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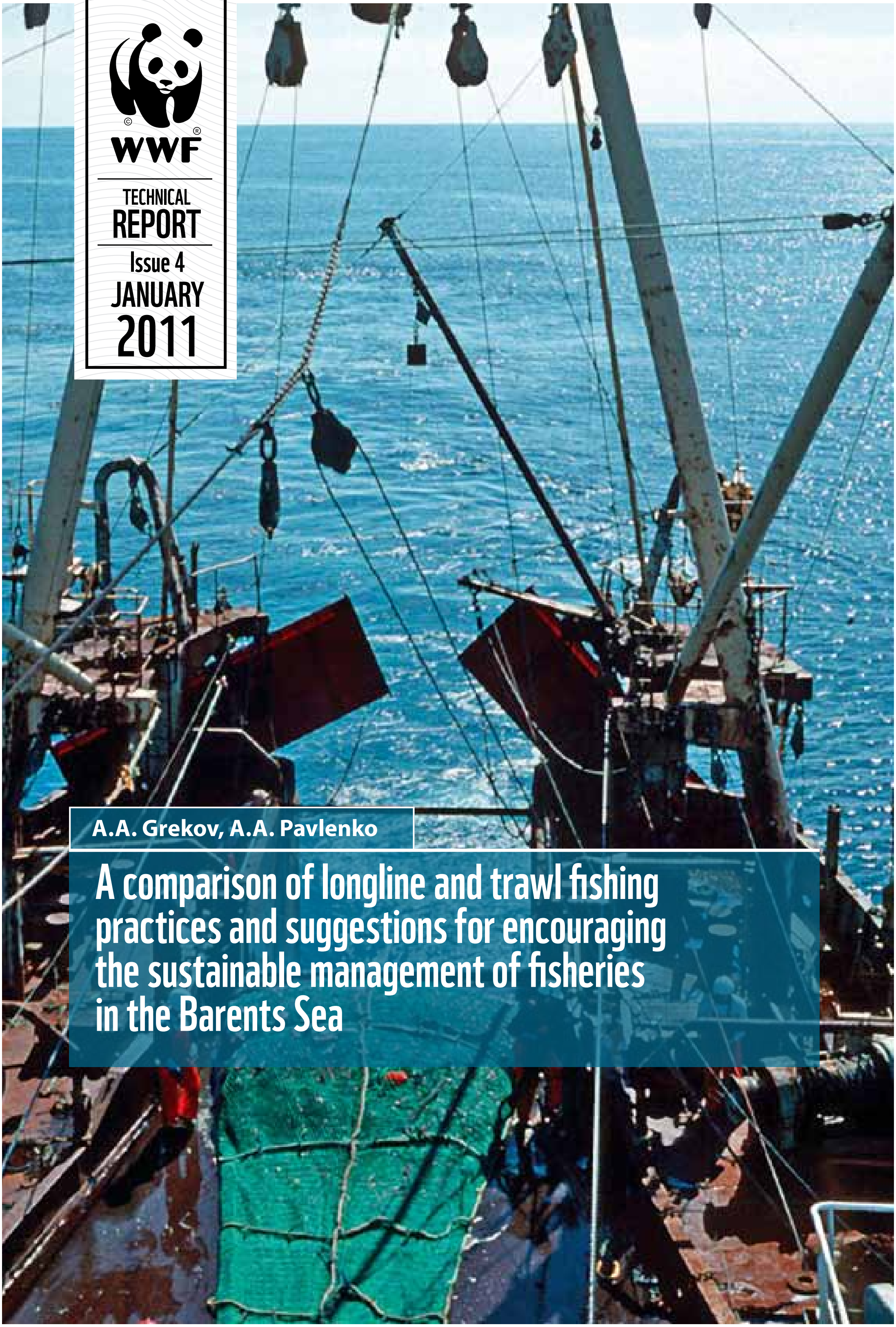

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A comparison of longline and trawl fishing practices and suggestions for encouraging the sustainable management of fisheries in the Barents Sea

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A comparison of longline and trawl fishing practices and suggestions for encouraging the sustainable management of fisheries in the Barents Sea, — Moscow-Murmansk, World Wide Fund For Nature (WWF), 50p.

Results of comparison of Russian trawling and long-line bottom fishing practices are presented. Biological, ecological and social-economic aspects are considered. Prospects of development of trawling and long-line fishing in the Barents sea are analysed and recommendations about rational use of marine living resources of the Barents sea are made.

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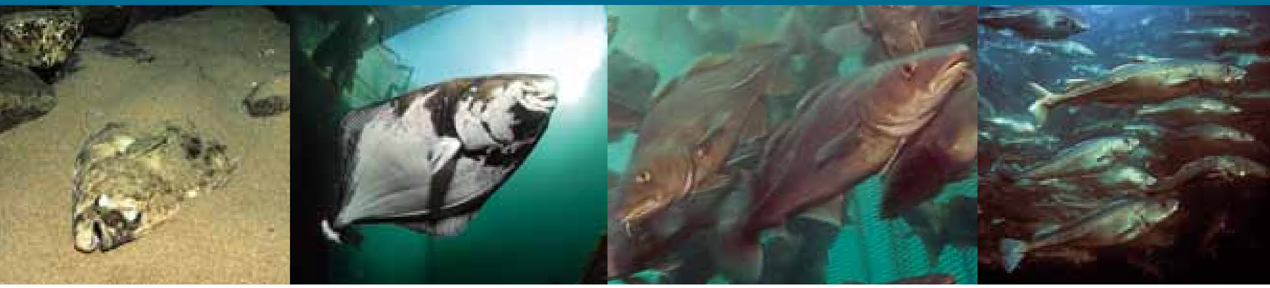

The beginnings of a longline fishery in the Barents Sea

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The bottom longline fishery at Murman has a centuries-old history. It can be supposed that this method of fishing was introduced to the North by *pomors*, natives of Veliky Novgorod, who appeared there in the 9th Century (Breitfus, 1913a; Alekseev, 1986; Semkov, 2000; Adrov, 2001, 2002). By the end of the 15th Century, they had already discovered the main areas of codfish concentration, as well as the timing and direction of movement of the fish along the coastline. They gained enough fishing experience to allow them to establish a successful fishery of bottom-dwelling fish in the waters of the Barents Sea. By the second half of the 16th Century, this was spread along the entire coastal region from Murman to the Finmark Province of Norway and the city of Troms (Anufriev, 1913; Shishov, 1947).

The reason for the coast-dwellers' success in fishing was the bottom longline. This was their main fishing gear, while the Norwegians widely used the jig (jigging fishery). The coast-dwellers used the jig whenever there was a lack of longlining gear, or during bad weather to avoid losing it (Ushakov, 1972). Fishing was conducted mostly from yawls and snows**.** Casting and hauling of lines were done manually, directly from on board the vessel.

To begin with, the fishing period lasted for only 2-2.5 summer months in Murman, but later the fishing season was extended to 5-7 months per year. The longline fishery was concentrated between 3 and 30 versts (10,500 and 105,000 feet) from the coast and its success depended on the intensity of the fish run.

Codfish was the principal item caught through longlining. At times, it constituted 70-90% of the total catch of the longline fishery (Danilevsky, 1862; Zhilinsky, 1917; Lisovsky and Shestopal, 1996). The by-catch of haddock represented less than 10% of the total catch (Danilevsky, 1862). Black halibut, together with Atlantic wolfish, were not highly regarded by fishermen (Adrov, 2002), while Atlantic halibut was considered to be the most valuable by-catch (Kharuzin, 1890).

Although coast-dwellers had long been involved in large-scale line fishing in the Barents Sea, such fishing gear only appeared in Norway during the late-1500s and early-1600s. Professor Alf Nielssen of Troms University and Director and Curator of the Lofoten Museum since 2001 has been researching the history of fishery development in Norway and writes that bottom lines appeared in his country only in the 1590s (Nielsen, 2008). Other Norwegian scientists (Bjordal and Løkkeborg, 1996) also indicate that the description of bottom longlines as being a new and highly effective fishing gear in the Norwegian chronicles applied to the cod fisheries in Møre and at Løfoten and referred to the beginning of the 17th Century. According to the chronicles, "bottom lines were used not by local fishermen but by aliens …".

Some Norwegian researchers believe that the bottom longline was introduced to Norway from the Mediterranean (Bjordal and Løkkeborg, 1996), while others consider it to have been borrowed from the Dutch (Alf R. Nielssen, pers comm.). However, the present authors can state with absolute confidence that **the founders of the longline fishery in the Barents Sea were Russian coast-dwellers**. They certainly imparted to the Norwegians their experience of working with the bottom longline and it was subsequently widely used along the northern coasts of Murman and into Scandinavia, all largely owing to Russian coast-dwellers.

To Norwegians, the bottom longline was not only a new fishing gear, but also a very expensive one that could only be bought by some fishermen. Using the bottom longline also sharply increased the effectiveness of fishing among some fishermen. Because of this, most Norwegian fishermen began to express their dissatisfaction with the use of longlines. In 1627, and in order to even out the chances of the fishermen, the Government of Norway passed a law prohibiting the use of the bottom longline. Since then this law has been extended many times and was still valid up until the second half of the 18th Century.

Socio-economic prerequisites of the longline fishery development in Russia and Norway: the rise of trawl fishing

Nowadays, Norway is recognised as being one of the world leaders in longline fishing. the level of development of which considerably exceeds that of the Russian longline fishing fleet.

The reason for such a state of affairs relates to a number of social and economic prerequisites that stimulated the development of the longline fishery in Norway whilst leading to the fishery's downfall in Russia. Firstly, since it began and up until the beginning of the 20th Century, the codfish longline fishery amongst Russian coast dwellers remained a manual exercise. Secondly, the Russian government did not take the necessary steps to develop and improve the domestic fishery.

At the same time, judicious policies of the Norwegian government during the 19th Century contributed significantly to the development of this fishing technique – the necessary infrastructure was developed, fishery and shipwreck salvage agencies were created, assistance was provided to purchase new vessels and there was a proactive restructuring and motorization of the longline fishing fleet.

As a result, the number of fishermen working at any one time at Lofoten varied from 18,000 in 1904 to 32,600 in 1985 (Breitfus, 1913b). In comparison, by the beginning of 20th century, only 3-4,000 fishermen worked in Murman.

The appearance in 1903 of English trawling vessels was a new landmark in the management of fishing resources in the Barents Sea. The first Russian trawler appeared in 1906 (Benko and Ponomarenko, 1972), while the large-scale development of the Russian trawling fishery began in 1920.

During the growth period of trawl fishing in the Barents Sea, the Norwegians did not have sufficient capital to invest in new fishing vessels and necessary equipment, There was therefore no proactive development of the trawling fishery in Norway. Fishermen themselves, furthermore, were ardently opposed to the use of trawls. Active opposition to trawlers by fishing communities was caused by the fact that, in their minds, trawlers considerably over-harvested juvenile fish, eventually leading to a reduction in the number of large fish moving to the coast in the winter/spring period and a drop in the effectiveness of the traditional coastal fishery. The negative attitude towards trawlers was supported by the Government of Norway and a ban on using trawlers in Norwegian territorial waters was put in place in 1908. For a long time, even the landing of fish caught by trawlers was prohibited in Norway (Hylen *et al.,* 2008). Norwegian trawlers first began fishing for cod only in 1926 (Olsen, 2008). Up until the beginning of the Second World War, the total number of trawlers did not exceed 10-11 vessels (Hylen *et al.,* 2008).

The longline fishery in Norway continued to develop throughout the whole of the 20th Century. In the early-1970s, Norway began to build new specialized longliners with steel hulls and automatic processing lines. By the end of 1978, 55 Norwegian longliners were equipped with the Autoline system produced by the company Mustad & Son (Shentyakov *et al.*, 1980). Meanwhile, a negative attitude within Norwegian society towards the trawling fishery prevailed and still exists even today (Bjordal and Løkkeborg, 1996).

Within the Soviet Union, in contrast, the trawling fishery developed intensively and by 1955 the number of trawlers in Murman reached 562 vessels (Vassiliev, 1997). In addition to the fact that trawling did not require the use of bait, the fishery was mechanized and more productive, so promising good prospects for development. As a result, **the demise of the Russian longline fishery was apparent throughout the whole of the first half of the 20th Century and, by 1950, it had ceased to exist** (Zherebenkov and Kozlov, 1990). From 1950 until 1980, the trawl became the predominant Russian fishing gear in the Barents Sea. This could be one of the reasons for why a shortage of raw materials appeared in 1970 and also why the cod and haddock fisheries declined drastically. At that time, the Russian trawler fleet had begun to operate actively in more distant seas and oceans. The need to develop alternative fishing techniques that could be adapted mostly for scratch fishing and require less expense on fuel had been obvious (Lisovsky (Ed.), 1983). The first attempts taken to revive the longline fishery demonstrated it had no future prospect for success without mechanization. Only in 1982 was the first automated Norwegian line 'Autoline' of Mustad & Son installed on a Russian re-equipped vessel of the MRT type, so allowing for 25-30,000 hooks to be processed per day (Budanov and Torokhov, 1983; Semenov and Kokorin, 1988; Kokorin, 1994).

Changes in the political climate in our country and the economic reforms of 1990 led to the Russian fleet being either disbanded, or considerably reducing its operations in the more distant oceans in order to focus its effort on the closer waters of the North Atlantic and the Barents and Norwegian Seas. This led to a considerable discrepancy between the fishing efforts of the trawlert fleet and the amount of fish available. The number of trawlers in the Northern Basin reduced. By 2005, approximately 280 trawlers worked in the Northern Atlantic, this being 20% less than the number in 1995.

Alongside the reduction in number of trawlers, which is apparent even today, the number of longliners gradually increased. From 2001-2008, there were between 17 and 22 longliners working in the Northern Basin. Nowadays, the domestic longline fishing fleet in the Basin consists of trawlers that have been re-fitted to suit longline fishing and specific target vessels that have been built abroad.

Despite the reduction in the number of Russian trawlers in the Barents Sea, trawlers still noticeably exceed the number of longliners. In Norway, the ratio of trawlers to longliners is 2:1.

Comparison of longline and trawl fisheries

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3.1 Fishing conditions

Trawl and longline fishing are both carried out all-year-round in the Barents Sea and almost over the entire area. Unlike trawlers, however, longliners are able to work in those areas not accessible to trawlers, particularly those which have a complex sea bed topography, rough ground or are at significant depth. Fishing for black halibut fishery can be especially difficult for trawlers over some areas of the continental slope.

Longliners reduce quite considerably losses in fishing time due to weather conditions. This is because when trawling is impossible, a longliner is still able to fish.

By-catch of undersized fish by longlining is fairly insignificant due to the selectivity of longlines. This is why those fishing grounds that are temporarily or permanently closed to trawlers because of overfishing of juveniles remain open to longliners.

Longliners are more effective at scratching for scattered schools of fish, while trawlers are more productive with dense populations of fish. Another positive feature of trawling is its high mobility and the possibility of changing location quickly should a trial haul be unsatisfactory or if the fish schools have moved. Longliners, in contrast, tend to be fixed to a particularly fishing ground and can only change their location once hauling operations are completed, usually up to 24 hours of fishing time later.

3.2 Principal species and fishing effectiveness

The principal target species for both trawl and longline fishing in the Barents Sea are Atlantic cod (*Gadus morhua morhua* (L.)), haddock (*Melanogrammus aeglefinus* (L.)), blue and spotted catfish (*Anarhichas latifrons* (Steenstrup & Hallgrimsson) and *Anarhichas minor* (Olafsen)), black halibut (*Reinhardtius hippoglossoides* (Walbaum)) and, especially for trawl fishing, saithe or pollock (*Pollachius virens* (L.)).

When exploiting combined fish stocks, however, the suitability of these stocks is different for trawlers and longliners. Species such as Atlantic cod, haddock and black halibut can be caught using both types of fishing gear. As for catfish, these species are removed by trawlers only as a by-catch, but they can be successfully targeted by longliners. On the other hand, only trawlers can target saithe, while longlines catch this species only occasionally.

Barsukov (1957; 1959) wrote that the low catching efficiency of trawls for catfish does not allow for the full utilisation of stocks of this species. He pointed out the need to develop specialised fishing gears that would catch catfish effectively by taking into account the species' biology (eg. sparse schools). One such gear is certainly the bottom longline. The advantages of longlines over trawls when fishing for catfish were discovered as long ago as the beginning of the 20th Century. It was noted that, under the same conditions and within the same fishing grounds, longline catches of catfish were at least 20 times larger than for catches made by trawlers (Knipovich, 1902).

Table 1

	Species					
	Total catch and gear share	Blue catfish	Spotted catfish	Atlantic cod	Haddock	Black halibut
1999	**Total catch,** ('000 tonne)	17,7	6,2	240,7	31,5	10,7
	Longline %	49,0	39,9	2,1	2,5	16,0
	Trawl %	51,0	60,1	97,9	97,5	84,0
2000	**Total catch,** ('000 tonne)	19,5	2,8	229,4	26,9	14,7
	Longline %	64,4	31,1	3,7	5,9	25,4
	Trawl %	35,6	68,9	96,3	94,1	74,6
2001	**Total catch,** ('000 tonne)	18,2	2,2	234,8	39,5	7,3
	Longline %	66,1	35,4	4,3	4,0	16,0
	Trawl %	33,9	64,6	95,7	96,0	84,0
2002	**Total catch,** ('000 tonne)	16,4	2,5	184,1	35,7	5,6
	Longline %	79,7	45,0	6,2	5,6	33,8
	Trawl %	20,3	55,0	93,8	94,4	66,2

Catch volumes of some groundfish by longlines and trawls in the Barents Sea and contiguous waters from 1999–2002 (Grekov and Shestopal, 2003)

From 1999-2002, the longline fishery for catfish was 13-34 times more effective compared with trawling for the same species. For example, in 2002, daily catch of bluefish by longliners averaged 3.4 tonnes, while trawlers caught only 0.1 tonne per day (Grekov and Shestopal, 2003). It can be seen that, even when taking into account the relatively small size of the longline fleet in the Northern Basin, 80% of the annual domestic catch of catfish is being taken by longliners (**Table 1**).

Trawl is a more productive fishing gear for *cod*. For example, in June 2005, a longliner and a trawler worked together fishing cod in the same area. The average fishing capacity for the trawling was 397 kg/h, while that of the longline fishing was 223 kg/1,000 hooks. At these rates, these two types of fishing could yield, respectively, 8.1

Table 2

Fishing method	Capacity, kg/1,000 hooks											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
	Kopytov area											
Target-specific fishing	n/a	217	350	265	213	341	340	300	296	285	232	222
By-catch	14	19	50	84	89	< 90	< 90	< 90	< 90	< 90	72	36
	Western slope of Medvezhinskaya Bank											
Target-specific fishing	n/a	93	149	184	148	119	191	200	n/a	149	140	n/a
By-catch	19	13	17	47	34	52	63	47	71	57	36	12

Monthly average capacity of black halibut longline fishing in the Kopytov area and on the western slope of Medvezhinskaya Bank as a target and by-catch** species (Grekov and Shestopal, 2003)*

and 6.7 tonnes of daily catch, or 9.3 and 9.9 tonnes per day if the by-catch is included (Grekov, 2007a).

Trawl can also be considered as the most effective fishing gear for *haddock*, whereas the effectiveness of a longline on this species depends on the size of the school being fished.

Nowadays, haddock trawl fishing contributes the most to the domestic catch within the Barents Sea, largely because of the much greater fishing effort. The majority of the haddock catch is made within the Russian Exclusive Economic Zone, where trawlers catch small, juvenile fish. Such fish are not suitable for longlines because of the highly selective nature of this type of fishing gear. This is why fishing for haddock using longlines is less effective. Longline fishing for haddock is possible when harvesting large-sized fish, particularly within spawning grounds in spring or during the spawning run in autumn/winter (Grekov and Shestopal, 2007).

Black halibut is harvested in the Barents Sea by both bottom trawls and longlines. However, there is an antiphase during a year between the catch volumes per fishing effort of trawlers and longliners (Grekov, 2007b). In the autumn/winter period, the gather-

* 1997–2002 data

** 1993–2001 data

ing of halibut on the spawning grounds is favourable to trawling, whereas the decrease in feeding activity of the spawning schools is negatively reflected in the effectiveness of longline fishing. In spring and summer, when black halibut are actively feeding, the productivity of longline fishing increases and the dispersal of fish reduces the efficiency of trawling (Grekov, 2007b).

The efficiency of black halibut trawling reaches its maximum (up to 1,500 kg/h of trawling) during the pre-spawning and spawning periods and its minimum (under 200 kg/h of trawling) during the spring and summer run (Gotovtsev *et al.*, 1998). At this time of year, longline fishing is more effective (**Table 2**).

On the whole, **the share of catch of different fish species by trawlers and longliners is determined not just by the accessibility of their stocks, but also to a large extent by the amount of fishing effort and the quotas**. Table 1 shows that trawl catches of Atlantic cod, haddock and black halibut considerably exceed the volumes of longline harvest, although the share of the latter could be increased significantly under certain conditions.

3.3 Biological and ecological aspects

3.3.1 Species selectivity

Species selectivity is the characteristic of a fishing gear to selectively retain species of one kind.

In general, neither the trawl nor the longline can be considered as fishing gears that have a high selectivity towards some species of fish. Trawl can hardly be called a selective fishing gear as it takes almost everything that comes into a forenet (Bjordal and Løkkeborg, 1996). As for the longline, it is more selective because of its passivity. The catch depends mostly on the behaviour, biology and physiology of the fish. In particular, most fish cannot be caught by a longline as they are simply unable to swallow a hook. For example, studies in the North Sea showed that, although haddock reacts to bait twenty times more often than cod, the latter swallows it and the harvest is therefore much better (Løkkeborg, 2000). Some fish do not view hooks as food, or they simply ignore them because of their physiology and therefore cannot be harvested using a longline.

Twenty-nine species of fish are harvested by longline in the Barents Sea (Grekov, 2007a). **The number of fish caught by trawl is much larger**. When carrying out trawler-acoustic counting of groundfish stocks, up to 70 types of fish were recorded in trawls with small mesh size and between 30-50 kinds of fish were found in bottom trawls with mesh sizes of 125-135 mm.

As noted above, all the main commercial species within the Barents Sea are harvested using both longline and trawl, with the exception of the haddock which is inac-

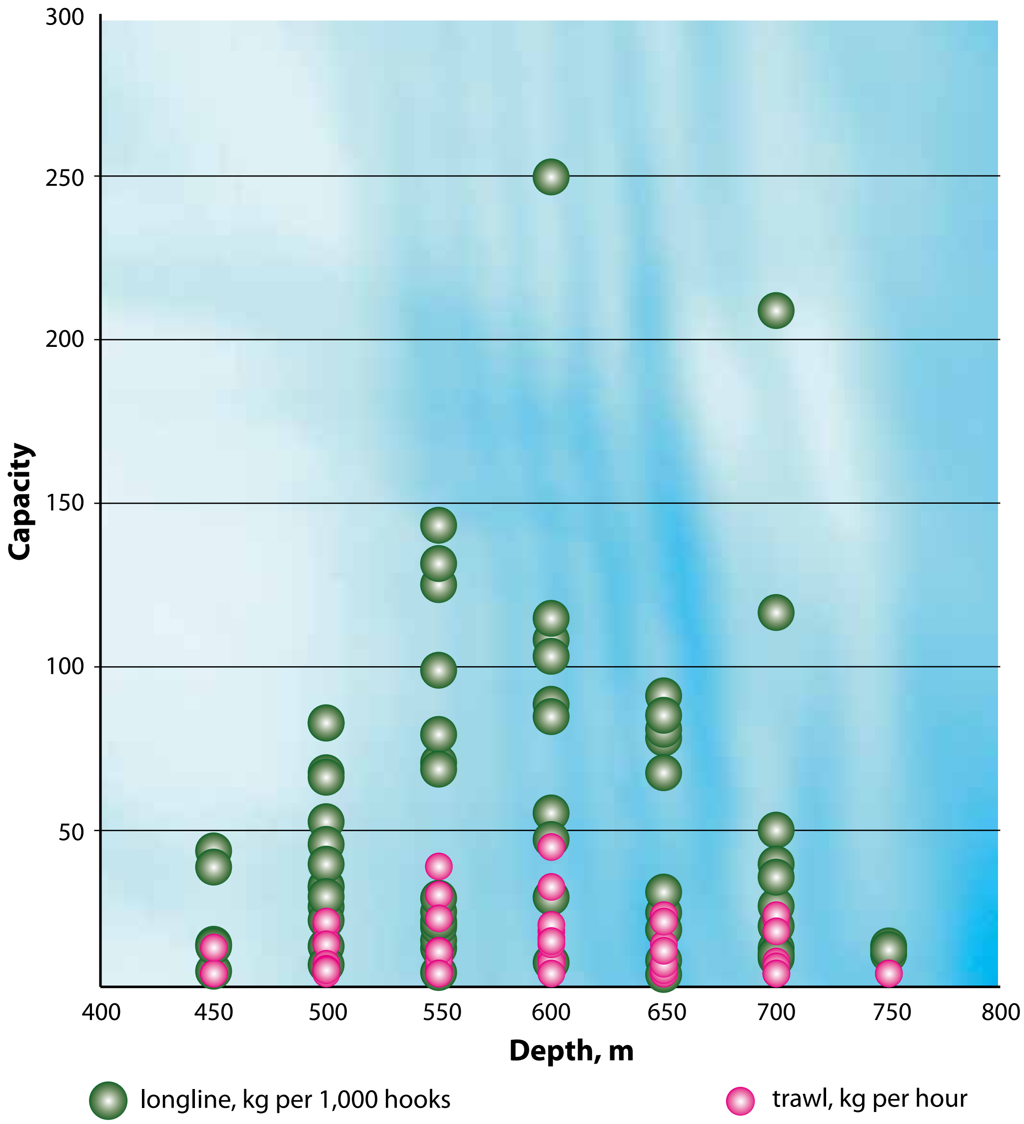

***Figure 1:** Capacity of longliners (kg per 1,000 hooks) and trawlers (kg per hour of trawling) when working on the same fishing grounds on the continental slope in 1999–2005 (according to Dolgov et al., 2008)*

cessible to bottom trawling. Since 2000, the maximum annual harvest of haddock by longliners totaled only 1,600 kg.

Plaice (*Pleuronectes platessa* L.), which can be caught as a target species by trawl during some periods of the year and in certain defined areas within the Barents Sea, is very seldom found in longline hauls.

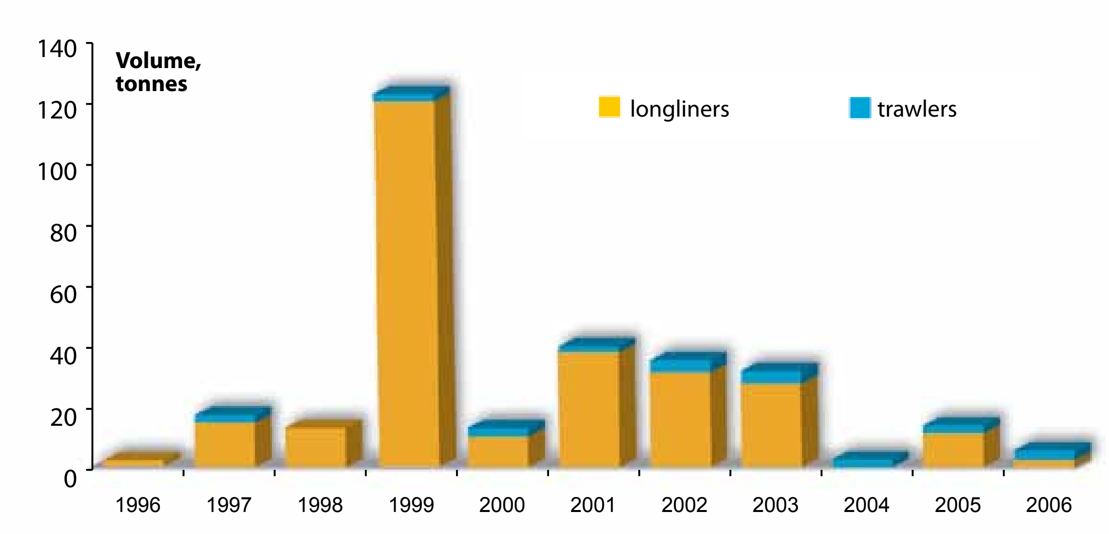

Figure 2: *Volume of rough-headed grenadier catches by Russian vessels in the Barents Sea in 1996-2006 (according to Dolgov et al., 2008).*

Such species as **American plaice** (*Hippoglossoides platessoides*) and **lumpfish** (*Cyclopterus lumpus* L.) are even less accessible as a longline fish. The selectivity of trawls is more appropriate for catching these two species, but selectivity is still not sufficient to establish a target fishery even if satisfactory stocks were to exist. This is why American plaice and lumpfish are harvested mostly by bottom trawling, but only as a by-catch.

Another valuable fish, **torsk** (*Brosme brosme*), is in contrast successfully harvested by longliners and is seldom found in trawl catches. For example, in 1994, Iceland caught 4,600 tonnes of torsk, of which 88.7% was harvested by longliners, 1.8% by manual longlines, 6.7% by gillnets and only 2.6% by trawls (Mangůsson *et al.*, 1997). Norwegians also undertake the targeted longline fishing of torsk (Mangůsson *et al.*, 1997; Havets Ressourser, 2002), harvesting up to 95% of the annual catch in the Norwegian Sea. From 1989-1993, the Norwegian average annual catch of torsk was 25,200 tonnes (representing 27% of the total annual catch by Norwegian longliners), second only to cod, which contributed 31,300 tonnes to the total catch (Bjordal and Løkkeborg, 1996). Domestic longliners do not fish torsk as a target species, but harvest it in small volumes (less than 100 tonnes per annum) as a by-catch.

As with torsk, longline catches of **rough-headed grenadier** (*Macrourus berglax*) are more plentiful in comparison with trawls. This has been proved by results from test fishing. For example, during 1974, some trawlers and longliners worked together at a depth of 600 metres in the same fishing grounds off the coast of Norway and Great Britain. The longlines caught 150 kg per 1,000 hooks, while the trawls yielded no more than 70 kg per hour of trawling (Savvatimsky, 1997).

Similar results were achieved during joint operations of trawlers and longliners on the continental slope of the Barents Sea. Longline catches of rough-headed grenadier were more abundant than trawl catches throughout the survey. The volume of by-catch of this fish varied considerably according to depth, while trawl catches were equally small regardless of the depth (**Figure 1**). In some trials, the grenadier catch did not exceed 50 kg over three hours of trawling (with the average length of trawl being 9.5 miles) and the yield of the longliners (a length of 7.5 miles or approximately 9,000 hooks) averaged 780 kg along the trawling route (Dolgov *et al.*, 2008).

As can be seen, rough-headed grenadier is less accessible to trawl gears than to bottom longlines. The maximum by-catch of this fish for trawl fishing in the Barents Sea does not exceed 20 kg per hour of trawling, or 2% of the total catch (Dolgov *et al.*, 2008). At the same time, the capacity of longline fishing for this species can achieve 350 kg per 1,000 hooks and the share of the total catch is over 55% (Grekov, 2001).

Despite the fact that the rough-headed grenadier is a non-quota species in the Barents Sea, catches of this fish are mostly thrown overboard. The reason for this is that these catches are insignificant on trawlers and there is no market for the fish. Therefore, the *official catch volume for this fish is considerably lower than the actual amount caught*. According to official statistics in 1996-2006, the longline fleet harvested less than 40 tonnes of grenadier annually (**Figure 2**). The exception was in 1999 when the official catch of grenadier totaled 122 tonnes, although one vessel alone landed 109.2 tonnes as a by-catch. Rough-headed grenadier was harvested by no more than five longliners over many years, with their total catch making up 87-100% of the entire catch of this fish by all Russian vessels working in the Barents Sea (Grekov, 2007a; Dolgov *et al.*, 2008).

The actual catch of rough-headed grenadier could be significant on the continental slope. According to PINRO (Polar Research Institute of Marine Fisheries and Oceanography) observers, a longliner may harvest up to 50 tonnes of grenadier a month as a by-catch when working at a depth of over 500 metres in the Kopytov area and on the western slope of Medvezhinskaya Bank (Grekov and Shestopal, 2003).

Rays are another fish which are caught by longliners with high effectiveness. Rays of several species are present in both trawler and longliner catches, although the catch per unit effort (ie. fishing days) by longliners is considerably higher than that for trawlers. Overall, the average by-catch of rays by trawlers throughout the Barents Sea is 10 kg per hour of trawling, ie. 150-160 kg per fishing day. The average by-catch of the starry ray (*Amblyraja radiata*) by long-liners is 20.6 kg per 1,000 hooks, ie. approximately 500 kg per fishing day (Dolgov *et al*, 2005).

In the coastal areas of Murman, longline fishing can yield 250 kg per 1,000 hooks and a daily catch of 4.0 tonnes. This is enough to create the conditions for a targeted fishery. Within those areas on the continental slope, the catch of the Northern Pole ray (*Amblyraja hyperborea*) can reach 175 kg per 1,000 hooks (Grekov, 2007a).

3.3.2 Size selectivity

Size selectivity is the characteristic of a fishing gear to selectively retain species of one kind depending on their size. This characteristic is highly dependent on the size of mesh used in the trawls. Size selectivity is very important to small-sized fish as it provides an opportunity for them to escape through the mesh. However, trawl selectivity is influenced by a number of factors, such as the direction of trawling, quantity of fish in the trawl bag, concentration of stocks, etc. (Sakhno and Sadokhin, 1983; Isaksen *et al.*, 1990). In particular, size selectivity can be significantly reduced when the volume of catch is large and the mesh is blocked with fish (Bjordal and Løkkeborg, 1996).

Unlike with a trawl, which catches everything it encounters along the way and the selective characteristics of which only manifest themselves after a fish is trapped by the fishing gear, size selectivity with a longline is determined by fish behaviour and biology.

The differences between the fishing strategies of an active fishing gear and a passive one determine the differences between their selection characteristics towards large-sized fish. Larger fish have better motion and a spurt of speed. This gives the fish an advantage when meeting a trawl as it allows them to escape the enclosure area and so avoid the trawl. There is an inverse effect with longline fishing. Firstly, having sensed the bait, larger fish reach the longline quicker than do the smaller ones. Secondly, having reached the longline, the larger fish wins the competitive struggle for the food (ie. the bait) over the smaller fish (Løkkeborg and Bjordal, 1992). As the number of hooks on a longline is limited, the hooking of a large fish reduces the number of free hooks and so lowers the chances of catching juveniles. Furthermore, the hook itself is also selective regarding fish size as small-sized fish can swallow a baited hook of no larger than a certain size. By changing the size of the hook and bait, therefore, one can satisfactorily control the volume of by-catch of small-sized fish. The difference in the selective characteristics of juveniles for the longline and trawl was demonstrated whilst fishing the same schools of fish. The share of small-size cod (under 42 cm long) caught in the trawls reached 14%, while that for the longlines did not exceed 5% (Grekov, 2007a).

In another example, this time whilst fishing from schools of haddock, it was found that the use of bait weighing 10 g increased the size of catch by a factor of two times. This was in comparison to bait weighing 30 g where the haddock can only bite the bait without swallowing the hook (Løkkeborg, 2000). It is necessary to note that, when reducing the size of bait, the volume of large fish caught does not change, but the catch of small-sized fish increases (Løkkeborg, 2000).

Distinct size selectivity of fishing gears also manifests itself when fishing for rays. All rays of small size (under 21-25 cm long), which were present in a sample catch using a trawl with a small mesh, are almost absent in commercial catches. However, irrespective of the size of mesh (125 or 135 mm) there was no difference in fish size in the commercial trawl catches. With longline catches, larger rays predominate. Differences in the

Table 3

Fishing gear	Total catch, tonnes	<45 cm, tonnes	<45 cm, %
Longline	178 667	10 853	6,1
Trawl	399 419	77 304	19,4

Amount of cod landed in northern Norway in 1978-1987 and the share of small-sized fish (under 45 cm long, headed) (Bjordal and Løkkeborg, 1996; Bjordal, 1989).

average length of fish caught by trawl and longline fishing increase with those species that have large maximum sizes (Dolgov *et al.*, 2005).

As is obvious from the above, **the selectivity of trawl and longline fishing gears differs**. Longliners generally catch larger fish. The degree of size selectivity of these fishing gears, however, depends on the fish and its physical condition, as well as on the design philosophy behind the gears. For example, the use of sorting systems in trawls, which have been obligatory for haddock and cod fisheries since 1997 ("Sort-V" or "Sort-X" sorting systems with a distance of 55 mm between the rods), must reduce the differences in size composition of catches in those trawls and longlines that are equipped with such systems.

Differences in the size composition of catches made by trawls and longlines can be demonstrated using an example of the simultaneous fishing of **black halibut** stocks (**Figure 3**). From Figure 3, it can be seen that the size composition of trawl catches during the year remains unchanged, while that of longline catches depends on the season within which the catch is made. This is confirmed by the fact that the size selectivity of the trawl depends, to a large extent, on its specific design, With longlines, however, the physical condition of the fish plays an important part (Grekov, 2007b).

The difference between trawl and longline size selectivity results in a respective ranging of fish weight. **Table 3** shows the results of cod fishing off the northern coast of Norway over the 10-year period from 1978-1987. The share of small-size cod (under 45 cm long) landed by trawlers was close to 20%, while that for longliners was approximately 6% of the total cod caught (Bjordal and Løkkeborg, 1996).

3.3.3 Survivability of fish after interaction with fishing gear

In general, it can be said that the issue of fish survivability after escaping from hooks has not been studied. It can be assumed that, when hauling a longline from the bottom, those fish which do not possess a swimbladder have more chance of surviving than

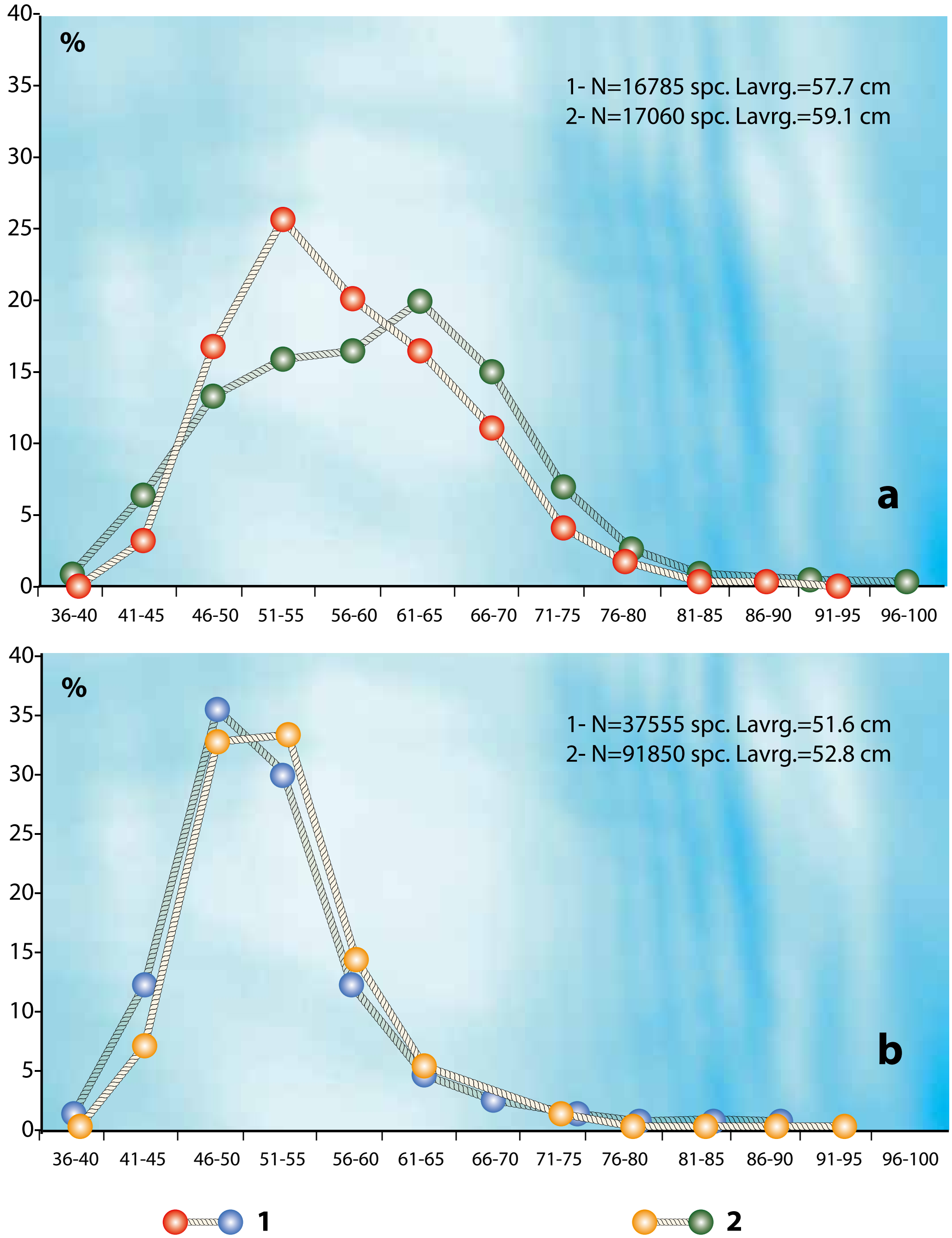

Figure 3: *Size composition of longline (a) and trawl (b) catches of black halibut in spring (feeding period — 1) and autumn/winter periods (pre-spawning and spawning periods — 2) (Grekov, 2007b)*

those fish that do. The latter have the chance of surviving only if they escape at the same depth that they normally live. Otherwise, while being raised from depth to the surface the fish's swimbladder swells, its internal organs are traumatized and the chances of survival drop. In most cases, some species, such as the rough-headed grenadier, torsk and sea bass, cannot survive after escaping from a hook on the water surface as their stomachs, guts and livers turn inside out through the mouth. Such a phenomenon is determined by the depth at which the fish was caught, the speed of hauling and the biological peculiarities of the fish itself. Some fish, for example the black halibut, can seriously injure their jaws.

Blue and spotted catfish are probably the most viable of all commercial species. Several hooks swallowed earlier have been found inside the stomachs of some catfish. The chances of survival are high for eelpouts and hake, especially if they are loosely held by the hook and do not tear their mouths.

Other than the above reasons, the survivability of those fish that drop off hooks as they board a longliner can be reduced when they fall onto the surface of the water and are pecked at by birds. Another factor reducing the survival of fish during longline fishing relates to the treatment they receive from fishermen. Once a fish is onboard, a fisherman tears it from the hook with a special boom (knop), piercing the fish with a metallic hook (usually the head) and then disposes of it by throwing it overboard), It is very doubtful that such fish survive.

There is still the question of the survivability of those fish that pass through trawl meshes. Some research has shown that the survival rate of cod and haddock, after escaping a trawl can reach 80-95% (Bjordal and Løkkeborg, 1996). With reference to expert evaluation in other sources, it is believed that 30-40% of fish lose their chance of survival after passing through a trawl mesh (Sorokin and Chumakov, 1995; Chumakov, 2008), while juvenile haddock do not survive at all (Chumakov, 2009). According to the principle of circumspective approach, all fish that have passed through a trawl bag mesh while being hauled to the surface should be considered as dead, largely because of the trauma they experience from the fall in hydrostatic pressure and bird attacks. Such fish may exceed 30% of the total volume of fish that manage to escape through the mesh while trawling (Breen *et al.*, 2007).

It can be added here that any technological improvement in fishing gears must lower the death rate of fish after interacting with the gear. In particular, trawling equipment with selective grids must increase the rate of survival of fish escaping from trawl bags.

3.3.4 Discards and fish losses.

In discussing sustainable management of fish resources in the Barents Sea, one cannot leave out the important issue of discards. In the first instance, fishermen dispose of the by-catch of non-commercial fish while, secondly, they throw away fish species that are not the target of their fishing at that particular time. This takes place because of a lack of quota or any commercial interest in such kinds of resources. Thirdly, juveniles of target species are thrown overboard, although this is mostly typical of trawlers. According to some data, the level of discard of abundant juvenile cod and haddock within the Barents Sea can reach 30-40% of the total trawl catch. As a result, neither fishermen nor scientists receive the expected level of recruitment within fish stocks (Chumakov, 2009).

The selective nature of longline fishing gears allows the discard of small-sized fish to reach a minimum. However, another side to the problem remains, namely the selective use of the catch where only certain species of fish are hauled onboard while others are cut off the hooks as the longline is being hauled in.

As the species selectivity of trawls and longlines differ, the species composition of the discards differs too. American plaice, blue catfish, rays and Norway haddock are mostly discarded from trawlers while rays, blue catfish, northern grenadier and torsk are discards from longliners. Volumes and species compositions of the underused portion of catches are determined by the fishing vessel's' focus on target species, quotas to followed, the value of fish and the occurrence of by-catch species.

For example, longliners which are granted cod quotas do not use the by-catch of blue catfish, preferring to throw them away in an effort to conserve space in the holds for cod. In contrast, those vessels which do not have codfish quotas harvest catfish, which are not on quota in some areas, and are forced to discard the by-catches of cod and haddock. Blue catfish and cod are usually taken off the hooks and discarded for the same reasons.

The actual volume of discards of both commercial and non-commercial species is not precisely known for either type of fishery, but some figures give a general idea of the problem. According to some studies (Grekov, 2007a), from 1996-2005 the unavoidable by-catch of the starry ray within the longline fishery was 6,800 tonnes, of which only 600 tonnes were used. In addition, approximately 100 tonnes of the northern ray are annually thrown overboard by longliners.

Overall, from 1996-2001 the Russian fishing fleet in the Barents Sea removed between 700 to 1,900 tonnes of rays annually (an average of 1,240 tonnes per annum) (Dolgov *et al.*, 2005). Unfortunately, all the catches of these species are not used and were thrown overboard.

A correction to the official figures trawl-caught cod was carried out in 1993-1995 by specialists from PINRO (Shevelev and Sokolov, 1997). The results of this correction showed that the earlier official catch figure for these years was 22-38,000 tonnes lower than the newly-calculated one, testifing to the actual volume of discards. Only 35-50% of the total by-catch was processed during this period.

During handling on deck, fishermen sort fish by species and size and discard non-commercial and juvenile fish. However, loss of a portion of the commercial catch also occurs, mainly through fish having lost their marketable value through being in poor physical condition. This type of discard is typical for longliners as, being hooked under the sea (sometimes for a long period), fish are often eaten by invertebrates, especially amphipods. For this reason, losses of marketable fish in longline catches can reach 55% in some areas of the Barents Sea (Zolotarev *et al.*, 2004). In general, however, losses of marketable fish caused through browsing by shellfish are estimated at between 2-3% of the total catch of the longline fleet.

Another reason for loss in quality is predation by some hydrobionts. For example, according to the results of one study (Klepikovsky *et al.*, 2007), a shoal of bottle-nosed whales can remove up to 40% of the black halibut hooked on longlines and many of the halibut left on the hooks were marked with tooth bites. Sharks also can eat fish hooked on longlines. Coast-dwellers did not pursue a longline fishery in Kola Bay exactly because of this reason, despite there being enough fish available.

Despite the fact that predation and browsing during longline fishing results in additional losses of fish, the relatively small size of the Russian longline fleet and the low level of fishing effort within this type of fishery are the main reasons why discards from longlining are insignificant here in comparison to trawl fishing. It should be noted that each non-commercial fish that is caught on a longline reduces the profitability of the longline fishery as it occupies a hook that could be taken by the commercially valuable fish. It can be argued that the fishermen themselves are interested and keen to minimize the size of by-catches of untargeted fish. **There is therefore a direct economic interest amongst fishermen in reducing the number of discards in the longline fishery**.

In conclusion, it can be said that the problem of fish discards exists not only in the Barents Sea, but also throughout the world's fishing industries. Discards from trawl catches can exceed those of longliners by a factor of 2-5 times (Bjordal and Løkkeborg, 1996).

3.3.5 Impact of trawls and longlines on bottom-dwelling communities and non-finfish by-catch

It goes without saying that there are no fishing gears available that do not have an impact on ecosystems of the world's oceans. The fishing gears described in this paper (trawl and longline) are bottom-fishing ones and as such they influence in the first instance bottom-dwelling communities. However, the degree to which each influences the bottom-dwelling communities differs.

Being an active fishing gear, trawl is towed along the sea bottom scraping the ground. This physically impacts on the habitat and damages bottom-dwelling life dependent on it. In some areas of the Barents Sea, sponges, clams, anemones, shell fish and other bottom-dwellers can be found in trawls in large quantities. Plowing the bottom with a trawl not only destroys the bottome-dwelling communities, but also degenerates the condition of the feeding grounds of mature fish and deprives juveniles of places of refuge. Furthermore, while trawling, a trail of sediment is formed in the water that makes it difficult for hydrobionts to breathe. Later, as the disturbed sediment settles, it coats sessile forms of bottom-dwellers. A clear example of this happening was reported in a study that found the average biomass of bottom-dwellers being reduced by 70% during a period of intense exploitation by ground-trawling fishing gears compared with the period when the trawling had just started (Chumakov, 2009). According to studies by some authors (Zolotarev, 1997), in 1995 the total weight of Icelandic scallop damaged by trawls reached 25,000 tonnes, considerably exceeding the amount allowed to be harvested. In addition to physical damage, working with a trawl creates noise that can frighten fish and prevent them from feeding. The combined effect of all these factors increases considerably when a large fleet of trawlers is operating in one area.

The advantage of scraping the sea bottom with a trawl is that it can help to release nutrients from the sea bed into the water. These are necessary first of all for autotrophic organisms, or primary producers, such as phytoplankton. Such an advantage, however, cannot be equated with the serious harm done to bottom-dwelling communities by elements of the trawl. The average mass in water of an otterboard used for trawling in the Barents Sea is 1.5-2.0 tonnes (Murmansk Research, Development and Technological Institute, 1990). The width of the footboard being 0.25 m and the length of the area of contact with the ground being 1 m, the area of contact with the sea bed is on average 0.25 m^2 (0.25 m x 1 m = 0.25 m^2). The force exerted by an otterboard on this area of the sea bed will be 15-20kN, corresponding to 600-800 g/cm^2. If the angle of attack is 40º (Central Design and Construction Technical Bureau, 1985), the width of the trace left on the sea bottom will be approximately 0.77 m (cos 40º x 1 m = 0.77 m) and the length of such a trace will be 6.5-7.5 km per hour of trawling at a vessel speed of 3.5-4 knots. The total area of impact of one otterboard being trawled along the sea bed for an hour will therefore be equal to 5.4×10^{-3} km^2 (7 km x 0.77 m), and **the average area of impact of two otterboards will be $10{,}8 \times 10^{-3}$ km^2 per hour of trawling**. This area would be subjected to the maximum direct impact of a bottom trawl.

The foot-rope has less of an impact on the sea bottom. The impact of a foot-rope on bottom-dwelling communities depends on the hardware used and its loading. If the average horizontal opening of a trawl is 18-30 m, the average total area of contact of the foot-rope with the sea bottom per hour of trawling is 0.17 km^2 (7 km x 24 m). Therefore, the **total area of impact of the ground trawl upon the sea bottom is the sum of the contacted areas of both the foot-rope and the two otterboards. At a trawling speed of 3.5-4 knots, this works out to be approximately 0.18 km^2 per hour of trawling**.

In contrast to the trawl, the bottom longline does not impart any obvious physical effect on the sea bottom, mainly because a groundline with snoods loses its weight in water and hardly impacts the sea bed at all. Exceptions do take place in emergency situations when, for example, a longline tangles on some unevenness on the sea bottom.. Closer contact with the sea bed occurs where longline anchors are set. As a rule, there are generally two such anchors on a longline, but their area of contact with the sea bed is not large.

In determining the average area of contact of a longline with the sea bed, a typical longline used by Russian fishermen in the Barents Sea can be considered (**Figure 4**).

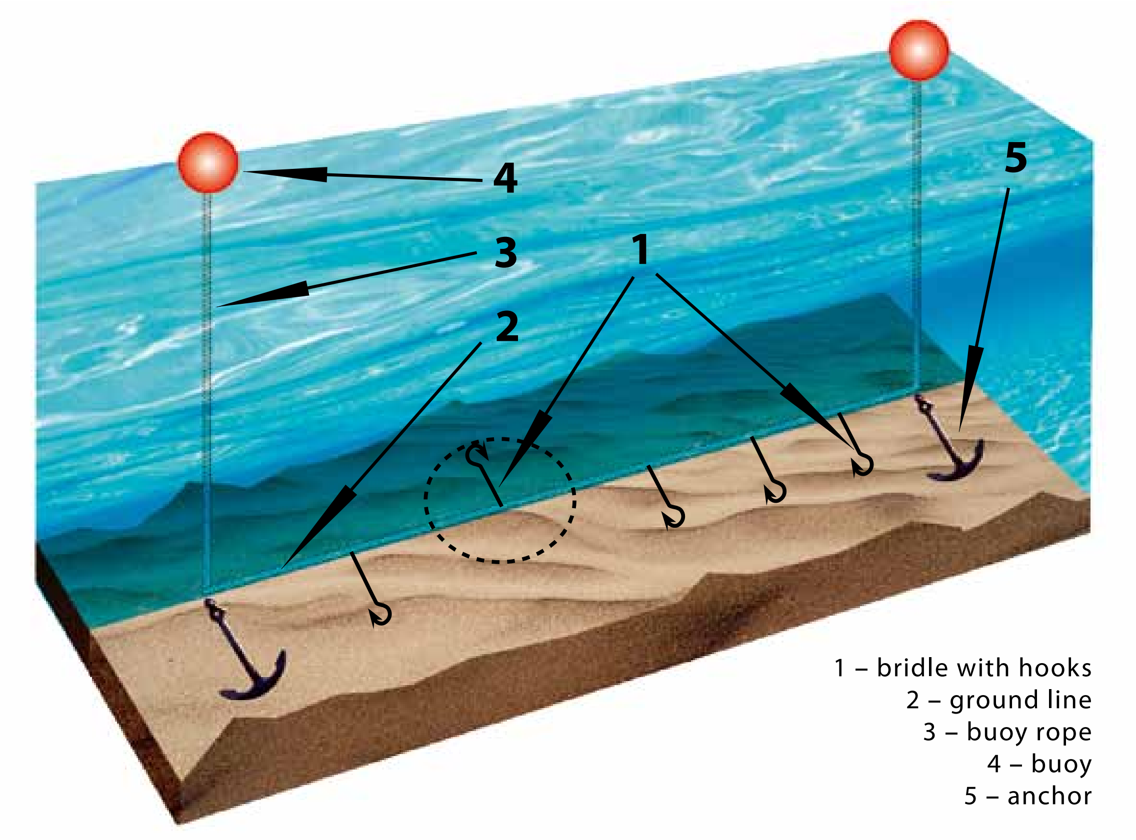

Figure 4: *Typical construction of a Russian longline*

The diameter of the groundline of such a longline is 9-11 mm. Snoods of 40 cm in length are attached to the groundline 1.5 m apart. Each snood can rotate around its point of fixture to the groundline, allowing each snood with a hook to cover an area on the sea bottom of 0.5 m^2 ($S = \pi r^2$ *or* $3.14 \times (0.4\ m)^2$). The total area of sea bed that comes into contact with 1,000 hooks is therefore 500 m^2.

The contact area of a longline can be evaluated using another method, namely the area of a rectangle with the length of the side equal to two lengths of a snood. The length of a 1,000-hook longline will be 1,498.5 m (1.5 m x 999 hooks). The total area of contact of a longline with that many hooks is therefore 1,199 m^2.

In the authors' opinion, even if this model of a longline's attachment to the sea bed is to be fully tested, the contact area on the sea bottom is very unlikely to be more than the areas just calculated.

In recent times (2004-2008), the Russian longline fleet in the Barents Sea processed an average of 87.8 million hooks per year (Grekov, 2009). Using the two calculation methods described above, the total area coming under contact by longlines can be estimated at, respectively, 44 and 105 km^2. Over the same period, the mean annual longline catch was estimated at 20,900 tonnes (Grekov, 2009). In order to catch this volume of fish, trawlers of the SRTM type, operating a 16-hour trawling regime and catching an average of 7 tonnes of fish per day, must spend 2,992 days or 47,900 hours at sea (Bondarenko, 2006). Having calculated above the area of contact of a ground trawl per hour of trawling as being 0.18 km^2, it follows that it would be necessary to plough an area of the sea bottom approximately 8,600 km^2 in size in order to achieve such catch volumes. This works out as being 82 or 196 times greater than the area that undergoes contact from a bottom longline. In other words, while catching an equal quantity of fish, **the contact area for longline fishing gears is only 0.5-1.2% of that of trawling**. It is necessary to also note that the impact of a longline on the sea bottom is much less than a bottom trawl because considerably less pressure is being exerted on the sea bottom by the fishing gear's hardware and there is a general absence of motion and mechanical friction. All the above allows one to state with assuredness that, with regards the impact of fishing gears on bottom-dwelling communities, the longline is a much more sparing fishing gear than is the bottom trawl.

With respect to bottom-dwellers such as anemones, crabs and others, swallowing the bait used on longlines happens rather infrequently and is not wide-scale.

One factor reducing the ecological compatibility of longline fishing gears is the swallowing of hooks by birds whilst the longline gear is being laid out. Two species of birds swallow ground longline hooks in the Barents Sea, namely, fulmars (*Fulmarus glacialis*) and juvenile glaucous gulls (*Larus hyperboreus*). The average number of sea bird deaths per year caused by the Russian longline fishery in the Barents Sea from 1999-2007 was approximately 16,000. According to Norwegian research, the number of fulmar deaths caused by longline fleet fishing activities (including the coastal fishery) is around 20,000 (Pavlenko *et al.*, 2010).

With trawling, the capturing of birds is very rare. However, sea mammals can be caught using this type of fishing gear. In the Barents Sea, the capture of sea mammals by longlines is also feasible, especially in cases where the animal becomes entangled in the mainline). Whales often eat fish that they have taken directly off the hooks.

The issue of coral reefs being impacted by bottom trawling is discussed in **Inset 1**.

3.3.6 Pollution

In Russia, trawl and longline fishing gears are found on the same type of fishing vessels. Consequently, the effect that these similar vessels, albeit fishing in a different way, have on the environment is approximately the same. However, it should be noted that trawlers expend much more fuel per day at sea than do longliners (see below). Emissions of exhaust gases from trawlers into the atmosphere are consequently higher. Furthermore, higher fuel consumption results in more frequent refueling of trawlers. While this is being done, the possibility of oil spills occurring increases.

INSET 1

Coral reefs give rise to many more new species than other tropical marine habitats, according to a new study.

Coral reefs attract scuba divers because these mounds of colour and texture harbour a rich variety of life, from fish to sponges to sea stars. But creatures don't just live on reefs - they're generated by them, according to a new study.

Scientists used fossil records stretching back 540 million years to work out the evolution rate at reefs. They report in the journal Science that new species originate 50% faster in coral reefs than in other habitats.

The team says its findings show that the loss of these evolution hotspots could mean «losing an opportunity to create new species» in the future.

Conservation efforts typically focus on places where species are disappearing most quickly. The new findings suggest that we also need to protect places where species are forming most rapidly.

Coral reefs harbour a huge number of marine species - they are often likened to rainforests in terms of their biodiversity. But they also provide a «pump of new marine species», according to Wolfgang Kiessling the scientist from Humboldt University in Berlin, Germany, who led this study.

He and his colleagues examined the fossil record to find the earliest evidence of benthic creatures - animals that live on the seafloor.

These creatures provide a good record of evolution. They remain on the seafloor once they die, and are often fossilised along with some of the remains of their original habitats.

This team of scientists looked for the earliest fossils from each benthic genus, or group of species, in the fossil record.

«We checked when and where each genus first occurred, explained Dr Kiessling. «So, for example, if the earliest fossils were 300 million years, we asked: 'Did it occur in a reef or outside?'.»

He and his colleagues had access to a record stretching back to the Cambrian explosion - when the vast majority of complex organisms are believed to have emerged more than 540 million years ago.

This huge data set was compiled by an international project called the Paleobiology Database, which was started in 2000.

«We had the best documentation of the fossil record at our fingertips,» Dr Kiessling told BBC News. «And there was also the geological context there, so we knew where each species occurred.

«Our study shows that reefs are even more important than currently assumed. They are not only ecologically important for the marine environment, but also in an evolutionary sense.»

But Dr Brian Rosen, a zoologist at the Natural History Museum in London, UK, warned that the accuracy of fossil records alone was «notoriously difficult to gauge from the literature».

He added that it could be useful for independent experts to re-examine some of the fossilised creatures.

Data «generated by direct examination of the specimens themselves by the relevant taxonomic specialists» is more reliable when it comes to working out important evolutionary patterns, he said.

Carl-Gustaf Lundin, head of the marine programme at the International Union for Conservation of Nature (IUCN), said that this was a «very welcome paper».

«Studies like this provide conclusive evidence that reefs are centres of marine biodiversity,» he told BBC News. «And now we see their importance in the evolutionary history of the planet.»

He added that currently the planet was losing 2% of its reefs each year, mainly because of increasing ocean temperature bleaching and stunting the coral's growth. And ocean acidification making it more difficult for corals to build their skeletons.

The findings, he said, add another dimension behind the need to protect coral reefs and other marine environments.

Dr Kiessling said: «If we lose reefs we lose [an] opportunity to create new species by evolutionary processes.»

Source: BBC News

Source article: Kiessling, W., Simpson, C. and Foote, M. (2010). Reefs as Cradles of Evolution and Sources of Biodiversity in the Phanerozoic. Science, 8 January 2010. Vol. 327, No. 5962, Pages 196-198; DOI: 10.1126/science. 1182241

Table 4

Type of Fishery	Fuel Consumption, kg/kg
Longline (coastal)	0,21
Longline (off-shore)	0,38
Gill net (coastal mostly)	0,30
Trawl (chilled fish)	0,79
Trawl (factory)	0,81

Fuel consumption (kg) per kg of fish caught by longline, gill net and trawl in Norway in 1989 (Bjordal and Løkkeborg, 1996 after Bjorcum, 1993).

3.4 Economic aspects

3.4.1 Fuel consumption

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

The results of modern-day research in the Barents Sea show that a longliner spends 0.3-0.6 tonnes of fuel per tonne of raw fish caught (Grekov, 2007a). This is approximately 20-40 % of the fuel consumption of a similar type trawler (Bjordal and Lokkeborg, 1996).

The fuel consumption of the Norwegian fishing fleet in catching 1 kg of fish product using different fishing gears is shown in **Table 4**.

3.4.2 Quality of fish

Despite the fact that both longline and trawl vessels can produce fish products of high quality, fish caught with longlines have certain advantages.

During longline fishing, the fish are hauled on board one at a time. Usually, they are alive at this time and are cut (bled) right after they've been landed, so ensuring an

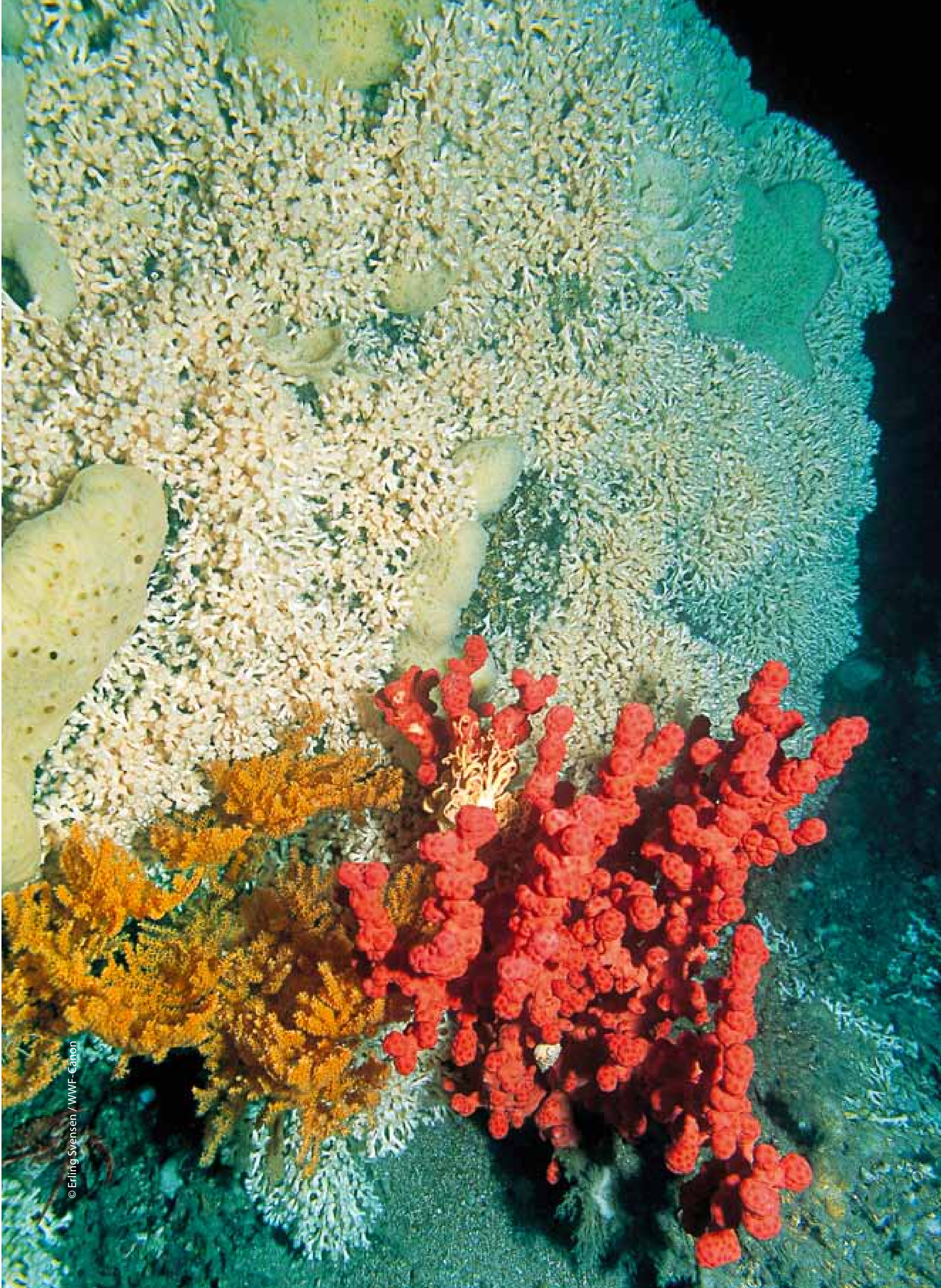

Table 5

Size, kg	Minimum price*, NOK/kg	Fishing gear, %		Value, NOK/tonne	
		Longline	Trawl	Longline	Trawl
< 1,0	10,00	28	44	2800	4400
1,0-2,5	12,75	48	50	6120	6375
2,5-5,0	15,25	20	6	3050	915
> 5,0	18,00	4	-	720	-
Всего:		**100**	**100**	**12690**	**11690**

Longline and trawl catches of cod according to fish size

excellent quality of product.

Fish caught by trawl, on the other hand, can be deformed and squeezed when being gathered into the trawl bag. Furthermore, when trawl catches are large, trawler crews cannot process them quickly and the sorting can take several hours. As a result, fish can become stale and die before being bled and processed. During trawl fishing, this can lower the quality of the fish product quite considerably.

3.4.3 Value of fish products

In general, the larger the fish, the higher its value. There are more large fish in longline catches and longliners tend to catch more products of large size. Consequently, more income is generated. Even though the daily catch of a trawler can exceed that of the same-type longliner, the value of catches from both forms of fishing can be compared.

A comparison of the results of trawl and longline fishing techniques is shown in **Inset 2**.

According to verbal information provided by ship owners, the market value of fish produced by longliners is 15-20 % higher than for trawlers, largely because of the higher quality of product harvested by longliners.

* Norwegian krone, July 2009, source: www.rafisklaget.no

Returning to the example given above of the joint fishing of cod aggregations by a trawler and a longliner in June 2005, the average daily trawl cod catch for the trawler and longliner was 8.1 and 6.7 tonnes, respectively. Including the by-catch, the total amount caught was 9.3 and 9.9 tonnes, respectively (see Section 3.2 above).

The trawler caught cod with an average size of 52.2-59.0 cm, while the average size of fish caught by the longliner was 63.5-68.4 cm (Grekov, 2007a). An analysis of size composition of the cod catches allows one to distribute the fish according to size (**Table 5**).

In the example, the minimum value of daily catch of cod caught by the trawl (5.4 tonnes of end product processed from 8.1 tonnes of raw fish) can be estimated at NOK 63,100, while that from the longliner (4.5 tonnes of end product derived from 6.7 tonnes of raw fish) is estimated at NOK 56,700. Bearing in mind that collection centres offer a better price for longline products (15-20% more) than they do for trawl ones (see above), it can be said that the value of longline daily catch increases to between NOK 65,200 and 68,000.

It is necessary to state that, in the above example, only cod is included in the value of daily catch. If the by-catches of haddock, catfish and other species are taken into account (3.2 tonnes for the longliner and 1.2 tonnes for the trawler), the value of fish produced by the longliner increases proportionately greater.

3.4.4 Profitability

It is clear, therefore, that despite achieving a smaller daily catch, the total value of longline fishing products is quite comparable to the value of products from same-type trawlers. However, it should be noted that a trawler spends 2.7 times more fuel than a longliner does. This considerably reduces the profitability of trawl fishing.

Only one factor tends to reduce the profitability of longline fishing, this being the additional expenses incurred in obtaining the bait for hooks, namely edible fish (eg. mackerel, saury, herring) and squid. The consumption of bait on a longliner in the Barents Sea is 40-70 kg per tonne of target species. It is clear, however, that, based on the same quantity of the fish caught, a longliner's expenditure on bait is considerably lower than what a trawler spends on fuel. This allows one to state that longline fishing is economically more profitable.

For example, the average consumption of diesel oil by a trawler of the SRTM type is approximately 4.5 tonnes a day. In 2008, the average price for one tonne of diesel oil was RUB 20,000. In this instance, the total expenditure on diesel oil for an entire fishing trip (105 days at sea) will be RUB 9.45 million. With same-type longliner, the total expenditure on diesel oil is only RUB 3.5 million. Clearly, **savings amount to almost RUB 6 million if not taking into account fuel-oil (over RUB 50,000 per day).**

INSET 2

A comparison of working results of a trawler and a longliner of equal tonnage in 2004

	Item	Trawler	Longliner
1	Cod quota, tonnes	500	845
2	By-catch, tonnes (species)	314(haddock)	586 (dogfish, etc.)
3	**Total catch, tonnes**	**814**	**1431**
4	Share of cod in total catch, %	61,4	59,0
5	**Output, tonnes**	**775,205**	**1177,797**
6	Days at sea	90	252
7	Output, tonnes per day at sea	8,61	4,67
8	**Sales proceeds, '000 roubles**	**35470**	**56638**
9	Losses, '000 roubles:		
	- Fuel and oil	2458	6547
	- Packing materials	507	579
	- Rigging	774	2071
	- Baits	-	5387
	- Provision	430	815
	- Subsistence money	1423	2639
	- Crew's salary	1960	3105
	- Tax charge	602	1155
	- Bioresources charge	2827	4047
10	**TOTAL losses, '000 roubles**	**10981**	**26345**
11	Balance, '000 roubles	24489	30293
13	Losses per day at sea, '000 roubles	122,011	104,544
14	Output per tonne of total catch, roubles/tonne	43574,94	39579,32
15	Output per rouble of losses	3,23	2,15
16	Output per tonne of cod, roubles/tonne	70940	67027
17	Idle time, days	275	113
18	Outage losses, '000 roubles	2750	1130
19	Annual vessel maintenance costs, '000 roubles	13731	27475
20	**Annual balance, '000 roubles**	**21739**	**29163**

A comparison of working results of Russian and Norwegian longliners in 2004

	Annual average index	Russia	Norway
1	Output per fishing day, tonnes	4,5	4,4
2	Assortment: quota/by-catch, %	53% / 47%	63% / 37%
3	Bait, kg per tonne of end product	92	88
4	Fuel and lubricants consumption, kg per tonne of end product	495	423

Source: Soyuz Rybopromyshlennikov Severa (The Fishermen Union of the North) (www.srps.ru)

3.5 Resource management

The principal aim of resource management is to minimize the detrimental effect of fishing activities on an ecosystem. It is necessary in the first instance to enforce those harvest quotas that have been granted. In the authors' opinion, **the solution to the problem of detrimental fishing would be simplified considerably by the large-scale introduction of longline fishing which is much more selective and sparing towards bottom-dwelling communities when compared with trawl fishing**. If longlines are introduced en masse, the control and monitoring of juvenile by-catches and fish discards lose their urgency.

The main point is that the maximum catching efficiency of a longline is limited by the number of hooks it has and the fact that the juvenile by-catches that are hooked reduce the chances of hooking larger fish. The level of juvenile by-catch, therefore, has a direct negative effect on the profitability of a catch. When the proportion of small-sized fish increases, the total volume of a longline catch decreases *pro rata*, resulting in a lower catch value. It is clear that fishermen are interested in catching larger fish because they are more valuable. Therefore, **the direct correlation between fish size and profitability is the most powerful stimulus for exploiting stocks of larger fish and reducing juvenile by-catch in longline fishing** (Bjordal and Løkkeborg, 1996).

The profitability of trawl fishing also reduces with an increase in the proportion of smaller fish caught. Unlike longlines, however, the proportion of smaller fish in trawl catches does not reduce the total catch volume. Therefore, while the trawl catches sufficient quantities of large fish together with juveniles, so ensuring a certain level of economic profitability, the captain does not have any incentive to stop fishing. All juveniles caught by a trawler will later be sold at a low price or simply discarded at sea. Therefore, in contrast to longline fishing, **trawl fishing does not have its own incentive to reduce the exploitation of juvenile fish** (Bjordal and Løkkeborg, 1996).

In view of the above-mentioned reasons, one can state that two vessels, one a longliner and the other a trawler, while officially harvesting the same quantity of fish, catch in fact different amounts. The trawler catches more fish, but throws juveniles and other untargeted fish overboard.

The use of longline fishing gears, therefore, satisfies both the biological aspects of rational fishing (ie. catching larger fish reduces the exploitation of commercial stocks and minimizes by-catch of juveniles) and the economic aspects (ie. high economic value).

Furthermore, the use of longline fishing gears would help address a number of pertinent issues, some of which have political overtones, which are connected with the harvesting of fish resources from the Barents Sea by trawlers. Such issues include the determination of optimum mesh sizes; minimum cod and haddock fishing size; the possible closure of fishing areas due to the overfishing of juveniles (Chumakov and Glukhov, 1994a, 1994b; Sorokin and Chumakov, 1995).

3.6 Social aspects

In the first few decades of the 20th Century, the development of world fishing went along the way of technical modernization of the fleet and fishing methods. This resulted in considerable expansion of fishing grounds, exploitation of new species of fish, a significant increase in the effectiveness of fishing gears, mechanization and automation of fishing methods and gear maintenance and a reduction in the labour-intensiveness of all these aspects.

The increase in the number of fishing vessels resulted in the growth of both catch volumes and the number of people employed in the industry. However, in the second half of the 20th Century, the world catch of fish reached a peak and most of the exploited fish resources turned out to be overharvested. As a result, the decrease in the amount of fish led to a reduction in the size of the world's fishing fleet. This in turn resulted in fewer people being employed within the industry.

Awareness of the necessity to conduct scientifically-based and sustainable fishing replaced the drive to increase catches at any cost. In this respect, the main criterion of the effectiveness of fishing methods must not be the productivity of the fishing gear, but such an index as *ecological compatibility of the fishing gear*. This is a measure of the gear's impact on fish resources and ecosystems as a whole.

Although a more productive fishing gear on the whole, the trawl is long behind the longline with regards its ecological compatibility. Longline, however, doesn't escape certain of its own drawbacks, such as the accidental hooking of birds, discards of non-commercial fish, etc.

Taking into account economic, ecological and social aspects, as well as the continued ageing of the Russian trawler fleet, it can be stated that refocusing of fishing efforts in favour of longliners will:

reduce the economic effectiveness of the Barents Sea fishery (this could be solved by building and acquiring new and more efficient as well as less expensive specialised longliners)

increase the ecological compatibility of the fishery in the Barents Sea (reduce discards of juvenile and untargeted species, impact on the bottom ecosystems, release of CO_2, etc);

increase employment (an increase in the number of longline vessels and the fishing effort will be required to keep catch volumes of hydrobionts at a certain level.

In other words, not only will fishing in the Northern Basin become more environmentally acceptable and the proportion of better quality produce increase, but there will also be an increase in employment opportunities for the region's population.

The regeneration of the traditional coastal longline fishery using small vessels at Murman is especially relevant. The development of this type of fishery would give a degree of hope that the lost infrastructure of coastal settlements in and around Murman would be regenerated and redeveloped. This would be especially important for the area from which the longline originated and which prospered from longline fishing. Up to the present day, the coastal longline fishery in Norway has had an important social and economic value. More than 10% of the population is employed in the coastal fishery and this type of fishery provides up to 20% and more of the total profit obtained from the catch of marine products. At the same time, the coastal trawl fishery (eg. off the Lofoten Islands) is completely banned.

Development of trawl and longline fisheries and sustainable management of marine resources in the Barents Sea

(c) Brian J.Skerry / National Geographic Stock / WWF

By the beginning of the 1990s, the share of trawl catches amounted to 70-80% of the total domestic catch, while longline catches contributed a mere 0.1 % (Karpenko, 1997). In the Barents Sea, the share of longline catches is 5% of the total harvest of cod (Grekov and Shestopal, 2005).

As can be seen, the **trawl still remains the principal fishing method for Russian fishermen**. With regards its further development, it should be pointed out that **all living marine resources available for this type of fishery are already being exploited**. Despite the positive trends seen within the last few years in the Barents Sea with respect to fish stocks (cod, haddock, pollock), there is still a disproportion between trawl fishing

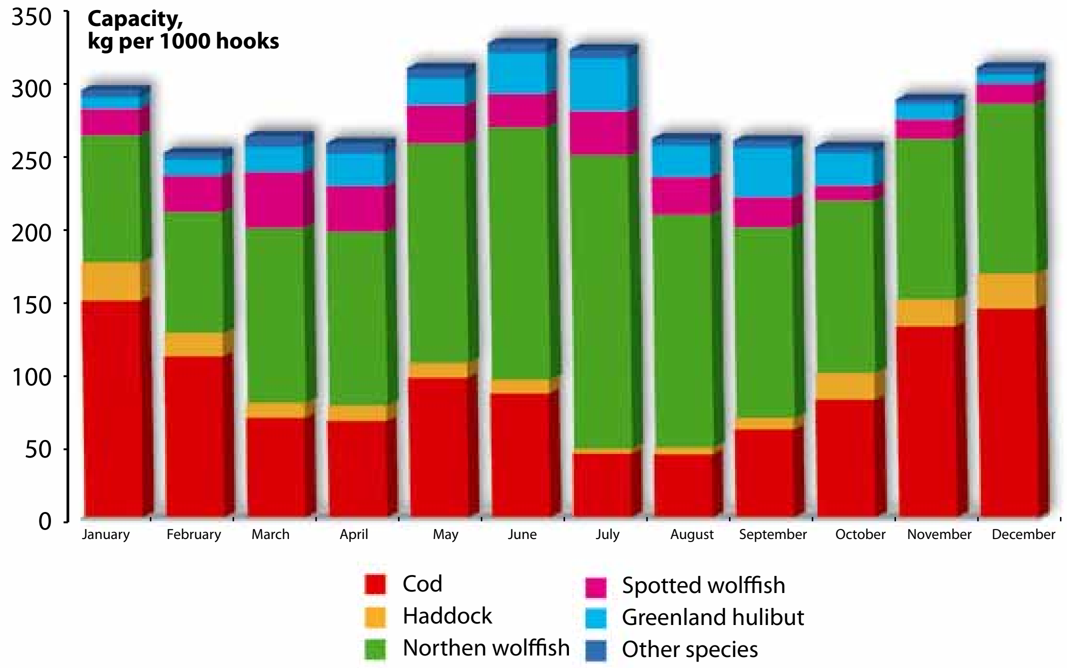

***Figure 5:** Average annual capacity of longline fishery in the Barents Sea (Shestopal et al., 2003)*

efforts and the potential of the raw material base. In the authors' opinion, if the total allowable catches of these fish increase, it will result in an increase in fishing pressure on stocks. This in turn will lead to an increase in juvenile discards and, consequently, will result in over-exploitation. The longline fishery will allow for the redistribution of fishing pressure from the juveniles to the adults. This is more justified from a biological point of view as it will allow fish to achieve their full growth and reproductive potentials and will give every species the opportunity to spawn at least once. For example, cod is intensively fished by trawlers starting from the age of three years old. At this age, the species is still largely inaccessible to longliners, with 4-year old and younger cod making up less than 0.5% of longline catches (Grekov, 2007a). Longline catches of cod could be significantly increased, but nowadays catches are limited by quota.

The Russian quota for haddock is mainly filled by trawlers within Russia's Exclusive Economic Zone (EEZ) with the harvest being of predominantly immature fish. There is a clear contradiction between the economic effectiveness of the fishery and the sustainable management of fish resources, especially as the impact of the fishery on recruitment is increasing. If the proportion of longliners within the cod fishery increases, the allocated resources will be used more sensibly and economic profit will be determined by filling up the national quota using the larger and more valuable fish..

The longline fishery, having its own living marine resource base that is different from the trawl fishery and in addition to other factors, has considerable po-

tential for development. Apart from those species that are jointly exploited by trawling, the longline fishing can successfully develop other (including unmanaged till now) resources that are inaccessible to trawling, such as catfish, torsk, ling, northern grenadier and rays. Unfortunately, while striving for quick profits, fisheries continue to focus on catching the most valuable fish and do not pay attention to other raw materials. As such, many fish continue to be discarded.

The problem of discards is of continued importance to both trawl and longline fisheries. It is possible that by creating the necessary economic conditions and incentives, fishermen will become interested in fully-utilising by-catches and avoid the discard of presently non-commercial species. To avoid discarding commercial fish, fishing vessels that are focused on target species should be given a balanced quota in order to catch other kinds of fish in volumes that are sufficient to allow the economic us of unavoidable by-catches.

With regards future trends in the development of longline and trawl fisheries in the Barents Sea, it should be noted that the trawler fleet is steadily getting older and presently consists of vessels which are 60-80% worn out. When old trawlers are taken out of commission, there is practically no replenishment of the trawler fleet. In the meantime, the longline fleet expands in size and technological capacity as new vessels built specifically for longline fishing are launched.

Furthermore, *in view of the future large-scale development of oil and gas fields on the Barents Sea continental shelf and the construction of a main pipeline, considerable areas of open water will become closed to trawl fishing. Consequently, the only possible method of commercial fishing remaining will be those using passive fishing gears, mostly bottom longlines* (Grekov, 2007a).

In the Barents Sea, longline fishing can be conducted all year round and with high productivity.

To achieve maximum catches through longline fishing, it is recommended distributing fishing effort efficiently amongst fishing areas and over seasons of the year, whilst taking into account the varying fishing productivity for different fish species (**Figure 5**). The most productive cod fishing in the Barents Sea during winter/spring is the Norwegian EEZ; in summer it is the region around the Spitsbergen archipelago and the adjoining fishing areas; in autumn it is Spitsbergen, the adjoining fishing area and the Russian EEZ. Maximum catches of haddock can be obtained during the end of winter and in spring in the Norwegian EEZ, while during autumn and early–winter they can be had in the adjoining fishing area and in the vicinity of the Spitsbergen archipelago. The most productive areas all year round for black halibut fishing are on the continental slope within the Norwegian EEZ and in the vicinity of Spitsbergen. Catching catfish is most productive in the adjoining fishing area, namely Spitsbergen and the Russian EEZ (Grekov, 2007a).

Conclusion

Table 6

Characteristics for comparison	Bottom longline	Bottom trawl
Fishing operating conditions:		
All-seasonality	+ +	+ +
Hard sea bed and great depth	+ +	–
Bad weather	+	–
Fishing in areas with juvenile by-catch restrictions	+ +	– – –
Scattered schools	+ +	–
Dense schools	+	+++
Mobility	–	+ + +
Production capacity:		
Cod	+ +	+ + +
Haddock	+	+
Black halibut	+ +	+ +
Blue and spotted catfish	+ + +	+
Saithe (pollock)	– – –	+ +
Other species:		
Sea bass	+	+ +
Plaice	– –	+ +
Flounders	+	+ +
Torsk	+ +	+
Rays	+ + +	+
Rough-headed grenadier	+ + +	+
Lumpfish	– –	+

In summarizing the results of this work, the authors have tried to present their evaluation of bottom trawl and longline fishing gears using various forms of comparison and by taking into account the future development of the Russian trawl and longline fleets within the basin of the Barents Sea (**Table 6**).

According to the results of our evaluations, it can be concluded that the longline has 1.5 times more advantages than trawl and fewer drawbacks. However, it should be noted that *longline fishing has the clear drawback of needing to use additional biological resources*, ie. squid, fish, shellfish, etc, *as bait for its hooks*. This negative characteristic of longline fishing, however, is compensated for by the much more sparing fishing qualities it has in comparison with bottom trawling. Despite the few drawbacks of longline

Table 6 *(continuation)*

Selective characteristics:		
Species selectivity	+ +	+
Size selectivity	+ +	+
Juvenile by-catch	+	– –
Spawning stocks exploitation	– –	–
Fish survivability	– –	– –
Discards	– –	– – –
Impact upon bottom biocenouses	+ +	– –
Other sea life by-catches	–	–
Pollution	–	– –
Economic profitability:		
Fuel consumption	+ +	–
Quality of products	+ +	+
Value	+ +	+
Profitability	+ +	+
Sustainable management	+ +	–
Future trends of inshore fishery	+ +	+
Future trends of fleet development	+ +	– –
Employment	+	– –
Summary:	**50(+); 16(-)**	**33(+); 25(-)**

*A comparison of bottom trawl and longline fishing gears: Barents Sea fisheries and future development trends of the Russian fleet **

fishing, its advantages over trawling are very clear. For this reason, it allows the authors to state that **the large-scale development of the longline fishery is one of the means of optimizing the exploitation of raw materials in the Barents Sea**. At the same time, it is necessary to state that the development of the longline fishery must not only be aimed at increasing the size of the fleet, but also at increasing the working efficiency of existing vessels. Any intensification in the exploitation of the fish resources in the Barents Sea must imply not only the increase in catch of the main commercial species (ie. cod, haddock, halibut), but also the catch of accidentally-caught fish, such as rays, torsk, grenadier and a number of other species. These species can be caught effectively using the longline, but remain inaccessible to the bottom trawl.

* Three-point merit rating of fishing gears

Historically, the Russian fishery in the Barents Sea went through a flourishing period with the development of the longline, followed by its almost complete disappearance and domination by trawl fishing. During the present regeneration of the longline, it will be necessary to avoid shifting preference over to longlines entirely. It is should be borne in mind that some stocks of fish, such as saithe (pollock) and plaice, are difficult for the longline to access and their exploitation is only possible using trawl fishing gears. Therefore, **only the combined use of these fishing gears will allow for the optimal utilisation of the resources of the Barents Sea, the weakening of fishing pressure on different age groups of exploited fish species, the rational distribution of fishing efforts according to fishing areas and seasons and the taking into account the various biological peculiarities of the fish being exploited**.

Refusing to strive for growth in catch volumes at any cost in favour of developing a rational, scientifically-based fishery is the only way of achieving a biologically safe and sustainable fishery. Decommissioning much of our old trawler fleet and replenishing our longline fleet up to a healthy balance will help us redress the current imbalance between fishing effort and the status of fish stocks and allow us to use them both rationally and optimally. Only in this way will our rich northern Barents Sea furnish us with its gifts for thousands of years to come.

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Addendum 1

WWF Position on Bottom Trawling, November 2007

WWF believes that human activities in the seas can be managed to ensure that regulated bottom trawling is sustainable and that healthy ecosystems are maintained. This is only possible when fishing is managed within effective, holistic, ecosystem-based management regimes and that IUU (illegal, unreported and unregulated), fishing is eliminated. It is also vital that fishing states exercise adequate responsibility, especially by maintaining and using a genuine link to vessels flying their flag.

Irrespective of whether it is conducted in an EEZ or on the high seas, bottom trawling can be a highly damaging fishing practice, especially when conducted in sensitive habitats or without adequate management.

WWF believes that, under the Precautionary Principle, bottom trawling should not be conducted unless an adequate, ecosystem-based management (EBM) plan is in place to ensure sustainable resource use and the protection of sensitive habitats, vulnerable species, ecosystem integrity and the livelihoods of legitimate fishers.

WWF further believes that a viable strategy to address the ecosystem impacts of bottom trawling, both within EEZs and on the high seas, requires five simultaneous sets of measures. These are:

freeze the footprint of bottom trawling (no new areas to be opened up)

minimize trawling impacts (conduct EIAs, designate MPAs, reduce capacity, avoid vulnerable marine ecosystems and aggregations)

halt all unregulated bottom trawling (fish only subject to coastal state or Regional Fisheries Management Organisation (RFMO) measures)

develop new management regimes for demersal fisheries and ecosystems

intensify efforts to eliminate IUU fishing and to reduce over-capacity.

If a bottom trawling fishery is conducted using the criteria of EBM and meets criteria set by independent certifiers, WWF would support the continuation of such a fishery. The 2006 United Nations General Assembly (UNGA) Fisheries Resolution provides an excellent policy framework for establishing the governance framework within which acceptable bottom trawling can be conducted. It is now up to states and the fishers for which they are responsible, with the help and support of markets, consumers and other stakeholders, to develop and apply the requisite management measures to give effect to the expectations of the UNGA and the hopes of the wider community.

Addendum 2

Fishing grounds and seasons closed to trawling in the Barents Sea There are five areas within the Barents Sea permanently closed to trawling (see Figure below).

These areas were established by *Fishing Rules for Northern Fishing Basin*, which approved by Order of the Russian Federal Agency for Fisheries, No. 13 of 16th January 2009 (Articles 10 and 13).

The history of these areas began in the 1970s. In the late-1970s and early-1980s, the areas and periods of distribution of juvenile cod in the Barents Sea were determined according to the results of studies on marine biological resources in the USSR economic zone.

The first area was established on 25th April 1974 as a wildlife preserve for cod juveniles and was closed to trawling all year round.

Area No. 2 was established on 15th November 1977. Trawling is banned here from 1st January until 30th June.

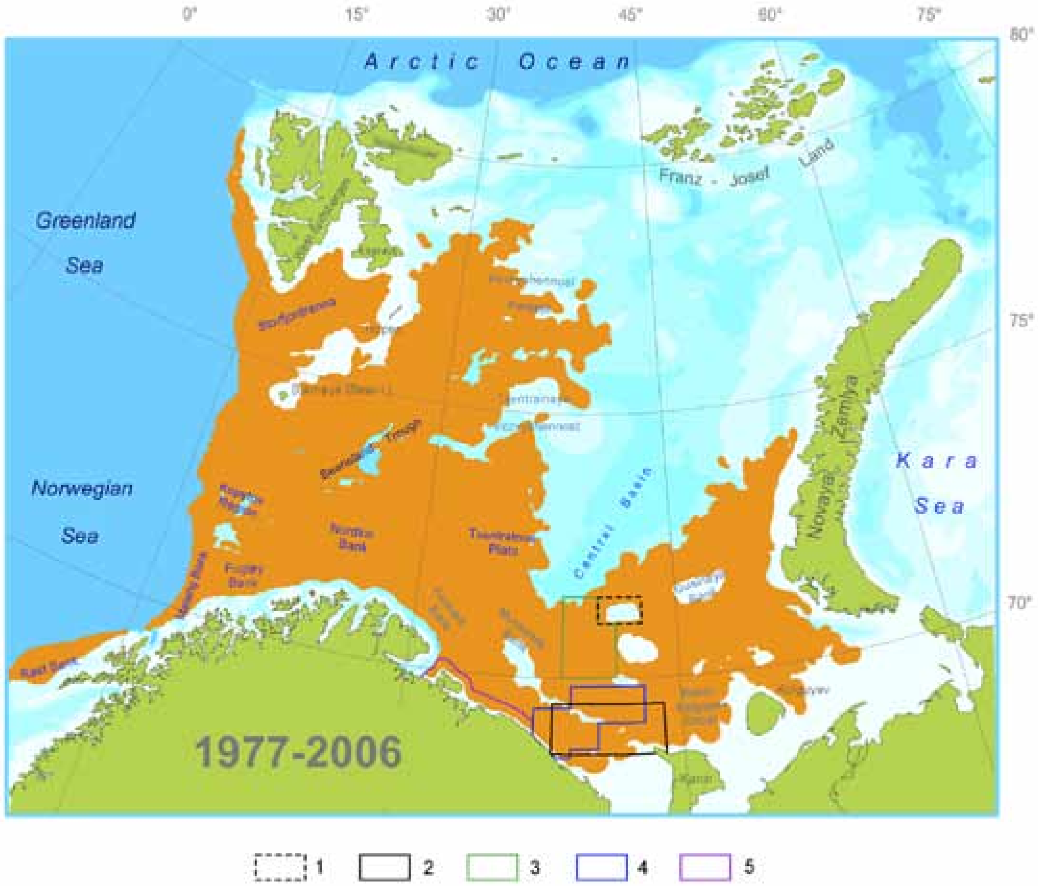
Area No. 3 was established on 15th July 1976 and there is complete closure of trawl fishing from 1st January until 15th April.

The introduction of these areas was necessary because the permitted fishable size of cod and haddock was set at 34 cm and 31 cm, respectively, and the mesh size at 120 mm. This allowed fishing vessels to harvest fish schools with large numbers of juveniles. Closure to trawling of areas with high aggregations of juveniles was the only measure available to limit such fishing and to preserve the juveniles. In 1981-1982, the minimum size of fish allowed to be caught was set at 42 cm for cod and 39 cm for haddock, while the mesh size was increased up to 125 mm. The decision of the 25th Session of the Joint Russian-Norwegian Fisheries Commission established that, starting from 1st January, trawls must be equipped with selectivity grids.

The order of the USSR Fisheries Ministry No. 356 of 1st July 1986 established *The Rules of Fishery, Protection and Exploration of Living Resources in the USSR Economic Zone of the Barents Sea for the Soviet Fishing Organizations and Vessels*, so fixing the three exclusion areas.

The ban on trawl fishing in territorial waters was not lifted in the above *Rules*. However, fisheries enforcement officials together with fisheries scientific organisations temporarily halted trawling in territorial waters when there was an abundance of juveniles. In the late-1990s/early- 2000s, trawling was temporarily banned along the Kola Peninsula from the Norwegian border up to 35°00´E. In 2006-2007, following approval of the Fishing Rules for the Northern Basin, the permanent ban on bottom trawling was lifted along the coast of the Kola Peninsula from the Norwegian border to the 37°00´E.

Major research on the king crab resource base preceded the establishment of Area No. 4 (the so-called "crab area"). As a result, PINRO scientists published a number of stud-



Area No.	x 1,000 km2	Period of closure	Subject of closure
1	5.0	annually	All types of trawling gear
2	16.4	1st Jan – 30th June	All types of trawling gear
3	24.7	1st Jan – 15th April	All types of trawling gear
4	21.8	annually	Bottom trawl
5	8.0	annually	Bottom trawl

Russian Cod fishing grounds in the Barents Sea (1,424,000 km2) in 1977-2006 and areas closed for trawling.

ies. One can consider The article entitled *Opening/closure of trawl fishing depending on king crab by-catches in the Barents Sea* and written by Yu.M. Lepesevich, B.I. Berenboim, E.V. Gusev and M.A. Pinchukov and then published in the magazine *Fishing Matters* in

2006 can be considered as the final study. These research studies resulted in the Order of the Agricultural Ministry No. 87 of 24th March 2006 which temporarily prohibited bottom trawling in this area in 2006.

In 2007, new *Fishing Rules for the Northern Basin* were approved by the Order of the Agricultural Ministry No. 245 of 28th April 2007. This confirmed Area Nos. 1, 2 and 3 and the periods of closure for them and established the permanent closure of Area Nos. 4 and 5.

The effective *Rules*… were set by the Russian Federal Agency for Fisheries' Order No. 13 of 16th January 2009. All five areas were confirmed.

A short note should be made about the short-term closure and opening of fishing grounds and changes in their boundaries. A temporary closure of some fishing grounds aimed at protecting marine biological resources was implemented in the Barents Sea from the end of the 1990s and into the beginning of this century. The measure was welcomed by both the Norwegian and Russian sides.

The Russian side closed the fishing grounds in two ways:

1) short-term closure of up to three days of small areas by the fisheries enforcement officials on the basis of scientific observers' recommendations and a further confirmation made by the fishing vessels with the observers or fisheries enforcement officials aboard

2) closure of some fishing areas for over three days by the fisheries enforcement officials with the agreement of higher bodies. This measure is implemented in instances when, according to the data of the fisheries enforcement officials and observers, there is an accumulation of juveniles and the formation of sedentary aggregations within this or that particular area. The above short-term measure is ineffective in this case.

Norwegian fisheries enforcement officials took the decision to close a fishing area based on the findings of an examination undertaken by the coast guard inspectors of the work done by fishing vessels. The Fisheries Directorate of Norway subsequently informed the Russian side about the decision that was taken.

In June 1998, the Joint Russian-Norwegian Fisheries Commission decided to develop a common decision-making procedure concerning the closure/opening of a fishery due to the overharvesting of juveniles. The project was developed in 1999 and implemented at a later stage by the fisheries enforcement officials.

At present, the recent reorganization of federal executive bodies and several restructurings within the fisheries have resulted in the complete disappearance of the possibility of introducing temporary fishing restrictions in emergency situations.