Original Article

Artificial light in baited pots substantially increases the catch of cod (Gadus morhua) by attracting active bait, krill (Thysanoessa inermis)

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The use of pots in the north Atlantic finfish fisheries is negligible because this fishing method typically has a low capture efficiency. Large numbers of individuals encounter baited pots, but the proportions of fish that enter the pot and become caught are low. Krill, which constitutes an important prey for cod (Gadus morhua), is attracted by light. The catching efficiency of baited cod pots with three light sources with different colours and intensities (white: 9744 mW m–2, white: 23 mW m–2, green: 8 mW m–2) were tested in coastal waters in northern Norway. Pots with the light source of highest intensity gave a 17 times higher catch rate of cod than that of control pots (with bait only). The light source of medium intensity gave about a five times higher catch rate, whereas the weakest light did not influence the catch. Cod caught in pots with light had more krill and arrowworms in their stomach and were observed feeding on these preys inside the pot. We concluded that light sources of increasing intensity attract more krill, and that cod were attracted into the pot by the dense swarms of prey and not the light per se.

Keywords: baited fish pots, catching efficiency, cod (Gadus morhua), krill (Thysanoessa inermis), light attraction

Introduction

Fish pots hold many attractive characteristics due to the low environmental impact of this fishing practice (Jennings and Kaiser, 1998; Thomsen et al., 2010), and Suuronen et al. (2012) classified pot as a low impact and fuel efficient (LIFE) fishing gear. Despite its position as a LIFE fishing gear, the use of pots in the north Atlantic finfish fisheries is negligible. Except for a few species (e.g. Pacific cod (Gadus macrocephalus) and sablefish (Anoplopoma fimbria)) pots typically have low catching efficiency for most ground-fish species compared with other fishing gears such as trawls, seines and gillnets (Thomsen et al., 2010). However, one study (Königson et al., 2015) has shown that, depending on season and operational conditions (e.g. depth and soak time), the catch per unit effort (CPUE) of pots can equal, and sometimes exceed, CPUE of gillnets and longline fishing in the Baltic Sea cod (Gadus morhua) fishery. In Norway, there are incentives for fishermen to develop pot fisheries as an alternative to gillnets, as pot caught fish have the potential for higher prices, because of better-quality, and are allocated extra quotas if the catches are landed alive for capture-based aquaculture (Dreyer et al., 2008). Although efforts have been made to improve the catching efficiency of pots (e.g. Furevik et al., 2008; Bryhn et al., 2014; Jørgensen et al., 2017), in particular for Atlantic cod (G. morhua), a financially viable pot fishery for gadoid species has yet to be developed.

The catching principle of baited gears takes advantage of the foraging behaviour of the target species. Behavioural studies have shown that large numbers of fish swim up current to baited hooks (Løkkeborg, 1998; Løkkeborg and Fernø, 1999) and pots (Furevik et al., 2008; Anders et al., 2016), and chemically stimulated...
rheotaxis is regarded as the most likely mechanism used by fish to locate odour sources (Carton and Montgomery, 2003; Lokkeborg et al., 2010). Although large numbers of individuals encounter a baited fishing gear, the proportions that are caught are generally low. Behavioural observations of cod demonstrated that only 9–11% of the fish that approached a baited pot were caught (Anders et al., 2016; Ljungberg et al., 2016), and observations of cod attracted to baited hooks showed that only 5% of the fish responded to the bait (Lokkeborg et al., 1989). Field studies have shown that >50% of large cod that entered a two-chamber pot escaped (Jørgensen et al., 2017), and that the low capture efficiency for this pot design was due to low entrance rate and high escape rate (Anders et al., 2016).

Thus, one way to improve pot catch efficiency could be to stimulate more fish to enter the pot and motivate fish to stay once caught. Most fish encountering a baited pot show chemically stimulated food search (Furevik et al., 2008; Lokkeborg et al., 2014). The pot and the bait (commonly contained in a bag) are unfamiliar to the approaching fish, and restrained responses towards attacking a novel prey have been demonstrated in several species (Beukema, 1968; Ware, 1971; Lokkeborg, 1990). Moreover, food search and prey capture involve several sensory modalities (Lokkeborg et al., 2010), and the additive effect of several stimuli acting simultaneously may be essential to elicit a strong feeding response. Cod use chemoreception and vision in prey capture (Brawn, 1969; Lokkeborg and Fernø, 1999), and additional visual stimuli might encourage more fish to enter a pot (Jørgensen et al., 2017). A study conducted in the Baltic sea (Bryhn et al., 2014) demonstrated that two-chamber pots equipped with a weak green lamp caught more cod than pots without artificial light, but the functional explanation for this effect of light was not clear. Artificial light is commonly used in longline fisheries targeting swordfish (Xiphias gladius) and has been shown to increase target catch rates (Hazin et al., 2005).

Most fishes and crustaceans show behavioural responses to variations in ambient light levels. Thus, artificial light could be an efficient stimulus source to manipulate behaviours in marine animals. Krill show vertical migration in response to light (Kaartvedt, 2010), and a laboratory study demonstrated that krill were attracted to broadband (425–700 nm) white and narrow band green (530 nm) light sources (Utne-Palm et al., 2018). The latter study also presented evidence that the tested light sources may have had a weak repulsive effect on cod, but a significant effect was obtained only for the 448 nm light. Krill constitutes an important prey item for cod (Dos Santos and Falk-Petersen, 1989; Dolgov et al., 2011), and Utne-Palm et al. (2018) concluded that an illuminated swarm of krill may produce a strong visual stimulus to foraging cod. In addition, the reaction distance in fish increases with increasing light intensity (Confer et al., 1978; Utne, 1997), and increased visibility should improve the ability of cod to capture active prey items. Cod has a dichromatic vision and is most sensitive to light in the range of 450–550 nm (Anthony and Hawkins, 1983; Bowmaker, 1990). Furthermore, prey movement has been shown to increase prey detection distance and a predator’s willingness to attack (Scott, 1987; Crowl, 1989; Utne-Palm, 1999; Utne-Palm, 2000).

On the basis of our current knowledge of how prey and predator respond to light and the behavioural responses in cod towards pots, we hypothesize that more cod will enter and fewer will escape baited pots with artificial light due to the accumulation of swarming krill. Thus, we compared the capture efficiency of baited cod pots with and without an artificial light source. We also determined the efficiency of artificial light in attracting krill by comparing the catches of krill in traps equipped with the same light source. Thysanoessa inermis has a visual spectral sensitivity curve that peaks at 470–490 nm (Figure 2 in Cohen et al., 2015), which is similar to many other mesopelagic crustaceans including the krill species Meganyctiphanes norvegica (Frank and Widder, 1999). The latter species have been shown to increase their swimming activity with increasing light intensity (Utne-Palm et al., 2018). The efficiency of a green light source previously proved to demonstrate increased catch rates (Bryhn et al., 2014) and white light of two intensities in attracting krill and catching cod were therefore tested.

**Material and methods**

The experiments were carried out in the Ramfjord (Troms, northern Norway, 69°32‘28.4”N 19°34’7”E) in September 2016. The bottom set version of the two-chamber cod pot described in detail by Furevik et al. (2008) was used. The pot is collapsible and when unfolded it is 100 cm wide, 150 cm long and 120 cm high. The pot has two wide entrances (25 × 15 cm) that lead into the lower chamber, and a single narrow entrance between the lower and upper chambers. The pots were baited with three frozen squid (Illex sp., ∼500 g in total) cut into five pieces and placed in a bait bag suspended in the lower chamber.

Three pots with artificial light and bait and three pots with only bait were attached alternately to a common ground rope at intervals of ∼50 m, giving a distance of ∼100 m between lights. Four fleets, each of six pots, were set each evening and hauled the next morning (∼14–16 h soak time), with each fleet was set at a minimum 150 m apart from each other. Three different light sources were tested. Green and white fishing lights [used for swordfish and tuna longline (www.artisanalfish.com), and hereafter referred to as “weak green” and “weak white”), were mounted by the bait bag in the same manner as in a previous study from the Baltic sea (Bryhn et al., 2014). Intense white light was produced by mounting a diving torch (Brinyte DIV01, 1050 lumen, www.brinyte.com) hanging centrally from the roof in the upper chamber of the pot, pointing towards the bait bag.

The intensity (irradiance, mW m⁻² nm⁻¹) of the three different light sources was measured using a Trios RAMSES ACC hyperspectral radiometer (sensitivity at 4.0 × 10⁻¹¹ W m⁻² nm⁻¹, Figure 1). The light sources were positioned 70 cm from the light meter with the strongest beam pointing towards the sensor on the radiometer. The intense white light, weak white light and weak green light had an integrated intensity of 9744, 23, and 8 mW m⁻², respectively.

In the field, a profile of the ambient light from the surface to 100 m depth was measured twice, once during daytime in broad daylight between 12:00–13:00 and later the same day after sunset in darkness between 21:30 and 22:00. During daytime integrated intensity was below 1 mW m⁻² at 70 m and below 0.1 mW m⁻² at 100 m. At night, integrated intensity was below 0.1 mW m⁻² at all depths. Measurements were made centrally in the experimental area near the pots. Vessel lights were shut off during light measurements. A preliminary trial conducted in September 2015 showed that light emitted from the weak green light could not be detected with the radiometer (i.e. <0.006 mW m⁻² nm⁻¹) at a distance of 5 m from the light source. During these measurements, the radiometer was placed at a depth of 65 m pointing upwards, with the light hung above the radiometer.
Artificial light in baited pots substantially increases the catch of cod

Figure 1. Wavelength distribution for the three lights tested and associated wavelength sensitivity curve for krill (Thysanoessa inermis). The latter is redrawn from Cohen et al. (2015, Figure 2). Note different y-scales.

measurements were taken between 22:00 and 23:00 in the evening.

The current speed and temperature were recorded throughout the experimental period every 5 min, using a SD-1000 (Sensordata A/S) current meter, suspended 1 m above the seabed. The current meter was placed centrally in the fjord at a depth of 123 m, close to the pots. The mean current speed was 1.3 m s$^{-1}$ (SD 0.82). The temperature was stable at 5.4°C (SD 0.05).

A total of 39 fleets were set (i.e. 234 pots) at depths of 115–137 m. A Go-Pro camera was mounted in some of the pots containing the intense light source to observe krill attraction and cod behaviour. The weak green and weak white lights were too dim for effective video recording by the Go-Pro camera. During hauling, the number of cod caught was recorded and the total length (TL) of all cod were measured. A total of 476 cod were randomly sampled from the catch and examined for stomach contents. The presence/absence of higher order taxa were recorded for all fish sampled to get a broad overview of their feeding preferences. The last 272 of these 476 cod were also examined for their stomach fullness. The stomach fullness was visually determined and categorized as “empty”, “some”, “half” and “full”.

The efficiency of the intense white light and the weak green light in attracting krill was determined by custom built light traps (Figure 2). The light traps were made of semi-transparent yellow plastic buckets (height 25 cm, diameter 20 cm), which had three entrances made from fully transparent plastic funnels (inner diameter 1.5 cm outer diameter 8 cm, length 6 cm), distributed evenly around the bucket and the centre of each entrance positioned 17 cm from the bottom of the bucket and 27 cm above the seabed. To ensure a stable and reproducible deployment, each trap had a float (with 0.5 kg buoyancy) fitted to the bucket lid and a 2 kg weight suspended on a 10 cm long rope below the bucket. The lights were attached in the same way as in the pots, either from the roof of the trap for the intense light or centrally for the weak light. The traps were deployed in the evening at a depth of 120–124 m after the fish pot deployment and hauled after pot retrieval the following day (soak time 14–16 h). Traps were set in pairs at a minimum distance of 200 m from each other and at a minimum distance of 500 m from the fish pots to avoid any interference. A total of five paired comparisons were made. Weak white light vs. weak green light were initially also planned to be tested, however the area chosen for this comparison yielded catches too low to allow comparison. The catches of krill were frozen and later analysed for species composition and wet weight.

Statistical analysis
Nonparametric Wilcoxon pairwise tests, using the sum of the three control pots and three experimental pots in each fleet as a pair, were used to test differences between control and experimental pots catch rates. Comparisons were made for all fish lengths pooled and for fish above and below minimum landing size [MLS = 44 cm TL]. Weight calculations were made based on length after Jørgensen (1992):

\[
\text{Weight (kg)} = 0.000009 \times TL^3 \text{(cm)}
\]

To test for differences in length distributions between experimental and control pots a Kolmogorov–Smirnov test was used. Stomach content and fullness was tested using a Fisher exact test (chi-square) with simulated p-values to test for independence amongst control and experimental treatments. Post-hoc tests (Pairwise test of independence for nominal data, using Fisher’s exact tests) was used to assess which experimental and control stomach samples differed.

Results
The catch rates of cod were affected by artificial light, and this effect was dependent on the type of light source used (Table 1). Pots with the intense white light source had a 17 times higher catch rate (by numbers) than that of control pots (Figure 3, Table 1). For the intense white light source, the effect was significant also when splitting the data according to MLS (Table 1). Mean catch rate per pot was 24.4 kg (SD = 49.7) for the pots with intense white light and 1.3 kg (SD = 3.1) for control pots, respectively. The highest catch in a single pot (47 fish; estimated weight 217 kg) was obtained in a pot equipped with intense white light. This pot was in fleet 80, with a total catch of 426 kg for the three experimental pots, vs. 5 kg for the control pots.

The weak white light had a catch rate about five times higher than the controls (Figure 4, Table 1), whereas the weak green light did not significantly increase the catch (Figure 5, Table 1). Mean catch rate per pot was 3.6 kg (SD = 2.6) for pots with weak white and 0.6 kg (SD = 1.4) for control pots. Maximum catch in a single pot equipped with weak white light was 15.2 kg. Mean catch rate was 2.2 kg (SD = 2.7) for weak green and 2.2 kg (SD = 2.5) for control pots. Maximum catch in a single pot equipped with weak green light was 13.4 kg.

Pots equipped with intense white light caught larger fish than control pots and pots with weak white and green lights. All four combinations had a peak in length distribution around 35 cm, while pots with intense white had a bimodal distribution with a secondary peak at ~75 cm. The length distribution in pots with intense white light was significantly different (p < 0.001) from
those of control pots and pots with weak white and green lights, whereas no differences were found between these three pots ($p > 0.05$) (Figure 6).

Of the cod captured in pots with a light source, 89% of the specimens had stomach contents, whereas for control pots 61% had content. The stomach samples were dominated by krill ($T$. *inermis*) and arrowworm ($S$. *sp.*), with only a few shrimp and small fish found in some samples (<10%). Of the cod caught in pots with light, 83% had krill in their stomachs vs. 42% for control pots, whereas for arrowworm this figure was 41% vs. 1%. There were significant differences in stomach fullness between experimental treatments and control (Table 2). The majority of cod caught in pots with white light, regardless of intensity, had stomachs that were full. There was also an indication that weak green light led to increased stomach fullness compared with control pots, but this difference was not significant. There were no indications of differences in stomach content or fullness between small and large cod.

The video showed that krill and arrowworms were attracted by the intense white light source. A dense swarm accumulated around the light within minutes of the pot being set on the seabed (see Supplementary Material). Cod inside the pot were observed feeding on these prey items.

The catches in the light traps were dominated by krill and arrow-worms, which in most cases constituted >99% of the total

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**Table 1.** Catch in numbers given as mean sum per fleet and mean per pot (in parentheses), for pots equipped with different types of light vs. control pots.

<table>
<thead>
<tr>
<th>Light tested</th>
<th>Fish length</th>
<th>N</th>
<th>Light</th>
<th>Control</th>
<th>Factor</th>
<th>W fleets (pots)</th>
<th>W-statistic</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intense white</td>
<td>All</td>
<td>33.9</td>
<td>2.0</td>
<td>17.0</td>
<td>11 (66)</td>
<td>0.0</td>
<td>0.001</td>
<td></td>
</tr>
<tr>
<td></td>
<td>≥44 cm</td>
<td>19.4</td>
<td>1.0</td>
<td>19.4</td>
<td>0.0</td>
<td>0.006</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt;44 cm</td>
<td>16.3</td>
<td>1.1</td>
<td>14.9</td>
<td>0.0</td>
<td>0.006</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weak white</td>
<td>All</td>
<td>8.9</td>
<td>1.6</td>
<td>5.4</td>
<td>11 (66)</td>
<td>3.0</td>
<td>0.014</td>
<td></td>
</tr>
<tr>
<td></td>
<td>≥44 cm</td>
<td>2.4</td>
<td>0.7</td>
<td>3.7</td>
<td>10.0</td>
<td>0.151</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt;44 cm</td>
<td>6.9</td>
<td>1.1</td>
<td>6.3</td>
<td>4.0</td>
<td>0.057</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weak green</td>
<td>All</td>
<td>8.3</td>
<td>9.5</td>
<td>0.9</td>
<td>17 (102)</td>
<td>108</td>
<td>0.141</td>
<td></td>
</tr>
<tr>
<td></td>
<td>≥44 cm</td>
<td>2.1</td>
<td>2.2</td>
<td>1.0</td>
<td>23.5</td>
<td>0.951</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt;44 cm</td>
<td>6.7</td>
<td>7.8</td>
<td>0.9</td>
<td>95.5</td>
<td>0.161</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Data and tests combined for all lengths and at lengths above and under minimum landing size. W statistic and $p$ values were calculated using a paired Wilcoxon test (one pair per fleet). Factor given as catch in number in light pots divided by catch in control pots per fleet.
Artificial light in baited pots substantially increases the catch of cod

Discussion

Artificial light had a pronounced effect on the catching efficiency of baited cod pots. The light source of highest intensity gave larger increases in catch rates compared with the light sources of lower intensity, and the high-intensity source was also more efficient in attracting krill and arrowworms. Also, cod caught in pots with light had more krill and arrowworms in their stomachs, and were observed feeding on these prey inside the pot. Thus, it is

catch. Traps with intense white light caught substantially more krill and arrowworms than traps with weak green light (mean catches: 1003 g and 3 g, respectively).

Table 2. Comparison of percentage stomach fullness for cod by pot types.

<table>
<thead>
<tr>
<th>Pot type</th>
<th>n-Fish</th>
<th>Empty</th>
<th>Some</th>
<th>Half</th>
<th>Full</th>
<th>Significance*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>53</td>
<td>25</td>
<td>34</td>
<td>21</td>
<td>21</td>
<td>a</td>
</tr>
<tr>
<td>Intense white</td>
<td>138</td>
<td>3</td>
<td>6</td>
<td>18</td>
<td>73</td>
<td>b</td>
</tr>
<tr>
<td>Weak white</td>
<td>55</td>
<td>4</td>
<td>5</td>
<td>18</td>
<td>73</td>
<td>b</td>
</tr>
<tr>
<td>Weak green</td>
<td>26</td>
<td>19</td>
<td>12</td>
<td>31</td>
<td>38</td>
<td>a</td>
</tr>
</tbody>
</table>

Groups sharing a letter are not significantly different (alpha = 0.05).
likely that cod were motivated to swim into the pots by the dense swarms of prey and not the light per se as cod has been shown in a laboratory experiment to be indifferent to a light source alone (Utne-Palm et al., 2018). Artificial light was shown to increase the catch rates of swordfish in pelagic longlining (Hazin et al., 2005). It was unclear whether the light attracted swordfish themselves or small prey (fish and squid), upon which swordfish feed. The authors stated that it is likely that the light source functions in part by attracting prey items, and their movement around the light may be critical to the capture of swordfish.

We demonstrated that the light source of highest intensity gave a 17-fold increase in catch rate, the weak white light a five-fold increase, and the weak green light had no effect. The green light has a lower intensity than the weaker white light, while both white lights and the green light have wavelength distributions that overlap with the sensitivity curve of the krill’s visual pigments (Figure 1). Thus, our findings are most likely explained by the difference in light intensity between the light sources tested and not by the difference in wavelength (i.e. colour). The high-intensity light source attracted much more zooplankton to our light traps than the weak green light; in particular krill, which is an important prey for cod (Eriksen and Dalpadado, 2011; Johannesen et al., 2012). Furthermore, a larger proportion of cod caught in pots with the two white light sources had stomachs that were full compared with cod caught in pots with the weaker green light (Table 2).

The effective footprint and catchment of intense lights covers a wider area and volume than the weaker lights, because the light emanating from increasingly more intense lights can travel further from the light source before being attenuated to an intensity that is too low to be detectable and stimulating to the prey or cod. Thus, we conclude that light sources of increasing intensity attract more krill leading to increased catch rates when used in cod pots. However, there is also likely to be a maximum intensity at which the light source becomes repulsive in the near-field and may thus preclude cod from entering the pots.

Cod is a light sensitive species and even larvae are able to feed by sight in light levels as low as 10^{-6} W m^{-2} (Vollset et al., 2011). The detection and reaction distance of an approaching cod, to light stimuli was not investigated in this study. However, preliminary trials demonstrated that the weak green light was not detectable by the radiometer at a distance of 5 m (with a sensitivity of 4 × 10^{-7} W m^{-2} nm^{-1}). Furthermore, the distance between any light being on the same fleet was ~100 m, and between fleets a minimum of 150 m. Thus, implying the effective footprint of the weak green lights was far less than the distance to the control pots. However, we did not change the experimental design during the trials when testing more powerful lights, nor did we measure the detectable distance of the light emitted from these more powerful lights. It would be informative for future research to investigate the behaviour of cod, including detection and reaction distance, when approaching artificial light stimuli; from different light sources under a range of ambient optical and lighting conditions.

The spectral distributions (Figure 1) show that none of the light sources had an optimal overlap with the sensitivity curve of krill. Thus, considerable savings on energy consumption could probably be obtained by tailoring lights for krill attraction by matching its sensitivity curve.

We did not find an effect of weak green light in our study at soak times of 14–16 h. In the study by Bryhn et al. (2014), at the resolution of 1–2 days soak time, they found that green lights had an effect in one of the two locations studied, while at 1–14 days soak time combined, an effect was found at both locations. The authors suggested that differences in prey availability and visibility between the two locations could be an explanation. Königson et al. (2015) also found that catches peaked at 6 days soak time even without light, and thus future experiments should focus on both investigating the optimum soak time with and without lights. The rationale for using only short soak times in our study was due to limited ship time available and the need for increasing the number of replicates.

Behavioural observations of cod have shown that only 9–11% of the fish that approached a baited pot entered the funnel and became caught (Anders et al., 2016; Ljungberg et al., 2016). The large proportion of fish that turned away from the pot was explained by cod being reluctant to enter funnels as the pot and its funnel likely represent a novel object (Ljungberg et al., 2016). This restrained response to enter a pot requires higher individual motivation to counteract it. When approaching a baited fishing gear, cod display chemically stimulated rheotaxis, which reflects foraging behaviour (Løkkeborg, 1998; Løkkeborg and Ferno, 1999). Food search and capture are based on a multitude of stimuli involving several sensory modalities (vision, olfaction, hearing, lateral line organ), and an array of different stimuli may have an additive/compound effect (Løkkeborg et al., 2010). The fish must integrate stimuli from different sensory channels before a response is triggered, and the combination of bait odour and visual stimuli might motivate more fish to enter a pot. Krill constitutes an important prey item for cod, and our findings demonstrated that an illuminated swarm of krill produced a strong visual stimulus that counteracted the restrained response in foraging cod to enter pots.

Pots equipped with intense white light caught larger fish than control pots and the two other light-bait combinations (Figure 6). This is supported by the results of Bryhn et al. (2014), who observed catch difference between test pots and control pots only for cod above MLS (38 cm). Contrary to Bryhn et al. (2014), we found increased catch in test pots both above and below MLS for intense lights, however the effect was larger for larger cod (Table 1). One explanation could be that larger fish find entering the pot physically more restricting due to the relatively narrow circumference of the entrance (15 cm height, 25 cm wide) and hence require a stronger motivational stimulus to enter. Another explanation would be that larger fish might see smaller fish in the pot more easily when there is light and then become more tempted to enter to prey on them. Aggressive behaviour with larger specimens of cod attacking and preying on smaller cod and saithe (Pollachius virens) inside pots has been observed (Bagdonas et al., 2012). This could potentially scare off smaller fish from entering once a large potential predator is inside the pot (High and Beardsley, 1970; Anders et al., 2017) and further decrease the number of smaller individuals by more escape attempts in the presence of a predator (Hartsuiker and Nicholson, 1981).

Vision is important in pursuit predation and the artificial light may have improved the capture success of the fish. In addition to attracting krill and arrowworm, the artificial light makes these prey items more visible to foraging cod. Increased visibility should improve the ability of cod to capture active prey, and prey movement has been found to increase a predator’s motivation to attack (Scott, 1987; Crowl, 1989; Utne-Palm, 1999, 2000). Furthermore, the reaction distance in fish increases with
increasing light intensity (Confer et al., 1978; Utne, 1997) and prey movement (Utne-Palm, 1999). Thus, we conclude that artificial light has an important role in increasing the catching efficiency of pots. First, the light attracts and aggregates a dense swarm of active prey items. Second, the illumination improves the ability of cod to detect and capture the prey, which provides sufficient motivation for the fish to enter and remain in a novel environment: the pot.

This study was conducted in a sheltered fjord, and a prerequisite for artificial light to increase catch rates is the concurrent presence of both cod and krill. Krill are largely distributed in the Barents Sea and along the coast (Eriksen and Dalpadado, 2011), and studies have shown that krill under certain conditions is an important prey also for large specimens of cod (Dos Santos and Falk-Petersen, 1989), which is an opportunistic predator (Link and Garrison, 2002). Furthermore, under strong current conditions planktonic prey, such as krill and arrow-worms, are not able to aggregate in the light. The application of this method thus relies on a spatial and temporal overlap in distribution of cod and krill in concert with low or moderate current velocity, which is not likely to occur in all habitats inhabited by cod. Therefore, the application of our findings in fisheries carried out in other areas and seasons needs further investigation.

**Supplementary data**

Supplementary material is available at the ICES/JMS online version of the manuscript.

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