

The feasibility of escape mechanisms in conical snow crab traps

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Laboratory observations and morphometric measurements of snow crab (*Chionoecetes opilio*) were conducted to examine the feasibility of incorporating rigid escape mechanisms into conical snow crab traps to improve trap selectivity. Under laboratory conditions, undersized adolescent male snow crab (≤ 94 mm carapace width) were capable of detecting, approaching, and interacting with escape mechanisms, and the location of the mechanisms was important in determining the likelihood of escape success. Escape mechanisms mounted low on the exterior wall of the trap received more than three times the number of penetration attempts than those mounted higher, although successful escape rates were very low. There was no difference in behaviour or escape success between traditional mesh traps and experimental wire (Aquamesh[®]) traps fitted with escape mechanisms. Morphometric measurements suggest that an escape diameter of 95 mm would optimize the egress of small crab and prevent the loss of legal-sized crab.

Keywords: conical trap, escape mechanism, size-selectivity, snow crab.

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Introduction

The snow crab (*Chionoecetes opilio*) fishery in Newfoundland and Labrador, Canada, began in the late 1960s, but did not experience significant growth until the 1990s. The total allowable catch (TAC) peaked in 1999 at 61 185 t and, in 2000, reached a landed value of more than CDN \$263 million. Recent indicators of stock decline led the federal Department of Fisheries and Oceans (DFO) to reduce the TACs in subsequent years and implement additional management measures, such as shortened fishing seasons to conserve stock biomass (DFO, 2005). Uncertainty about the survival of undersized adolescent male crab that are not yet recruited to the fishery but are routinely caught and discarded is a concern. Handling-induced mortality of these prerecruits may well have a serious impact on the future fishery. Several reports have recommended that research initiatives focus on trap modifications that reduce the catchability of prerecruits to improve and sustain stock health (Grant, 2003; DFO, 2005; FRCC, 2005).

In Newfoundland and Labrador, snow crabs are currently harvested using Japanese-style conical traps set in longline fleets. Regulations stipulate that meshing on the traps must have a minimum mesh bar length of 6.5 cm, which produces roughly a 13.3 cm stretched mesh (Anon., 1985). Harvesters are permitted to use larger mesh sizes to reduce undersized crab, but this tends to increase the egress and loss of legal-sized crab. Alternative trap designs or selectivity devices that improve the precision of size selectivity would be beneficial.

Escape mechanisms are rigid selectivity devices providing non-targeted individuals that accidentally enter a trap the opportunity to escape voluntarily before the trap is hauled. Size selectivity can be more precise than mesh, owing to the rigid shape of escape

openings, the rigid exoskeleton of decapods, and the dexterity of decapods in orientating themselves in the most advantageous position for escape (Miller, 1990, 1995). They are one of the most common devices used to minimize the capture of undersized animals in decapod fisheries and have proven effective for tanner crab (*C. bairdi*), snow crab, and king crab (*Lithodes* spp.) in the Bering Sea off Alaska (Stevens, 1995; Pengilly, 2000; Byersdorfer and Pengilly, 2001), as well as red king crab (*Paralithodes camtschaticus*) in Norwegian waters (Salthaug and Furevik, 2004).

The purpose of this study was to determine the feasibility of incorporating escape mechanisms into conical snow crab traps to improve trap selectivity. Behavioural observations were conducted under laboratory conditions to investigate whether undersized adolescent male snow crabs [≤ 94 mm carapace width (CW)] were capable of detecting and interacting with escape mechanisms that were installed at different heights in either traditional mesh traps or a prototype wire trap made of Aquamesh[®] material. The effect of escape diameter on size selectivity was assessed through morphometric measurements and the manual insertion of dead crabs through escape openings of different size.

Material and methods

Laboratory observations

Live snow crabs were captured using conical crab traps in Conception Bay, Newfoundland. Water temperature at the capture site was -0.8°C and 13.0°C at the seabed and surface, respectively. Only hard-shelled crabs (80–105 mm CW) that appeared in good physical condition (e.g. no missing limbs) were selected. They were transported to the Northwest Atlantic Fisheries Centre in St John's, Newfoundland, where they were

held in flow-through holding tanks (1.7 m diameter \times 1.5 m depth) with a continuous supply of ambient temperature seawater, and were fed a diet of chopped squid (*Illex illecebrosus*) every few days to satiation. A period of 3 months was permitted for tank adaptation before commencing the experiment in January 2004.

Two types of experimental trap were used in the study: (i) traditional 14.0 cm mesh traps, and (ii) wire traps constructed of 5 \times 5 cm Aquamesh[®] material (Riverdale Mills Corp., USA). Both trap types were comparable in shape and dimension with traps used in the commercial crab fishery in Newfoundland and Labrador.

Escape mechanisms (140 mm width \times 250 mm length) were constructed from black high-density polyethylene plastic (\sim 4 mm thick), with two rigid circular openings with a 95 mm diameter. The mechanisms were incorporated into the side of the experimental traps at two heights along the exterior wall: 5 cm and 10 cm off bottom, for the low and high treatments, respectively.

Behavioural observations were made over a period of 12 d, using a large rectangular tank (3.2 \times 2.3 \times 1.1 m) equipped with a continuous supply of ambient temperature seawater (mean = 2.4°C, s.d. = 0.3). Each morning, ten crabs (\leq 94 mm CW) were randomly selected from a group of 50 in the holding tank and placed directly into an experimental trap in the rectangular tank. Four traps were tested: (i) a meshed trap with an escape mechanism installed low; (ii) a meshed trap with an escape mechanism installed high; (iii) a wire trap with an escape mechanism installed low; and (iv) a wire trap with an escape mechanism installed high.

An underwater colour camera (Simrad OE 1367) was positioned to view the trap, with the escape mechanism positioned directly within the field of view. The crabs' behaviour towards the escape mechanism was monitored over a 24 h period and recorded digitally onto a laptop computer using time-lapse recording (30 frames per minute). Each trap ($n = 4$) was tested on three separate days at random intervals over the period of study. Chopped squid bait was placed in a perforated bag in the upstream end of the tank to encourage the crabs to leave the trap. At the end of each observation period, the crabs were removed and a new group of ten was chosen for the next test. The crabs were not marked or individually identifiable, making it likely that each crab was tested more than once; however, based on random selection from the holding tank, individual crabs were not expected to exceed three tests over the period of the study.

The snow crabs' behavioural response towards the escape mechanisms was quantified by viewing the video footage and recording the frequency of recognizable patterns of movement. Each sequence began when an individual approached the escape mechanism and successfully penetrated the opening with part of its body, and terminated when the individual discontinued the attempt or completed an escape.

Morphometric measurements

Carapace length (CL) is the primary limiting factor that determines whether a crab will pass successfully through an escape opening. Measurements on the dimensions of dead male crabs were recorded to the nearest millimetre (\pm 1.0 mm) to develop a relationship between CW and CL. As with Guillory and Hein (1998), each crab was manually inserted sideways through a series of escape openings of 2 mm increments, ranging from 91 to 103 mm in diameter, until the minimum opening that the individual crab would pass through was determined. This is based on the premise that the smallest opening an animal can be pushed through by hand is also the smallest opening that it can pass through voluntarily (Stasko, 1975).

Results

Laboratory observations

Analysis of the video footage revealed 652 behavioural responses, or penetration attempts, six of which resulted in a successful escape from the trap. Escape behaviour was characterized by four distinct behavioural stages (Figure 1). Escape always began (stage 1) with the crab approaching the opening with the body low and extending three or four of its hind legs through the opening. Stages 2 and 3 involved raising and orientating the carapace through the opening, as well as extending the closest claw (i.e. cheliped) through the mechanism. Stage 3 sometimes preceded stage 2, but both were essential to escape success. Failure to properly orientate the carapace or to bring the claw through the opening always ended in escape failure. Finally, stage 4 involved bringing the trailing claw through the opening and lowering the body onto the exterior side of the trap. Hind limbs on the trailing side of the body always exited last.

Escape location significantly affected the crabs' likelihood of discovering and attempting to penetrate an escape mechanism ($F_{[18]} = 16.650$, $p = 0.004$). Mechanisms mounted low on the exterior wall received more than three times the number of penetration attempts (by all parts of the body) on average per day than escape mechanisms mounted high, for both trap types (Figure 2). This follows from the observation that, although the crabs crawled comfortably on the walls of the trap, they spent most of their time moving about the floor of the trap, and were therefore more likely to discover and attempt to penetrate mechanisms mounted at that level. In no instance was a successful escape observed for traps with escape mechanisms mounted high.

Comparison of the mesh and wire trap types revealed no significant difference in the mean number of penetration attempts over a 24 h period ($F_{[18]} = 0.234$, $p = 0.642$). This indicates that the snow crabs' behaviour towards escape mechanisms

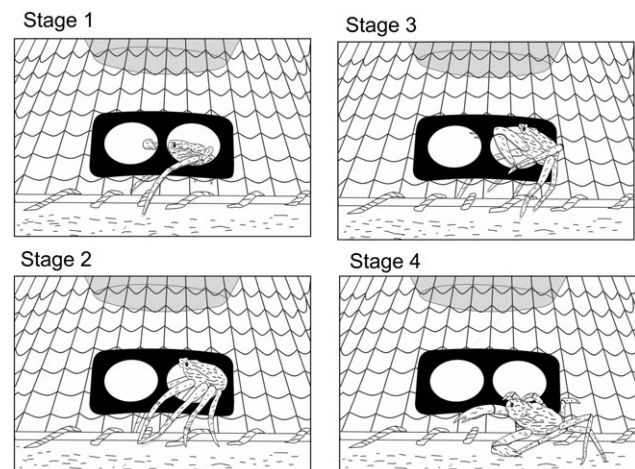


Figure 1. Four stages of snow crab escape behaviour. The drawings depict an undersized male crab exiting through an escape mechanism mounted low on the exterior wall of a wire trap. Stage 1: approach low and extend three or four limbs through the opening. Stage 2: raise body and orientate the carapace through the opening. Stage 3: extend the closest cheliped/claw through the opening. Stage 4: bring the trailing cheliped through the opening and lower the body. Hind limbs on the trailing side exit last.

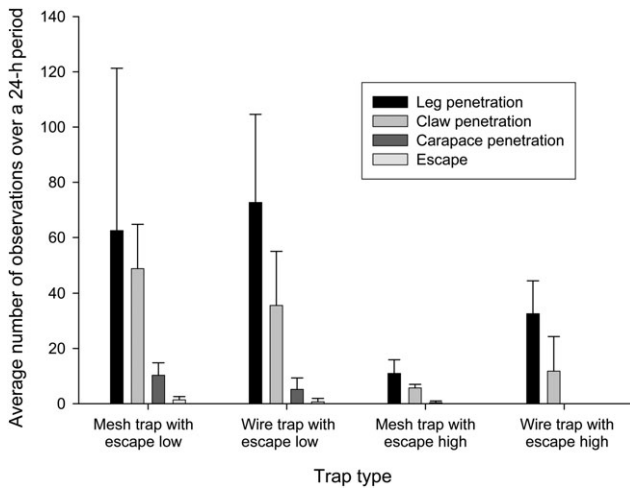


Figure 2. Effect of escape location and trap type on the frequency of penetration by different parts of the body and successful escape.

was independent of trap type. Although the wire trap with the escape mechanism mounted high did receive slightly more leg and claw penetrations than the mesh trap with the same rigging (Figure 2), this difference was not statistically significant ($p > 0.05$).

Morphometric measurements

CL was linearly related to CW for the size range examined (Figure 3, $n = 425$). The mean ratio of CL to CW was 1.01 (s.d. = 0.02), and the relationship could be expressed by $CL = 1.755 + 0.989 CW$, using least-squares regression ($F_{[1424]} = 3.69 \times 10^4$, $p < 0.001$, $r^2 = 0.989$).

Manual insertion of the crab through escape openings of different size (91–103 mm diameter) revealed knife-edge size selectivity (Figure 4). The CW at which 50% of the crab were retained (CW_{50}) ranged from 85 to 99 mm, and was highly sensitive to changes in escape diameter. The minimum legal landing size for crab in Newfoundland and Labrador is 95 mm CW. The optimal escape diameter, for which $CW_{50} = 95$ mm, is 99 mm, although this might occasionally release legal-sized crab in the 95–97 mm

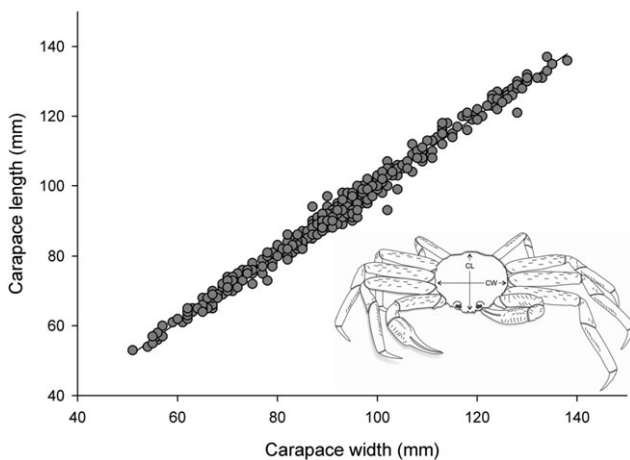


Figure 3. Relationship between CL and CW for male snow crab.

CW size range. Choosing an escape diameter closer to 95 mm would prevent the loss of legal-sized animals.

Discussion

Our results demonstrate that undersized snow crabs (≤ 94 mm CW) are capable of detecting, approaching, and interacting with escape mechanisms. We found that this species was very successful at penetrating the escape openings with different parts of the body, and like lobster (Nulck, 1978), were capable of orientating the carapace with sufficient dexterity to achieve escape success. However, unlike lobster, snow crabs have several large appendages that need to be coordinated to achieve a successful escape. Whether escaping through the mesh or through an escape mechanism, many penetration attempts were typically needed to achieve a successful escape. Failure to orientate the carapace properly or to bring the claw through the opening always ended in escape failure.

It became apparent that the location of the escape opening was important in determining the likelihood of escape success. In this study, mechanisms mounted low on the exterior wall received more than three times the number of penetration attempts on average than those mounted high, irrespective of trap type. This followed from the observation that, although the crab crawled comfortably on the walls of the trap, they spent most of their time moving about the floor, and were therefore more likely to discover and attempt to penetrate mechanisms mounted at that level. This finding is consistent with previous studies on blue crab, *Callinectes sapidus* (Guillory and Merrell, 1993), tanner crab, *Chionoectes bairdi* (Pengilly, 2000), and snow crab, in the Bering Sea (Byersdorfer and Pengilly, 2001), which noted that, the closer an escape mechanism was to the floor of a trap, the more effective it was at allowing non-targeted animals to escape. In fact, the last-named study found that, of the three most critical factors (location, escape size, and number of escapes), location was the most important in reducing bycatch rates (Byersdorfer and Pengilly, 2001).

That the type of trap used played no role in the crabs' behaviour towards escape mechanisms indicates that crabs respond in a similar manner to this selectivity device, regardless of whether the trap is made of mesh or wire. Wire traps are not currently permitted in the snow crab fishery in Atlantic Canada; however, the material is commonly used to construct lobster traps throughout the Northwest Atlantic. Wire has several potential advantages, including long life, low maintenance, resilience to weather, and stability in strong currents, owing to its slightly heavy design. However, the selectivity of wire traps is almost always achieved through selectivity devices such as escape mechanisms, not the wire itself. Further studies will be needed to investigate the performance of wire crab traps under commercial fishing conditions.

The knife-edged size selectivity achieved by inserting dead crabs manually through escape openings of different sizes implies that the same may be true for live animals. This, and the fact that slight changes in escape diameter produced abrupt changes in the corresponding CW_{50} , suggests that escape mechanisms may have the sensitivity necessary for fine adjustments to the size selectivity of traps targeting snow crab. The authors speculate that rigid selectivity devices may be more precise in their selective release of prerecruits and retention of legal sized crabs than mesh alone. This is based on the premise that (i) mesh is flexible and therefore likely to be less precise by nature; (ii) mesh tends to shrink over time, changing the selective properties of traps; (iii) trap construction

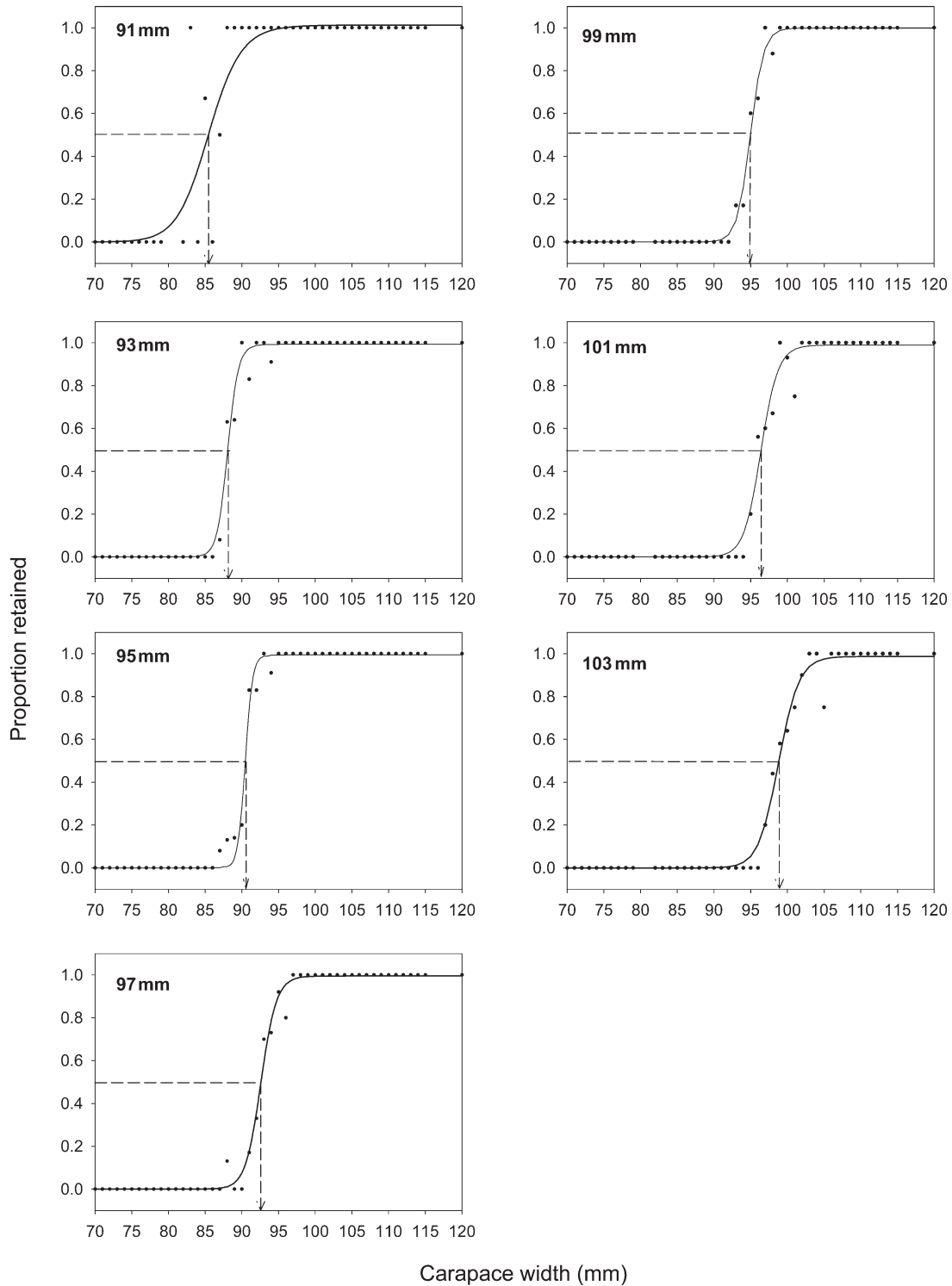


Figure 4. Proportion of crabs at size retained for different escape diameters. The CW at which 50% of the crabs are retained (dashed line, CW₅₀) increases with increasing escape size.

is poorly regulated, which has led to large variation in the hanging ratios of mesh among trap manufacturers, introducing a potentially significant bias in the selectivity of traps used commercially.

In summary, this study supports the feasibility of using escape mechanisms as selectivity devices for conical snow crab traps based

on behavioural observations and morphometric measurements. The findings revealed that escape mechanisms worked equally well in both mesh and wire traps, but were only effective when installed low on the exterior wall. The frequency of behaviours observed (e.g. penetrations and escapes) is probably low under

laboratory conditions, and would be expected to differ under field conditions. Comparative fishing experiments at sea are required, because this study is unable to predict the performance of escape mechanisms under commercial fishing conditions. Finally, given that ghost fishing can be a serious concern for this species (Vienneau and Moriyasu, 1994; Hébert *et al.*, 2001), we suggest that the mechanisms could be installed using biodegradable or corrodible material. If the trap were lost or abandoned at sea, the mechanism would eventually fall inwards, effectively disabling the trap (Blott, 1978; Gagnon and Boudreau, 1991). In this way, the mechanism could function as a selectivity device as well as an anti-ghost-fishing device.

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References

- Anon. 1985. Atlantic Fishery Regulations. Department of Justice, Canada. <http://laws.justice.gc.ca/en/f-14/sor-86-21/120732.html>
- Blott, A. J. 1978. A preliminary study of timed release mechanisms for lobster traps. *Marine Fisheries Review*, 40: 44–49.
- Byersdorfer, S. C., and Pengilly, D. 2001. Analysis of effectiveness of alternative escapement configurations in commercial snow crab pots. Alaska DFG Working Paper.
- DFO. 2005. Stock assessment report on Newfoundland and Labrador snow crab. DFO Canadian Scientific Advisory Secretariat Science Advisory Report, 2005/017.
- FRCC. 2005. Strategic conservation framework for Atlantic snow crab. Fisheries Resource Conservation Council, FRCC.05.R1.65 pp.
- Gagnon, M., and Boudreau, M. 1991. Sea trials of a galvanic corrosion delayed release mechanism for snow crab traps. Canadian Technical Report of Fisheries and Aquatic Sciences 1803. 17 pp.
- Grant, S. M. 2003. Mortality of snow crab discarded in Newfoundland and Labrador's trap fishery: at-sea experiments on the effect of drop height and air exposure duration. Canadian Technical Report of Fisheries and Aquatic Sciences 2481. 25 pp.
- Guillory, V., and Hein, S. 1998. A review and evaluation of escape rings in blue crab traps. *Journal of Shellfish Research*, 17: 551–559.
- Guillory, V., and Merrell, J. 1993. An evaluation of escape rings in blue crab traps. Louisiana Department of Wildlife and Fisheries Technical Bulletin 44.
- Hébert, M., Miron, G., Moriyasu, M., Vienneau, R., and DeGrâce, P. 2001. Efficiency and ghost fishing of snow crab (*Chionoecetes opilio*) traps in the Gulf of St Lawrence. *Fisheries Research*, 52: 143–153.
- Miller, R. J. 1990. Effectiveness of crab and lobster traps. *Canadian Journal of Fisheries and Aquatic Sciences*, 47: 1228–1251.
- Miller, R. J. 1995. Options for reducing bycatch in lobster and crab pots. *In Solving Bycatch: Considerations for Today and Tomorrow*, pp. 163–168. Alaska Sea Grant College Program Report 96–03. University of Alaska, Fairbanks.
- Nulk, V. E. 1978. The effects of different escape vents on the selectivity of lobster traps. *Marine Fisheries Review*, 40: 50–58.
- Pengilly, D. 2000. Relationship between variable mesh/escape rings in crab traps and the escape and retention of tanner crabs *Chionoecetes bairdi*. Report prepared for the Alaska Board of Fisheries. 12 pp.
- Salthaug, A., and Furevik, D. M. 2004. Size selection of red king crabs, *Paralithodes camtschaticus*, in traps with escape openings. *Sarsia*, 89: 184–189.
- Stasko, A. B. 1975. Modified lobster traps for catching crabs and keeping lobsters out. *Journal of the Fisheries Research Board of Canada*, 32: 2515–2520.
- Stevens, B. G. 1995. Crab bycatch in pot fisheries: causes and solutions. *In Solving Bycatch: Considerations for Today and Tomorrow*, pp. 151–158. Alaska Sea Grant College Program Report 96–03. University of Alaska, Fairbanks.
- Vienneau, R., and Moriyasu, M. 1994. Study of the impact of ghost fishing on snow crab, *Chionoecetes opilio*, by conventional conical traps. Canadian Technical Report of Fisheries and Aquatic Sciences 1934. 9 pp.

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