



Does the Seal Licensing System in Scotland Have a Negative Impact on Seal Welfare?

Laetitia Nunny^{1*}, Fritha Langford² and Mark P. Simmonds³

¹ Royal (Dick) School of Veterinary Studies, The University of Edinburgh, Edinburgh, UK, ² Animal and Veterinary Sciences, Scotland's Rural College, Edinburgh, UK, ³ School of Veterinary Sciences, University of Bristol, Bristol, UK

OPEN ACCESS

Edited by:

Rob Harcourt,
Macquarie University, Australia

Reviewed by:

Clive Reginald McMahon,
Sydney Institute of Marine Science,
Australia
Mary George,
University of Malaya, Malaysia
Christian T. K.-H. Standtlander,
Independent Researcher, St. Paul,
USA

*Correspondence:

Laetitia Nunny
laetitia.nunny@mac.com

Specialty section:

This article was submitted to
Marine Affairs and Policy,
a section of the journal
Frontiers in Marine Science

Received: 18 March 2016

Accepted: 27 July 2016

Published: 23 August 2016

Citation:

Nunny L, Langford F and
Simmonds MP (2016) Does the Seal
Licensing System in Scotland Have a
Negative Impact on Seal Welfare?
Front. Mar. Sci. 3:142.
doi: 10.3389/fmars.2016.00142

This study examined the licensing system that permits seal shooting in Scotland, which was established under Part 6 Conservation of Seals of the Marine (Scotland) Act 2010. Four approaches were used: data were collated and analyzed from both the Scottish Government and Scottish Marine Animal Stranding Scheme; a survey was sent to current license holders and informal interviews were conducted with key stakeholder types. Between February 2011 and the end of October 2015, 1229 gray seals, and 275 common seals were reported shot under license to the Scottish Government. The numbers of seals reported as shot has reduced year-on-year since the licensing system was put in place. While some license holders, notably fish farms, were using some non-lethal forms of deterrent to reduce seal-related damage, these were often used alongside seal shooting. Of the seals reported as shot to the Scottish Government, only a small percentage were also reported to the Scottish Marine Animal Stranding Scheme, despite this being a licensing requirement. Only 2.3% of the shot gray seals and 4.5% of the shot common seals were necropsied. There is evidence from these necropsies that some seals had not died instantly or had not been shot in the manner recommended by the Scottish Seal Management Code of Practice. These preliminary results show that more carcasses need to be recovered and necropsied if the welfare implications of current seal shooting practice are to be properly assessed. The current legislation does not specify closed seasons to protect breeding seals and 35% of necropsied seals were pregnant gray seals. Seals have also been shot during their lactation periods when pups are dependent on their mothers. This raises significant welfare concerns. The re-introduction of closed seasons specific to each species of seal is recommended along with greater effort to deploy non-lethal methods. Independent assessment of the number of seals being killed would also improve the credibility of the system.

Keywords: gray seal, common seal, harbor seal, seal management, fish farm, fishery, welfare, aquaculture

INTRODUCTION

Scotland has a large and growing aquaculture industry and is the third largest producer of Atlantic salmon (*Salmo salar*) in the world (Scotland's Aquaculture, 2016). In addition, Scottish waters are famed for their fishing, drawing anglers from across the world (Marine Scotland, 2016a). Gray seals (*Halichoerus grypus*) and common seals (*Phoca vitulina*) have long been viewed as in conflict with

the Atlantic salmon and sea trout (*Salmo trutta*) fisheries (Butler et al., 2011). Seals prey on the fish and, potentially, affect the number available for capture as well as interfering with fishing activities and damaging nets and fish (Butler et al., 2011). Seals also predate on salmon at fish farms and are present at 81% of aquaculture sites in Scotland (Quick et al., 2004). Most damage at fish farms is reported as being caused by gray seals (Northridge et al., 2010).

Many Scottish rod fisheries and netting stations believe that seals have a significant impact on fish stocks and catches (Butler et al., 2011). A survey of such stakeholders from the Moray Firth in Scotland found that 77% believed that all seals are the problem and 47% thought that culling to reduce the overall seal population was desirable (Butler et al., 2011). Conversely, most fish farm managers believe that “rogue” individuals acting in a way that is not typical of all seals are responsible for most of the damage caused and that removing an individual seal means that attacks stop for a period (Northridge et al., 2010). Studies have been undertaken to ascertain whether certain seals do, in fact, behave differently to the majority of the population. A study in the Moray Firth observed that only a small number of gray and common seals were using rivers (Graham et al., 2011). Digestive tract samples taken from eight shot seals and one live-caught seal found in rivers were compared to 182 scat samples collected at haul-out sites (Graham et al., 2011). It was concluded that there are individual “rogue” seals that eat more salmonids than the general seal population (Graham et al., 2011). A study in the Baltic Sea also suggested that certain individual gray seals specialize in raiding fishing gear; even returning to the same fish traps over two seasons (Königson et al., 2013). These specialist fish trap-raiding seals accounted for only 1% of the local seal population (Königson et al., 2013).

The Moray Firth Seal Management Plan (MFSMP), which aimed to specifically target such “rogue” seals, was successfully implemented in 2005 and led to the introduction of a new seal licensing system throughout Scotland under Part 6 Conservation of Seals of the Marine (Scotland) Act 2010 (The Stationery Office, 2010; Butler et al., 2011). Prior to this, seals had been managed in Scotland under the Conservation of Seals Act 1970. This Act provided some protection for seals through the implementation of closed seasons although it still permitted the killing of seals in closed seasons under certain circumstances, for example to prevent a seal from damaging a fishing net, fishing tackle or a fish caught in a net (The Stationery Office, 1970). Although the Conservation of Seals Act 1970 was repealed in Scotland when the Marine (Scotland) Act 2010 was introduced, it still applies to England and Wales (The Stationery Office, 1970, 2010).

The first licenses to shoot seals under the new system were issued on 31 January 2011 (Marine Scotland, 2015). Scottish Ministers can grant licenses allowing the killing or taking of seals for various reasons including “to protect the health and welfare of farmed fish” and “to prevent serious damage to fisheries or fish farms” (The Stationery Office, 2010). The Marine (Scotland) Act 2010 requires that seal licenses impose conditions including the type of firearm used, the area and circumstances in which a seal can be shot, the species to be killed, periods when seals cannot

be taken and regarding the recovery of carcasses (The Stationery Office, 2010).

License applicants request permission to shoot a certain number of seals and Marine Scotland (the department of the Scottish Government which is responsible for marine and fisheries issues) grants the quota deemed appropriate taking into account the number applied for and using a Potential Biological Removal (PBR) approach which determines, hypothetically, the number of seals that can be removed from a population without causing the population to decline (Marine Scotland, 2016b). The PBR is calculated by the Sea Mammal Research Unit (SMRU) at the University of St Andrews using a minimum population estimate, the population growth rate and a recovery factor (Thompson et al., 2014; Marine Scotland, 2016b). This is intended to ensure that Scottish seal populations are maintained at a “favorable” conservation status as required by the European Union Habitats Directive (Council of the European Union, 1992).

As well as concern for the conservation status of managed seal populations, the potential impact on the welfare of individual animals deserves consideration. Some authors advocate that if high standards of welfare are important in production animal husbandry then, for consistency, the same welfare standards should be ensured for wildlife that are affected by human activity (Sainsbury et al., 1995). Wherever wild animals are killed by humans, for example the shooting of seals to protect fisheries and fish farms, there is potential for these animals to experience pain and distress (Littin and Mellor, 2005). Warburton and Norton (2009) express the view that “nuisance” animals must be killed in a way that can be justified and as part of a management program with clear aims and which is carefully monitored. Gregory (2003) makes recommendations for improved humaneness in pest control including the increased use of deterrents rather than lethal methods and the assessment of killing methods based on how the animals die.

A variety of methods to deter seals from preying at fish farms and fisheries exist. The Royal Society for the Prevention of Cruelty to Animals (RSPCA) recommends that fish farms should use non-lethal methods which aim to physically exclude predators from fish enclosures (RSPCA, 2015). The use of appropriately tensioned enclosure nets, predator nets and Acoustic Deterrent Devices (ADDs) are recommended as well as the regular removal of dead fish (RSPCA, 2015). Fisheries may try methods such as lifting gear frequently, moving to other fishing grounds and changing the type of materials used in nets and traps as well as modified net and trap design (Hemmingsson et al., 2008). In river fisheries, non-lethal deterrence methods have not been extensively developed (Graham et al., 2009) and lethal control of seals continues to play a part in seal management in both fisheries and fish farms throughout Scotland.

Where seal killing is concerned, much of the research into welfare has focused on the commercial harp seal (*Pagophilus groenlandicus*) hunt which takes place in Canada (Daoust and Caraguel, 2012). This hunt, clearly, has different aims, killing methods and outcomes to the seal killing that happens in Scotland. However, for comparison, it is noted that the Canadian commercial seal hunt requires seals to be killed in a three-step process: stunning, followed by external palpation of the skull

(to ensure it is crushed), and bleeding out (Minister of Justice Canada, 2011). Seals killed for management reasons in Scotland are killed in a one-step process as they should be shot with “a rifle using ammunition with a muzzle energy not less than 600 foot pounds and a bullet weighing not less than 45 grains” (Marine Scotland, 2011). The Scottish Seal Management Code of Practice recommends a shot to the head noting that “the brain of a seal is a very small target” (Marine Scotland, 2011). Centerfire rifles with expanding bullets should be used for public safety and animal welfare reasons (Marine Scotland, 2011).

In addition to the welfare of the shot individual, the killing of one wild animal may indirectly affect the welfare of another. For example, the possibility of shooting a female who has dependent young is an important issue when assessing the humaneness of shooting an animal (Macdonald et al., 2000). In the case of seals, it is possible that the shot animal could be pregnant or lactating causing potential suffering to the unborn fetus or the neonate pup. Seals other than the target seal which are present in the immediate area when shooting takes place may also experience a negative impact on their welfare (Bonner, 1993).

The present study uses a mixed methods (quantitative-qualitative) approach to try to answer the following overarching questions:

1. Is there a difference in the proportion of seals shot of each species?
2. Are the numbers of seals being shot changing over time?
3. Does the Seal Management Area where the fishery or fish farm is located affect the number of seals granted and the number shot?
4. Does seal shooting activity differ over the seasons and is this likely to be related to the physiological status of the seals?
5. Does the type of establishment (e.g., fish farm or fishery) affect the way in which problems with seals are dealt with?
6. Do necropsied seals give any indication that the welfare of shot seals is being negatively impacted?
7. Is there evidence that the welfare of non-target seals is being negatively impacted?

In addition, gaps in research and knowledge are assessed and recommendations are made as to how to improve seal welfare.

MATERIALS AND METHODS

This study was carried out in part fulfillment of the MSc International Animal Welfare, Ethics and Law at the University of Edinburgh. It was approved by the Veterinary Ethics Committee at the Royal (Dick) School of Veterinary Studies, University of Edinburgh. Four approaches were used to gather quantitative and qualitative data.

Approach 1—Official Data Available to the Public

Although licenses can be issued for a number of reasons the main two license types that are issued by Marine Scotland and for which details are given on the Marine Scotland website, are the “License to Shoot Seals to Protect the Health and Welfare of Farmed Fish in Scotland” and the “License to Shoot Seals

to Prevent Serious Damage to Fisheries in Scotland” (Marine Scotland, 2016b).

From the “Licenses and Returns” section of the Marine Scotland website, data for 2011–2014 were collected for both gray and common seals including the total population, the PBR, the number of seals applied for, the number of seals granted and the number of seals reported as shot. For 2015, the PBR, number of seals applied for, granted and reported as shot for the first 3 quarters of the year were taken from the “Seal Licensing” homepage of the Marine Scotland website (<http://www.gov.scot/Topics/marine/Licensing/SealLicensing>). Data are presented according to Seal Management Area without identifying individual sites.

The numbers summarizing how many seals were shot by fish farms and by fisheries or netting stations from 2011 to 2014 were extracted from the Annexes of the Report of the Inaugural Quinquennial Review of the Operation of Seal Licensing System Under the Marine (Scotland) Act 2010 which is available from the Marine Scotland “Seal Licensing” homepage (Marine Scotland, 2015).

Approach 2—Necropsy Data

The Scottish Marine Animal Stranding Scheme (SMASS) at Scotland’s Rural College (SRUC) Wildlife Unit reports to Marine Scotland annually describing the seal management cases that have been reported to them and any necropsies that they or the staff at SMRU have carried out. Completed reports were available for 2012–2014 from the Seal Licensing Team at Marine Scotland (SRUC Wildlife Unit, 2012; Brownlow and Davison, 2013, 2014).

The details of necropsied seals shot under the licensing system were extracted from the reports including how many seals of which species were necropsied, whether or not the animals had died instantaneously from their wounds and whether or not the female seals were pregnant. Details of seals which had not been reported to SMASS under the seal licensing system but which were considered (from post-mortem examination) to have been shot were also collected.

In addition to the reports, the lead author discussed the project with the SRUC Wildlife Unit in order to fully appreciate the reporting procedures and to acquire data relating to seal management cases which were necropsied in 2011 and which had not been written up in a formal report.

The data from these reports and discussions were tabulated to show the species, sex and reproductive state of shot seals necropsied by SMASS and SMRU by Seal Management Area and to allow comparison with seals reported as shot to Marine Scotland and the number of seal carcasses recovered and/or reported to SMASS.

Approach 3—License Holder Survey

A questionnaire was sent to seal license holders. The questions were developed based on the requirements outlined in the Marine (Scotland) Act 2010, the Scottish Seal Management Code of Practice and the application forms that license applicants are required to complete (The Stationery Office, 2010; Marine Scotland, 2011, 2016c).

The names of license holders were obtained from downloaded excel spreadsheets available from the “Licenses and Returns”

section of the Marine Scotland website. As only the company or organization name was available, searches were then conducted online for postal addresses. In November 2014 the survey was posted to 52 seal license holders accompanied by a letter of explanation and a pre-paid return envelope. License holders were also given the option of completing the survey online at: https://www.surveymonkey.com/s/seal_management.

License holders were asked to complete and return the survey before 16th January 2015. In early January 2015, follow-up e-mails were sent to the license holders whose e-mail address had been found during the online searches. The e-mail thanked the license holders for participating in the survey and reminded them that they could still complete the survey if they had not already done so.

The following questions were presented in the survey:

Question 1. *What problems have you experienced with seals? Tick all that apply.* Optional answers were “Seals kill/eat fish,” “Seals injure/damage fish,” “Presence of seals affects fish behavior,” “Seals cause fish to escape from nets/net pens,” “Seals damage equipment e.g., nets,” “Other (please specify).”

Question 2. *Do you use or have you used Acoustic Deterrent Devices (ADDs) also known as pingers or seal scarers?* Optional answers were “Yes” and “No.” Those who responded “No” to Question 2 were asked to go directly to Question 4.

Question 3. *Did the device deter seals from entering the target areas?* Optional answers were “Yes, the device was effective,” “Sometimes,” and “No, the device did not seem to have any effect.”

Question 4. *Have you used other methods to deter seals? (Tick all that apply).* Optional answers were “Floats or buoys,” “Predator nets,” “Tensioned or false-bottom nets to exclude seals,” “Removal of dead fish from dead-fish basket,” “Screening blinds,” “Shooting seals,” and “Other (please specify).”

Question 5. *Has shooting individual seals helped deter other seals from approaching or entering the fishery/fish farm?* Optional answers were “Yes,” “No,” and “Don’t know.”

Question 6. *Have you injured (but not killed) any seals and therefore had to locate them and humanely dispatch them afterwards?* Optional answers were “Yes” and “No.” If the response was “Yes” they were asked to specify how many seals.

Question 7. *Have you recovered the carcasses of any shot seals?* Optional answers were “Yes, all shot seals have been recovered,” “Yes, some shot seals have been recovered,” “No, no shot seals have been recovered,” and “No, we have not shot any seals.”

Question 8. *How many carcasses have you recovered?* Respondents were required to give a number.

Question 9. *What did you do with the recovered carcass(es)? (Tick all that apply).* Optional answers were “Reported it to the Scottish Agricultural College/SRUC,” “Reported it to Marine Scotland,” “Photographed it (please specify what you did with photo),” “Left it without reporting it,” and “Other (please specify).”

Question 10. *If you answered “no” or “some” to Question 7, what has prevented you from recovering the carcasses? (Tick*

all that apply). Optional answers were “Bad weather,” “Bad sea conditions,” “Seal sank after it was shot,” “Seal swam away after it was shot,” “It was too dangerous for the marksman to reach the seal,” “We didn’t know that we were supposed to recover seal carcasses,” and “Other (please specify).”

Question 11. *Details of license holder. Please indicate whether you are:* Optional answers were “A fish farm,” “A fishery,” “An academic institution,” and “Other (please specify).”

Question 12. *Please indicate which Seal Management Area(s) you hold or have held a license for:* Optional answers were “East Coast,” “Moray Firth,” “Orkney and North Coast,” “Shetland,” “South West Scotland,” “West Scotland,” and “Western Isles.”

Approach 4—Interviews

A field visit was made to the West Scotland and Moray Firth Seal Management Areas in April 2015. Informal semi-structured interviews were conducted with three people involved in seal management including a fish farm manager, a bag net fisherman, and the head bailiff of a fishery board. These visits provided qualitative data on the situation as experienced by a representative of each different industry reliant on salmon that may come into conflict with seals.

The fish farm manager was introduced to us via an academic contact who put us in touch with one of the largest fish farm companies in Scotland who, in turn, recommended that we visit this specific fish farm. The bag net fisherman responded to the survey and sent an e-mail offering to help with any further information that we might require. A fishery board director enclosed a letter with the completed survey also offering assistance with further information and, later, arranged the meeting with the head bailiff.

Statistical Analysis

The data collected and collated for this paper come from either (a) a variety of publicly available sources or (b) questionnaire or interview data collected by the authors. As such, only a limited inferential statistical analysis can take place. Where comparisons have been possible, the data from the questionnaire have been analyzed using Fisher’s Exact tests. For comparisons made between data from the license reports, first all percentage data were transformed using the ArcSine transformation to approximate the normal distribution. Where data were not normally distributed, Mann-Whitney and Kruskal Wallis tests were used. Where equal variance were achieved, the data were analyzed using General Linear Model adding in the “year” as a repeated measure and using Tukey Test for *post-hoc* analysis. The post-mortem analysis were carried out using the Freeman-Halton extension of Fisher’s exact test in a 2×3 contingency table. All data were analyzed in Minitab 17.

RESULTS

Approach 1—Official Data Available to the Public

When applying for a license, applicants indicate the maximum number of each species of seal that they are seeking permission to

shoot in the next license year. **Table 1** shows the total population for each species, the PBR, how many seals have been applied for, how many have been granted by Marine Scotland and how many have been reported as shot for each year as well as showing the percentages that the reported shot seals represent of the total population and the allocation of granted seals.

Seals Granted by Marine Scotland

For both gray and common seals, although the PBR and the number of seals applied for annually has fluctuated, the numbers granted by Marine Scotland have been decreasing each year (see **Table 1**). How do the numbers of seals granted relate to the total populations and the PBRs?

Between the years 2011 and 2015 a significantly higher percentage of the total population of common seals (median 1.3% IQR 1.1–1.5%) were granted to be shot in comparison to gray seals (median 0.8% IQR 0.7–0.9%) ($W = 15.0, P < 0.05$).

The number of seals granted by Marine Scotland to license holders is always fewer than the PBR for each Seal Management Area. The percentage of the gray seal PBR figures granted to be shot differed according to Seal Management Area. When the data across years 2011 to 2014 is combined (accounting for the difference between years as a repeated measure), it can be seen that Shetland ($57.4 \pm 7.6\%$) was granted the highest percentage of its PBR and that this percentage is statistically significantly different from the percentage granted to the Western Isles ($32.2 \pm 1.5\%$) and Orkney and North Coast areas ($24.2 \pm 5.2\%$) [$F = 5.44_{(6, 21)}, P < 0.01$].

The percentage of the common seal PBR granted to be shot also differed depending on Seal Management Area. After combining the data across years 2011 to 2014 (accounting for the difference between years as a repeated measure), it can be seen that Moray Firth ($83.7 \pm 8.5\%$) and South West Scotland ($83.6 \pm 3.17\%$) were granted the highest percentage of the PBR and that this percentage is statistically significantly different from the percentage of common seals granted to the Orkney and North

Coast ($39.8 \pm 5.6\%$), West Scotland ($39.5 \pm 2.6\%$), and Shetland ($37.5 \pm 6.2\%$) areas [$F = 22.89_{(6, 21)}, P < 0.001$].

Seals Reported as Shot under License to Marine Scotland

It is important to note that the numbers reported shot are based exclusively on returns received from license holders and there is no independent assessment of numbers. Since the start of the licensing system in 2011 and up to the end of October 2015, a total of 1229 gray seals and 275 common seals were reported as shot to Marine Scotland (Marine Scotland, 2016b).

Each year the number of gray seals reported as shot has declined. The percentage of the total gray seal population reported as shot has not exceeded 0.36% (the percentage for 2012). The number of common seals reported as shot has varied according to year but, generally, appears to be decreasing. In 2011, 0.46% of the common seal population was reported as shot under the license system. This is the highest percentage recorded so far. The numbers of seals reported as shot as a percentage of the total population of the species did not differ by species (median for common seals: 0.2% IQR 0.1–0.4%; median for gray seals: 0.2% IQR 0.1–0.3%; $P > 0.05$).

The numbers of seals reported as shot as a percentage of the numbers granted by the Scottish Government did not differ significantly between the two species. However, there was a weak tendency for a higher percentage of the gray seals granted to be reported as shot (median 30.7% IQR 18.4–38.3%) compared to the common seals (median 17.1% IQR 14.3–27.6%) ($P < 0.1$).

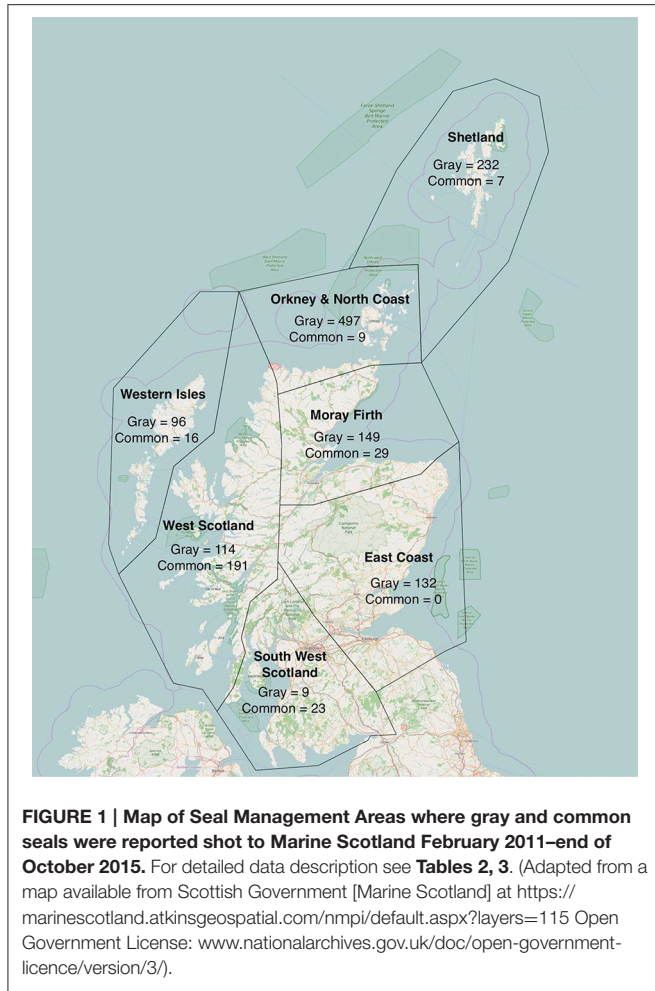
Location of Seals Reported as Shot under License to Marine Scotland

The distribution of reported seal shootings by Seal Management Area is shown in **Figure 1** and **Tables 2, 3**. Most reported shot gray seals were killed in the Orkney and North Coast Seal Management Area (497 gray seals representing 40.4% of shot gray seals) while the majority of common seals have been reported

TABLE 1 | Gray seal and common seal total populations, Potential Biological Removal (PBR), numbers of seals applied for, granted and reported as shot, the percentage of the total population reported as shot and the percentage of the granted seals reported as shot in Scotland 2011–2015 (Marine Scotland, 2016b).

Year	2011		2012		2013		2014		2015	
	Gray seals	Common seals	Gray seals	Common seals	Gray seals	Common seals	Gray seals	Common seals	Gray seals	Common seals
Total population	108,000	20,400	100,000	20,500	100,000	20,500	100,000	20,500	101,000	20,700
PBR	2301	593	2301	589	3002	617	3002	617	2830	627
No. of seals applied for	1706	794	3008	812	1347	602	1327	547	1047	484
No. of seals granted	1025	314	878	289	774	265	765	240	662	197
No. of seals reported shot	366	93	359	74	238	36	164	41	102*	31*
Percentage of total population reported as shot (%)	0.34	0.46	0.36	0.36	0.24	0.18	0.16	0.20	0.1*	0.15*
Percentage of seals granted reported as shot (%)	35.7	29.6	40.9	25.6	30.7	13.6	21.4	17.1	15.4*	15.7*

*Refers to the first three quarters (1st February–31st October) of 2015 only.



shot in West Scotland (191 common seals representing 69.5% of the shot common seals).

The percentage of granted gray seals that were reported as shot differed depending on Seal Management Area. When combining the data across years 2011 to 2014 (accounting for the difference between years as a repeated measure), it can be seen that Shetland ($50.6 \pm 8.6\%$) reported shot the highest percentage of the granted gray seals and that this percentage is statistically significantly different from the West Scotland ($17.5 \pm 2.3\%$), Western Isles ($16.7 \pm 3.6\%$), and South West Scotland ($7.1 \pm 3.1\%$) areas [$F = 7.88_{(6, 21)}, P < 0.001$].

There was no significant statistical evidence for a difference between areas in the percentage of the granted common seals reported as shot [$F = 2.07_{(5, 18)}, P > 0.1$].

Time of Year When Seals Reported as Shot under License to Marine Scotland

To consider whether seals are more likely to be shot at particular times of the year, the numbers of seals reported shot in each quarter for the years 2011–2014 are presented in **Tables 4, 5** (2015 is not included as data are not yet available for the whole licensing year).

TABLE 2 | Gray seals applied for, PBR, gray seals granted, the percentage of PBR granted, gray seals reported shot and percentage of granted seals reported shot by Seal Management Area 2011–2015.

	2011					2012					2013					2014					2015								
	Applied	PBR	Granted (% of PBR)	Reported shot	% of granted seals shot	Applied	PBR	Granted (% of PBR)	Reported shot	% of granted seals shot	Applied	PBR	Granted (% of PBR)	Reported shot	% of granted seals shot	Applied	PBR	Granted (% of PBR)	Reported shot	% of granted seals shot	Applied	PBR	Granted (% of PBR)	Reported shot	% of granted seals shot	Applied	PBR	Granted (% of PBR)	Reported shot *
East Coast	246	277	132 (48)	46	35	849	277	114 (41)	42	37	142	314	82 (26)	28	34	128	314	74 (24)	11	15	92	297	66 (22)	5					
Moray Firth	85	152	75 (49)	16	21	836	152	100 (66)	43	43	145	174	90 (52)	43	48	239	174	90 (52)	25	28	120	201	70 (35)	22					
Orkney/N Coast	461	959	349 (36)	167	48	475	959	280 (29)	140	50	355	1448	220 (15)	87	40	330	1448	232 (16)	64	28	315	1240	220 (18)	39					
Shetland	384	163	120 (74)	69	58	341	163	109 (67)	73	67	240	236	105 (45)	54	51	198	236	105 (45)	28	27	89	235	82 (35)	8					
SW Scotland	115	45	31 (69)	4	13	63	45	26 (58)	3	12	63	57	26 (46)	1	4	66	57	25 (44)	0	0	65	57	15 (26)	1					
West Scotland	206	297	170 (57)	36	21	206	297	126 (42)	27	21	204	386	126 (33)	15	12	188	386	123 (32)	19	15	183	414	120 (29)	17					
Western Isles	209	408	148 (36)	28	19	238	408	123 (30)	31	25	198	387	125 (32)	10	8	188	387	116 (30)	17	15	183	386	89 (23)	10					
TOTAL	1706	2301	1025 (45)	366	36	3008	2301	878 (38)	359	41	1347	3002	774 (26)	238	31	1337	3002	765 (26)	164	21	1047	2830	662 (23)	102					

*Refers to the first three quarters (1st February–31st October) of 2015 only.

TABLE 3 | Common seals applied for, PBR, common seals granted, the percentage of PBR granted, common seals reported shot and percentage of granted seals reported shot by Seal Management Area 2011–2015.

	2011					2012					2013					2014					2015				
	Applied	PBR	Granted (% of PBR)	Reported shot	% of granted seals shot	Applied	PBR	Granted (% of PBR)	Reported shot	% of granted seals shot	Applied	PBR	Granted (% of PBR)	Reported shot	% of granted seals shot	Applied	PBR	Granted (% of PBR)	Reported shot	% of granted seals shot	Applied	PBR	Granted (% of PBR)	Reported shot ***	
East Coast	92	3	0 (0)	0	-	106	2	0 (0)	0	-	54	2	0 (0)	0	-	39	2	0 (0)	0	-	14	1	0 (0)	0	
Moray Firth	52	23	20 (87)	6*	30	82	20	19 (95)	10	53	34	17	16 (94)	3	19	24	17	10 (59)	6	60	15	16	5 (31)	4	
Orkney/N Coast	53	18	10 (56)	4	40	58	18	7 (39)	3	43	37	17	5 (29)	1	20	39	17	6 (35)	1	17	37	11	0 (0)	0	
Shetland	47	18	10 (56)	2	20	32	18	6 (33)	1	17	23	18	6 (33)	3	50	17	18	5 (28)	1	20	5	18	3 (17)	0	
SW Scotland	153	35	31 (89)	12	39	104	35	30 (86)	8	27	88	35	30 (86)	0	0	91	35	26 (74)	3	12	82	35	18 (51)	0	
West Scotland	296	442	203 (46)	58	29	310	442	184 (42)	50	27	291	446	163 (37)	28	17	266	446	152 (34)	29	19	260	464	137 (30)	26	
Western Isles	101	54	40 (74)	11**	28	120	54	43 (80)	2	5	75	82	45 (55)	1	2	71	82	41 (50)	1	2	71	82	34 (42)	1	
TOTAL	794	593	314 (53)	93	30	812	589	289 (49)	74	26	602	617	265 (43)	36	14	547	617	240 (39)	41	17	484	627	197 (31)	31	

*Includes one unidentified seal counted as a common seal.

**Includes three unidentified seals counted as common seals.

***Refers to the first two quarters (1st February–31st October) of 2015 only.

TABLE 4 | Gray seals reported shot in Scotland 2011–2014 by quarter (Marine Scotland, 2015, 2016b).

	2011	2012	2013	2014	Total	% of total shot in each quarter	Mean shot in each quarter
1st quarter (Feb, Mar, Apr)	62	86	77	25	250	22.2	62.5
2nd quarter (May, Jun, Jul)	117	115	90	72	394	35	98.5
3rd quarter (Aug, Sep, Oct)	115	87	49	36	287	25.5	71.8
4th quarter (Nov, Dec, Jan)	72	71	22	31	196	17.4	49.0

TABLE 5 | Common seals reported shot in Scotland 2011–2014 by quarter (Marine Scotland, 2015, 2016b).

	2011	2012	2013	2014	Total	% of total shot in each quarter	Mean shot in each quarter
1st quarter (Feb, Mar, Apr)	20	29	8	10	67	27.5	16.8
2nd quarter (May, Jun, Jul)	17	12	5	9	43	17.6	10.8
3rd quarter (Aug, Sep, Oct)	30	22	12	6	70	28.7	17.5
4th quarter (Nov, Dec, Jan)	26	11	11	16	64	26.2	16.0

There was a difference in the time of year when gray seals were shot. The second quarter of the year (May, June, and July) had the highest mean percentage of animals shot ($36.4 \pm 2.8\%$) and this was significantly higher than the means in the first (February, March, and April: $22.1 \pm 3.9\%$) and fourth (November, December, and January: $16.9 \pm 2.6\%$) quarters [$F = 7.71_{(3,12)}$, $P < 0.01$]. The fourth quarter is when the fewest gray seals were shot.

Twenty eight point seven per cent of common seals reported as shot were killed in the third quarter (August, September, and October) making it the quarter when the majority of common seal shootings took place. The mean number of common seals shot in that quarter is 17.5. The quarter when the fewest common seals have been reported as shot is the second (May, June, July) which accounts for 17.6% of shot common seals (a mean of 10.8 seals per year for that quarter). However, there is no statistical evidence for a difference in the percentage of common seals shot in each quarter.

Establishment Types Responsible for Shooting

In September 2015, Marine Scotland published a review of the first 4 complete years of seal licensing. From this report it is possible to see that more seals have been reported as shot by river fisheries and netting stations (737 seals) than by fish farms (634 seals) (see **Table 6**). Fish farms have reported fewer shot seals each successive year. In 2014, 39% of reported shot seals were shot at fish farms and 61% were shot at fisheries and netting stations.

Approach 2—Necropsy Data

The majority of the seal management cases necropsied at Scotland's Rural College (SRUC) Wildlife Unit were found to have been shot effectively with a single shot destroying the cranial vault (SRUC Wildlife Unit, 2012; Brownlow and Davison, 2013, 2014). However, each seal management case study report highlights at least one case of concern. In 2012 two seals (out of the 21 examined) showed signs of multiple gunshot wounds and blood aspiration which suggested that they had not been killed by the first shot (SRUC Wildlife Unit, 2012). In 2013, one seal (out of the seven examined) had been shot in the neck and, in 2014, one (out of the six examined) had been shot through the mandible (Brownlow and Davison, 2013, 2014).

Table 7 shows the species, sex and reproductive state of shot seals necropsied by SMASS and SMRU between 2011 and 2014. Thirty-seven seals were necropsied in total; 26 gray seals and 11 common seals. Thirteen of them were pregnant gray seals, 11 of which were necropsied in 2012. They were reported between 11th May and 20th August (SRUC Wildlife Unit, 2012). One pregnant gray seal was necropsied in 2013 and another in 2014, both were reported in June (Brownlow and Davison, 2013, 2014). The pups of the pregnant females necropsied by SMASS were in various stages of gestation (Brownlow A., 2015, pers. comm.).

The two species differed significantly in the distribution of sex and physiological status of necropsied seals (Fisher's Exact Test, $P = 0.006$). To see where the difference lay, further tests were carried out. The distribution of males and females did not differ between species. The distribution of pregnant and non-pregnant females did differ by species (Fisher's Exact Test, $P = 0.02$) with all of the necropsied pregnant seals being grays.

Table 8 compares the number of cases reported to SMASS (some of which were recovered for necropsy) with the number of animals reported as shot to Marine Scotland. For the years 2011–2014, only 5.1% of gray seals and 3.7% of common seals reported as shot to Marine Scotland were also reported to SMASS. Two unidentified carcasses were also reported to SMASS in 2012 but, even if they were included, the percentages would not be much higher (5.3% if they were both gray or 4.5% if they were both common). The actual necropsies of shot seals carried out by

SMASS and SMRU accounted for 2.3% of the gray seals reported shot and 4.5% of the common seals reported as shot¹.

Approach 3—License Holder Survey

All returned surveys were received anonymously except where the license holder chose to give their contact details. Of the 52 surveys sent out 31% ($n = 16$) were returned. Two surveys were filled in on-line and 14 paper surveys were returned. The responses received are presented here.

Responses

Question 1: What problems have you experienced with seals?

It can be seen in the responses to Question 1, as shown in **Figure 2**, that a greater number of respondents felt that seals were killing or causing severe damage as compared to less severe damage resulting in the escape of fish or the damage to equipment.

Question 2: Do you use or have you used Acoustic Deterrent Devices (ADDs) also known as pingers or seal scarers?

56% of respondents ($n = 9$) answered "Yes," that they use ADDs.

Question 3: Did the device deter seals from entering the target area?

Of the nine respondents that use ADDs, two said that the device was effective in deterring seals from entering the target area; four said the device was sometimes effective in deterring seals; two ticked "yes" and "sometimes" (one of them specifying that it was effective on the coast and sometimes effective in-river); one respondent ticked "yes," "sometimes," and "no" then specified that it was effective for the first 3 years, was only effective sometimes in the third and fourth year of use and had ceased to be effective in the fifth year of use.

Question 4: Have you used other methods to deter seals?

None of the respondents use floats or buoys to deter seals. Four of them use predator nets and seven use tensioned or false-bottom nets to exclude seals. Dead fish are removed from the dead-fish basket by four of the respondents and 2 respondents use screening blinds. Thirteen respondents shoot seals to deter attacks. Other methods used included the use of poison (prior to 1970) and using boats to chase the seals away.

Question 5: Has shooting individual seals helped deter other seals from approaching or entering the fishery/fish farm?

Six respondents (37.5%) said that shooting individual seals had helped deter other seals. One said it had not deterred other seals. Nine respondents did not know whether it had deterred other seals or not.

Question 6: Have you injured (but not killed) any seals and therefore had to locate them and humanely dispatch them afterwards?

All 16 respondents said they had not injured any seals and had to locate and dispatch them afterwards.

¹The apparent discrepancy in the percentage of common seals reported to SMASS and the number necropsied is because, in 2014, no common seals were reported to SMASS by seal license holders and yet two stranded seals were diagnosed as shot at necropsy.

TABLE 6 | Number of gray and common seals reported shot by fish farms and river fisheries and netting stations 2011–2014 (Marine Scotland, 2015).

Year	Fish farms		River fisheries/Netting stations		Total
	Seals reported as shot	Percentage of total	Seals reported as shot	Percentage of total	
2011	241	52.5	218	47.5	459
2012	208	48	225	52	433
2013	105	38	169	62	274
2014	80	39	125	61	205
Total	634	46.2	737	53.8	1371

TABLE 7 | Species, sex, and reproductive state of shot seals necropsied by Scottish Marine Animal Stranding Scheme (SMASS) and Sea Mammal Research Unit (SMRU) by Seal Management Area 2011–2014 (SRUC Wildlife Unit, 2012; Brownlow and Davison, 2013, 2014; Davison N., 2015, pers. comm.).

	Gray seals			Common seals			Total
	Male	Pregnant female	Non-pregnant female	Male	Pregnant female	Non-pregnant female	
East Coast	1	1	2				4
Moray Firth	5	12	1	4		1	23
Orkney/N Coast						1	1
Shetland						1	1
Southwest Scotland			2	1			3
West Scotland			1	2		1	4
Western Isles	1						1
Total	7	13	6	7	0	4	37

Question 7: Have you recovered the carcasses of any shot seals?
No respondents have recovered all of the seals they have shot and only four of them have recovered some of the shot seals. 62.5% ($n = 10$) of respondents had not recovered any of the seals that they have shot and two respondents replied that they have not shot any seals yet. Therefore, of the respondents that have shot seals, 71% of them have not recovered any carcasses and the remainder had only recovered some (not all) of the seals they had shot.

Question 8: How many carcasses have you recovered?

Of the four respondents who have recovered some carcasses, two said they had each recovered 1 carcass. Another said they had recovered 20% and the other said they had recovered “most” shot seals.

Question 9: What did you do with the recovered carcass(es)?

Of the four respondents who have recovered some carcasses, two said they reported it to the Scottish Agricultural College/SRUC. One of these also reported it to Marine Scotland. One of the other respondents also reported their carcass to Marine Scotland. One respondent ticked “other” and specified that they had reported it to SMRU.

Question 10: If you answered “no” or “some” to question 7, what has prevented you from recovering the carcasses?

See **Table 9** for responses.

Question 11: Please indicate whether you are a fish farm, fishery, academic institution or other.

Twelve survey respondents were fisheries and four were fish farms.

Question 12: Please indicate which Seal Management Area(s) you hold or have held a license for.

See **Table 10** for responses.

Analysis of License Holder Survey Results

Using the data gathered from the license holder survey, a number of statistical tests were carried out.

There was no statistically significant evidence that fish farms and fisheries were different in their use of Acoustic Deterrent Devices (ADDs). However, there is a weak tendency, suggesting that if there had been more respondents, it may have been shown

that fisheries were less likely to use ADDs than fish farms (Fisher’s exact test, $P < 0.09$).

There was no statistical evidence that the response to question 3 (did the device deter seals from entering the target area?) differed between establishment type. Neither fisheries nor fish farms had differing opinions on how well ADDs work (Fisher’s exact test, $P > 0.4$).

When asked about methods of deterring seals other than ADDs, there was a significant difference found between license holder types. Fisheries were more likely than fish farms to rely on shooting seals rather than other non-lethal methods to deter seals (Fisher’s exact test, $P < 0.02$).

The answers to question five showed no statistical evidence of a difference in opinion between fish farms and fisheries on whether seal shooting was effective at deterring other seals (Fisher’s exact test, $P > 0.4$).

There was no statistical evidence showing that fisheries or fish farms were more or less likely to recover carcasses (Fisher’s exact test, $P = 1$).

Approach 4—Interviews

Relevant information gathered during the informal interviews held with seal management stakeholders is presented here in three case studies.

Case Study 1—Fish Farm Manager, West Scotland Seal Management Area

The fish farm manager explained that in the past, the fish farm had experienced problems with seals attacking salmon at their net pens. They had, therefore, relied on a local marksman to shoot the seals that he identified as being responsible for the attacks. The manager reported that for the last 4 or 5 years they have been using an Airmar dB Plus II Acoustic Deterrent System. Since installing it they have not had any problems with seal attacks and have not had to resort to lethal methods. The ADD is switched on all the time and is checked regularly. The pingers are positioned around the perimeter of the site and the System alternates which pinger sounds at any time.

TABLE 8 | Gray and common seals reported as shot to Marine Scotland, seal carcasses recovered and/or reported to Scottish Marine Animal Stranding Scheme (SMASS), shot seals necropsied by SMASS and Sea Mammal Research Unit (SMRU) and the percentages these represent of the seals reported as shot 2011–2014 (SRUC Wildlife Unit, 2012; Brownlow and Davison, 2013, 2014; Marine Scotland, 2015; Davison N., 2015, pers. comm.).

	Gray seals					Common seals				
	Reported to Marine Scotland	Recovered and/or reported to SMASS	% of seals reported shot to Marine Scotland that were reported to SMASS	Necropsies carried out by SMRU or SMASS	% of seals reported shot to Marine Scotland that were necropsied	Reported to Marine Scotland	Recovered and/or reported to SMASS	% of seals reported shot to Marine Scotland that were reported to SMASS	Necropsies carried out by SMRU or SMASS	% of seals reported shot to Marine Scotland that were necropsied
2011	366	2	0.5	1	0.3	93	2	2.2	2	2.2
2012*	359	32	8.9	16	4.5	74	5	6.8	5	6.8
2013	238	21	8.8	5	2.1	36	2	5.6	2	5.6
2014	164	3	1.8	4	2.4	41	0**	0	2**	4.9
Total	1127	58	5.1	26	2.3	244	9	3.7	11	4.5

*Two unidentified seals were also reported to SMASS in 2012 but they are not included in this table.

**No common seals were reported to SMASS in 2014, however 2 stranded seals were diagnosed as shot at necropsy.

Case Study 2—Bag Net Fisherman, Moray Firth Seal Management Area

The fisherman described the problems he has with seals entering his nets to eat trapped salmon and also attacking the fish from outside the nets. Damaged fish cannot be sold. When his nets are in use he empties them a few times each day. If a seal is in the net, he will shoot it as he believes there is no safe way to release the seal from the net. He commented that seals have sharp teeth and strong jaws and pose a danger to a fisherman who tries to handle them. He has shot seals around his nets too. He uses a Rugar. 243 rifle and shoots the seal from his boat. He always tries to recover the carcass and said that this is relatively easy if the seal is shot in the net. He explained how he ties the carcass to a buoy before reporting it to SMASS. In recent years he has worked alongside SMRU to trial ADDs including the Lofitech ADD. In order to undertake these studies he has had to apply to Marine Scotland for a License to Disturb Marine Species which is granted under regulation 44(2)(g) of the Conservation (Natural Habitats,&c.) Regulations 1994. It authorizes him to disturb the European protected species of Harbor Porpoise (*Phocoena phocoena*) and Bottlenose Dolphin (*Tursiops truncatus*) subject to various conditions. The fisherman reported that using ADDs has helped tackle the problem to some extent but that some individual seals do not seem to be deterred by them. When the seal licensing system was first introduced, the fisherman applied for his own, individual license. He has since joined with a group of other fisheries and they apply together for one license but with various individuals named as authorized marksmen.

Case Study 3—Fishery Board Head Bailiff, Moray Firth Seal Management Area

The head bailiff explained that he shoots seals, when necessary, within the river or at the mouth of the river and the stretch of coast next to the estuary. He uses a .223 caliber rifle with a 62 grain head/bullet or a .270 caliber rifle with a 120 grain bullet. He described how he always tries to recover the carcasses but as the river is very fast flowing this is not always possible as the carcasses quickly get washed away. After a shooting, the bailiff will attempt to locate the carcass in the following days; sometimes they are found at the mouth of the river on the beach. The bailiff believes that the seals which enter the river to feed on salmon are mainly old, ill or juvenile seals. Most of the problem seals are grays. When asked about whether it is possible to identify a seal's sex before shooting it, he said that, in his opinion, it is not possible because the seals are shot in the water with only the head visible.

The bailiff referred to the busy nature of the river and the bay where the river meets the sea (it is a popular spot for tourists, dog walkers, bird watchers etc.,) and how it means that there are many times when it is inappropriate or dangerous to shoot a seal especially during the summer months. Therefore, at times, the bailiff has to refrain from shooting a seal which he would prefer to remove. The bailiff believes that alternative means of seal control such as ADDs are not, so far, appropriate for seal control in the area as it is a constantly changing environment and, therefore, where to position an ADD is not clear. There is no electricity supply and monitoring battery-operated devices might be difficult.

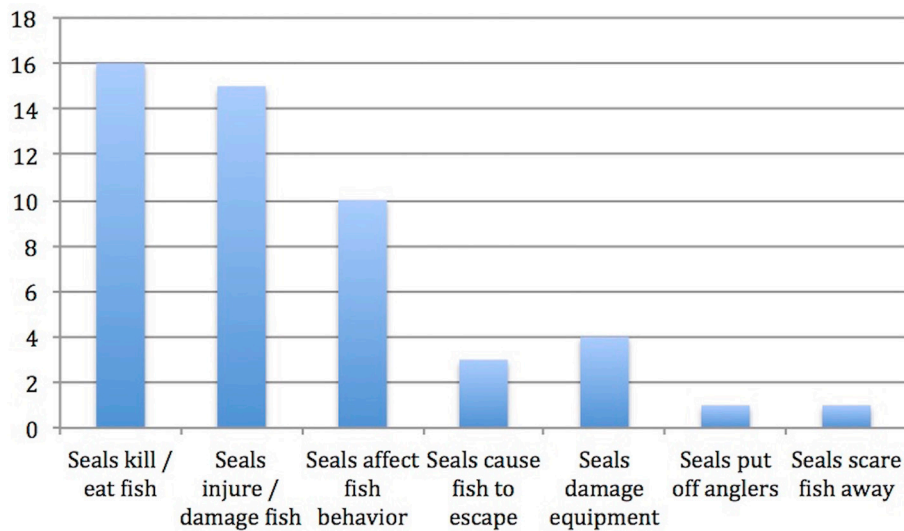


FIGURE 2 | Responses to Question 1 of License Holder Survey “What problems have you experienced with seals?”

DISCUSSION

Number of Seals Shot under License in Scotland

The data gathered by Marine Scotland and presented on their website relies on accurate reporting from license holders. These data are not independently verified and are, potentially, subject to error (for example in the numbers reported and species identification). The numbers themselves do not give information on whether the welfare of the shot seals is being negatively impacted but, when considered along with other available information, they show that there is cause for concern (see section on Monitoring the Welfare of Shot Seals).

The main findings from approach 1 show that a higher percentage of the total common seal population is allowed to be shot each year compared to the percentage of the gray seal population. As common seal populations around Scotland have been declining rapidly in recent years (Jensen et al., 2015) and are less numerous around Scotland than gray seals, this may seem counter-intuitive. However, the percentage of granted gray seals reported as shot shows a weak tendency to be higher than that of common seals. This difference in the numbers allocated and reported shot means that the percentage of the total population that are reported as shot each year is very similar between the two species.

The number of seals reported as shot has declined over time. In 2011, 366 grays and 93 commons were reported as shot. By 2014 (the last year for which the complete year’s data is available) this had fallen to 164 gray seals and 41 common seals.

License holders in Shetland not only were granted a high percentage of the PBR of gray seals but also shot the highest percentage of the allocated number. License holders in Orkney and the North Coast were granted the lowest percentage of the gray seal PBR and yet reported shot a high percentage of this quota. License holders in South West Scotland were granted a

high percentage of the PBR of gray seals in their area and yet reported that they shot the lowest percentage of this allowance.

In the Moray Firth and South West Scotland, high percentages of the PBR of common seals for each area were granted to license holders. The Moray Firth common seal population had been declining but is now considered stable (Jensen et al., 2015). However, it is possible that the additional pressure placed on a population by granting a high percentage of the PBR needs rethinking if the population is to be maintained at a favorable conservation status.

For gray seals, significantly more animals are shot in the second quarter (May–July) than in the first and fourth quarters (the period covering November–April). This could be because seals have higher nutritional demands during this period for some reason and, therefore, are more likely to come into conflict with fisheries and fish farms. For female gray seals in Scotland this is the period when they are approaching advanced pregnancy. However, in Canada it was found that female grays have higher energy requirements during the period after the breeding season due to their need to recover the body mass lost during lactation and which is needed to support pregnancy (Beck et al., 2007). In Scotland, the post-breeding period is October to January/February which coincides with when fewer seals are being shot. Perhaps the times when more seals are shot relates, not to the feeding requirements of the seals, but to periods when the weather is better and therefore seals are more likely to be sighted by license holders and when marksmen can shoot safely. In the case of fisheries, some are not operational in the winter and, therefore, have no cause to shoot seals during those months.

Use of Non-lethal Methods

The Scottish Seal Management Code of Practice recommends that seals should only be shot as a last resort (Marine Scotland, 2011). However, what constitutes a “last resort” is not specified. It may be that under certain circumstances, such as when a seal

TABLE 9 | Responses to Question 10 of License Holder Survey.

Reason for not recovering carcass	Response
Bad weather	1
Bad sea conditions	1
Seal sank after it was shot	12
Seal swam away after it was shot	0
It was too dangerous for the marksman to reach the seal	7
We didn't know that we were supposed to recover seal carcasses	0
Other (please specify)	1
	(1: H & S reasons, disposal issues, fish welfare, staff welfare, distance to SAC ^a)

^aIt is assumed that H & S means "Health and Safety" and that SAC means "Special Area of Conservation," although the survey respondent did not specify this.

TABLE 10 | Responses to Question 12 of License Holder Survey.

Seal management area	Response*
East Coast	3
Moray Firth	5
Orkney and North Coast	0
Shetland	2
South West Scotland	2
West Scotland	4
Western Isles	2

*Some license holders have establishments in more than one Seal Management Area.

is trapped inside a bag net, as described in Case Study 2, seal shooting is unavoidable, but these scenarios should, ideally, be exceptional.

From the survey carried out for this study, it appears that fisheries are more likely to resort to shooting than fish farms, rather than using non-lethal methods. This could be because there are more means of deterring seals from fish farms than fisheries. Indeed, in the questionnaire, some of the non-lethal methods listed were specific to fish farms. However, some methods are available to fisheries. Trials by Harris et al. (2014) concluded that ADDs can be an effective way to reduce seal predation from fishing nets. However, the license holder survey showed a weak tendency that fisheries are less likely to use ADDs than fish farms. Although the river bailiff interviewed for this study (Case Study 3) suggested that the river he manages may not be a suitable site for ADDs, experiments carried out by Graham et al. (2009) found that the use of ADDs reduced the likelihood of a seal being spotted upstream of the ADD by one half in their study river. Responses to the license holder survey suggested that ADDs are less effective in some locations and that they lose efficacy over time. These are issues that merit further research especially as it appears that more seals are being shot by fisheries than by fish farms and, therefore, fisheries need effective deterrence methods to reduce the number of seals they are shooting.

The results of the license holder survey and the interviews clearly demonstrated that fisheries and fish farms are concerned about seals killing and injuring salmon. As well as being of economic importance for these stakeholders it is also a fish welfare issue especially for the farmed salmon which are directly under human protection. Hence, whichever methods of seal deterrence are employed by fish farms and fisheries, they will be chosen, partly, because they do not have a negative impact on fish welfare.

Before granting a seal license, Marine Scotland must "have regard to any information they have about the effectiveness of non-lethal alternative methods of preventing seal damage to the fishery or fish farm concerned" (The Stationery Office, 2010). Such information should be provided to Marine Scotland via the application forms submitted by license applicants.

Monitoring the Welfare of Shot Seals

A seal license must impose conditions about the recovery of carcasses (The Stationery Office, 2010). However, the license holder survey found that 71% of respondents who had shot seals had not recovered any carcasses. This result is supported by the information collected from SMASS (see **Table 8**) which shows that very small percentages of shot seals are reported to them and, therefore, few carcasses are recovered for necropsy. The number of shot seals actually necropsied between 2011 and 2014 represents only 2.7% of the total number of seals reported as shot to Marine Scotland.

SMASS suggests that cases submitted for necropsy are not representative of all seals shot under license (SRUC Wildlife Unit, 2012; Brownlow and Davison, 2013). Marksmen may choose to only recover seals that have been shot well. Seals that were shot badly may dive or swim away with their injuries. These seals are not available for necropsy. Seal carcasses that wash up and are subsequently found by landowners or members of the public go some way to alleviating this bias but these cases are few and far between and, often, are not in a good condition for study.

Of the license holders that had shot seals but failed to recover them, 85.7% gave the seal sinking as a reason. Butler et al. (2008) reported that most shot animals sink immediately. During the pilot Moray Firth Seal Management Plan, 12% of seals killed at netting stations were recovered and only 5% of those shot in rivers (Butler et al., 2008). According to the North Atlantic Marine Mammal Commission (NAMMCO) the nutritional state of a seal affects its buoyancy: fat animals float and thin animals sink (NAMMCO, 2006). For harp seals in Greenland this is considered to be a seasonal issue relating to breeding periods and the condition of the seals' prey (NAMMCO, 2006). If more carcasses are to be recovered in Scotland, the likelihood of whether shot gray and common seals will float or sink during particular periods of the year could be investigated.

By consulting with license holders, it may be possible to determine what other factors are contributing to so few seals being collected and to explore ways of increasing the number of recoveries. Forty-four percent of respondents to the survey said it was too dangerous for the marksman to retrieve the carcass. As no specific details about what dangers are involved were given, this needs further investigation. The possibility of

photographing carcasses or tagging them in order to associate seal management cases with carcasses which subsequently wash up could be considered. The use of independent witnesses or assessors to monitor seal shooting incidents could allow the practicalities of carcass retrieval in differing circumstances to be assessed.

Despite the low numbers of shot seals being necropsied, there is clear evidence of seals being shot in ways that do not follow the Scottish Seal Management Code of Practice guidelines and which could negatively impact on the welfare of the seals being shot. The seals that were shot in the mandible and neck and the others which had multiple gunshot wounds as detailed in the Seal Management Cases reports for 2012, 2013, and 2014 show that there is cause for concern. If a greater number of carcasses were recovered for necropsy, then a more detailed picture of how seal welfare is being impacted by the licensing system would emerge.

One survey respondent ticked that “bad weather” was a reason for not recovering a carcass. Another indicated that “bad sea conditions” had prevented them from retrieving the carcass. The European Food Safety Authority (EFSA) concluded that shooting seals in bad weather and on bad habitat means there is a reduced chance of an effective hit and that greater suffering is, therefore, “likely” to occur (EFSA, 2007). As the Scottish Seal Management Code of Practice clearly states that shooting should only take place “in suitable weather conditions when there is sufficient visibility and sea conditions are such as to allow a clear shot” (Marine Scotland, 2011), it is of concern that some license holders are not following this guidance. The introduction of refresher training courses for nominated marksmen could help to ensure that the Code of Practice is being properly adhered to.

The welfare implications of using firearms (and other hunting methods) to stun seals was assessed by EFSA (2007). They concluded that, when used correctly, it was “very likely” to “likely” that a seal would be effectively shot and that suffering would be “negligible”. It was considered “unlikely” that a seal would be ineffectively shot or killed but that suffering would be “high” if that did happen. Sainsbury et al. (1995) state that human actions that cause instantaneous deaths do not negatively impact on welfare because there is no fear, distress, or pain. Therefore, if carried out properly, shooting should not have a negative impact on seal welfare.

The concern is for seals which are ineffectively shot and which subsequently suffer (EFSA, 2007). How does the Marine (Scotland) Act 2010 provide for this possibility? In Section 112 (1) (b), the Act states that a seal license should specify what to do if a seal is injured during an attempt to kill it “in order to reduce the risk of it suffering unnecessarily” (The Stationery Office, 2010). The Scottish Seal Management Code of Practice states that steps should be taken to prevent a “prolonged and painful death” by finding and humanely killing any injured animals (Marine Scotland, 2011). No details are given about how to achieve this, though it is something that marksmen are trained in during completion of the Seal Management Professional Development Award (SQA, 2011). The checking of seal consciousness by palpation of the skull, as recommended in Canada, may not be appropriate or possible in Scotland where seals are always shot in the water (Marine Scotland, 2015). This, in itself, is also a cause

for concern. Burdon et al. (2001) state that “shooting seals in open water can never be humane” and the Independent Veterinarians’ Working Group on the Canadian Harp Seal Hunt recommended that seals should not be shot in water because of the potential for wounded animals to be lost (Smith, 2005). Daoust and Caraguel (2012) reported that, in Canada, shooting a seal in the water meant a 30% chance of a poor welfare outcome compared to a 2.6% risk for seals shot on ice.

According to the responses to the license holder survey, none of the respondents had had to locate and humanely dispatch an injured seal and none of them said that a seal had swum away after being shot. However, SMASS have had two cases of seal carcasses showing multiple gunshot wounds that had not been killed rapidly and so, clearly, there are cases of seals being injured and not killed instantly (SRUC Wildlife Unit, 2012). This has clear negative implications for seal welfare.

With so few carcasses being recovered, it is impossible to know how many seals need to be shot more than once and whether some seals are escaping or sinking and drowning after being hit, but not killed, by an initial shot. Though a quick death is the objective according to the Scottish Seal Management Code of Practice, there is no specific mention of what is an acceptable Time to Death (TTD) for a shot seal. This is something that deserves consideration as a criterion for the future monitoring of seal shooting incidents.

Welfare of Non-target Seals Pregnant and Lactating Seals

The Marine (Scotland) Act 2010 and the Scottish Seal Management Code of Practice do not specify closed seasons and do not detail how to ensure that pregnant females are not targeted (The Stationery Office, 2010; Marine Scotland, 2011). Thirty-five per cent of the shot seals necropsied by SMASS during 2011–2014 were pregnant and it is likely that other, unrecovered, shot seals were also pregnant. The legislation states that a seal license may specify periods when seals may not be killed such as when females are likely to be in an advanced state of pregnancy (The Stationery Office, 2010).

After impregnation, gray seals in the North East Atlantic have a period of suspended development of ~104 days, followed by an active gestation of 246 days (Yunker et al., 2005). The delayed implantation in common seals in Alaska lasts ~77 days with an active gestation of about 252 days and it is assumed that common seals in Scotland have a similar period of active gestation (Pitcher and Calkins, 1979). Advanced gestation is considered to be the latter half of the third trimester (Brownlow A., 2015, pers. comm.) and, therefore, for both gray and common seals could be considered to be, roughly, the last 40 days before parturition. In Scotland the majority of gray seal pups are born between September and late November/early December (Russell et al., 2013; SMRU, 2014). Therefore, female gray seals will be in a state of advanced pregnancy from late July. In 2012, pregnant gray seals were shot in this period in Scotland (SRUC Wildlife Unit, 2012). **Table 4** shows that the majority of gray seals were shot in the period May–July, significantly more than in two of the other quarters. Many of these could have been pregnant females. Common seals give birth to their pups from late May to early July

(SMRU, 2014; Duck, 2010) and, therefore, their advanced stage of gestation starts in mid-April. Common seals have been shot during these periods. If pregnant seals are not to be targeted, then closed seasons need to be implemented.

Some authors assert that the ability of fetuses to experience pain *in utero* has been overestimated (Mellor et al., 2007). Mellor and Diesch (2006) state that for an animal to suffer it must be sentient and conscious and that, until at least halfway through pregnancy, fetuses are not sentient. Even once the fetus is capable of sentience, it remains unconscious and, therefore, does not perceive the sensory input that it receives (Mellor and Diesch, 2006). This suggests that, even in late pregnancy, the fetus is incapable of suffering. These conclusions are based on observations of fetuses and new-born farmed ungulates (Mellor and Diesch, 2006). Whether or not these results are applicable to all other mammals, including marine mammals is unclear. However, if it is the case that seal fetuses are incapable of suffering, then the shooting of pregnant seals in Scotland is not a welfare issue for the fetuses, though it is, of course, still necessary for the mother seal to be shot accurately to ensure that she experiences a quick death.

The Marine (Scotland) Act 2010 states that licenses may specify that female seals cannot be shot when they have dependent pups (The Stationery Office, 2010). Gray seal pups suckle from their mothers for between 16 and 23 days, while lactation lasts for between 4 and 6 weeks in common seals (Atkinson, 1997; Duck, 2010; SMRU, 2014). Marine Scotland (2014) notes that lactating females often leave their pups alone while they go foraging at sea. It is therefore, possible for a lactating mother to be targeted under the licensing system and for her dependent pup to be left to starve to death. **Tables 4, 5** show that gray and common seals are being shot during the periods when pups are born and are dependent on their mothers.

A review of sick and injured gray seal pups which were presented for rehabilitation in South-west England found that 91% of the unweaned pups had been separated from their mothers and that they would have become malnourished if they had not been rescued (Barnett et al., 2000). Anderson et al. (1979) found that in over 50% of gray seal pup deaths, the main cause of death was failure of or disturbance to the mother-pup bond. If the pup loses contact with its mother during the lactation period then its chances of survival are very low (Anderson et al., 1979). Osinga et al. (2012) observed that orphaned common seal pups in the Wadden Sea, Netherlands were never taken care of or allowed to suckle by other mothers in the area. Therefore, the shooting of any females that have dependent young will, most likely, result in two deaths: the death of the mother and the starvation of the pup.

Is it possible for a marksman to know whether an adult female seal has a dependent pup? Osinga et al. (2012) found that common seal mothers and pups stay close together on land and in the water. In their study the mothers were not seen to leave their pups in order to go foraging but this may be because the geography of the Wadden Sea means there is nowhere safe for a mother to leave her pup while she forages. The authors state that whether or not females leave their pups differs according to different populations. Indeed, studies in Sable Island, Canada and Maine, USA found that mother common

seals did not fast during the lactation period and were reliant on foraging in order to produce enough milk to feed their pups (Boness et al., 1994; Skinner, 2006). A study of common seals in the Moray Firth, Scotland found that females do not feed much immediately after parturition and during the early stages of lactation but that they do resume foraging before the pups are weaned (Thompson et al., 1994). The radio-tagged females in the study stayed close to haul-out sites for the first 2 weeks after pupping before spending more time at sea. It was not clear whether pups accompanied their mothers on feeding trips although some of the studied females changed their haul-out site when they started foraging suggesting that pups moved to the new haul-out site with their mothers. There are fewer studies of foraging in lactating gray seals, but that of Lydersen et al. (1994) suggests that at least some lactating female gray seals are actively foraging prior to weaning their pups.

To avoid the shooting of a mother seal with a dependent pup, it is clear that a mother should never be shot when a pup is visible, including if the pup is swimming. As feeding mothers may not be possible to differentiate from other seals, closed seasons would be the best way to prevent mothers with dependent pups from being targeted.

Other Non-target Seals

Six respondents (37.5%) to the License Holder Survey thought that shooting seals deterred other seals from approaching the area. Rifle shots can disturb non-target seals (Bonner, 1993) and, if they are on land and flee to the sea over rocky shores, they could be injured (Simmonds and Robotham, 2015). Human-caused disturbance of hauled-out seals can also lead to pups becoming separated from their mothers (Osinga et al., 2012) and this is, potentially, another negative welfare impact of seal shooting. To assess whether this is an issue for seals in Scotland, it is necessary to find out whether seals are being shot near breeding sites where pups could be disturbed.

A Note on the Approaches Used

Although each of the approaches used in this study has its own limitations and our investigations can be considered preliminary, by combining and comparing the approaches, the issue of seal welfare under the licensing system can be considered. By comparing the number of seal management cases reported to SMASS to the number reported to Marine Scotland, it is clear that there is a huge discrepancy and that the reporting and carcass recovery system requires significant improvement.

The data from the survey and the interviews have highlighted some of the issues affecting some license holders. However, it must be noted that the majority (75%) of respondents were fisheries or fishery boards. Only four replies came from fish farms. The fish farms represented areas in Shetland, South West Scotland, West Scotland, and the Western Isles. Unfortunately no replies came from Orkney which is the Seal Management Area where the greatest number of gray seals have been reported shot to Marine Scotland (see **Figure 1**).

Inconsistencies in the answers given to the survey questions may have impacted on the results. For example, it is noted that

one respondent did not answer question 4 to say which methods other than ADDs they used to deter seals but then, subsequently, gave answers to questions 5, 7, 8, and 10 indicating that they had shot seals.

Those license holders who completed the survey may not be representative of all license holders. Those who responded might have wanted to contribute to register their views of the current licensing system. The respondents may have wanted to demonstrate that the licensing system is transparent and that they have nothing to hide especially if they are not shooting any or many seals. Unanswered surveys may be due to a concern that their survey responses would paint them in a bad light. License holders who shoot a lot of seals may have chosen not to reply because they are worried about reprisals from activist groups. It is recognized by many that the issue of seal shooting is a sensitive subject. Some people may, simply, not have had the time or inclination to complete the survey.

CONCLUSION

The results presented here represent the first independent assessment of seal shooting in Scotland under the current legislation. From the data available, it can be seen that the number of seals reported as shot has reduced year-on-year since the licensing system was introduced. An independent assessment of the numbers being killed could improve the accuracy and reliability of the data. As only very low numbers of gray and common seal carcasses are being recovered after they have been shot by fish farms and fisheries it is difficult to assess welfare implications but, despite this, there is evidence that some seals are having their welfare negatively impacted because marksmen are failing to follow the guidance in the Marine (Scotland) Act 2010 and the Scottish Seal Management Code of Practice. Regular or refresher training courses for license holders and/or marksmen could improve adherence to the legislative requirements. Effective enforcement of the law is necessary to guarantee improved seal welfare and, in some areas, the Marine (Scotland) Act 2010 would benefit from some amendments. In particular, if the legislation aims to protect the welfare of seal fetuses and dependent pups, closed seasons need to be introduced to eliminate the shooting of pregnant and lactating females because, to date, a large proportion of the gray seals which have been necropsied were pregnant.

REFERENCES

- Anderson, S. S., Baker, J. R., Prime, J. H., and Baird, A. (1979). Mortality in Grey seal pups: incidence and causes. *J. Zool.* 189, 407–417. doi: 10.1111/j.1469-7998.1979.tb03972.x
- Atkinson, S. (1997). Reproductive biology of seals. *Rev. Reprod.* 2, 175–194. doi: 10.1530/ror.0.0020175
- Barnett, J. E. F., Woodley, A. J., Hill, T. J., and Turner, L. (2000). Conditions in grey seal pups (*Halichoerus grypus*) presented for rehabilitation. *Vet. Rec.* 147, 98–104. doi: 10.1136/vr.147.4.98
- Beck, C. A., Iverson, S. J., Bowen, D., and Blanchard, W. (2007). Sex differences in grey seal diet reflect seasonal variation in foraging behavior and reproductive expenditure: evidence from quantitative fatty acid signature analysis. *J. Anim. Ecol.* 76, 490–502. doi: 10.1111/j.1365-2656.2007.01215.x

To make improved recommendations for ensuring that the seal licensing system does not negatively impact seal welfare, more data are required. A significant increase in the number of shot seal carcasses that are recovered and presented for necropsy would be a good place to start. We have shown that fish farms seem to be using non-lethal methods of seal deterrent more than fisheries and netting stations. More research and knowledge transfer about the availability and use of non-lethal deterrents should be a priority to enable all types of license holders to maintain fish stocks and fish welfare without having to employ the “last resort” method of shooting a seal.

AUTHOR CONTRIBUTIONS

LN researched this topic for the MSc International Animal Welfare, Ethics and Law at the University of Edinburgh and wrote the bulk of the paper. MS and FL offered guidance, editing and critical comment on the subject matter and relevance of results. FL carried out statistical analysis of the data.

FUNDING

The study was funded and completed by LN as part of her MSc at the University of Edinburgh. This project was awarded a stipend from the Humane Society International. Travel and postage expenses were covered by the University of Edinburgh. Authors FL and MS acted as supervisors and thus received no funding for this research.

ACKNOWLEDGMENTS

The first author carried out this project in part fulfillment of the MSc International Animal Welfare, Ethics and Law at the University of Edinburgh. The authors thank the Humane Society International and the University of Edinburgh for supporting this project. Thanks also go to Andrew Brownlow and Nicholas Davison at SRUC and to the fish farm manager, bag net fisherman and the fishery board head bailiff for their help. Thank you to the Seal Licensing Team at Marine Scotland for answering our queries and the license holders who responded to the survey. The opinions presented here are those of the authors and do not necessarily reflect those of the organizations with which they are affiliated.

- Boness, D. J., Bowen, W. D., and Oftedal, O. T. (1994). Evidence of a maternal foraging cycle resembling that of otariid seals in a small phocid, the harbor seal. *Behav. Ecol. Sociobiol.* 34, 95–104. doi: 10.1007/BF00164180
- Bonner, W. N. (1993). “Killing methods,” in *Antarctic Seals: Research Methods and Techniques*, ed R. M. Laws (Cambridge, UK: Cambridge University Press), 155–160.
- Brownlow, A., and Davison, N. (2013). *Seal Management Cases 1 January to 31 December 2013 for Marine Scotland*, Scottish Government. Scottish Marine Animal Stranding Scheme.
- Brownlow, A., and Davison, N. (2014). *Seal Management Cases 1 January to 31 December 2014 for Marine Scotland*, Scottish Government. Scottish Marine Animal Stranding Scheme.
- Burdon, R. L., Gripper, J., Longair, J. A., Robinson, I., Ruehlmann, D., and Fielder, J. (2001). *Veterinary Report Canadian Commercial Seal Hunt Prince Edward*

- Island March 2001. IFAW. 36pp. Available online at: http://www.ifaw.org/sites/default/files/2001_Veterinary%20Report%20Canadian%20Commercial%20seal%20hunt.pdf (Accessed February 22, 2016).
- Butler, J. R. A., Middlemas, S. J., Graham, I. M., and Harris, R. N. (2011). Perceptions and costs of seal impacts on Atlantic salmon fisheries in the Moray Firth, Scotland: implications for the adaptive co-management of seal-fishery conflict. *Mar Policy* 35, 317–323. doi: 10.1016/j.marpol.2010.10.011
- Butler, J. R. A., Middlemas, S. J., McKelvey, S. A., McMyn, I., Leyshon, B., Walker, I., et al. (2008). The Moray Firth Seal Management Plan: an adaptive framework for balancing the conservation of seals, salmon, fisheries and wildlife tourism in the UK. *Aquat. Conserv.* 18, 1025–1038. doi: 10.1002/aqc.923
- Council of the European Union (1992). *Council Directive 92/43/Eec Of 21 May 1992 on the Conservation of Natural Habitats and of Wild Fauna And Flora*. Available online at: <http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31992L0043> (Accessed October 28, 2015).
- Daoust, P.-Y., and Caraguel, C. (2012). The Canadian harp seal hunt: observations on the effectiveness of procedures to avoid poor animal welfare outcomes. *Anim. Welf.* 21, 455–455. doi: 10.7120/09627286.21.4.445
- Duck, C. (2010). “Section 3.5: Seals,” in *UK Marine Monitoring and Assessment Strategy. Charting Progress 2 Healthy and Biological Diverse Seas Feeder Report*, eds M. Frost and J. Hawridge (London; Department for Environment Food and Rural Affairs on behalf of UKMMAS), 506–539.
- EFSA [European Food Safety Authority] (2007). Scientific Opinion of the Panel on Animal Health and Welfare on a request from the Commission on the Animal Welfare aspects of the killing and skinning of seals. *EFSA J.* 610, 1–122. doi: 10.2903/j.efsa.2007.610
- Graham, I. M., Harris, R. N., Denny, B., Fowden, D., and Pullan, D. (2009). Testing the effectiveness of an acoustic deterrent device for excluding seals from Atlantic salmon rivers in Scotland. *Int. Counc. Explor. Sea J.* 66, 860–864. doi: 10.1093/icesjms/fsp111
- Graham, I. M., Harris, R. N., Matejusová, I., and Middlemas, S. J. (2011). Do ‘rogue’ seals exist? Implications for seal conservation in the UK. *Anim. Conserv.* 14, 587–598. doi: 10.1111/j.1469-1795.2011.00469.x
- Gregory, N. (2003). “Assessing the humaneness of pest control methods. In: Solutions for achieving humane vertebrate pest control,” in *Proceedings of the 2003 RSPCA Australia Scientific Seminar, Telstra Theatre, Australian War Memorial*, ed B. Jones (Canberra, CA).
- Harris, R. N., Harris, C. M., Duck, C. D., and Boyd, I. L. (2014). The effectiveness of a seal scarer at a wild salmon net fishery. *ICES J. Mar. Sci.* 71, 1913–1920. doi: 10.1093/icesjms/fst216
- Hemmingsson, M., Fjälling, A., and Lunneryd, S.-G. (2008). The pontoon trap: description and function of a seal-safe trap-net. *Fish. Res.* 93, 357–359. doi: 10.1016/j.fishres.2008.06.013
- Jensen, S.-K., Lacaze, J.-P., Hermann, G., Kershaw, J., Brownlow, A., Turner, A., et al. (2015). Detection and effects of harmful algal toxins in Scottish harbor seals and potential links to population decline. *Toxicon* 97, 1–14. doi: 10.1016/j.toxicon.2015.02.002
- Königson, S., Fjälling, A., Berglind, M., and Lunneryd, S.-G. (2013). Male gray seals specialize in raiding salmon traps. *Fish. Res.* 148, 117–123. doi: 10.1016/j.fishres.2013.07.014
- Littin, K. E., and Mellor, D. J. (2005). Strategic animal welfare issues: ethical and animal welfare issues arising from the killing of wildlife for disease control and environmental reasons. *Rev. Sci. Tech.* 24, 767–782. doi: 10.20506/rst.24.2.1611
- Lydersen, C., Hammill, M. O., and Kovacs, K. M. (1994). Activity of lactating ice-breeding grey seals, *Halichoerus grypus*, from the Gulf of St Lawrence, Canada. *Anim. Behav.* 48, 1417–1425. doi: 10.1006/anbe.1994.1377
- Macdonald, D. W., Tattersall, F. H., Johnson, P. J., Carbone, C., Reynolds, J., Langbein, J., et al. (2000). *Managing British Mammals: Case Studies from the Hunting Debate*. Oxford, UK: Wildlife Conservation Research Unit.
- Marine Scotland (2011). *Scottish Seal Management Code of Practice. Marine (Scotland) Act 2010: Part 6 – Conservation of Seals 2011*. Available online at: <http://www.scotland.gov.uk/Resource/Doc/295194/0121503.pdf> (Accessed February 18, 2016).
- Marine Scotland (2014). *Guidance on the Offence of Harassment at Seal Haul-out Sites*. Available online at: <http://www.gov.scot/Resource/0045/00452869.pdf> (Accessed February 10, 2016).
- Marine Scotland (2015). *Report of the Inaugural Quinquennial Review of the Operation of Seal Licensing System under the Marine (Scotland) Act 2010*. Available online <http://www.gov.scot/Resource/0048/00484588.pdf> (Accessed February 18, 2016).
- Marine Scotland (2016a). *Salmon and Recreational Fisheries*. Available online at: <http://www.gov.scot/Topics/marine/Salmon-Trout-Coarse> (Accessed February 19, 2016).
- Marine Scotland (2016b). *Seal Licensing*. Available online at: <http://www.gov.scot/Topics/marine/Licensing/SealLicensing> (Accessed February 18, 2016).
- Marine Scotland (2016c). *How to Apply for a Licence*. Available online at: <http://www.gov.scot/Topics/marine/Licensing/SealLicensing/applications> (Accessed February 18, 2016).
- Mellor, D. J., and Diesch, T. J. (2006). Onset of sentience: the potential for suffering in fetal and newborn farm animals. *Appl. Anim. Behav. Sci.* 100, 48–57. doi: 10.1016/j.applanim.2006.04.012
- Mellor, D. J., Diesch, T. J., Gunn, A. J., and Bennet, L. (2007). “Fetal ‘awareness’ and ‘pain’: What precautions should be taken to safeguard fetal welfare during experiments?” in *Proceedings 6th World Congress on Alternatives and Animal Use in the Life Sciences* (Tokyo). AATEX 14, Special Issue: 79–83.
- Minister of Justice Canada (2011). *Marine Mammal Regulations (SOR/93-56). Last Amended on February 10, 2011*. Available online at: <http://laws-lois.justice.gc.ca/PDF/SOR-93-56.pdf> (Accessed February 18, 2016).
- NAMMCO [North Atlantic Marine Mammal Commission] (2006). *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.
- Northridge, S. P., Gordon, J. G., Booth, C., Calderan, S., Cargill, A., Coram, A., et al. (2010). *Assessment of the Impacts and Utility of Acoustic Deterrent Devices. Final Report to the Scottish Aquaculture Research Forum, Project Code SARF044. 34pp*. Available online at: <http://www.sarf.org.uk/reports/> (Accessed February 19, 2016).
- Osinga, N., Nussbaum, S. B., Brakefield, P. M., and Udo de Haes, H. A. (2012). Response of common seals (*Phoca vitulina*) to human disturbances in the Dollard estuary of the Wadden Sea. *Mamm. Biol.* 77, 281–287. doi: 10.1016/j.mambio.2012.02.005
- Pitcher, K. W., and Calkins, D. G. (1979). *Biology of the Harbor Seal, Phoca vitulina richardsi in the Gulf of Alaska. Final Report Outer Continental Shelf Environmental Assessment Program Research Unit 229, Contract Number 03-5-002-69*. Alaska Department of Fish and Game. 231–208.
- Quick, N. J., Middlemas, S. J., and Armstrong, J. D. (2004). A survey of antipredator controls at marine salmon farms in Scotland. *Aquaculture* 230, 169–180. doi: 10.1016/S0044-8486(03)00428-9
- RSPCA [Royal Society for the Prevention of Cruelty to Animals] (2015). *RSPCA Welfare Standards for Farmed Atlantic Salmon*. Available online at: <http://science.rspca.org.uk/sciencegroup/farmanimals/standards/salmon> (Accessed February 13, 2016).
- Russell, D. J. F., McConnell, B., Thompson, D., Duck, C., Morris, C., Harwood, J., et al. (2013). Uncovering the links between foraging and breeding regions in a highly mobile mammal. *J. Appl. Ecol.* 50, 499–509. doi: 10.1111/1365-2664.12048
- Sainsbury, A. W., Bennett, P. M., and Kirkwood, J. K. (1995). The welfare of free-living wild animals in Europe: harm caused by human activities. *Anim. Welf.* 4, 183–206.
- Scotland’s Aquaculture (2016). *Scotland’s Aquaculture*. Available online at: http://aquaculture.scotland.gov.uk/our_aquaculture/our_aquaculture.aspx (Accessed February 18, 2016)
- Simmonds, M. P., and Robotham, R. (2015). The Grey Seals of Bardsey. *British Wildl.* 27, 2–9.
- Skinner, J. P. (2006). *Physical and Behavioral Development of Nursing Harbor Seal (Phoca vitulina) Pups in Maine*. Thesis, B.S. Colorado State University.
- Smith, B. (2005). *Improving Humane Practice in the Canadian Harp Seal Hunt. A Report of the Independent Veterinarians’ Working Group on the Canadian Harp Seal Hunt*. Available online at: <http://www.thesealfishery.com/files/IVWGReportAug2005.pdf> (Accessed February 22, 2016).
- SMRU [Sea Mammal Research Unit] (2014). *Scientific Advice on Matters Related to the Management of Seal Populations: 2014*. Available online at: <http://www.smru.st-and.ac.uk/documents/2259.pdf> (Accessed March 18, 2016).

- SQA [Scottish Qualifications Authority] (2011). *Arrangements for: Professional Development Award (PDA): Seal Management at SCQF level 6*. SQA. Available online at: http://www.sqa.org.uk/sqa/files_ccc/ArrangementsSealManagement.pdf (Accessed February 10, 2016).
- SRUC Wildlife Unit [Scotland's Rural College Wildlife Unit] (2012). *Scottish Marine Animal Stranding Scheme*. Seal Management Cases 1 January to 31 December 2012 for Marine Scotland, Scottish Government.
- The Stationery Office (1970). *Conservation of Seals Act 1970 (c.30)*. London. Available online at: <http://www.legislation.gov.uk/ukpga/1970/30/contents> (Accessed March 18, 2016).
- The Stationery Office (2010). *Marine (Scotland) Act 2010 (asp 5)*. UK. Available online at: <http://www.legislation.gov.uk/asp/2010/5/contents> (Accessed March 18, 2016).
- Thompson, D., Morris, C. D., and Duck, C. D. (2014). *Provisional Regional PBR values for Scottish seals in 2015*. Seal Mammal Research Unit. SCOS – BP 14/05. P144-151 in *Scientific Advice on Matters Related to the Management of Seal Populations: 2014*. Available online at: <http://www.smru.st-and.ac.uk/documents/2589.pdf> (Accessed November 18, 2015).
- Thompson, P. M., Miller, D., Cooper, R., and Hammond, P. S. (1994). Changes in the distribution and activity of female harbour seals during the breeding season: implications for their lactation strategy and mating patterns. *J. Anim. Ecol.* 63, 24–30. doi: 10.2307/5579
- Warburton, B., and Norton, B. G. (2009). Towards a knowledge-based ethic for lethal control of nuisance wildlife. *J. Wildl. Manage.* 73, 158–164. doi: 10.2193/2007-313
- Yunker, G. B., Hammill, M. O., Gosselin, J.-F., Dion, D. M., and Schreer, J. F. (2005). Foetal growth in north-west Atlantic grey seals (*Halichoerus grypus*). *J. Zool.* 265, 411–419. doi: 10.1017/S0952836905006503

Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Copyright © 2016 Nunny, Langford and Simmonds. This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY). The use, distribution or reproduction in other forums is permitted, provided the original author(s) or licensor are credited and that the original publication in this journal is cited, in accordance with accepted academic practice. No use, distribution or reproduction is permitted which does not comply with these terms.