the fishing boat “Angelo Padre”, Monopoli.

5.6.7 Soaking time

Several fishermen in the present investigation pointed out that the longlines first deployed (i.e., at night), tend to have lower catch efficiency than the longlines deployed later (i.e., at dawn). The fishermen believed that the lower catch efficiency of the first longlines deployed is due to the relatively shorter soaking time compared to the lines deployed later. However, studies have shown that soaked bait looses its attractiveness after a while due to the reduction in the concentration of attractants, thereby reducing catch efficiency with time (Løkkeborg and Bjordal 1992; Bjordal and Løkkeborg 1996). The low catch efficiency of the lines deployed first could also be explained by predation of bait by benthic animals. The most common benthic scavengers are sealice, starfish, sea cucumber, sea urchins, crabs and other decapods crustaceans. These species are particularly active during the night when the longline is first deployed. In Norway scavenging of bait has been reduced by lifting the line off the bottom. Previously the Italian longline was lifted off the ground, but the line was again placed on the bottom because this type of rigging slowed down the fishing procedures onboard. The Norwegian rigging of the line could perhaps solve these problems. This could also reduce discarding of fish that dies prior to hauling and are consumed by scavengers.

5.7 Remunerability of the longline fishery and possible automations

The revenues of the longline fishery depend on the number of hooks daily set as well as the prevalence of large specimens in the catch (Løkkeborg and Bjordal 1992; Kenchington 1996).

The absence of mechanization in the Italian longline fishery requires the fishery to have large crews to ensure continuity in the work at sea. These problems could be alleviated by installing mechanisation systems to increase the number of hooks operated per unit of time (Romanelli and Tarulli 2001).

Two automated systems were tested in the 1990's in Adriatic waters; MARCO and STAGAtech, respectively produced in USA and Germany. Both systems were composed of one baiter plus a single hauler by which the long line were alternatively set and retrieved. Both systems required two or three crew members, constituting a large difference when compared to the 6-7 crewmembers on board of a traditional longline boat. In the STAGA system the baiter using whole fish during the trials reached a percent of hooked bait of 80 %. During the fishing trials the STAGAtech system had an average deploying time of 12 hooks /

minute and a hauling speed of 8 hooks / minute. The MARCO system has a deploying time using a random baiter of 35 hooks / minute and a retrieval time (hauling speed) of 19 hooks / minute. The fishing yield reached with the two automatic systems ranged from 3 to 7 kg / 100 hooks (Ferretti, Tarulli et al. 2002). These yields were low when compared with the output of fishing operations carried out with standard, traditional commercial longline.

The adaptability of the longline rigging imposed by the mechanization to the standard longline rigging used by the commercial fishermen represents consistent problems for the introduction of these systems in the Adriatic Sea. Furthermore, the use of pelagic long line by the boats operating in the area during some periods of the year makes these systems less versatile and not so economically profitable (Romanelli and Tarulli 2001). According to economical considerations, the minimal costs for the installation of this mechanized long line were 30 000 Euro. This does not represent a high cost compared to the value of the fishing boat but it is at the same time enough to discourage a family business (Ferretti, Tarulli et al. 2002).

Given the recent E.U. regulations 1967/2006/CE that fix the maximum number of hooks allowed on board to 7000 (Comunità Europea 2006) and considering the opinion of the fishermen that have tried the automatic systems (N. Damasco, personal communication[12]), the spread of such mechanisation systems in the area is considered unlikely to happen. It must be kept in mind that nowadays in this fishing district, a well skilled crew is able to deploy a daily number of hooks that is superior to that imposed by the EU regulations. Therefore, there might be no need to recommend longline automation, which implies a radical change in the structure of fishery. Instead, a more beneficial course would be to improve catch efficiency and selectivity of the current fishing method.

Innovative hook designs and a careful choice of the material used for the rigging of the line represent a clear step forward in this direction. Results from research on fishery in Italian waters, which is currently lacking, would provide the information needed to make these improvements.

[12] Nicola Damasco, captain of the fishing boat “Attila”. Monopoli.

5.8 Suggested investigations for progress of the Italian longline fisheries

On the basis of the results from the present study and my own experience from the Adriatic fisheries, I suggest further investigations to improve the Italian longline fisheries:

1)More research is needed to confirm the trends in different hook catch efficiency revealed by these fishing trials. The results show that the interaction between the two bottom morphologies and the different hook types has to be deeply investigated. It is recommended that the number of fishing trials performed in similar experiments is increased in order to compensate for the low catches registered in this specific fishing area. Moreover, the fishing trials should cover the whole year to avoid seasonal variations.

More investigations regarding the species selectivity of the hooks are recommended. This has also a strategic-economical importance due to the large variations in the price between different Adriatic species.

2) Based on their experience, the local fishermen are convinced that hook size number 7 is the most adequate size for the bottom longline fishery in the area. This should be validated by scientific means testing different hook sizes.

3) Nowadays, it is commonly accepted that knowledge of fish behaviour is essential when developing or improving fishing gears (Løkkeborg, Bjordal et al. 1993). To my knowledge, neither laboratory nor field experiments on the behaviour of Mediterranean fish toward baited hooks are undertaken. Such an experiment could for example provide useful information on the relevance of bait size or species specific hook selectivity.

4) In the light of Norwegian investigations, we recommend a future comparison on the bait efficiency using a combination of sardine/mackerel versus pure sardine.

5) The Italian hook-spacing should be investigated and related to the different fishing grounds given that the species abundance and distribution can vary considerably between the muddy and rocky bottoms.

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7. APPENDICES

Appendix 1: Longline definitions

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Appendix 1: Longline definitions

The longline consists of four basic parts;

The main line: The principal line of various materials, thickness and strengths according to type of fishery.

The snood: A thinner line, often made from transparent material, attached at certain intervals along the main line. The hook is attached to its end.

The bait: In most fisheries natural baits, i.e. whole fish or pieces of fish, are used.

The hook: Today the hooks are made exclusively from steel but to make its corrosion resistant it is also coated by an electrolysis process using different metals such as tin, nickel, cadmium or other anti-corrosives.

When the different rigging of a longline is described, the term “hook spacing” is often used. It indicates the distance between the attachment points of two neighbouring snoods on the stretched mainline (Bjordal and Løkkeborg 1996).

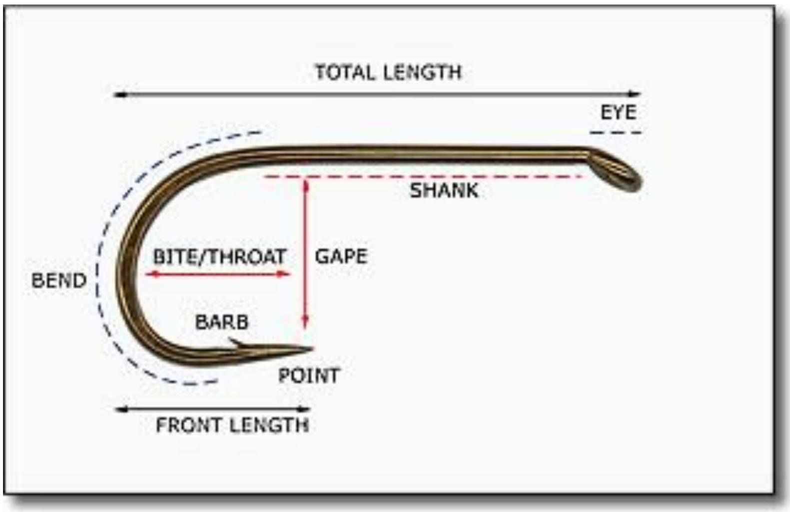
The longline, depending on the species of fish being sought, can be set at different depths and it requires different rigging and material used.

Pelagic long line: The long line is drifting in the mid water and it does not have any kind of connection to the bottom. The ends of the line are signalled by marker buoys. Between the marker buoys the main line is suspended on the sea by several floats. This method is used for pelagic species.

Semi pelagic long line: The long line is suspended to a certain height off the bottom. The outer ends of the line are fastened to the bottom with anchors or weights. Buoy ropes link the moorings of the long line to buoys that enable the boat to locate the line.

Bottom long line: The main line is laid and anchored on the bottom. The extremities of the line are connected with buoy ropes to marker buoys on the surface. The bottom long line is used for demersal species.

Appendix 2: Hook anatomy



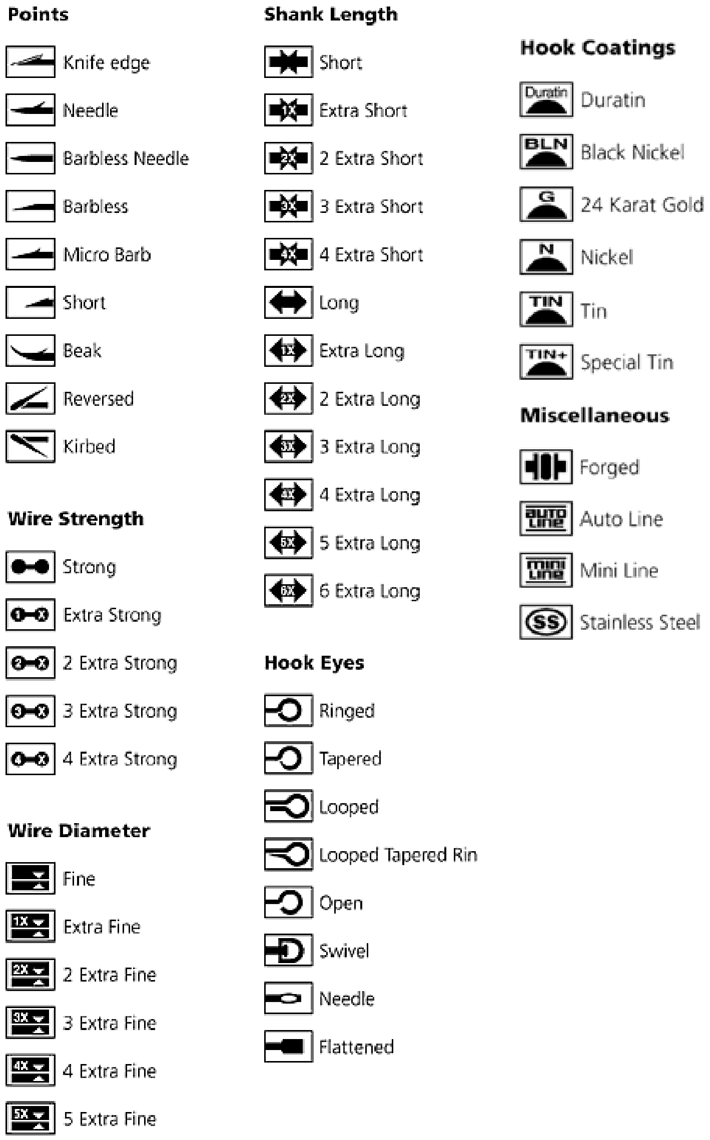
Hook anatomy parts (Source: © O. Mustad & Son A.S.)

The gape represents the distance between point and shank, and for bite/throat is considered the distance from the apex of the bend to its intersection with the gape. This represents the basic hook anatomy.

The size of a fish hook can vary considerably and unfortunately there is no uniform system of hook measurements. Although attempts have been made to set a standard by measuring the hook in fractions of an inch, the system has never been successfully adopted. It is due to the different special hook features that make the hook a two-dimensional object. The absence of international standardised terminology includes also the hook anatomy. In this manuscript we use the same terminology as used by the hook manufacturer O. Mustad & Son A.S., since all the hooks tested were produced by the cited company. Furthermore, the same terminology is also used to a large degree by the main hook manufacturers.

Appendix 3: Hook symbology

A special terminology/symbology that is reported on the label of the hook. The terminology varies between companies and a wider terminology is used for the sports fishing hooks.



Mustad hook symbology (Source: © O. Mustad & Son A.S.)

Appendix 4: Italian bottom longline regulation

In Italy, as in the other European countries, fishing is regulated by the European laws. These can be substituted by national law, but only insofar as the national rules are more restrictive than the EU rules.

Regarding the bottom set longline, the rules in force are from the EU regulation 1967/2006. This establishes the overall number of hooks allowed for vessel to five thousand. It is also prohibited to have on board or set more than thousand hooks per person on board. By way of derogation, each vessel undertaking fishing trips longer than three days may have on board a maximum number of seven thousand hook (Comunità Europea 2006).

The minimum legal size for the landed fish species in Italy are established by the EU regulation 1967/2006 CE and the D.P.R. 1639/1968 (Repubblica Italiana 1969; Comunità Europea 2006).

Minimum legal size (right column) for the landed species in Italy (left column), established by the EU regulation 1976/2006 CE and the D.P.R. 1369/1968.

SPECIES	Minimum legal size (cm)
Dicentrarchus labrax	25
Diplodus annularis	12
Diplodus puntazzo	18
Diplodus sargus	23
Diplodus vulgaris	18
Engraulis encrasilocus	9
Epinephelus spp.	45
Lythognathus mormyrus	20
*Merluccius merluccius**	20
Mugil spp.	11
Pagellus acarne	17
Pagellus bogaraveo	33
Pagellus erythrinus	15
Pagrus pagrus	18
Polyprion americanus	45
Sardina pilchardus	11
Scomber spp.	18
Solea vulgaris	20
Sparus aurata	20
Trachurus spp.	15
Sarda sarda	25
Thunnus thynnus	70
Thunnus alalunga	40
Euthynnus alletteratus	30
Xiphias gladius	140

*Untill 31/12/2008 is allowed for Merluccius merluccius a tolerance of 15% in weight for specimen with a total length between 15 and 20cm.

Appendix 5: The Adriatic Sea

The Adriatic Sea stretches from 40°N to 46°N and 12°E to 20°E. It has a narrow and long shape (around 800km) with NW – SE direction. The Adriatic Sea has an area of 180 square kilometres and an average width of 200km, with a restriction of only 72km on the Otranto channel. In the Northern Adriatic Sea the continental shelf connects the two opposite coasts ;the Southern Adriatic has a sub circular shape with a maximum depth of 1253m, "Fossa di Bari". The two opposite coasts of the Adriatic Sea represent big differences: on the Italian side the bottom depth is slowly going down, but on the Albanian Side it decreases steeply. The Italian coast morphology does not have deep creaks and there are cliffs only in some restricted areas (Zunica 1992). The Italian side is marked out by an almost total absence of islands. The Balkan coasts are mainly high, with cliffs and with several creaks protruding in peninsulae and several small islands (Castiglioni 1979).

A coastal stream that sails up the coast of the Venice Gulf, then turns and follows the Italian coasts in southern direction, produces the surface water circulation. The abyssal water circulation is mainly determined during the winter period by the sinking of the cold water in the Northern Adriatic, but it has less importance on the entire water circulation.

The Southern Adriatic Sea

The Southern Adriatic presents specific characteristics when compared to the rest of the Adriatic Sea. Its extension is around 2200 km^2 and it stretches from the Gargano promontory to the Otranto Cannel (42° 30' N; 40° 00' E). The continental shelf starts south of the Gargano promontory where the depth drops from 200m to 1253m in the central part. In the Northern Adriatic the depth is generally not more than 100m, with a depression outside Pescara of 250 m, "Meso-Adriatic depression".

Related to the chemical characteristics of the water, there is a big reduction in the concentration of Nitrogen and Phosphorus (between 25-35 µg/l N e 7-12 µg/l P) in the Southern Adriatic compared to the rest of the Adriatic. The salinity is between 37 and 39 ppm (Mosetti 1964).

In the Southern Adriatic, after a certain depth (100-200m), the temperature has a constant value around 13° C.

Appendix 6: Setting positions

Nr. Settings	LATITUDE	LANGITUDE	DEPTH average(m)	BOTTOM MORPHOLOGY
1	41.26.60	019.00.23	130	Rocky
2	41.16.36	019.00.50	107	Rocky
3	41.13.18	019.00.76	104	Rocky
4	41.14.18	018.53.42	278	Muddy
5	41.10.44	018.53.21	306	Muddy
6	41.13.65	018.57.29	119	Rocky
7	41.21.19	018.52.10	315	Muddy
8	41.21.20	018.52.10	296	Muddy
9	41.12.19	018.53.68	291	Muddy
10	41.20.23	018.53.14	267	Muddy
11	42.32.34	016.00.08	120	Rocky
12	42.28.51	015.56.02	139	Rocky
13	42.32.41	016.02.15	111	Rocky
14	42.34.24	016.01.90	122	Rocky

Appendix 7: Technical specifications of the fishing boat "Angelo Padre"

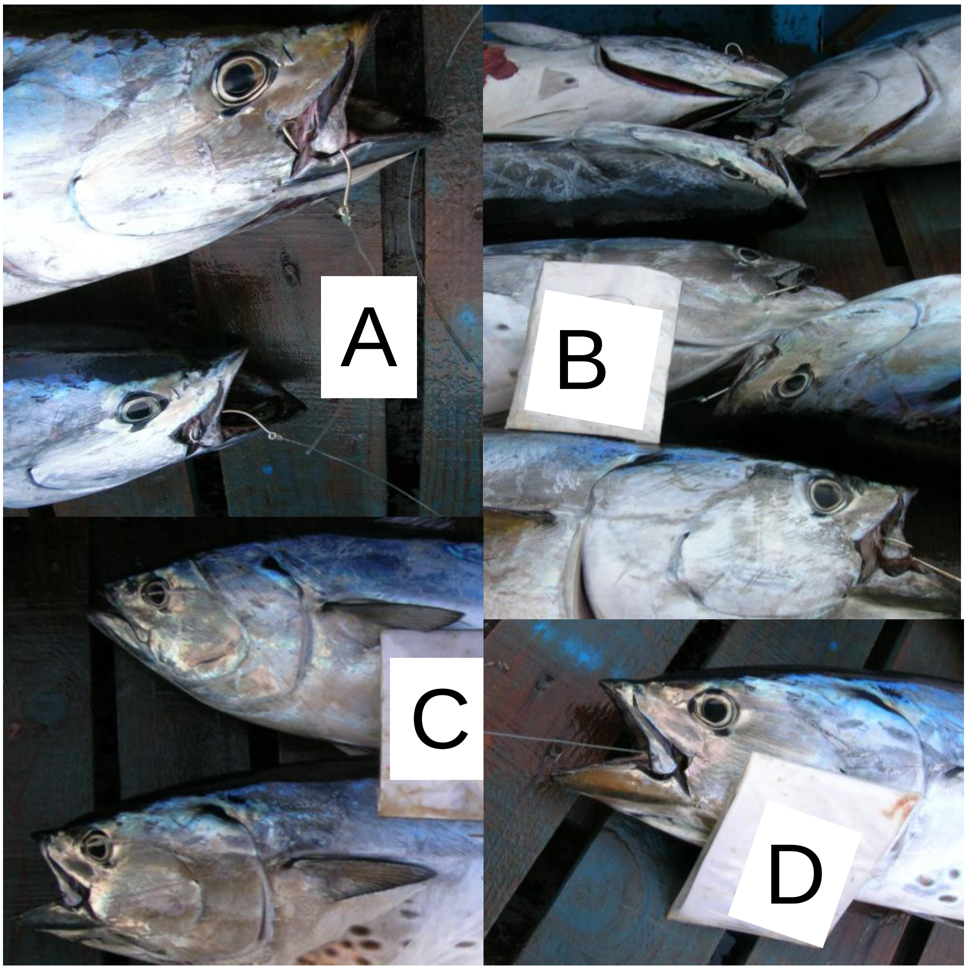
Lenght overall	18 m
Maximum breadth	4,5 m
Tonnage	9 t
Engine	1200 hp
Crewmembers	6

Appendix 8: Southern Adriatic fish prices

In the left column, species normally caught with bottom longlines in the investigated area. In the right column, relative species price paid by the wholesaler (€).

SPECIES	PRICE per KG (€)
Teleosts	
Conger conger	1
Dentex dentex	18
Euthynnus alletteratus	3,5
Lepidopus caudatus	1
Merluccius merluccius <1,5kg	6,5
Merluccius merluccius >1,5kg	5,5
Pagellus bogaraveo	18
Pagrus pagrus	18
Pagrus pagrus	18
Phycis blennoides	6,5
Phycis phycis	6,5
Scomber japanicus	1
Scorpaena sp.	10
Thunnus alalunga	4
Trachurus trachurus	1
Trigla lucerna	10
Xiphias gladus <10kg	9
Xiphias gladus >10kg	11,5
Elasmobranchs	
Hexanus griseus	3,5
Raja clavata	3,5
Raja sp.	1
Squalus acanthias	2,5
Squalus blanvillei	2,5

Appendix 9: Location of the hooks in *E. alletteratus*



Specimens of *E. alletteratus* caught in the same deployment by the experimental longline rigged with A, B, C, D hooks. Clock wise from the top-left: 2 specimens hooked by Wide Gap Eyed (A), 6 specimens hooked by EZ-baiter (B), 1 specimen hooked by Wide Gap (C), 2 specimens hooked by Round Bend Sea (D).