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A review of animal welfare implications of the Canadian commercial seal hunt

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ABSTRACT

The Canadian seal hunt is the world's largest commercial slaughter of marine mammals and, as such, has been the subject of veterinary scrutiny for half a century. In that time, veterinary experts have made multiple recommendations to improve welfare at the seal hunt, some of which have been included in Canadian sealing regulations. Yet analysis of video material and studies on the outcomes of the hunt suggest that the potential for suffering during the hunt continues, and may, in fact, be increasing. In the past decade, numerous countries have taken action to prohibit their trade in products of commercial seal hunts in response to public concerns about the welfare of the seals. With these actions now being examined at the World Trade Organization, it is important to determine if these concerns are warranted. This paper reviews relevant veterinary science, exploring the intrinsic elements of commercial sealing and unique physical adaptations of seals that prevent effective and consistent application of humane slaughter methods at the seal hunt. The review of available data indicates that generally accepted principles of humane slaughter cannot be carried out effectively or consistently in the commercial seal hunt.

1. Introduction

Harp seals (*Phoca groenlandica*) are ice-breeding marine mammals that migrate annually between arctic and subarctic regions of the Atlantic. Northwest Atlantic harp seals, the primary focus of Canada's commercial seal hunt [1], spend the summer in the Canadian Arctic and along the Greenland coast and migrate south in the late autumn to overwinter off the northeast coast of Newfoundland (the "Front"), or in the Gulf of St. Lawrence (the "Gulf "). The adult females give birth in March. The pups are born with white fur (lanugo) and are weaned at approximately 12 days. After weaning, the young seals are abandoned by their mothers, and then fast for 4 to 6 weeks [2]. During this time, the commercial sealing season opens off Canada's east coast. The seals are hunted primarily for their fur and carcasses are routinely abandoned [3]. While trade in products of newborn seals is forbidden in Canada, once the seals begin to shed their white coats (a process that coincides with weaning), their products can be legally traded. The skins of young seals are the most valuable [4] and nearly all (98%) of the harp seals killed in recent years have been less than three months of age [5].

Most of the seals are killed in just a few days in late March (in the Gulf) and mid April (in the Front), with the opening day in each region the most lucrative [6]. During the years 2003–2008 commercial sealers in Canada landed 1,782,560 animals [7]. In the past half-century, veterinary experts have made multiple recommendations to improve welfare at the seal hunt (for example: Simpson [8,9], Rowsell [10–13], Burdon et al. [14], Daoust et al. [15] and Smith [16]). Some of these regulations have been reflected in Canadian regulations and conditions of licenses. Regardless, studies on the outcomes of the hunt suggest that the potential for suffering continues and is, because of the impacts of climate change, increasing. In 2009, the European Union prohibited trade in the products of commercial seal hunts. In response, Canada revised its Marine Mammal Regulations [17], claiming the new rules made the hunt humane, and challenged the EU regulation at the World Trade Organization. Since that time, the Russian Federation, Belarus and Kazakhstan have prohibited their trade in harp seal fur, sparking threats of further measures at WTO by the Canadian government.

This paper seeks to determine if the actions of nations in prohibiting seal product trade can be justified from an animal welfare perspective. It examines the current Canadian sealing regulations in comparison to generally accepted principles of humane slaughter to determine if these rules prescribe a humane death for seals. It also evaluates the unique physical adaptations of seals for marine life, which may present obstacles to humane

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Table 1
The author panel composition, date, and seal hunt or video material observed in the studies assessed in this paper [14,15,18]

Paper	Panel composition	Date	Seal hunt events observed	Video events observed
Burdon et al. [14]	International panel of veterinarians with expertise in a variety of specialties	2001 (1998–2000 video data)	Observed firsthand 127 seals killed during the commercial seal hunt in 2001 and conducted post mortems on 76 seal carcasses abandoned on the ice floes during the 2001 commercial seal hunt	Observed video material from 179 seal kills during three commercial seal hunts (1998–2000 inclusive)
Daoust et al. [15]	Veterinarians with a variety of specialties	1999 and 2001	Two members of the panel examined carcasses of 225 seals killed, mainly with a hakapik (see later for description of permitted methods), in the Gulf of St. Lawrence during 1999. Two panel members provided data on 47 seals shot at the Front the same year. One panel member provided data on 167 seals shot or killed by hakapik in the Gulf in 2001	The panel reviewed video evidence of 116 'interactions between harp seals and sealers' from the 2001 seal hunt
Butterworth et al. [18]	International veterinary and zoological experts with a variety of specialties	2007 (2003–2007 video data)	The panel carried out post-mortem examinations on 17 clubbed seals collected in 2007 in the northern Gulf of St. Lawrence. The report presented data on an Expert Opinion Analysis where 133 experts were sent sequences of events extracted from the videos for a single seal kill and asked 'How do you rate the overall welfare of this animal during the processes which resulted in its death?'	Examined video evidence of 169 seal kills from four seal hunts (2003–2007 inclusive) in the Gulf of St. Lawrence and the Front

slaughter, and other impediments to humane killing in the context of commercial seal hunting.

2. Materials and methods

In this paper, the findings from a number of veterinary studies (Table 1) on the Canadian commercial seal hunt conducted in the past five decades are reviewed, focusing primarily on three of the most recent of these.

This paper also contains video evidence (accessible as links in the Appendices) that has been collected by NGOs licensed by the Canadian government to observe the commercial seal hunt. Filming of the seal hunt has been undertaken in three ways:

- from the ice using video cameras;
- from inflatable vessels using video cameras; and
- from the air with the use of a Cineflex camera.

3. Review of the results of multiple studies

Veterinary studies on the outcomes of commercial sealing reveal consistent problems in the application of three central components of humane slaughter: stunning, monitoring for unconsciousness and bleeding.

3.1. Stunning

Canadian sealers are permitted by law to stun seals by clubbing, with wooden bats or with a pole known as a hakpik (by regulation consisting of a metal ferrule with a slightly bent spike not more than 14 cm in length attached to a wooden handle that measures not less than 105 cm and not more than 153 cm in length and not less than 3 cm and not more than 5.1 cm in diameter) or by shooting, with rifles and shotguns [17]. In addition, gaffs (wooden poles with hooks at the end) are frequently observed being used as clubbing implements [14,18] though their use has been prohibited for more than four decades [19] because their size and weight are not suitable for rendering seals unconscious. Both shooting and clubbing are considered stunning rather than killing methods as neither technique can assure immediate death in the field environment of the commercial seal hunt [17]. Clubbing is likely to be the preferred method given that the prices paid for seal fur are reduced with each bullet hole found [20] and consistent accuracy when shooting is improbable under the conditions of the seal hunt [21,16,18]. However, sealers are now targeting older pups and so the killing occurs weeks later in the spring. This, paired with the impacts of climate change, means sealers are increasingly shooting seals from vessels because the sea ice is not solid enough to walk on. Shooting is now the predominant primary stunning method at the front, where two thirds of the hunt occurs [22].

3.1.1. Clubbing

In examining skulls of seals clubbed by Canadian sealers, veterinarians and official observers have consistently identified a lack of cranial injury that would correlate with insensibility [9,23–29,12,14,18]. Of 70 seals observed killed in 2001 by Burdon et al. [14], several seals were clubbed in excess of eight times, with 22% clubbed more than three times. Burdon et al. found that of the cases observed in video footage from 1998, 1999 and 2000, sealers returned to strike or shoot the seal for a second time in 40% of cases (32% of the clubbed seals and 92% of the shot seals) and that the average time between strikes was 27 s.

Of the 76 post mortems conducted by Burdon et al. [14], 17% had no apparent skull fractures. For these seals, it was indicated that assured association with unconsciousness would be highly improbable, and that it could be questioned whether any alteration in consciousness occurred in these cases. A further 25% had minimal fractures including hairline or non-displaced fractures, or moderate fractures. Burdon et al. stated that cases of minimal fractures could be associated with neural damage but that unconsciousness could not be guaranteed to have occurred. This same report noted that moderate fractures would be more likely to be associated with unconsciousness, but would still not have a high level of assurance that unconsciousness had been achieved. In total, 42% of seals examined did not show enough evidence of cranial injury to be associated with a high probability of unconsciousness.

Burdon et al. concluded,

> "*The current methods and competency of clubbing is significantly inaccurate in location, resulting in severe and unacceptable suffering. In order to highlight this point it should be noted that 28% of seal skulls observed had blows to the head region resulting in mandibular fractures where the bottom of the head had clearly been struck instead of the top.*"

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Of 100 seals observed clubbed in Daoust et al. [15], 14% had skulls that were either not crushed or were only partially crushed. In 2% of cases where the killing method was observed, the seals were still alive after being brought onto the vessel (very likely after being impaled on a gaff and hoisted onto the boat), and were subsequently clubbed. Another nine (six percent) were clubbed or shot and then lost in the ocean (struck and lost).

Of 169 seal kills observed in video evidence by Butterworth et al. [18], start sequences could be determined for 88% of the events, and 63% of these seals were clubbed. When sealers approached groups of seals, the prime aim was to prevent seals escaping into the water. Sealers were often running whilst they clubbed seals, and the seals were either trying to escape into the sea, or were rearing up in defense; all of these factors work together to prevent accurate placement of blows. Furthermore, sealers sometimes struck the seals when holding the hakapik in one hand, thereby reducing the power of the blow and further reducing their accuracy. The problem was sometimes exacerbated because the sealers often slipped whilst running on the ice. Notably, 39% of the seals that were clubbed required two separate series of blows. The mean time between series of blows was 23.9 ± 3.2 s; this was because sealers were not immediately checking seals and/or were moving on to strike other seals before returning to the first one struck. Of 180 blows where the site of impact could be determined by Butterworth et al. [18], 63% were on the head, 21% the face, 6% the neck and 10% the body/back. After having been clubbed, 25% of seals subsequently responded to stimuli. Most sealers used legal implements to strike seals, predominantly hakapiks (93%) or clubs (4%), but some used illegal implements such as gaffs (3%).

Of the 17 seals examined *post-mortem* in Butterworth et al. [18], all had been clubbed (one had also been shot). Of these, 47% had been clubbed on the face or neck, and 82% had ocular (eye) damage. At the end of the *post-mortem* examination, each animal was given a subjective score from 1 to 10 (where 1 = good welfare, 10 = poor welfare) by the person who undertook that *post-mortem* examination, based on his assessment of whether: the animal was dead at the time of skinning; whether the animal had been rendered insensible immediately; and whether the animal had suffered distress following the first insult. Based on analysis of these scores, and two other measures (whether blood was present in the stomach and the presence of facial injuries), for 15 of the 17 animals, there were significant concerns about the way they had been killed. Most seals had multiple fracture sites and 59% had extensive damage to the skull (Fig. 1). A significant number (59%) had pre-mortem bleeding in the mouth or nostrils, and blood in their un-perforated (intact) stomachs, indicating they were alive and swallowing blood after the first strike. The majority of seals had sustained multiple blows. Whilst 88% of the seals had fractured skulls, clubbing sites were frequently recorded on other parts of the head or body, and 59% had damage to the face and lower jaw, indicating a poor placement of blows. Of the animals examined, only 12% had no blood in the stomach and no facial injuries. For the remaining animals (88%) there were welfare concerns about the way they had been killed (Butterworth et al. [18]).

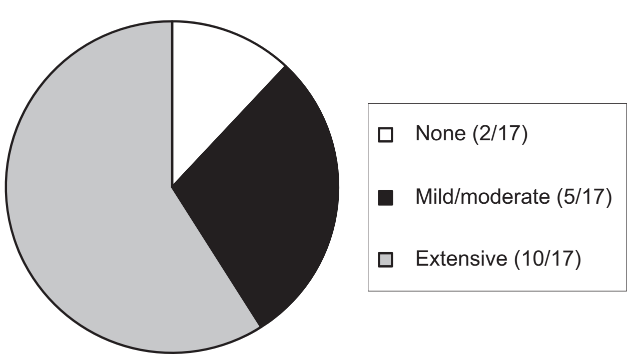

Fig. 1. Extent of skull damage assessed during *post-mortem* of harp seals from the 2007 hunt [30].

3.1.2. Shooting

Of 179 seal kills observed in video evidence by Burdon et al. [14], 92% of the seals that were shot were struck for a second time. Of 57 seal kills directly observed by Burdon et al., 5% were shot and then lost in the ocean, 37% were shot and then clubbed, and one seal was shot and not immediately recovered despite signs of life. Of the seals that were shot and pulled by gaffing onto vessels prior to confirming unconsciousness, one seal was observed being clubbed on board the boat. Thus, more than 40% of the seals observed being shot were likely not rendered immediately unconscious as evidenced by further clubbing action carried out by the sealers. Of 47 carcasses examined in 1999 by Daoust et al. [15], 35 (75%) had been shot in the head, with the skull and brain being "completely destroyed" in 28 cases, the mandible and base of the cranial cavity destroyed in 5 cases, and the snout and frontal region of the cranial cavity destroyed in 2 cases. Destruction of the frontal part of the face (the snout particularly) would have been unlikely to induce immediate insensibility in these animals. Six (13%) of the 47 animals had been shot in the neck, with complete transection of the cervical portion of the vertebral column; three (6%) had been shot in the ventral region of the neck with destruction of soft tissues, including major blood vessels. The remaining three seals (6%) had been shot in the thorax or abdomen, one of which was "found alive by itself on an ice floe and was immediately killed with a hakapik by a DFO officer."

Of 43 seals observed shot in 2001 by Daoust et al. [15], 93% were struck again with a club. For the vast majority ($\geq$85%), Daoust recorded the interval between the shot and the blow(s) was less than or equal to one minute. The report noted that, "*A certain proportion of animals* (*3 of 8*, *in one instance where exact records were kept*) *were still alive during that interval*, *as shown by the conspicuous movements of their head*."

Among 55 cases of particular concern highlighted in video evidence reviewed by Daoust et al. [15], 24 were based on the apparent failure of the sealer to kill the seal instantaneously with the initial shot. In eight (33%) of those cases, the authors agreed that the seal had not been killed instantaneously. When specifically timed, it was determined an average of 45.2 s elapsed between the animal being shot and a sealer striking it with a hakapik, or in once instance, being brought on board without being struck. In video evidence of seals being shot observed by Butterworth et al., [18], the sites of impact could be determined in 51 cases. The authors reported that 41% were shot in the head region; 55% of shots were located on other parts of the body such as the back, abdomen or chest; and 4% of shots missed their target. Most shot seals (66%) were subsequently clubbed with a hakapik or club, whilst an additional 16% were responding to stimuli after being shot, but were not dispatched with a hakapik or club. Thus, 82% of seals were not killed by the first shot.

3.1.3. Struck and lost

Seals that are wounded and escape beneath the surface of the water are known as "struck and lost." Seals that are "struck and lost" can die shortly after escaping or survive with injuries that can profoundly affect their continued survival in the wild [31,30].

Struck and lost rates for beater seal pups have been estimated at 10–25% [32], 5% [33], 2% (for beaters taken on the ice) and

0–10% (for seals shot at in the water). The Canadian government currently estimates a 5% struck and lost rate in the commercial seal hunt, which in many years is tens of thousands of seals [30].

3.1.4. Monitoring for unconsciousness

In video evidence of 179 seal kills observed by Burdon et al. [14], sealers failed to apply a test for unconsciousness in 79% of cases despite this being a condition of sealing licenses (*Condition 7. Every person who disembarks onto the ice to retrieve a Seal that has been shot shall proceed to the Seal without delay and upon reaching the Seal palpate the cranium immediately to confirm that the cranium has been crushed.*

Condition 8. Regardless of the method used for killing the Seal (*i.e. hakapik, club or firearm*) *the Seal must be bled as soon as possible after palpation of the cranium has confirmed that the cranium has been crushed*). Of 116 seal kills observed by Daoust et al. [15] from video evidence, sealers failed to apply a test for unconsciousness in 87% of cases. Of 169 seal kills assessed by Butterworth et al. [18], corneal reflex or skull palpation tests were observed in only 33% of cases. Moreover, the checks that were witnessed were generally either poorly performed or inadequate. Twenty three percent of seals that had been checked still responded to stimuli or required a further blow(s) with an implement some time after a check was performed (19%). Following the blinking reflex tests and/or cranial palpations, 14% of seals were clubbed again, and the seal was rechecked for consciousness in only half of these cases.

3.1.5. Delays between stunning and bleeding, and effectiveness of the bleeding process

Shooting and clubbing are simple stunning methods that can induce temporary loss of consciousness and must be promptly followed by bleeding to cause death [34]. Thus, even properly stunned animals have the potential to regain brain and body functions if left unbled [35]. This is evidenced by the documented high wounding rates and instances of stunned seals regaining consciousness at the commercial seal hunt. Responsible humane slaughter guidelines require that bleeding, following a simple stunning method, occur within a specific time frame or "without delay" [36–39]. Notably, in Newfoundland, the Canadian province in which the vast majority of the seal hunt occurs, the Meat Inspection Act (1996) specifies that the animal should be rendered unconscious *immediately prior to bleeding*. Exsanguination (bleeding out) following stunning has been a requirement at the Canadian seal hunt since 2008, and has been recommended in industry handbooks for a number of years. Animals should be bled without delay following confirmation of unconsciousness [39,14,35–37] and for seals, the bleeding should occur on the ice [16]. Canada's Marine Mammal Regulations only require that bleeding occur prior to skinning. Mention of bleeding has also been made in previous versions of the Marine Mammal Regulations. In addition, multiple veterinary recommendations on commercial sealing have identified bleeding out as a key part of the slaughter process in the commercial seal hunt [14,16]. Despite these facts, exsanguination appears to be used relatively infrequently and often to be improperly applied. Burdon et al. [14] found that the seal was bled immediately after impact with a club or hakapik in only six of 179 (3.3%) examples of killing in video evidence of the 1998, 1999 and 2000 seal hunts. The veterinarians observed the seal hunt from the air through high-powered Wescam lenses. They found the seal was bled where struck in only 25 of 127 (20%) instances of killing witnessed. Of 169 seal kills analyzed by Butterworth et al. [18], skinning or cutting the seal with a knife was witnessed in only 10% of cases. The majority (78%) of these seals were not checked prior to the onset of cutting/skinning. This was a considerable welfare concern, since 83% responded to stimulus after cutting had begun; in 33% of cases the sealers stopped cutting to club the seal again.

In contrast, Canada's Marine Mammal Regulations do not require bleeding to occur immediately following stunning, or even within a set period of time. Instead, imprecise wording such as "as soon as possible" allows broad interpretation of the law. Because of the nature of the commercial seal hunt, there are often long delays between applications of stunning methods and bleeding, creating the clear potential for seals to regain consciousness prior to or during the bleeding period.

3.1.6. Monitoring during the bleeding process

Exsanguination can be used to ensure death, however, because anxiety is associated with hypovolemia (reduced blood volume), bleeding can only be humane if the animal remains unconscious for the duration of the process [37]. Thus, it should be possible for the animal to be observed, inspected and accessed throughout the bleeding period, and any animal exhibiting signs of regaining consciousness should be immediately re-stunned [36]. The high wounding rates recorded at the commercial seal hunt, paired with the strong potential for skull palpation tests to be administered or interpreted incorrectly (or not administered at all), underscores the need for sealers to ensure unconsciousness persists through completion of the bleeding process. However, the Marine Mammal Regulations do not require that seals be monitored for signs of consciousness during the bleeding process.

3.1.7. Gaffing and dragging prior to and during bleeding

In video evidence of three seal hunts (1998–2000), Burdon et al. [14] found that 69% of seals observed killed were impaled with a gaff and dragged across the ice without a check for unconscious. In many cases, the seals appeared to be alive as they were dragged across the ice. In their firsthand observations of the 2001 seal hunt, the authors noted numerous instances of sealers failing to perform tests for unconsciousness and then impaling the seals with gaff hooks and dragging them across the ice floes. Daoust et al. [15] also recorded instances of seals being hooked and then dragged with gaffs and hoisted aboard sealing vessels in video evidence from the 2001 seal hunt. Of 169 instances of seals being killed, in video evidence from four seal hunts (2003–2007) by Butterworth et al. [18], 61% were observed being gaffed. No blinking reflex test or cranial palpation was performed on 79% of the seals prior to gaffing, and 44% responded to stimuli after being gaffed.

3.2. Comparison of results from veterinary studies

As highlighted in Table 2, the results from three veterinary reports on the commercial seal hunt show similar findings in a number of areas.

3.3. Humane slaughter principles

In Canada, the United States and Europe, there are generally accepted principles of humane slaughter, which include:

- Minimizing distress experienced by the animal prior to and during stunning [40,41,37,42].
- Rendering the animal unconscious (and therefore insensitive to pain) without the need to repeat the application of the stunning method [43–46].
- Confirming unconsciousness by monitoring for multiple indicators of consciousness [40,37].
- Delivering death *without delay* through an accepted euthanasia method [36,38,43].
- Ensuring unconsciousness persists until death occurs [36,42,43].

Table 2
A comparison of different welfare measures between Burdon et al. [14], Daoust et al. [15] and Butterworth et al. [18]*.

	Burdon et al. [14]	**Daoust et al.** [15]	**Butterworth et al.** [18]
Did not palpate cranium or undertake blinking reflex test	79%	87%	67%
Time from being shot to first contact by sealer	–	Mean 45.2 (range 12–111) seconds	Mean 48.8 $\pm$ 9.4 s
% of seals that required a second series of blows	40%	–	39%
Time to second series of blows	27 s	–	23.9 $\pm$ 3.2 s
Damage to face/jaw	61%	–	59%
Bled out	6%	–	6%
Extent of cranial fractures	None (17%), minimal–moderate (25%), extensive (58%)	–	None (12%), minimal–moderate (29%), extensive (59%)

* Only data from measures that are directly comparable are included.

Canada's Marine Mammal Regulations and Conditions of Sealing licenses fail to adequately prescribe any of these steps, allowing sealers to legally herd seals prior to stunning, stun and kill animals in view of each other, repeatedly club or shoot seals to achieve unconsciousness, leave wounded seals to suffer for extended periods of time, impale conscious seals on metal hooks and drag them across the ice, and cut open seals whilst they may be responsive to pain.

The failure of the regulations to prescribe a humane slaughter process in line with internationally recognized principles is, perhaps, unsurprising, in that most existing veterinary advice on commercial sealing has sought to achieve a compromise between methods that could constitute humane slaughter and measures sealers can practically take in the environment in which the seal hunt operates. For example, Canada's Marine Mammal Regulations are largely based on recommendations of Smith [16], which state:

> "*Members recognize that the seal hunt takes place under very difficult and challenging conditions…The Group recognizes that part of contributing to improved animal welfare and reduced suffering is to produce recommendations that are realistic in the context of the hunt, so that sealers will accept and implement them. There needs to be a realistic balance between ideal procedure and methodology, and what is practical and achievable.*"

Veterinary advice and the regulations that result from it have thus not solely focused on how to ensure that the killing is *humane* (as required in established commercial slaughter), but rather how to make it *less inhumane* by adopting methods that are practical on the ice (but which would be considered primitive in a slaughterhouse on land). Despite this, in countering concerns that the commercial seal hunt is inhumane, sealing proponents have stated that commercial sealing is as humane as, or more humane than, killing processes carried out in abattoirs [47–51]. It therefore seems appropriate to make a reasoned and detailed comparison between commercial sealing practices and internationally recognized humane slaughter principles.

3.3.1. *Distress prior to stunning*

Seal hunts that involve herding animals prior to slaughter (as in Canada's gray seal hunt) are likely to cause fear [30]. Moreover, animals should not be stunned within view of each other [39] yet this is standard practice throughout the commercial seal hunt.

3.3.2. *Methods of stunning—Clubbing*

Stunning via delivery of a manual percussive blow (such as clubbing) is not recommended for general use [40], and should only be used as a backup method when there are no other stunning methods available [40]. Moreover, stunning via a manual percussive blow should be used only on neonatal or small animals under specific body weights [40,37]. The Council of the European Union regulation (2009) specifies that a percussive blow to the head should only be permitted for animals (including fur animals) less than 5 kg in weight. Yet virtually all seals killed in Canada's seal hunt are "beaters" [5] in the region of 25–35 kg (DFO 2011d). The Regulation also states that no person should kill by percussive blow to the head more than seventy animals per day, while sealing vessels in Canada, a number of which carry as few as two sealers [31], are permitted to take up to 400 seals per day in some regions, and an unlimited number in other areas [52]. Moreover, effective clubbing of seals while sealers scramble across broken, unsteady and slippery ice floes is unlikely to be achieved consistently [21]. Canada's Seal Protection Regulations (1978) prohibited striking a live seal "on any part of its body except its forehead." Yet while the current Regulations indicate that sealers should strike the seal "on top of the cranium" when clubbing, they do not specify that it is an offense to strike the seal elsewhere. While wooden bats continue to be legal and widely used killing implements in the Canadian seal hunt, they are not considered a humane method of dispatching "beater" seal pups [30,53] because the accuracy with which a bat can be used is less than for other methods. In the case of the hakapik, Canada's Marine Mammal Regulations do not specify which end of the implement should be used to club the seal. Video evidence from recent years shows sealers stabbing seals in the skull with the metal spike of the hakapik rather than striking them with the recommended hammer end. This act equates to pithing, which is not considered a humane method of euthanasia without prior stunning [37].

3.3.3. *Shooting*

For shooting to be humane, the animal must be accurately shot in the head [16,37,41] because a shot anywhere else will not immediately render the animal unconscious [37]. Yet Canada's Marine Mammal Regulations do not require that seals be shot in the head. This is likely because, in the field, it can be difficult to accurately shoot the relatively small target area of the head [54]. Intrinsic elements of the seal hunt make it unlikely to obtain an acceptably high proportion of clean headshots, including long distance shooting, shooting from moving boats, targeting moving animals and shooting at seals in the water [21,30]. Smith [16] estimated the distance for sealers shooting at seals from their vessels to be 40–50 m and noted that a variety of factors such as boat and seal movement create difficulties for sealers shooting at seals. Butterworth et al. [18] also highlighted the practical problems involved in shooting seals from boats (even in relatively calm seas) and reported very high wounding rates (> 80%) in seals that had been shot during the commercial seal hunt. The main disadvantage with shooting in the commercial seal hunt is

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the risk of targeted animals being hit with insufficient force/accuracy to cause immediate death or unconsciousness and this will be the case for a certain proportion of the seals shot [30]. The established practice of sealers shooting seals in open water also poses specific and significant welfare concerns, including the inability to confirm unconsciousness prior to gaffing, and the high potential for loss of wounded animals [16]. To retrieve seals in the case of open water shootings, sealers must impale the animals on a gaff hook and hoist them out of the water and onto a sealing vessel. In cases when seals have not been rendered insensible by the shots, they must endure this grossly traumatic process while conscious. Walsh [55] noted, "the possibility of suffering with the taking of beaters, either in open water or on small pans of ice by small fishing boats is great." Smith [16] recommended that, "*a seal should not be shot in the water, or in any circumstance when it is possible the carcass cannot be recovered*", yet the Canadian government failed to prohibit shooting in open water in the 2009 amendments to the Marine Mammal Regulations.

In video evidence from five commercial seal hunts (2003–2007), Butterworth et al. [18] established that the mean duration of the time from first shot to contact by the sealer was 48.8 ± 9.4 s, indicating a substantial period of potentially poor welfare before sealers could ensure the animals were insensible. Of the seals that were clubbed, 39% required two separate series of blows; mean time between series was 23.9 ± 3.2 s. Of the 100 sequences where the authors could time events from the first strike to the last action, the mean duration was 38.9 ± 3.4 s (range 1–162 s). The authors noted that these times should be viewed as minima because restrictions caused by filming (filming of longer sequences often ended even though the seal was still responding to stimuli). For some seals, the period during which they were injured, prior to bleeding, was considerable. The authors viewed cases of injured seals moving and responding to stimuli for up to 34 min (in addition to an unknown time from first insult and to an unknown end point).

3.3.4. Repeated application of stunning methods

For mechanical stunning to be humane the general requirement is that insensibility be accomplished with the first application [56,35,37,18] in that repeated application may result in pain, fear and distress [14,18,30]. Yet Canada's Marine Mammal Regulations do not require that stunning is achieved with one strike, or that sealers refrain from attempting stunning in conditions that hamper accuracy.

3.4. Confirmation of unconsciousness

3.4.1. Monitoring methods

While EFSA [30] identified seven signs of an effective stun, the Marine Mammal Regulations require only one testing method and the Conditions of Sealing Licenses includes a second.

3.4.1.1. Skull palpation. Canada's Marine Mammal Regulations require that sealers palpate the seal's cranium to confirm it has been crushed following clubbing and shooting. Yet in the context of the commercial seal hunt, it has been argued that skull palpation is not a reliable test for unconsciousness. A partially crushed skull can be compatible with consciousness [30,18]. That interpretation of the severity of the crush injury rests solely with a sealer working in extreme conditions, often beset by fatigue and with a rushed work schedule and usually wearing thick work gloves, makes skull palpation likely to be a less than reliable method for confirming unconsciousness. Burdon et al. [14] states:

> "*…skull palpation is not the most reliable as a means of interpreting death or level of consciousness. The location and severity of crush injuries…will affect the possible outcome; it is therefore open to misinterpretation.*"

3.4.1.2. Directed movement. The conditions of sealing licenses require that sealers monitor seals for signs of "directed movement" after shooting and, if such movement is observed, requires that they shoot again. Yet harp seals exhibit a "fear-induced paralysis" when they perceive a threat, characterized by tonic contraction of the whole body. These immobile seals could be interpreted as unconscious or dead and still be conscious [15,30]. Notably, Lydersen and Kovacs [57] found that of 382 seal pups presented with threatening stimuli, 86% displayed a paralysis response. Reliance on "directed movement" as an indicator of consciousness is problematic, and yet it is the only assessment method available to sealers shooting seals at a distance.

3.4.1.3. Corneal reflex test. A corneal reflex test was mandated in the Marine Mammal Regulations prior to the 2009 amendments, but is no longer prescribed. While one of several standard methods used to evaluate consciousness in abattoirs, a corneal reflex test alone may not provide a reliable means of determining unconsciousness in the field environment of the commercial seal hunt. The test can be difficult to perform by a sealer on the ice [16] and sealers are likely to neglect the check when they are tired or in a hurry, or when they perceive no one is watching them [21]. It may be that, given the commercial scale of the hunt, the nature of the animals involved and the field environment in which the killing occurs, there are no fail-safe methods for determining levels of consciousness in wounded seals. Inability to reliably monitor this essential humane endpoint (unconsciousness) in such a large number of commercially hunted animals must be considered a cause for very serious concern.

3.4.2. Delays in monitoring

Confirmation of unconsciousness should occur immediately following application of a stunning method [39,14,30]. Yet while the Marine Mammal Regulations require monitoring without delay in the case of clubbing, the same is not mandated in instances of shooting. Instead, the Marine Mammal Regulations state that after shooting a seal, sealers should palpate the cranium *as soon as possible* to confirm it has been crushed. This broad wording allows for long delays as the sealer must leave the boat and travel across the ice between the time of shooting and checking. The regulations also permit sealers to shoot multiple animals prior to checking any for unconsciousness.

3.5. Anatomical and physiological adaptations of seals for marine life

The specific adaptations of seals to the aquatic and diving life raise significant concerns when 'conventional' slaughter processes are proposed. Harp seals may dive to depths exceeding 400 m and have extraordinary ability to withstand the effects of the progressive asphyxia–hypoxia, hypercapnia and acidosis. They hold their breath (apnea), reduce their heart rate (bradycardia) and vasoconstrict the blood vessels in the skin and peripheral tissues to conserve oxygenated blood and the arterial oxygen partial pressure (Pa_{O2}) in seals can be as low as 3.2×10^2 Pa [58], which is equivalent to the degree of hypoxia experienced by human climbers on the top of Mt. Everest (approximately 8850 m). Seal muscle is rich in myoglobin, containing up to 1200% of the amount found in the muscle of some land mammals and seals have a high circulating blood volume as well as a higher resting number of blood cells in a given volume of blood (hematocrit)

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than land mammals [59]. Blood and muscle oxygen stores in seals are among the highest reported for any mammal and blood volume has been reported as up to ~21% of body mass. Recent findings of myoglobin levels in harp seals (*Pagophilus groenlandicus*) were thought to be the highest values ever reported in marine mammals [60,61]. In seals, the blood is the most important oxygen store in the body (generally about 65% of total), followed by the muscle (30%) and the lung (5%) [62].

The seal has a number of anatomical adaptations that allow pooling and reservoirs of oxygenated blood to be used when diving. Seal hearts may be better adapted to withstand low O_2 conditions than hearts of land mammals [63]. The pericardial venous plexus, and the aortic bulb act as a significant store of oxygenated blood, along with the spleen. The caval sphincter controls release of oxygenated blood into the circulation from the hepatic sinus and the spleen, which may contain up to one fifth (20%) of the seal total blood volume and is a significant storage reservoir for oxygenated blood. A young seal resting on the ice would be relaxed and so have a dilated (full) spleen. If it died 'immediately' following shooting from a distant boat then it would be anticipated to be dead with a full spleen. If the seal is shot and injured, or is approached by a hunter and killed using the hakapik, this would probably result in splenic contraction. In early post-mortem studies [64], the spleens of all seals assessed were either fully dilated or fully contracted after death and this may have been related to degree of 'handling' prior to killing.

The tissues of seals may have the capacity to withstand poor levels of oxygenation that would not routinely be survivable by terrestrial species [60]. The brain of seals may be adapted to withstand comparatively low oxygen availability. This adaptation may give seal neurons increased tolerance to hypoxia and may explain in part the ability of deep diving mammals to sustain neuronal activity during prolonged dives [65]. Emptying of the spleen and the large circulating volume of oxygenated blood may give the seal a 'long refractory period' after head trauma—i.e. it is possible that it would take a long period of time for the tissues of the seal to die following immobilization by hakapik or clubbing. The interaction between the diving adaptations of seals and the killing methods has not been researched. It is proposed that it should be assumed (precautionary principle) that seals will not die rapidly as a result of anoxia or reduced oxygen tension in the blood or tissues in the same time scale as terrestrial animals. There is a real potential for prolonged life and the potential for prolonged suffering in these animals adapted to prolonged low level oxygen utilization. Seals are highly adapted mammals and any assumptions that 'normal' killing methods can be applied should be questioned until proven otherwise.

3.6. Additional obstacles to humane slaughter

The killing environment in a slaughterhouse can be controlled. The animal can be immobilized, killing implements can be regulated and inspected, supervisors can be on hand to supervise the killing, and inspectors can observe the killing at any time. This is not the case in a wilderness environment, and conditions found in the field are far more challenging than those that are controlled [37]. Hunters targeting wild terrestrial animals face challenges to delivering a humane death such as moving targets and the distance at which they must shoot, and sealers face an even broader range of challenges [16].

3.6.1. Extreme weather conditions

High swells, gale force winds, dense fog, extreme low temperatures, freezing rain and dangerous ice conditions are all common elements in sealing areas, and seal hunters work in adverse weather conditions as a matter of course [66]. The extreme weather elements of the northwest Atlantic can compromise the ability of any sealer to deliver a humane death to seals, creating obstacles to accuracy in both clubbing and shooting and the ability of sealers to retrieve wounded animals. According to Walsh [55], "The harsh environmental conditions where the sealing operations take place both in the Gulf and in the front reduce the likelihood that the killing of seals could ever be conducted in a humane manner."

3.6.2. Strong winds

High winds, at times gale force ($>$34 knots/h), have been regularly recorded on the opening days of the commercial seal hunt in the front throughout the past 10 years (see Table 3). Wind is responsible for more missed shots than any other single factor [67], and significant shooting inaccuracy has been observed in high wind conditions at the seal hunt [68].

3.6.2.1. High seas. Historic data show that high waves are an intrinsic element of sealing areas (see Table 3) and, in the past decade, wave heights of up to 18 ft have been regularly recorded on the opening days of the commercial seal hunt. High oceans swells/waves cause the small vessels sealers operate from to pitch and roll, creating an unstable platform for sealers to shoot from. Aiming stability is an essential determinant of shooting precision [69–72] and there are significant negative relations between sway and performance accuracy [71]. Boat movement creates significant challenges to sealers delivering accurate head shots [21,16]. Moreover, the small, broken ice pans upon which seals are found move significantly in dynamic sea conditions. Seals are already mobile on the ice floes, and the movement of their sea ice platforms compounds the situation.

3.6.2.2. Extreme cold. Sealers work for extensive hours in extreme low temperatures and exposure to cold reduces core body temperature. This induces shivering and muscle stiffness and depresses the central nervous and respiratory systems, impairing cognitive and manual dexterity [73,74]. The effects of mild hypothermia have a significant negative effect on cognitive processing speed and efficiency [75] and fine and gross manual dexterity [76,77,69]. In cold temperatures, rifle chamber pressure decreases and the bullet exits the muzzle at a lower velocity, impacting the target below the point of aim. Moreover, cold air is dense, creating greater resistance to the bullet, and this causes the bullet to travel slower and experience greater deflection from wind. Extreme cold can affect a person's ability to concentrate and that if the shooter's hands are numb, he may have difficulty holding a cold rifle and executing effective trigger control [78]. Grebot and Burtheret [79] reported shooting accuracy impairment in negative temperature shooting conditions. It would be logical to conclude that prolonged exposure to cold reduces the proportion of accurate headshots delivered in the commercial seal hunt.

3.6.3. Low visibility

Sea fog is common in locations where boundaries with cold ocean currents can be found [80]. The Grand Banks, located off the coast of Newfoundland, is considered the foggiest region in the world. In focus groups conducted with Newfoundland fishermen, "sealing in fog" was identified as a key element that causes risk to crews and vessels. The presence of sea ice along the coast of Newfoundland generates surface conditions that produce freezing drizzle [81]. Newfoundland receives the most freezing precipitation annually in North America, with an annual frequency that is almost twice the highest frequency observed elsewhere [82].

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Table 3
Wind speeds, wave heights (feet) and temperatures on the opening days of the commercial seal hunt in the front (2007–2011) (derived from National Oceanic and Atmospheric Administration data available at 〈http://www.ndbc.noaa.gov/〉).

Year	Date	Region	Max Average Wind Speed (knots)	Maximum gusts (knots)	Average Wave Height (ft)	Max Wave Height (ft)	Number of seals killed
2011	April 11	Front	20	27	6.8	8.8	4330
	April 12	Front	34	46	14	18	2629
	April 13	Front	21	42	13	17	3868
	April 14	Front	17	23	5.7	7.4	2534
	April 15	Front	21	29	12	16	2066
2010	April 8	Front	14	19	4.2	5.4	6845
	April 9	Front	24	33	12	15	8310
	April 10	Front	23	31	9.8	13	4622
	April 11	Front	22	30	8.9	12	5504
	April 12	Front	20	27	6.8	8.8	6239
2009	April 15	Front	12	16	4.9	6.3	2870
	April 16	Front	25	34	10	13	834
	April 17	Front	17	23	11	15	3388
	April 18	Front	20	27	8.8	11	2603
	April 19	Front	20	27	14	18	4036
2008	April 12	Front	19	25	8.1	11	34,679
	April 13	Front	18	24	10	13	23,341
	April 14	Front	15	20	6.7	8.7	13,139
	April 15	Front	22	30	7.8	10	13,094
	April 16	Front	18	24	7.1	9.2	17,130
2007	April 13	Front	16	21	7.8	10	91,566
	April 14	Front	6	9	7.3	9.5	3
	April 15	Front	12	16	6.5	8.4	35,675
	April 16	Front	14	19	5.7	7.5	1674
	April 17	Front	19	25	8.5	11	490

Notably, northeastern Newfoundland (where two thirds of commercial sealing occurs) has the highest number of hours of freezing drizzle. The human visual system becomes less efficient when the amount of visual information is low [83]. Fog, rain, or any element that obscures vision will make targets appear farther away [78,83], and the farther away an object appears to be, the less brightness and contrast occurs, and the less clearly the human eye can see it. Fog also distorts and reduces visual information including appearance of size of targets [83]. Decreases in visual acuity negatively affect marksmanship performance [84]. In these conditions of low visibility, it is reasonable to assume that shooters are more susceptible to errors in targeting. This, in turn, helps to explain the high wounding rates evidenced at the commercial seal hunt.

3.6.4. *Intensity of killing*

When the sealing season opens, all licensed vessels in the region are able to hunt for as many seals as they want until the regional quota is reached, and the opening day of the seal hunt is the most lucrative for sealers [6]. In some regions, the conditions of sealing licenses prevent individual sealing boats from landing more than 400 animals per day. In others, no such restriction exits, and vessels compete against each other, killing seals as quickly as possible, to collect the maximum number of skins before the quota is filled. Though the sealing season spans six months, the bulk of the killing occurs over just a few days in late March (in the Gulf of St. Lawrence) and in mid April (in the front).

3.6.5. *Competing fisheries*

Sealing vessels are licensed for a number of other fisheries, including shellfish [85]. Soon after the sealing season opens, multiple other fisheries do as well, including crab, shrimp and lobster. In 2010, shellfish accounted for 84% of the landed value of Newfoundland's fishery, while seals accounted for less than one half of one percent (0.5%) of the landed value [86]. It is reasonable to assume that fishers would prefer to regulate their time at the commercial seal hunt, to enable them to engage in the other lucrative fisheries.

3.6.6. *Danger to vessels and crew and the link to insurance deductibles*

Fishing is the most dangerous occupation in Newfoundland and Labrador, with rates of reported injuries and fatalities having doubled in recent years [87]. Search and rescue events in the waters northeast of Newfoundland increased by nearly 460% between 1993 and 1998, an increase which search and rescue authorities reported was due in large part to resumption of commercial sealing activities. The seal hunt, in particular, is considered a "high risk activity," one that invariably results in a high number of search and rescue incidents each year [66]. The presence of sea ice in commercial sealing operations increases the risk factor for vessels considerably, and also impairs search and rescue response. The fishing vessels used at the seal hunt are neither designed nor constructed for navigation in ice and the resulting risks are well recognized. Between 1990 and 2005, 227 occurrences involving fishing vessels operating in ice-infested waters were reported. The majority of these involved hull damage, and 21 vessels were lost. During March and April of 2008 alone, 41 requests for assistance were reported from sealing vessels [88]. Commercial sealing has contributed only a small fraction (0.5–3%) to the landed fishing value in Newfoundland in recent years. Yet, in some years, 24% of all search and rescue incidents in the fishing industry involved sealing vessels and, between 1993 and 2000, the sealing industry accounted for 13% of the fishing related fatalities for vessels under 65 ft in length [89]. A $250,000 insurance excess (deductible) is imposed for fishing vessels when operating at the seal hunt, compared to a $5000 excess when the fishing vessel is not operating in ice [90]. Regardless, many fishermen fail to carry insurance [66]. Given the clear safety and economic implications of working far offshore, in extreme weather conditions, amidst sea ice, it is reasonable to conclude that sealing captains would prefer to spend as little time as possible in this hazardous environment. These multiple elements create additional pressures for crews to work quickly and to potentially sacrifice humane procedures for speed.

3.6.7. Operator fatigue

Fishermen work long hours at sea, with little time for sleep, resulting in increased carelessness [91]. Under considerable pressure to work quickly, in adverse weather conditions, sealers are particularly susceptible to fatigue. Moreover, stunning by manual application of a percussive blow to the head (clubbing) is physically exhausting for personnel and can result in operator fatigue [35], and the risk of developing operator fatigue when applying this stunning method increases with larger slaughter numbers [92]. Fatigue may lead to inefficient application of the stunning method and result in poor welfare to the animal [35,92]. The effects of fatigue can include decreased vigilance, perceptive and cognitive functions [93]. Tharion et al. [94] found that a combination of fatigue (caused by sleep deprivation) and operational and environmental stress reduced marksmanship accuracy, as demonstrated by a 37.5% increase in percentage of missed targets and a 38% increase in distance from center of mass of the target. Knapick et al. [95] reported that marksmanship accuracy decreased by 26% for number of target hits and 33% for distance from the centre of the target following a period of significant physical exertion.

3.6.8. Lack of monitoring/enforcement

According to the Department of Fisheries and Oceans [96], up to 6000 fishers participate in the seal hunt. These fishers routinely operate from more than 1000 vessels, spread out over thousands of square kilometers of ocean in different regions. Individual sealers often move far away from their vessels in skiffs (small boats) or on foot on the ice. Close monitoring of the commercial seal hunt by authorities is a practical impossibility [8,9,16,18,21,28,30,97] given that the area to be patrolled is extensive, the number of sealers is large, and sealing operations are multifaceted. In particular, the Front (where two thirds of sealing occurs) is not well monitored by authorities because of its remoteness and difficult environmental conditions. To further complicate the situation, Coast Guard vessels are often called away from monitoring and enforcement of the hunt to perform other duties, such as icebreaking for other vessels [16].

4. Discussion: Impacts of climate change

Our climate is changing, sea ice is declining [100] and extreme events are increasing in frequency [98]. Harp seals, the primary target of the Canadian commercial seal hunt, are ice dependent animals, and diminished sea ice cover can reduce reproductive success of adult females and result in higher rates of pup mortality [99,101]. Over the past 40 years, a declining trend in accumulated ice has been observed in both the Gulf and the Front, and an increase in seal mortality is likely in future years [102]. Diminishing sea ice and the increased number of extreme weather events are compromising animal welfare by changing the ways hunters interact with seals. As sea ice cover continues to decrease, the related negative welfare impacts are likely to be more frequently observed. These are explained in the following sections.

4.1. Increasing rates of wounding

Stunning methods at the seal hunt (clubbing or shooting) are largely influenced by ice conditions. Shooting from sealing vessels is the method of choice when broken and fragile sea ice makes it difficult to approach seals on foot [31]. Unfortunately, shooting of seals involves higher struck and lost rates [32,103] and high wounding rates [18]. As ice conditions continue to deteriorate, reliance on long distance shooting as a primary stunning method will increase in the commercial seal hunt. Regardless, a significant proportion of seals will likely continue to be stunned by clubbing. It is difficult for sealers to accurately club seals on the ice given the slippery conditions and the possibility of a moving target [21], and these challenges are compounded by the impacts of climate change. In the present day seal hunt, sealers are attempting to club seals on fragile, broken ice floes that move quickly in the water and present an unstable platform to operate on.

4.2. Increased numbers of seals shot in or near open water

Effective application of humane slaughter methods is a practical impossibility when shooting seals in open water. According to Côté and Pigeon [101], a prohibition on shooting seals in open water in years with poor ice conditions, would have a detrimental effect on the sealing industry. This is an admission that shooting in open water is more prevalent in years with less ice cover; thus it is logical to assume a likely correlation between the anticipated decrease in sea ice cover and an increase in open water shooting at the commercial seal hunt. When taken in open water, loss rates for seals less than one year of age are five times higher, and for seals over a year of age ten times higher, than for seals taken on the ice [103]. Moreover, the ice floes are smaller and surrounded by open water, presenting increased opportunities for wounded seals to escape into the ocean. As more seals are targeted in or near open water, the number of 'struck and lost' seals will likely increase. Moreover, when seals are shot in the water, or on ice floes too fragile for sealers to stand on, the only way to retrieve the seal is by impaling the animal with a gaff and dragging it onto the vessel [104]. In these situations, it is impossible to verify the seal is unconscious prior to gaffing. This results in the profoundly inhumane yet common process of impaling and dragging live mammals when they remain capable of experiencing fear, pain and distress.

4.3. Potential for delay in dealing with wounded seals

Because seals are shot at distances of 40–50 m, there is an inevitable delay between stunning and confirmation of unconsciousness [16]. Most sealing vessels are not constructed for navigation in ice-infested water [88] and must be maneuvered cautiously through sea ice to reach the wounded seals. Butterworth et al. [18], in reporting wounding rates of 82% in seals they observed shot in video evidence, noted that, "*the mean duration from first shot to contact by the sealer was 48.8 $\pm$ 9.4 seconds, indicating a considerable period of potentially poor welfare*." Reliance on long distance shooting, and the related incidence of delay between shooting and checking, is likely to increase as sea ice diminishes.

4.4. Reduced ability to bleed out seals on the ice

Animals should be bled without delay following confirmation of unconsciousness [39,14,35,37]. For seals, the bleeding should occur on the ice [16] and animals should be monitored during the

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bleeding process to ensure unconsciousness persists until death [39,37]. In contrast, Canada's Marine Mammal Regulations require only that bleeding be completed prior to skinning, allowing sealers to subject seals to acts that cause avoidable fear, pain and suffering, including gaffing, dragging and throwing. Deteriorating sea ice conditions makes it often dangerous, difficult or impossible to bleed out seals on the ice and for sealers to remain with the seals throughout the process to monitor for signs of consciousness.

5. Conclusions

When animals are slaughtered and killed for commercial purposes, the expectation is that they are rendered immediately insensible without avoidable pain or undue distress, and they remain unconscious until the time that they die. Recommendations and regulations in both Canada and the European Union are designed to ensure that these expectations are met, and specific standards aim:

- to minimize distress during restraint and during the application of the stunning equipment;
- to induce unconsciousness painlessly and without the need to repeat the application of the stunning method;
- to ensure that the animals remain unconscious until death occurs.

The first expectation is hard to achieve in the Canadian seal hunt and it would be impossible to avoid some period of distress prior to clubbing. Seals show distress in the period immediately prior to being clubbed, trying to escape or showing defensive responses such as rearing up at the sealer and/or hakapik. Seals are often shot within view of each other and show behaviors that indicate distress.

The methods used in hunting seal pups fall short in the second expectation because significant numbers of seal pups have to be shot or struck more than once, and because insufficient care is taken in applying the regulatory checks to ensure that each animal is rendered insensible before the operator performs further tasks (gaffing, dragging, throwing onto boats, skinning). In the Canadian seal hunt, the number of affected animals hunted is very large—this being the largest of all mammal hunts. The wounding rate has been shown in a number of studies to be high, and delay in dealing with injured animals is often prolonged resulting in periods of distress that can be protracted and can affect huge numbers of animals. It is common for sealers to strike several animals before returning to check those that have already been struck. The degree and position of skull and facial bone damage and fracture in animals subject to post-mortem indicates poor accuracy of clubbing and inadequate checking. Very high rates of wounding are recorded when seals are shot. The evidence presented in this analysis leads us to the conclusion that both shooting and clubbing of seals in the context of commercial sealing should be viewed as inherently inhumane, and that the current methods seen in the commercial hunt of very large numbers of animals compares extremely unfavorably with the societal and legal expectations for commercial slaughter conditions. Seals have a number of physiological and anatomical adaptations that bring into question whether 'conventional' thinking on slaughter can be applied to these animals. Seals have the potential to store and control oxygenated blood (and oxygen stores in muscle) and may also have tissues, including heart and neural tissue, with the capacity to withstand low oxygen tensions.

There are a number of factors that affect the capacity of sealers to carry out the seal hunt to a high level of 'care'. These include the time and economic pressures which result from the speed at which the hunt must be conducted, the climate and ice conditions in which sealers work and the changes in the ice state which have come with climate change. Changes in ice conditions may push sealers to work at higher 'risk' and this may severely affect the 'quality' of the killing process and the regard that is shown to the requirements of the law. The three-step process recommended by the Independent Veterinarians' Working Group [16]—*stunning, checking by palpation of the skull and bleeding, to be carried out in sequence as rapidly as possible*—are not detailed enough in their specification to give confidence that 'in field' application of these measures will result in a humane death. The IVWG three-step process does not require that sealers perform these processes in immediate succession, and it does not require sealers to remain with the animals through the bleeding process. It is clear from observation based reports that the three step process is rarely applied, and the extent of 'meaningful' checking of the animals' state of sensibility is low despite this being a legal requirement. In a similar fashion, the Marine Mammal Regulations do not prescribe the endpoint for a humane death for seals as internationally recognized principles do for other commercially slaughtered species. What a civilized society would and could expect and anticipate—is that the professionals who are given authority to kill wild animals for profit (the sealers) would be given detailed and comprehensive instructions that they should follow with care and skill. The evidence is strong that this is not the case.

In this paper, it is apparent that there is reliable data indicating that cruelty takes place on a large scale during the Canadian commercial seal hunt. The video material provided in association with this paper is not placed there to shock (although it may do this) but to provide the reader with examples—tangible evidence of the types and range of inherently inhumane events that are taking place. This is a scientific paper, but it is also critical that the informed reader watches and digests the video material to gauge for him or herself what happens to these animals, and, along with the scientific, anatomical and physiological data provided in this paper, can make an informed opinion. In response to concerns from citizens that the commercial killing of seals is cruel, many nations have restricted their trade in seal products. With some of those measures currently under examination at the World Trade Organisation, it is important to evaluate if the best available scientific evidence supports citizens' concerns. The evidence, which continues to be available year on year, through observer data, video material, and veterinary study is clear: Canada's commercial seal hunt adopts procedures, and has measurable outcomes that do not meet internationally recognized standards of humane slaughter. There are unacceptable (and unlawful) things being done to animals for profit in this hunt. The evidence clearly shows that the actions of governments in prohibiting seal product trade are, and will continue to be, justified.

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Appendix A. (Skull injuries and impacts)

Clip 4: March 2005, Gulf of St. Lawrence ⋙ Clip 5: March 2005, Gulf of St. Lawrence ⋙ Clip 6: March 2005, Gulf of St. Lawrence ⋙ Clip 7: March 2005, Gulf of St. Lawrence ⋙ Clip 8: March 2005, Gulf of St. Lawrence ⋙ Clip 9: March 2005, Gulf of St. Lawrence ⋙ Clip 10: March 2005, Gulf of St. Lawrence ⋙ Clip 11: April 2008, Newfoundland Front ⋙

Appendix B. (Shooting impacts)

Clip 1: April 2010, Newfoundland Front ⋙ Clip 2: April 2010, Newfoundland Front ⋙ Clip 3: April 2009, Gulf of St. Lawrence ⋙ Clip 4: April 2011, Northern Gulf of St. Lawrence ⋙ Clip 5: April 2008, Gulf of St. Lawrence ⋙ Clip 6: April 2008, Gulf of St. Lawrence ⋙ Clip 7: April 2010, Newfoundland Front ⋙ Clip 8: April 2008, Gulf of St. Lawrence ⋙ Clip 9: April 2007, Gulf of St. Lawrence ⋙ Clip 10: April 2011, Northern Gulf of St. Lawrence ⋙ Clip 11: April 2011, Northern Gulf of St. Lawrence ⋙ Clip 12: April 2011, Northern Gulf of St. Lawrence ⋙ Clip 13: April 2011, Northern Gulf of St. Lawrence ⋙ Clip 14: April 2011, Northern Gulf of St. Lawrence ⋙ Clip 15: April 2011, Newfoundland Front ⋙ Clip 16: April 2011, Newfoundland Front ⋙

Appendix C. (Struck and lost)

Clip 1: April 2010, Newfoundland Front ⋙ Clip 2: April 2011, Northern Gulf of St. Lawrence ⋙ Clip 3: April 2011, Northern Gulf of St. Lawrence ⋙ Clip 4: April 2011, Newfoundland Front ⋙

Appendix D. (Failure to monitor for unconsciousness)

Clip 1: April 2010, Newfoundland Front ⋙ Clip 2: April 2007, Gulf of St. Lawrence ⋙ Clip 3: April 2010, Newfoundland Front ⋙ Clip 4: April 2010, Newfoundland Front ⋙ Clip 5: April 2010, Newfoundland Front ⋙ Clip 6: April 2010, Newfoundland Front ⋙ Clip 7: April 2010, Newfoundland Front ⋙ Clip 8: March 2010, Gulf of St. Lawrence ⋙ Clip 9: April 2011, Northern Gulf of St. Lawrence ⋙ Clip 10: April 2011, Northern Gulf of St. Lawrence ⋙ Clip 11: February 2011, Hay Island ⋙

Appendix E. (Examples of interval between impact and bleedout)

Clip 1: April 2010, Newfoundland Front ⋙ Clip 2: April 2010, Newfoundland Front ⋙ Clip 3: April 2010, Newfoundland Front ⋙ Clip 4: April 2010, Newfoundland Front ⋙ Clip 5: April 2010, Newfoundland Front ⋙ Clip 6: April 2011, Northern Gulf of St. Lawrence ⋙ Clip 7: April 2010, Newfoundland Front ⋙ Clip 8: April 2010, Newfoundland Front ⋙ Clip 9: April 2011, Northern Gulf of St. Lawrence ⋙

Appendix F. (Failure to bleed out)

Clip 1: April 2010, Newfoundland Front ⋙ Clip 2: April 2010, Newfoundland Front ⋙ Clip 3: April 2010, Newfoundland Front ⋙ Clip 4: April 2010, Newfoundland Front ⋙ Clip 5: April 2010, Newfoundland Front ⋙ Clip 6: April 2011, Northern Gulf of St. Lawrence ⋙ Clip 7: April 2010, Newfoundland Front ⋙ Clip 8: April 2010, Newfoundland Front ⋙ Clip 9: April 2011, Northern Gulf of St. Lawrence ⋙

Appendix G. (Hooking, gaffing, dragging)

Clip 1: April 2010, Newfoundland Front ⋙ Clip 2: April 2010, Newfoundland Front ⋙ Clip 3: April 2010, Newfoundland Front ⋙ Clip 4: March 2005, Gulf of St. Lawrence ⋙ Clip 5: March 2005, Gulf of St. Lawrence ⋙ Clip 6: April 2011, Northern Gulf of St. Lawrence ⋙ Clip 7: April 2011, Northern Gulf of St. Lawrence ⋙ Clip 8: April 2011, Northern Gulf of St. Lawrence ⋙ Clip 9: April 2011, Northern Gulf of St. Lawrence ⋙ Clip 10: April 2011, Northern Gulf of St. Lawrence ⋙ Clip 11: April 2011, Northern Gulf of St. Lawrence ⋙ Clip 12: April 2011, Northern Gulf of St. Lawrence ⋙ Clip 13: April 2011, Newfoundland Front ⋙ Clip 14: April 2011, Newfoundland Front ⋙ Clip 15: April 2011, Newfoundland Front ⋙ Clip 16: April 2010, Newfoundland Front ⋙ Clip 17: April 2011, Northern Gulf of St. Lawrence ⋙

Appendix H. Supporting information

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References

[1] Department of Fisheries and Oceans (DFO). Frequently asked questions about Canada's seal harvest. Question 2 – which species of seals are harvested? 2011. 〈http://www.dfo-mpo.gc.ca/fm-gp/seal-phoque/faq-eng.htm#faq2〉 [accessed April 2012].
[2] Worthy GAJ, Lavigne DM. Energetics of fasting and subsequent growth in weaned harp seal pups, *Phoca groeniandica*. Can J Zool 1983;61:447–56.
[3] House of Commons. FOPO, Number 009, 1st Session, 39th Parliament. June 15 2006. 〈http://www.parl.gc.ca/HouseChamberBusiness/ChamberPublicationIndexSearch.aspx?arpist=b&arpit=&arpidf=2006%2f04%2f03&arpidt=2007%2f09%2f14&arpid=False&arpij=False&arpice=True&arpicl=10480&arpialtid=27738&arpitp=J&arpics=False&arpicp=True&arpicd=False&arpico=False&arpicc=False&arpicpd=2293772&ps=Parl39Ses1&Language=E&Mode=1&Parl=41&Ses=1#Para140409〉 [accessed 26/01/2012].
[4] Department of Fisheries and Oceans (DFO). Frequently asked questions about Canada's seal harvest. Question 9—Why do sealers target young animals? 2011. 〈http://www.dfo-mpo.gc.ca/fm-gp/seal-phoque/faq-eng.htm#faq9〉 [accessed April 2012].
[5] Humane Society International/Canada. More than 98 percent of seals killed at less than three months of age. May 26, 2011. 〈http://www.hsi.org/world/canada/work/protect_seals/research/seal_pups killed_young.html〉 [accessed April 2012].
[6] Department of Fisheries and Oceans (DFO). Frequently asked questions about Canada's seal harvest. Question 16—What can happen if a sealer violates the regulations? 2011. 〈http://www.dfo-mpo.gc.ca/fm-gp/seal-phoque/faq-eng.htm#faq16〉 [accessed April 2012].
[7] Leaper R, Lavigne DM, Corkerton P, Johnston DW. Towards a precautionary approach to managing Canada's commercial harp seal hunt. ICES J Mar Sci 2010;67(2):316–20.
[8] Simpson E. Observations on the seal hunt in the Gulf of St. Lawrence, March 1966. Final report for New Brunswick SPCA, Fredericton; 1966.
[9] Simpson E. Observations on the seal hunt in the Gulf of St. Lawrence, March 7–9, 1967. Rep. WFPA: Zurich; 1967.
[10] Rowsell HC. Sealing activities by Newfoundland landsmen and ships on the Front. Report to Commission on Seals and Sealing; 1977.
[11] Rowsell HC. Sealing operations—Gulf and Front, 1979. Report to Commission on Seals and Sealing; 1979.
[12] Rowsell HC. Observations on the harp seal hunt: the Front—1980. Report to Commission on Seals and Sealing; 1980.
[13] Rowsell HC. The seal hunt at the Front 1981. Report to Commission on Seals and Sealing; 1981.
[14] Burdon RL, Gripper J, Longair JA, Robinson I, Ruehlmann D. Veterinary report Canadian Commercial seal hunt Prince Edward Island March; 2001. 〈http://www.infurmation.com/pdf/fielder01.pdf〉 [accessed April 2012].
[15] Daoust PY, Crook A, Trent K, Bollinger TK, Campbell KG, Wong J. Animal welfare and the harp seal hunt in Atlantic. Can Vet J 2002;43:687–94.
[16] Smith BL. Improving humane practice at the Canadian harp seal hunt: a Report of the Independent Veterinarians' Working Group on the Canadian Harp Seal Hunt; 2005. 〈http://www.thesealfishery.com/files/IVWGReportAug2005.pdf〉 [accessed April 2012].
[17] Marine Mammal Regulations. The Canada Gazette, Part II, vol. 137, no. 8, SOR 2003-103. Government of Canada; 2009.
[18] Butterworth A, Gallego P, Gregory N, Harris S, Soulsbury C. Welfare aspects of the Canadian seal hunt: preliminary report, 30 p. and final report, 45 p.

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Document submitted to EFSA; 2007. 〈http://www.efsa.europa.eu/en/scdocs/doc/610.pdf〉 [accessed April 2012].
[19] Seal Protection Regulations, C.R.C., c. 833. Fisheries Act. Department of Justice Canada; 1978.
[20] Cizriot M. Death on the Ice. Dive International Publishing Ltd.; 1998. 〈http://www.ukdiving.co.uk/conservation/articles/death on ice.htm〉 [accessed April 2012].
[21] Malouf A. Methods of killing seals. In: Seals and Seal Protection Regulations, Government of Canada 1964, 1972 and other years. Seals and Sealing in Canada—improvements to seal hunt management measures fisheries and oceans, Canada; 1986. 〈http://www.dfo-mpo.gc.ca/fm-gp/seal-phoque/reports-rapports/facts-faits/facts-faits regs-eng.htm〉 [accessed April 2012].
[22] Department of Fisheries and Oceans (DFO). Frequently asked questions about Canada's seal harvest. Question 11—What percentage of seals is harvested in the Gulf of St. Lawrence versus Newfoundland and Labrador? 2011. 〈http://www.dfo-mpo.gc.ca/fm-gp/seal-phoque/faq-eng.htm#faq11〉 [accessed April 2012].
[23] Hughes TI. Report of inspection of 1966 seal hunting in the Gulf of St. Lawrence. Ontario Humane Society, Toronto; Hughes TI (1968). Report of observations of the 1968 seal hunt in the Gulf of St. Lawrence. Ontario Humane Society, Toronto; 1966.
[24] Hughes TI. 1981 Sealing report. Report for Commission on Seals and Sealing; 1981.
[25] Simpson E. Seal hunting in the Gulf of St. Lawrence. Nature 1967;214 [June 14].
[26] Scott TH. Annual seal hunt—Northwest Atlantic: Gulf of St. Lawrence area, 1971 season. Report of the International Society for the Protection of Animals: London; 1971.
[27] Scott TH. Landsmen and the long liner seal hunt off the northeast coast of Newfoundland, April 1977. Report for the International Society for the Protection of Animals: London; 1977.
[28] Jordan WJ. The killing of harp seal pups. Report for Royal Society for the Prevention of Cruelty to Animals; 1978.
[29] Taylor GB. Report on the seal cull off the Magdalen Islands. Report for ISPA, London; 1979.
[30] European Food Safety Authority (EFSA). Welfare aspects of the Canadian seal hunt: preliminary report, 30 p. and final report, 45 p.; 2077. EFSA report at 〈http://www.efsa.europa.eu/en/scdocs/doc/610.pdf〉 [accessed April 2012].
[31] North Atlantic Marine Mammal Commission (NAMMCO). Report of the NAMMCO workshop to address the problems of "Struck and Lost" in seal, walrus and whale hunting. North Atlantic House. Copenhagen: Denmark; 14–16 November 2006. 〈http://www.nammco.no/webcronize/images/Nammco/818.pdf〉 [accessed April 2012].
[32] Lavigne DM. Estimating total kill of northwest Atlantic Harp seals. 1994–1998. Mar Mamm Sci 1999;15(3):871–8.
[33] Gagne J. Proceedings of the National Marine Mammal Review Committee; 1999. 〈www.dfo-mpo.gc.ca/csas/Csas/Proceedings/1999/p99_14.pdf〉 [accessed April 2012].
[34] European Commission. Council Regulation (EC) no 1099/2009 of 24 September 2009 on the protection of animals at the time of killing. Official Journal of the European Union; 2009. 〈http://ec.europa.eu/food/animal/welfare/slaughter/regulation 1099 2009 en.pdf〉 [accessed April 2012].
[35] European Food Safety Authority (EFSA). Welfare aspects of animal stunning and killing methods; 2004. 〈http://www.efsa.europa.eu/en/scdocs/doc/45ax1.pdf〉 [accessed April 2012].
[36] World Organisation for Animal Health (OIE). Terrestrial Animal Health Code. 7.5.1. Slaughter of animals; 2011. 〈http://www.oie.int/index.php?id=169&L=0&htmfile=chapitre 1.7.5.htm〉 [accessed April 2012].
[37] American Veterinary Medical Association. Guidelines on euthanasia; 2007. 〈http://www.avma.org/issues/animal welfare/euthanasia.pdf〉 [accessed April 2012].
[38] Farm Animal Welfare Council. Report on the welfare of farmed animals at slaughter or killing. Part 1: Red meat animals. London; 2003. 〈http://www.fawc.org.uk/reports/pb8347.pdf〉 [accessed April 2012].
[39] Welfare of Animals (slaughter or killing) Regulations (WASK). United Kingdom; 1995. 〈http://www.legislation.gov.uk/uksi/1995/731/contents/made〉 [accessed April 2012].
[40] Council of the European Union. Council Regulation (EC) no 1099/2009 of 24 September 2009 on the protection of animals at the time of killing; 2009. 〈http://eur-lex.europa.eu/LexUriServ/LexUriServ.do〉?uri=OJ:L:2009:303:0001:0030:EN:PDF [accessed April 2012].
[41] Canadian Veterinary Medical Association (CVMA). Position statement on euthanasia; 2007. 〈http://canadianveterinarians.net/ShowText.aspx〉?ResourceID=34 [accessed April 2012].
[42] Council of the European Union. Council Directive 93/119/EC of 22 December 1993 on the protection of animals at the time of slaughter or killing; 1993. 〈http://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31993L0119:EN:HTML〉 [accessed April 2012].
[43] Council of Europe. Recommendation no. R(91) 7 of the Committee of Ministers to Member States on the Slaughter of Animals; 1991. 〈https://wcd.coe.int/wcd/com.instranet.InstraServlet?command=com.instranet.CmdBlobGet&InstranetImage=572260&SecMode=1&DocId=597330&Usage=2〉 [accessed April 2012].
[44] Council of Europe. European Convention for the Protection of Animals for Slaughter; 1979. 〈http://conventions.coe.int/Treaty/EN/Treaties/Html/102.htm〉 [accessed April 2012].
[45] Criminal Code of Canada. Section 446. Department of Justice Canada; 1990. 〈http://laws-lois.justice.gc.ca/eng/acts/C-46/page-283.html〉 [accessed April 2012].
[46] Humane Slaughter Association. Stun-to-Stick Times (Electrical stunning); 2006. 〈http://www.hsa.org.uk/Resources/Publications/Technical%20Notes/TN17.pdf〉 [accessed April 2012].
[47] Daoust PY. Letter from Dr. Pierre-Yves Daoust, Atlantic Veterinary College; 2011. 〈http://www.sealsandsealing.net/view.php?id=333&type=2〉 [accessed April 2012].
[48] Barry D. Seal hunting well regulated. Sudbury Star; 2010. 〈http://www.thesudburystar.com/ArticleDisplay.aspx?e=3095361〉 (accessed September 2011).
[49] Keddy G (chair). Ensuring a sustainable and humane seal harvest. Report of the Standing Committee on Fisheries and Oceans; 2007. 〈http://www.parl.gc.ca/HousePublications/Publication.aspx?Language=E&Mode=1&Parl=39&Ses=1&DocId=2872843&File=0〉 [accessed April 2012].
[50] Winter J. Sealing: a rightful occupation; 2007. 〈http://thesealfishery.com/articleView.php?id=27&page=0&sub=1&status=1〉 [accessed April 2012].
[51] Department of Fisheries and Oceans (DFO). The Atlantic seal hunt: sustainable, viable and humane; 2005. 〈www.dfo-mpo.gc.ca/misc/seal briefing e.ppt〉 [accessed September 2011].
[52] Department of Fisheries and Oceans (DFO). Conditions of seal licenses 2011–2012; 2011.
[53] Rowsell HC. Studies on killing methods at the Front, April 1–5 1973. Report to the Committee on Seals and Sealing; 1973.
[54] Canadian Council on Animal Care (CCAC). Guidelines on: the care and use of wildlife; 2003. 〈http://www.ccac.ca/en/CCAC Programs/Guidelines Policies/GDLINES/Guidelis.htm〉 [accessed April 2012].
[55] Walsh JC. Submission to the Royal Commission on Seals and the Sealing Industry in Canada, on behalf of Fauna and Flora Preservation Society and WSPA; 1985.
[56] Humane methods of livestock slaughter. United States Code Annotated. Title 7. Agriculture. Chapter 48. United States of America; 1958. 〈http://www.animallaw.info/statutes/stusfd7usca1901.htm〉 [accessed April 2012].
[57] Lydersen C, Kovacs K. Paralysis as a defence response to threatening stimuli in harp seals (*Phoca groenlandica*). Can J Zool 1995;73(3):486–92.
[58] Davis RW, Kanatous SB. Convective oxygen transport and tissue oxygen consumption in Weddell seals during aerobic dives. J Exp Biol 1999;202: 1091–113.
[59] Thornton SJ, Hochachka PW. Oxygen and the diving seal. Undersea Hyperb Med 2004;31(1):81–95.
[60] Burns JM, Lestyk KC, Folkow LP, Hammill MO, Blix AS. Size and distribution of oxygen stores in harp and hooded seals from birth to maturity. J Comp Physiol B 2007;177:687–700.
[61] Hassrick JL, Crocker DE, Deutschel NM, McDonald BI, Robinson PW, Simmons SE, et al. Condition and mass impact oxygen stores and dive duration in adult female northern elephant seals. J Exp Biol 2010;213: 585–92.
[62] Kooyman GL. Diverse divers: physiology and behaviour. Berlin: Springer; 1989.
[63] Burns JM, Skomp N, Bishop N, Lestyk K, Hammill M. Development of aerobic and anaerobic metabolism in cardiac and skeletal muscles from harp and hooded seals. J Exp Biol 2010;213:740–8.
[64] Barcroft J, Stephens JG. Observations upon the size of the spleen. J Physiol 1927;64:1–22.
[65] Mitz SA, Reuss S, Folkow LP, Blix AS, Ramirez JM, Hankeln T, et al. When the brain goes diving: glial oxidative metabolism may confer hypoxia tolerance to the seal brain. Neuroscience 2009;163:552–60.
[66] Maritime search and rescue. Fishing vessel safety review. Fisheries and oceans Canada; 2000. 〈http://www.safetynet.mun.ca/pdfs/CFVSafetyReview.pdf〉 [accessed April 2012].
[67] Lonsdale MV. Sniper II: a guide for special response teams. Specialized Tactical Training Unit. Los Angeles; May 1995.
[68] Platt C. 1970 Sealing season: a report on the activities of Norwegian sealers in the "Front" area of the Northwest Atlantic. Report for International Society for the Protection of Animals; 1970.
[69] Cheung S, Montie DL, White MD, Behm D. Changes in manual dexterity following short-term hand and forearm immersion in 10 °C water. Aviat Space Environ Med 2003;74(1):119–24.
[70] Konttinen N., Lyytinen H. and Viitasalo J. Rifle-balancing in precision shooting: behavioral aspects and psychophysiological implication. Scand J Med Sci Sports 1998; 8: 78–83. 10.1111/j.1600-0838.1998.tb00172.x.
[71] Mononen K, Konttinen N, Viitasalo J, Era P. Relationships between postural balance, rifle stability and shooting accuracy among novice rifle shooters. Scand J Med Sci Sports 2007;17:2 [Blackwell Publishing Ltd.].
[72] Lakie M. The influence of muscle tremor on shooting performance. Exp Physiol 2010;95:441–50 (doi: 10.1113/expphysiol.2009.047555).
[73] Askew EW. Nutrition for a cold environment. Physician Sports Med 1989;17(12):77–89.
[74] Wittmers LE. Pathophysiology of cold exposure. Minn Med 2001;84(11): 30–6.
[75] Richardson M. Event related potential analysis of a continuous performance task during whole body cooling. Dalhousie University; 2002. 〈http://web.mac.com/mattochsara/iWeb/Svenska/Omgivningsfysiologi files/Matt's%20MSc%20thesis.pdf〉 [accessed April 2012].

[76] Giesbrecht G, Bristow G. Decrement in manual arm performance during whole body cooling. Aviat Space Environ Med 1992;63:1077–81.
[77] Havenith G, Heus R, Daanen HA. The hand in the cold, performance and risk. Arct Med Res Suppl 1995;54(2):37–47.
[78] United States Marine Corps. Rifle Marksmanship; 1999. 〈http://www.txmarks.org/cdfiles/Individual%20Weapons/MC%20Marksmanship.pdf〉 [accessed April 2012].
[79] Grebot C, Burtheret AJ. Effects of temperature changes on the mechanical and ballistic responses in biathlon shooting. Appl Mech 2007;74:1037, http://dx.doi.org/10.1115/1.2712229 [2007].
[80] Gultepe I, Tardif R, Michaelides SC, Cermak J, Bott A, Bendix J, et al. Fog research: a review of past achievements and future perspectives. Fog and boundary layer clouds: fog visibility and forecasting. Pageoph topical volumes.Birkhauser Basel; 2007 [p. 1121–59].
[81] Strapp JW, Stuart RA, Isaac GA. A Canadian climatology of freezing precipitation, and a detailed study using data from St. John's, Newfoundland. In: Proceedings of the international conference on in-flight icing. vol. II. Springfield, VA, Federal Aviation Administration, DOT/FAA/AR-96/81; 1996. p. 45–55.
[82] Stuart RA, Issac GA. Freezing precipitation in Canada. Atmosphere—Ocean 1999;37:87–102.
[83] Ross H. Mist, murk and visual perception. New Sci 1975;66:658–60.
[84] Wells KH, Wagner H, Reich LN, Hardigan PC. Military readiness: an exploration of the relationship between marksmanship and visual acuity. Mil Med 2009;174(4):398–402 [Apr].
[85] Department of Fisheries and Oceans (DFO). Vessel fishing licenses, Newfoundland and Labrador Region; 2006.
[86] Department of Fisheries and Aquaculture. The Economy; 2011. 〈http://www.economics.gov.nl.ca/E2011/Fishery.pdf〉 [accessed April 2012].
[87] Bass D, Vera J, Cumming D, Akinturk A. Safer fishing vessel seakeeping; 2005. 〈http://www.safetynet.mun.ca/pdfs/SFVS.pdf〉 [accessed April 2012].
[88] Transport Safety Board. Marine Reports—M08M0010; 2008. 〈http://www.tsb.gc.ca/eng/rapports-reports/marine/2008/m08m0010/m08m0010.asp〉 [accessed April 2012].
[89] Canadian coast guard. Presentation at Shrimp Vessel Design & Economics Forum. Gander: Newfoundland; 8–9 March 2004. 〈http://www.ccfi.ca/secure/svp/Canadian%20Coast%20Guard%20[Read-Only].pdf〉 [accessed April 2012].
[90] Newfoundland and Labrador. Minister Noel meets with FFAW officials to discuss marine insurance concerns. News Release, 6 March 2002; 2002. 〈http://www.releases.gov.nl.ca/releases/2002/gsl/0306n07.htm〉 [accessed April 2012].
[91] Murray M, Rodgers T. Injured fish harvesters; 2005. 〈http://www.med.mun.ca/sf/reports/InjuredReport%20-%20July.pdf〉 [accessed April 2012].
[92] European Food Safety Authority (EFSA). The welfare aspects of the main systems of stunning and killing applied to commercially farmed deer, goats, rabbits, ostriches, ducks, geese and quail; 2006. 〈http://www.efsa.europa.eu/en/scdocs/doc/326ax1.pdf〉 [accessed April 2012].
[93] Krueger GP. Sustained military performance in continuous operations: combatant fatigue, rest and sleep needs. In: Gal R, Mangelsdorff AD, editors. Handbook of military psychology. Chichester, England: John Wiley & Sons, Ltd.; 1991 [p. 244–77].
[94] Tharion WJ, Shukitt-Hale B, Lieberman HR. Caffeine effects on marksmanship during high-stress military training with 72 h sleep deprivation. Aviat Space Environ Med 2003;74(4):309–31 [April 2003 (6)].
[95] Knapik J, Staab J, Bahrke M, Reynolds K, Vogel J. Soldier performance and mood states following a strenuous road march. Army Research Institute of Environmental Medicine. Natick: MA; 1990. 〈http://oai.dtic.mil/oai/oai?verb=getRecord&metadataPrefix=html&identifier=ADA217895〉 [accessed April 2012].
[96] Department of Fisheries and Oceans (DFO). Frequently asked questions about Canada's seal harvest. Question 19—How much of Canada's population benefits directly from the seal harvest? 2011. 〈http://www.dfo-mpo.gc.ca/fm-gp/seal-phoque/faq-eng.htm#faq19 (Accessed April 2012〉.
[97] Jordan WJ. Testimony before the Royal Commission on Seals and the Sealing Industry in Canada. On behalf of People's Trust for Endangered Species and IFAW. 9 April 1985. London; 1985. vol. 1, p. 121–142.
[98] McCarthy JJ, Canziani OF, Leary NA, Dokken DJ, White KS, editors. Climate change 2001: impacts, adaptation, and vulnerability. Intergovernmental Panel on Climate Change. New York, N.Y.: Cambridge University Press; 2001.
[99] Johnston DW, Friedlaender AS, Torres LG, Lavigne DM. Variation in sea ice cover on the east coast of Canada from 1969 to 2002: climate variability and implications for harp and hooded seals. Clim Res 2005;29:209–22.
[100] Moore SE, Huntington HP. Arctic marine mammals and climate change: impacts and resilience. Ecol Appl 2008;18:S157–65.
[101] Côté F, Pigeon M. Climate change and seal populations in Canada. Parliamentary information and research service; 2007. 〈http://www.sealsandsealing.ca/resources/ClimateChange07.pdf〉 [accessed May 2011].
[102] Department of Fisheries and Oceans (DFO). A review of ice conditions and the harp seal total allowable catch (TAC) for 2010. Canadian Science Advisory Secretariat. Science response. 2010/004. 2010 [accessed April 2012].
[103] Sjare B, Stenson B. Estimating struck and lost rates for harp seals (*Pagophilus groenlandicus*) in the Northwest Atlantic. Mar Mamm Sci 2002;18(3): 710–20.
[104] Hanes A. More humane seal hunt takes to ice. National Post; 2008. 〈http://bleudeterre.wordpress.com/2008/03/23/more-humane-seal-hunt-takes-to-ice/〉 [accessed April 201]).

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