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Catches in abandoned snow crab (*Chionoecetes opilio*) pots in the Barents Sea

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ABSTRACT

During a 2018 retrieval cruise for abandoned snow crab (*Chionoecetes opilio*) pots in the Barents Sea, approximately 8600 pots abandoned 1.5 years earlier were recovered. Forty-three percent of a subsample of 1000 pots contained snow crabs, with an average of three crabs per pot. Most of the crabs were alive (~98%) and dominated by large males. Pinch injuries and limb loss were common and tended to decline with increasing crab size. Reflex testing showed that the crabs were vital (i.e. the crabs moved their legs, chelipeds and maxillipeds when stimulated), which was supported by a relatively high meat content. However, energy reserves in the digestive glands (hepatopancreas reserves) were low, indicating overall energy deficiencies. Our results indicate considerable unaccounted mortality due to self-baiting, continued catch and cannibalism. The findings demonstrate that snow crab pots which are lost or abandoned in the Barents Sea fishery maintain huge potential for ghost-fishing impacts.

1. Introduction

Abandoned, lost, or otherwise discarded fishing gear (ALDFG) is a worldwide environmental and socioeconomic problem that is of great concern for fisheries sustainability (Macfadyen et al., 2009; Gilman, 2015; Richardson et al., 2019). Globally, derelict pots are a prevalent form of ALDFG, and they have significant negative ecological impacts (Hebert et al., 2001; Bilkovic et al., 2014; DelBene et al., 2019). The impacts of ALDFG include continued catch of target and non-target species (ghost fishing), alterations to the benthic environment, introduction of synthetic material into the marine food web, hazards to navigation and safety at sea and financial costs associated with gear loss and retrieval (Macfadyen et al., 2009). Factors that cause fishing gear to be abandoned or lost may include illegal fishing, adverse weather conditions (including arctic sea ice), gear conflicts, and maritime traffic (Gilman, 2015).

The snow crab (*Chionoecetes opilio*) population in the Barents Sea became viable for commercial fishing relatively recently. Snow crab was first observed at the Goose Bank in the Russian part of the Barents Sea in 1996 (Kuzmin et al., 1999). The highest densities of snow crabs are still found in the eastern part of the Barents Sea, where it inhabits muddy and sandy grounds at depths around 200 to 400 m (Alvsvåg et al., 2009; Agnalt et al., 2011). The hydrological conditions suitable for snow crabs are optimal in many parts of the Barents Sea, and in recent years the population has extensively expanded westward (Siikavuopio et al., 2019a; Zakharov et al., 2020).

Thus, in 2012 a new fishery for snow crabs was established in central parts of the Barents Sea, a region actively fished by Norwegian fishers. The Norwegian snow crab fishery has shown rapid growth from 2 tons landed in 2012 to about 4300 tons in 2020 (Norwegian Fishermen's Sales Organization). The fishery is expected to continue to grow, and the total allowable catch for 2021 is set at 6500 tons. With the steady expansion of this fishery and improvements in the lifespan of synthetic materials, potential impacts of ghost fishing in this harsh and vulnerable environment may become a serious ecological problem.

Conical pots are commonly used in the commercial snow crab fisheries in the Barents Sea. They were adopted from the practices of other snow crab fisheries, mainly those in Newfoundland and Labrador in

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Canada (Nguyen et al., 2019). A single Norwegian snow crab vessel may set and retrieve 1500 pots per day in strings of 200–400 pots and operate up to 9000 pots with a maximum soak time of three weeks (Lorentzen et al., 2018). The Norwegian Directorate of Fisheries carries out an annual gear retrieval program, and about 1200 and 2400 abandoned snow crab pots were retrieved in the Barents Sea in 2019 and 2020, respectively. The high numbers of retrieved crab pots suggest that ghost fishing is already a severe problem in this fishery.

A ghost fishing experiment carried out in the Gulf of St. Lawrence (Canada) showed that deliberately abandoned snow crab pots captured crabs to their saturation level during the summer season (Hebert et al., 2001). The number of crabs then slowly decreased due to cannibalism and predation, before self-baiting re-initiated a new ghost fishing cycle the following spring. The mortality rate of snow crabs trapped in the pots was estimated at 95% per year. Crab ghost-fishing impacts additionally include welfare issues such as starvation and predation (Siikavuopio et al., 2017, 2019b) which lead to unaccounted mortality.

In 2016, approximately 9000 snow crab pots were abandoned in the Barents Sea due to a legal dispute regarding fishing rights. A retrieval cruise was carried out by the Norwegian Directorate of Fisheries in June 2018, with the main objective to retrieve the pots to remove marine litter and prevent further potential ghost fishing (Langedal and Kalvenes, 2018). This occasion provided a rare and unique opportunity to assess the consequences of prolonged soak time of abandoned pots. An observer from the Institute of Marine Research participated in the cruise to sample data to obtain detailed information about the catches with regards to species, numbers, and sizes. Subsamples were taken to assess injuries, vitality, meat content, and internal status of the crabs.

2. Materials and methods

2.1. Collection period, area, vessel, and pot retrieval

The retrieval cruise was carried out onboard the fishing vessel *M/S Morten Einar* (67.5 m LOA) in the central Barents Sea (Fig. 1) from 1 to 20 June 2018. Start and stop positions for each abandoned fleet (string) of pots were available from the Norwegian coast guard (i.e. the positions where the pots were deployed by the original fishing vessel). However, due to the wear and tear after extended soak time, only a few of the surface buoys remained. Thus, a grapnel gear consisting of an anchor and 5 m of chain was attached to a trawl warp and used to retrieve the abandoned fleets. The vessel was positioned upstream from the fleet, approximately at the middle of the start/stop positions. The grapnel gear was dropped via a snatch block from the starboard ship side to the sea bottom, and the vessel then drifted at a speed of 1.5–2.5 knots perpendicular and across the fleet until it was hooked. Hooking was registered by the increased warp tension and drop in vessel speed. The duration until hooking varied between 20 and 40 min for each trial.

Upon surfacing, the ground rope was cut and a surface buoy attached to one end of the cut rope. The other end was attached to a trawl drum via a snatch block so that the line could be hauled onboard the vessel. Next, the previously released surface buoy was retrieved and the second part of the fleet was hauled onboard. Once hauling of pots started, a new pot was retrieved approximately every 30 s. Quick release of crabs back into the sea was obtained by cutting loose the bottom lock rope and releasing the catch while the pots were hanging over the water.

Subsamples of pots were taken and emptied onto the deck to obtain detailed catch data (see below). Counts of pots, length of rope, and any other debris were recorded. The pots had a section sewn with an approximately 5 mm thick cotton twine resembling the rot thread used in pots to avoid ghost fishing in Canada (Winger et al., 2015). Threads from 25 pots were sampled and tested in the laboratory for their breaking strength using a digital tensiometer (Sauter model FH 1K, max 1000 N, KERN & SOHN GmbH, Balingen, Germany).

2.2. Observer data collection

Subsamples were taken, as all data were recorded by the same observer, with 32 unique fleets subsampled. Seventeen fleets of pots were subsampled to determine the number of crabs found within each

Table 1
Summary of data collection (CPUE = catch per unit effort (number of crabs per pot), CW = carapace width, HI = hepatopancreas index, MC = meat content).

Datasets	Stations	Pots	Number of crabs
CPUE	17	1000	2971
Size distribution (CW)	12	131	825
Injuries, HI, MC, and stomach contents	4	28	109
Vitality and shell age	12	216	216

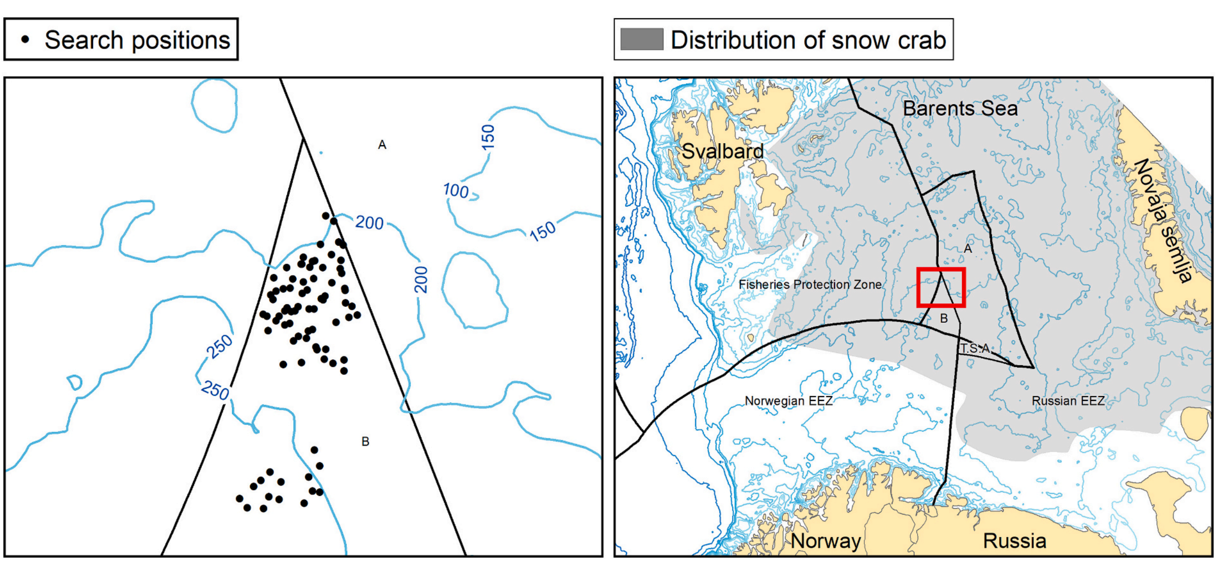

Fig. 1. Left: Positions of abandoned snow crab fleets in the central Barents Sea. Right: Study area (in red) and distribution of snow crab in the Barents Sea (shaded). A: Russian part of the Loophole, B: Norwegian part of the Loophole. The Loophole is international waters, however snowcrab is a sedentary species and adhere to the continental shelf of Norway and Russia (Hansen, 2016; Bertheussen et al., 2020). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

pot (i.e. CPUE) and their associated conditions (Table 1). The condition of the crabs was recorded as either alive, dead, or shell fragments. Numbers of bycatch species were also noted. Crab size and sex distribution were collected from twelve fleets sampled. Carapace width (CW) was measured to the nearest mm using a Vernier calliper with an accuracy of 0.1 mm. Samples frozen for later analyses of injuries, macroscopic stomach contents, hepatopancreas index (HI), and meat content (MC) were collected from four fleets. Injury assessment of limb loss, pinch marks, and tip loss was conducted by visual inspection using a quantitative scoring system (Siikavuopio et al., 2017). All limbs were included in the scoring scheme. HI and MC were determined for the same frozen samples used for injury assessment. HI was calculated as HI $= (H / W) \times 100$, where H is the weight of hepatopancreas and W is the live weight of the crab. The MC of boiled legs was measured by analysing images of cross sections in the middle of the merus, and is expressed as: MC (%) $=$ (Area occupied by meat / Total inner area) $\times$ 100.

Crab vitality (the state of being active) was tested using reflex action tests (Stoner et al., 2008; Stoner, 2009; James et al., 2019). Six tests were initially included, however one test (eye reflex) could not be used due to inconsistency in observations and methodology during preliminary onboard testing. Four of the tests (leg flare, chela closure, mouth closure, ventral flap) are described in Stoner et al. (2008) and James et al. (2019). The other test (chela lift) was added due to frequent observation of its occurrence during the preliminary testing. These tests are described below the following paragraph.

Immediately after retrieval of a pot, a crab was sampled from the pot and tested. Only one crab per pot was tested to avoid any additional stress from air exposure, temperature shifts, and handling. All crabs were tested within 1 min. Crabs were selected to obtain a wide range of sizes. The reflexes tested were given a score of one if present and zero if absent (impaired) as follows:

1. Leg flare: Lift the crab by the carapace with the dorsum facing up. Response: legs move and spread (1); legs hang motionless (0).
2. Chela lift: Lift the crab as described above. Response: chela (claw) moves and lifts to horizontal orientation or higher (1); chela hangs motionless (0).
3. Chela closure: Lift the crab as described above and stimulate the chela by touch. Response: chela opens and closes without or with stimulation (1); chela does not respond to lift or stimulation (0).
4. Mouth closure: Lift the crab as described above. If the mouth is closed, attempt to draw the third maxillipeds (one of the mouth appendages) downwards with a dissecting probe; if the mouth is open, draw the maxillipeds downward. Response: maxillipeds retract to cover the smaller mouth parts, droop open, or move in agitated manner (1); no motion after removing the probe (0).
5. Ventral flap (ventral kick in Stoner et al., 2008): Lift the crab by the carapace with the ventral (abdominal) side facing up. With a dissecting probe, lift the abdominal flap away from the body. Response: motion and agitation of legs or chelipeds (1); no motion of legs or chelipeds (0).

Approximation of time since last moult (shell age 0–5) was determined using the Institute of Marine Research protocol for shell age determination and Biological Field Techniques for Chionoecetes Crabs (Jadamec et al., 1999). Category 1 is characterized by a soft shell (4–6 weeks since moulting); category 2 is characterized by a hard clean shell (3–12 months); category 3 is characterized by a hard clean shell with some biofouling (1–2 years); category 4 is characterized by a hard shell with substantial biofouling (3–4 years); and category 5 is a characterized by leathery and soft discoloured shell (5+ years).

2.3. Data analyses

All statistical analyses were carried out using the R statistical computing language and environment (R Core Team, 2020). To analyse relationships between injuries and crab size (CW), generalized linear models (GLM) were applied. Pinch marks, limb loss, tip loss, and injury score (sum of the first three) are count data and thus were analysed accordingly using the negative binomial GLM. HI was analysed by applying a conventional linear regression. Percentages are typically analysed using a GLM with a binomial distribution (Zuur et al., 2009). MC proportions were thus analysed as binary data. A quasi-binomial GLM with a logit link was applied to account for overdispersion in the MC data. The linear components for the models were $\alpha + \beta \times$ CW, and we investigated size-dependency of injuries by testing whether the slope parameter β deviated from zero (H_0: $\beta = 0$ vs. H_1: $\beta \neq 0$). Relationships between vitality scores, CW, limb loss, and shell age were assessed by visual inspection of pairwise plots and linear regressions.

3. Results

3.1. Gear retrieval

Of the 80 total fleet positions where recovery efforts occurred, 75 abandoned fleets were successfully retrieved from 82 retrieval attempts. Approximately 8600 pots were retrieved, and all fleets contained pots with crabs. In total, 270 km of rope, 50 surface buoys, and more than 100 anchors were also retrieved (Langedal and Kalvenes, 2018).

The retrieved pots (Fig. 2) were of a conical type resembling the ones used by the Norwegian fleet (Nguyen et al., 2019) in the Barents Sea. None of the rot threads (obtained from 25 pots) were broken after 1.5 years in the sea. A large variation was observed in the threads examined, with a mean breaking strength of 17 kg (Table 2).

3.2. Catch statistics

Catch data were obtained from 17 fleets of recovered pots, and all recovered fleets contained snow crabs. Crabs were found in 43% of the pots recovered from these fleets. In total, 2971 snow crabs were caught, with an average of three crabs per pot (Table 3). Variations were also observed both between fleets of recovered pots, and between recovered pots within individual fleets. Eleven percent of all pots recovered contained more than 10 crabs, with a maximum of 41 crabs found within a single pot (Table 4). The catches were dominated by large males with a mean carapace width of 112 mm (Fig. 3). About 15% of the catch was below minimum landing size (100 mm). Only one female was observed in the subsample of almost 3000 individuals. Most of the snow crabs were alive (98%), and dead crabs (~2%) and shell fragments (empty carapaces) were scarce (<0.5%). Non-target species were mainly catfish (n = 94) and flatfish (n = 18).

3.3. Injuries, MC, and HI

Only 1 crab out of 109 examined from the pot retrieval efforts was found to be completely flawless (i.e. no injuries). Pinch injuries were the most commonly observed type of injury, and were observed in 96% of all crabs sampled, followed by tip loss (69%) and limb loss (60%). The number of pinch marks varied from 0 to 9 (mean = 3.3, median = 3), limb loss from 0 to 7 (mean = 1.25, median = 1), and tip loss from 0 to 9 (mean = 2.3, median = 1) (Table 5). The three injuries combined for a total injury score ranged from 0 to 15 (mean = 6.8, median = 6). All categories of injury tended to decrease with CW (Fig. 4, Table 5). This trend was statistically significant for the total injury score ($\beta = -0.087$, $p = 0.018$) and limb loss ($\beta = -0.31, p < 0.001$), but not for pinch marks ($\beta = -0.05$, $p = 0.22$) and tip loss ($\beta = -0.025$, $p = 0.75$).

MC was high on average, varying from 37.8 to 100% (mean = 83% ± 17% SD, Table 5). The HI index was low (mean = 2.3 ± 0.8 SD, Table 5), varying from 0.8 to 5.5, which suggests that many crabs were in an energy deficit. MC increased significantly with crab size ($\beta = 0.22$, $p = 0.011$) (Fig. 4, Table 5). HI showed the same trend, but this relationship was not statistically significant ($\beta = 0.082$, $p = 0.15$).

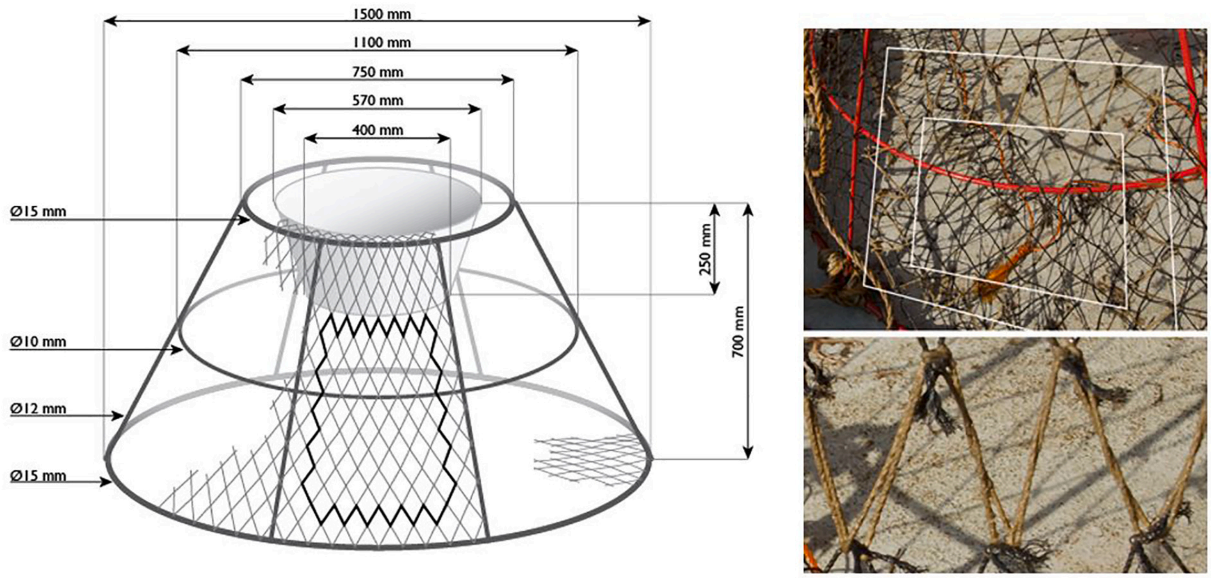

Fig. 2. Left: Dimension of the retrieved pots resembling the ones used by the Norwegian fishing fleet (Nguyen et al., 2019). Right: All pots had sections of the pot cut loose and sewn using a different twine of 5 mm diameter. Sections like these are normally sewn with biodegradable twine as a measure to prevent ghost fishing (Winger et al., 2015).

Table 2
Breaking strength in N (kg in parentheses) of the 5 mm twine rot threads sewn into the pots.

Mean	SD	Min	Max	n
167 (17)	131 (13)	34 (3)	534 (54)	25

3.4. Stomach content

Fifty-six percent of the crab stomachs examined were found to contain some type of stomach contents (including either plastic or shell fragments, unidentified biological material, or other unidentified non-biological material, Table 6). Apart from plastic and shell fragments, the content could not be identified other than stating if it was or was not clearly biological material.

3.5. Vitality and shell age

The reflex testing showed that in general the crabs were in very good condition, with a mean reflex of 4.64 out of a possible 5 (Table 7). The majority of the crabs (>70%) showed a positive response in all reflex tests, and only a few crabs (<10%) scored ≤3. Shell age was dominated by category 2 (~12 months since moulting), with an average of 2.32 (0.48 SD, Table 7). No significant relationship was observed between either crab size and reflex impairment, or crab size and shell age ($p > 0.05$).

Table 4
Percentage of pots within a given crab catch interval.

n crabs	% pots
0	57.1%
1–10	31.9%
11–20	8.9%
21–30	1.8%
31–41	0.3%

Table 3
Summary catch statistics for each station.

Station	n pots	n pots with crab	% pots with crab	n crab	CPUE	SD	n alive	% alive	n dead	n carapax
4	130	41	32%	324	2.49	5.52	316	98%	8	0
6	60	13	22%	28	0.47	1.17	28	100%	0	0
7	44	8	18%	99	2.25	6.72	98	99%	1	1
9	90	27	30%	87	0.97	3.04	84	97%	3	0
10	21	10	48%	129	6.14	8.98	121	94%	8	0
13	30	5	17%	14	0.47	1.53	14	100%	0	0
14	92	12	13%	19	0.21	0.6	19	100%	0	0
17	114	86	75%	843	7.39	6.55	828	98%	15	0
18	29	13	45%	74	2.55	4.62	74	100%	0	0
19	24	18	75%	170	7.08	6.74	144	85%	26	0
20	120	73	61%	457	3.81	4.85	455	100%	2	1
23	101	42	42%	100	0.99	2.05	100	100%	0	0
24	29	11	38%	138	4.76	10.4	135	98%	3	0
29	29	9	31%	16	0.55	1.21	16	100%	0	0
30	29	14	48%	31	1.07	1.73	30	97%	1	0
31	29	23	79%	158	5.45	5.08	158	100%	0	0
36	29	24	83%	284	9.79	8.56	284	100%	0	7
Total	1000	429	43% (mean)	2971	2.97 (mean)	5.58 (mean)	2904	98% (mean)	67	9

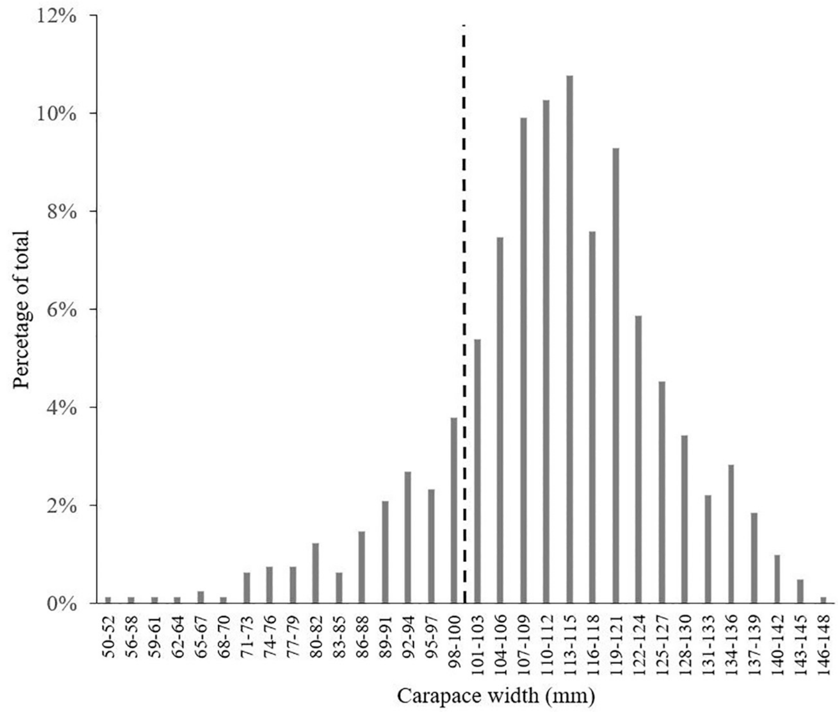

Fig. 3. Size distribution (CW) of snow crab captured in abandoned pots with a soak time of 1.5 years (n = 825). Dashed line indicates minimum landing size (100 mm).

Table 5
Average number of tip loss, average number of limb loss (both walking legs and claws), average number of pinch marks, and associated meat content (MC) and hepatopancreas index (HI) by size (CW).

CW (mm)	Tip loss	SD	Limb loss	SD	Pinch marks	SD	MC (%)	SD	HI	SD
80–90	3.50	2.66	2.50	1.64	2.83	1.33	69.44	19.02	1.96	0.56
90–100	1.70	2.54	2.30	1.89	3.10	2.28	79.42	20.11	2.31	0.82
100–110	2.28	2.42	1.68	1.84	3.88	2.17	80.26	18.42	2.15	0.65
110–120	2.55	2.31	1.00	1.04	3.66	2.02	84.75	18.40	2.38	0.91
120–130	1.88	2.26	0.64	0.70	2.88	2.13	87.47	14.21	2.42	1.01
130–140	1.30	0.95	1.00	1.25	3.10	1.10	80.70	13.76	2.40	0.71
140–150	4.50	3.42	0.25	0.50	1.75	0.50	98.95	2.10	2.59	0.87
Total	2.27	2.35	1.25	1.44	3.31	2.00	83.16	17.40	2.32	0.83

4. Discussion

The magnitudes of the crab catches in recovered abandoned crab pots, with on average three snow crabs found per pot after 1.5 years soak time, demonstrates a high potential for crab pot ghost fishing in the Barents Sea. This catch rate is higher than the average catch rate of approximately two crabs per pot that Nguyen et al. (2019) observed for baited pots in the commercial fishery, although this was considered to be a low catch rate. Our results support those of Hebert et al. (2001) who observed that snow crab pots continued to catch crabs after bait depletion due to the self-baiting effect (i.e., attraction of newly caught individuals to wounded or dead crabs).

The catches in the abandoned pots were dominated by legal-sized males. Only about 15% of the crabs were below minimum landing size compared to 32% in commercial catches (Nguyen et al., 2019). Olsen et al. (2019) found that a soak time of 9 days would be sufficient to achieve the full selectivity potential of snow crab pots. They argued that upon bait depletion, the smallest crabs (including the females) will escape through the meshes. The low proportion of under-sized crabs may also be due to cannibalism (see below). The presence of some smaller crabs in the abandoned pots could result from continued self-baiting. Havens et al. (2008) showed that the occurrence of self-baiting in abandoned blue crab pots doubled their catch rate. Such unaccounted mortalities frequently remove snow crabs that would otherwise contribute to valuable commercial fisheries (Bilkovic et al., 2014).

Most crabs found in the abandoned pots were alive (98%), with reflex tests showing that they were also vital and active. The high reflex value indicates that the crabs were neither weak nor moribund. Few dead crabs and negligible shell fragments indicate that moribund crabs were rapidly preyed upon. We speculate that the absence of dead crabs in the pots means that small crabs were consumed by larger crabs. High frequency of pinch injuries and more frequent limb loss in smaller crabs indicates cannibalism. Our observation of shell fragments in the stomach contents of 38% of the crabs checked supports this premise. Autotomy is well-documented in other crustaceans as a means of avoiding predation or limiting the effects of wounds (Juanes and Smith, 1995; Siikavuopio et al., 2017). Furthermore, shell fragments may have been washed out during gear retrieval, as the hauling process was stopped and re-started every time a pot was taken on board and emptied.

Although vital, most crabs were in energy-deficient, as indicated by the overall low HI index (average 2.3, Table 5). Siikavuopio et al. (2019b) reported an average HI index of 3.2 for snow crabs after 100 days of food deprivation, which was a big decrease from the initial value of 6.2 before starvation. Correspondingly, most of the crabs in our study

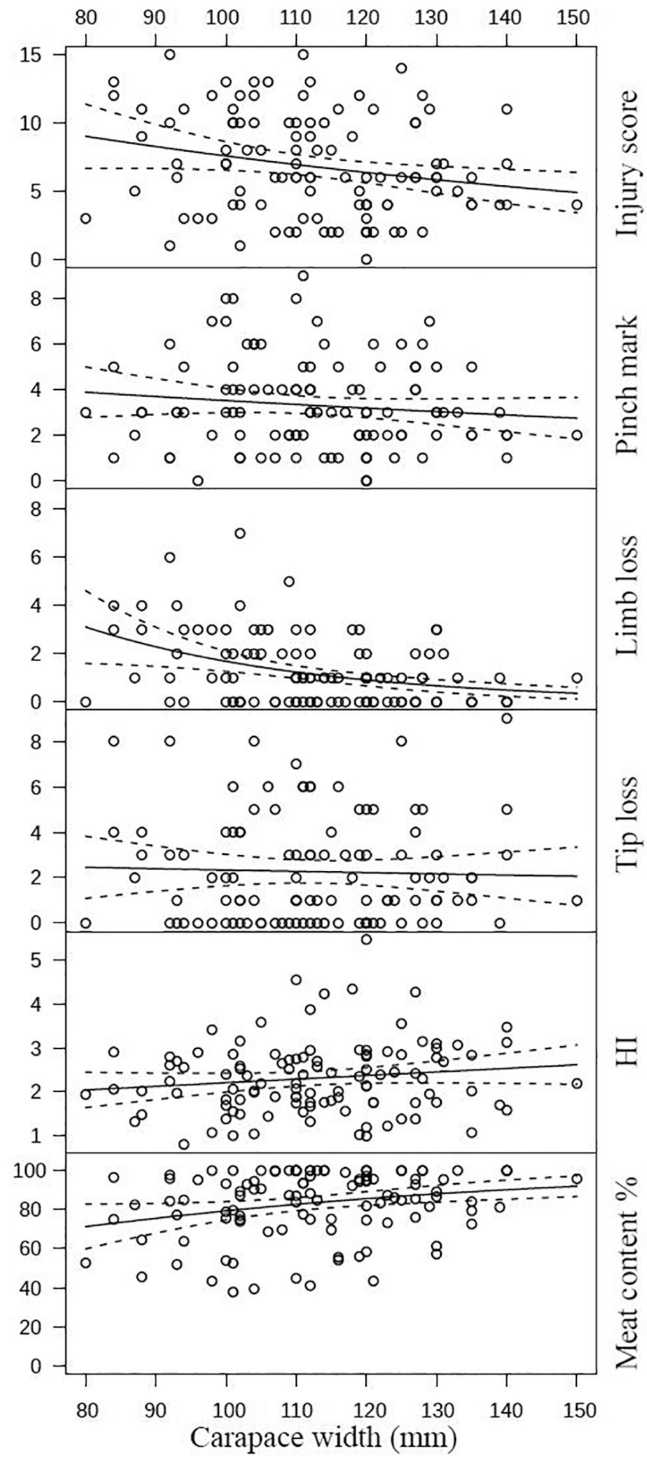

Fig. 4. Injury score, number of pinch marks, number of limb loss, number of tip loss, hepatopancreas index (HI), and meat content by crab size (CW).

Table 6
Occurrence of macroscopic stomach contents.

(n = 45)	Occurrence	%
Content	25	56%
Plastic fragments	4	9%
Shell fragments	17	38%
Unidentified biological material	25	56%
Unidentified non-biological material	9	20%

Table 7
Average of reflex index (0–5) and shell age (0–5) per 10 mm carapace width (CW) size category.

CW (mm)	Reflex index	SD	Shell age	SD	n
50–59	4.50	0.71	2.50	0.71	2
60–69	4.92	0.29	2.00	0.00	12
70–79	4.72	0.53	2.03	0.33	29
80–89	4.68	0.65	2.35	0.49	31
90–99	4.74	0.56	2.42	0.51	19
100–109	4.70	0.56	2.39	0.50	23
110–119	4.25	1.24	2.44	0.51	16
120–129	4.72	0.50	2.35	0.48	43
130–139	4.42	0.83	2.37	0.49	38
140–150	5.00	0.00	3.00	0.00	3
Total	4.64	0.68	2.32	0.48	216

likely spent more than 100 days in the pots, although the HI range (0.8–5.5) also suggests a continuous ingress of crabs. Furthermore, overall MC was high, indicating that starvation had not reached the point at which the crabs were catabolizing their tissues for energy.

5. Concluding remarks

Deliberate, long-term ghost-fishing studies are often considered controversial due to an inherent risk of poor welfare for the captured animals studied. Thus, information about the capture efficiency of abandoned gear and the species and size distribution, fate (including injuries, vitality, and mortality), and welfare of captured animals is scarce. The data obtained from the gear retrieval program examined in this study provided a unique opportunity to investigate these ghost-fishing parameters. However, controlled ghost-fishing experiments in the field and under laboratory conditions are also needed to obtain conclusive data about factors such as cumulative catches, escape rate of captured animals, agonistic behaviour (cannibalism), and food deprivation.

The retrieval cruises carried out by the Norwegian Directorate of Fisheries and the catch rates of abandoned pots documented in this study demonstrate the potential impacts of ghost fishing in the Barents Sea pot fishery for snow crabs if pots are lost or otherwise left to soak for extended periods of time. Although the full scale of the problem is still unknown, measures should be developed and implemented to mitigate impacts of abandoned and lost pots. Efforts should first be made to prevent the occurrence of abandoned pots by identifying the reasons for gear loss (e.g., adverse weather conditions, gear conflicts) and then specifically address each cause. Additionally, technical solutions (e.g., acoustic devices) to locate and retrieve pots lost due to drifting ice and gear conflicts (the two main causes of gear loss, skipper K.O. Pettersen pers. comm.) should be given priority in the Barents Sea pot fishery. Such technical measures can limit but not prevent the occurrence of abandoned pots and additional measures should also be made mandatory. Several technological solutions, usually biodegradable escape panels, have been developed to disable abandoned pots and allow animals to escape (Winger et al., 2015). Mitigation measures to prevent ghost fishing in the Norwegian snow crab fishery are currently not being implemented. However, studies are in progress to identify best practices for this fishery, including underwater acoustic buoys to prevent losses due to drifting ice and pots with biodegradable materials.

CRediT authorship contribution statement

Humborstad Odd-Børre: Conceptualization, Methodology, Writing – original draft. **Krøger Eliassen Lasse:** Investigation, Writing – review & editing. **Siikavuopio Sten:** Methodology, Writing – review & editing. **Løkkeborg Svein:** Writing – review & editing. **Ingolfsson Olafur:** Formal analysis, Writing – review & editing. **Hjelset Ann Merete:** Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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