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Floated fish pot eliminates bycatch of red king crab and maintains target catch of cod

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Abstract

Today bycatch of red king crab (*Paralithodes camtschaticus*) in stationary fishing gears targeting cod (*Gadus morhua*) is a severe problem in the Barents Sea, causing extra work for fishermen and damaging their gear and catches. Attempts to use bottom-set pots as an alternative to gillnets and longlines have been unsuccessful, as pots too are affected by large bycatches of crab. In this field study, pots were floated off the bottom in order to avoid crab bycatch. A standard two-chamber groundfish pot was modified by mounting a suspension arrangement that allowed the pot to orient itself with the current about 70 cm above the seabed. Fishing trials were conducted in the Varangerfjord (northern Norway) to compare floated and bottom-set reference pots. Floating the pots off the bottom eliminated king crab catches, while bottom-set pots caught an average of 21 crabs each. Moreover, floated pots caught significantly more cod than bottom-set pots (3.6 and 2.5 cod per pot, respectively), with the majority of the 45% increase being cod below minimum legal size. The catch increase was explained by the fact that the entrance of floated pots always maintained a down-current orientation, whereas in bottom-set pots shifting current directions may lead the odour plume away from the entrance, thereby reducing the rate of entry of cod. Full-scale fishing trials are needed in order to evaluate whether floated pots could become a commercially viable method of catching cod.

Keywords: Bycatch reduction; Fish pots; Alternative gear; Gear modification; Red king crab (*Paralithodes camtschaticus*); Cod (*Gadus morhua*)

1. Introduction

In the 1960s, red king crabs (*Paralithodes camtschaticus*) were released into the Barents Sea (Murmansk Fjord, Russia) with the intention of establishing a commercial king crab fishery (Orlov and Ivanov, 1978; Kuzmin et al., 1996). The stock is now abundant also along the Norwegian coast of Finnmark (Sundet and Hjelset, 2002), and today there is a valuable pot fishery for red king crab. However, the red king crab is causing severe problems for fishermen using stationary gear to target fish. In particular, extra work load and damage to gear and fish catch due to large bycatches of crabs have effectively reduced the once viable gillnet fishery for cod (*Gadus morhua*) (Godøy et al., 2003). Gear modifications to gillnets and longlines have been tested in an attempt to solve this problem, and considerable bycatch reductions were achieved by floating the gear off the bottom (Godøy et al., 2003; Godøy, 2005). However, this mitigation measure caused pronounced reductions in the gillnet catch rates of target fish species.

Pots are generally regarded as environmentally friendly fishing gears with low potential for undesirable side effects (Jennings and Kaiser, 1998). Bottom-set pots have been tested as an alternative method of catching cod, and have occasionally given high catch rates of the target species (Furevik and Hågensen, 1997). However, pots too are affected by large crab bycatch, causing similar problems when they are used to target cod. If cod pots are to be an alternative to gillnet and longline, they will have to be modified to reduce bycatch of king crabs and at least maintain the catch of the target species.

We approached this challenge by taking advantage of differences in the food search behaviour of the target and bycatch species, and designed a pot that is floated above the seabed. Both cod and king crab use chemically stimulated rheotaxis when they detect and locate baited fishing gear (Løkkeborg et

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al., 1989; Løkkeborg, 1998; Stiansen et al., 2008). However, crab can only follow the track of a bait whose odour plume is close to the bottom, while food search behaviour in cod is not limited in this way. Furthermore, a floated pot may be designed like a windsock to ensure that the entrance is always oriented towards the approaching fish. We therefore hypothesized that floating the fish pots in this way would: (1) reduce the location of pots by crabs, (2) decrease the ability of crabs to enter the pots if located and (3) increase catch rates of cod. We performed fishing experiments and behavioural observations to test these hypotheses, and compared pots floated off the bottom and traditional bottom-set pots with regard to catches of target species and bycatches of king crab.

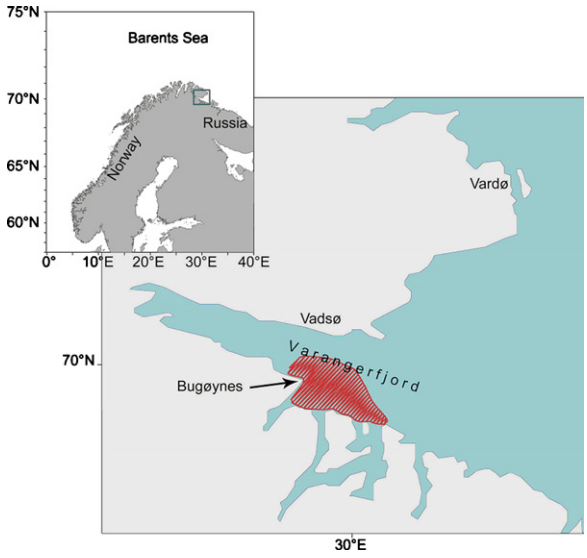

Fig. 1. The area in which the fishing trials were carried out.

2. Materials and methods

Comparative fishing experiments were performed in the Varangerfjord, near the Russo-Norwegian border (Fig. 1), at depths of 70–250 m in August/September 2003 and 2004. Two types of pots were used; a standard bottom-set two-chamber groundfish pot, and a floated version of the same pot. The standard pot is collapsible and is built around a lower steel frame and a middle and upper frame of aluminium. The amount of float on the upper frame is adjusted to produce enough lift in water to unfold the pot while maintaining bottom contact of the lower frame. A fully unfolded pot is 100 cm wide, 150 cm long and 120 cm in height. The standard pot has two wide entrances that lead into the lower chamber, and a single narrow entrance between the lower and upper chambers.

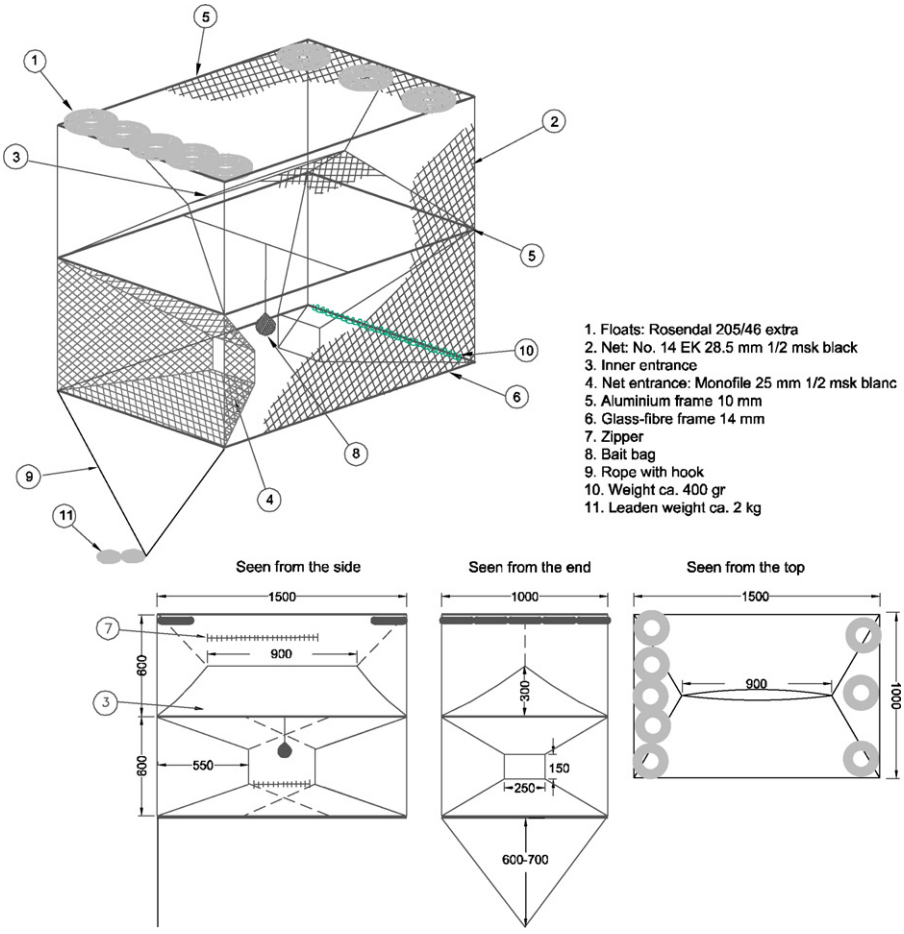

Fig. 2. Design of the floated pot tested in the fishing trials.

The modified pot was floated off the bottom by adding more floats to the upper frame and by replacing the lower steel frame with a lighter glass-fibre frame (Fig. 2). A suspension arrangement was mounted on one of the short sides on the lower frame and attached to the groundline, allowing the pots to orient themselves with the current about 70 cm above the seabed. Weights were placed on the down-current side of the lower frame to compensate for instability in pot geometry caused by the suspension arrangement and the additional floats added to produce buoyancy. The pots were baited with three frozen squid (*Ilex* sp.), each cut into five pieces and put in a bait bag. The bag was centred between the pot's two lower entrances.

Comparative fishing trials were based on fleets of 10 pots. Floated and bottom-set pots were attached alternately to the same groundrope, and the distance between consecutive pots was 55 m. The order of pots in a fleet was systematically reversed between each setting. Each fleet was set and hauled before midday giving a soak time of about 24 h. A total of 16 fleet settings were made (Table 1). The total catch of each species in floated and bottom-set pots in a fleet was used as one pair of observations in the data analyses. Some pots were excluded because of operational problems, and analyses were corrected accordingly for difference in the number of pots per fleet. Overall mean catches and corresponding standard errors were based on means for each fleet and pot type, as catches in pots on the same fleet are pseudoreplicates.

In situ video observations of floated pots were made during the comparative fishing experiments (the observation platform is described in Svellingen et al., 2002). The objectives of these preliminary recordings were to confirm that the floated pot maintained a down-current orientation under shifting current directions and to observe the behaviour of approaching cod and king crabs. The swimming direction of 256 approaching cod were categorized as up-current, down-current and across-current.

3. Results

A total of 1646 crabs were caught by the bottom-set pots. Mean catch per pot was 21.4 (S.E. = 4.3) and the highest catch in a pot was 116. In contrast, only two floated pots caught crabs (two and three crabs, respectively; Table 1).

Cod dominated the catches of fish taken by both pot types, comprising 70–90% of the number of fish caught (Table 1). Floated pots caught significantly more cod than bottom-set pots (mean catches per pot were 3.63 (S.E. = 0.43) and 2.46

Table 1
Fleetwise catches in number of fish and king crab in floated (F) and bottom-set (B) pots

Date	Fleet number	Pot type	Np	Species			
				Cod	Haddock	Tusk	Crab
2003.09.04	1	F	5	11	5	0	0
		B	5	6	0	4	17
2003.09.05	2	F	5	27	0	1	2
		B	5	29	1	0	57
2003.09.06	3	F	3	20	0	0	0
		B	5	7	0	0	21
2003.09.07	4	F	5	27	0	0	0
		B	5	26	0	0	86
2003.09.08	5	F	5	22	0	0	0
		B	5	12	1	1	136
2003.09.09	6	F	2	9	0	0	0
		B	3	5	0	0	51
2003.09.10	7	F	4	12	0	0	0
		B	5	18	2	0	98
2004.09.01	8	F	5	4	0	0	0
		B	5	11	0	3	26
2004.09.02	9	F	5	11	1	2	3
		B	4	15	0	6	128
2004.09.02	10	F	4	9	1	1	0
		B	5	7	0	6	237
2004.09.03	11	F	5	5	0	5	0
		B	5	10	1	14	40
2004.09.03	12	F	5	16	3	1	0
		B	5	11	0	6	124
2004.09.04	13	F	5	13	0	1	0
		B	5	6	0	0	60
2004.09.04	14	F	5	20	0	0	0
		B	5	6	0	1	60
2004.09.06	15	F	5	27	1	0	0
		B	5	9	1	0	361
2004.09.06	16	F	5	26	7	0	0
		B	5	10	2	0	115
Total	16	F	73	259	18	11	5
	16	B	77	188	8	41	1617

Np indicates the valid number of pots in a fleet.

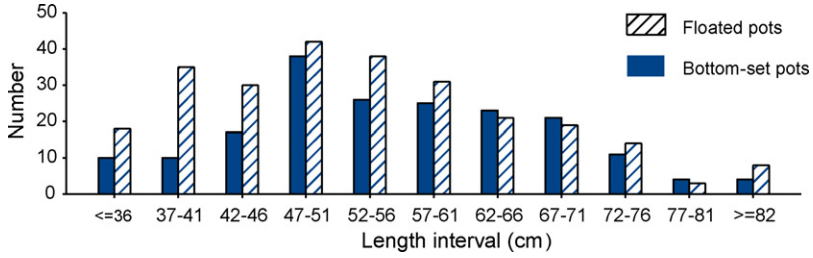

Fig. 3. The catch of cod on floated and bottom-set pots by 5 cm length groups.

(S.E. = 0.35) fish, respectively, Wilcoxon sign rank test, $p < 0.05$, $n = 16$). However, this increase was mainly due to the catch of undersized cod (Fig. 3), which was more than twice as high for floated (mean = 1.13, S.E. = 0.25) as for bottom-set pots (mean = 0.49, S.E. = 0.14). For cod of commercial size (≥47 cm) the difference was not statistically significant (mean = 2.50 (S.E. = 0.30) and 1.97 (S.E. = 0.28) fish, respectively). Floated pots also caught significantly more haddock (*Melanogrammus aeglefinus*), but this species was taken in small numbers (mean catches per pot were 0.17 (S.E. = 0.09) and 0.05 (S.E. = 0.03) fish, $p < 0.05$, $n = 10$). Catches of tusk (*Brosme brosme*) were significantly higher in bottom-set than floated pots (mean catches per pot were 0.47 (S.E. = 0.20) and 0.13 (S.E. = 0.07), $p \leq 0.05$, $n = 10$).

The video observations showed that the floated pot always oriented down-current irrespective of shifting current directions. Most cod (95%) swam up-current, while the remaining (5%) swam across-current, when approaching the floated pot. No king crab was observed in the vicinity of the floated pot.

4. Discussion

This fishing experiment showed that traditional bottom-set pots caught an average of around 20 red king crabs, whereas the experimental pots floated 70 cm off the bottom virtually eliminated the bycatch of king crabs. Moreover, the catch of cod of commercial size was at least as high on the floated as on the bottom-set pots.

Our pot design was based on the fact that chemoreception plays an important role in the food search behaviour of many aquatic species (Atema, 1980; Rittschof, 1992; Løkkeborg, 1998; Finelli et al., 2000), and the observations that both fish and crustaceans use chemically stimulated rheotaxis when they detect and locate baited fishing gear (Løkkeborg et al., 1989; Zimmer-Faust et al., 1995; Skajaa et al., 1998; Løkkeborg and Fernö, 1999). By rigging the floated pot in such a way that it would maintain down-current orientation also under shifting current directions, we hypothesized that floated pots should increase catch rates of target fish. Our video observations showed that cod approached floated pots upstream. Bottom-set pots, however, do not change orientation when the current direction changes, and observations have shown that cod that encountered pots when the current was perpendicular to the entrance stayed within the odour plume and thus did not find the entrance area (unpublished data). We obtained increased total catch rates for floated pots, and these results are most likely explained by higher rate of entry for these pots compared to the pots that sat immobile on the seabed. Godøy (2005) did not obtain increased catch rates of cod for floated pots, and his result supports our explanation, as the design of these pots did not allow them to orient themselves with the current.

Although the total catch of cod was significantly higher on the floated than on the bottom-set pots, most of the increase was for fish below the minimum legal size (MLS). However, other experiments have shown that the catch of under-sized fish can easily be avoided in pots by mounting size selective escape devices (e.g. Stewart and Ferrell, 2002; Shepherd et al., 2002), or by selecting web mesh size in accordance with the minimum landing size. (Robichaud et al., 1999; Sary et al., 1997; Stewart and Ferrell, 2003). The catch of sub-legal sized fish is therefore not likely to be a problem but further fishing experiments should include trials with large-meshed escape panels.

The elimination of the king crab bycatch in the floated pots may result from the crabs having problems in locating the pots or by the crabs not being able to reach pots floated 70 cm above the seabed. Chemically stimulated rheotaxis play an important role in king crabs approaching pots and because the baits in the floating pots were more than 70 cm above the seabed, the bait odour plume reached the seabed at a certain distance (probably a few metres, Miller, 1980) down-current of the pot. Approaching crabs therefore lost contact with the odour plume before they came into close contact with the pot. They were thus more likely to switch from chemically oriented searching to random searching, which would reduce the probability of locating the pot. This explanation is supported by our behavioural observations, which showed no crabs in the close vicinity of the floated pot, and by Zimmer-Faust et al. (1995) who showed that blue crabs (*Callinectes sapidus*) changed search pattern when they lost track of an odour plume. Furthermore, low catching efficiency has been observed for pots where the bait and the entrance had different vertical positions (Zhou and Shirley, 1997; Stiansen et al., 2008).

The problem of large bycatches of king crab has also been addressed in gillnet and longline fisheries, and the use of semi-pelagic longline with 3.5 m long poles and gillnets set with 1 m norsels significantly reduced but did not eliminate the crab bycatch (Godøy et al., 2003; Godøy, 2005). These mitigation measures caused reduced catch rates of target fish species for norsel nets, while target catch rates were maintained for semi-pelagic longlines compared with the bottom-set standard gears.

In this study we took advantage of the food search behaviour of both the bycatch and the target species, and demonstrated a solution that eliminated crab bycatch and maintained the catch of cod of commercial size. Although the use of pots is encouraged by fisheries managers due to a conservation oriented approach (Kaiser et al., 2000; Blyth et al., 2004), full-scale fishing trials are required to confirm the large-scale applicability of the promising results presented here.

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