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Comparison of the thickness of the calvarium between young grey (*Halichoerus grypus*) and harp (*Pagophilus groenlandicus*) seals

Comparaison de l'épaisseur de la calotte crânienne entre les jeunes phoques gris (*Halichoerus grypus*) et les jeunes phoques du Groenland (*Pagophilus groenlandicus*)

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ABSTRACT

Young harp seals (*Pagophilus groenlandicus*) have traditionally been hunted along the Canadian Atlantic coast, and regulations are now in place to ensure that this hunt meets adequate standards of animal welfare. These young seals are killed by a blow to the head from a hakapik or a club or by a bullet to the head. A hunt for young grey seals (*Halichoerus grypus*), using similar methods, occurs intermittently on a smaller scale around the Canadian Maritime provinces. However, field observations suggest that the skull of young grey seals is substantially thicker than that of young harp seals. The results of this study confirm these field observations and suggest the need for further research when adapting the current hunting methods for young harp seals to grey seals.

RÉSUMÉ

Les jeunes phoques du Groenland (*Pagophilus groenlandicus*) ont historiquement été chassés sur la côte atlantique du Canada, et des règlements sont maintenant en place pour assurer que cette chasse se déroule selon des standards de bien-être animal adéquats. Ces jeunes phoques sont tués par un coup de hakapik ou de gourdin sur la tête ou par une balle de carabine dans la tête. Une chasse à plus petite échelle pour les jeunes phoques gris (*Halichoerus grypus*), utilisant des méthodes similaires, se fait de manière intermittente dans les provinces maritimes. Cependant, les observations sur le terrain suggèrent que le crâne des jeunes phoques gris est nettement plus épais que celui des phoques du Groenland. Les résultats de cette étude confirment ces observations et suggèrent un besoin de recherche pour adapter les méthodes de chasse courantes pour les jeunes phoques du Groenland aux jeunes phoques gris.

INTRODUCTION

The population of grey seals (*Halichoerus grypus*) in the northwest Atlantic has expanded considerably during the past few decades (Thomas et al. 2007), and there is strong interest on the part of some coastal communities in the Canadian Maritime provinces to develop and expand a commercial hunt for young animals of this species. These young seals are approximately 5-7 weeks old when killed and are here referred to as beaters, in analogy to the animals of a similar age group targeted during the Canadian harp seal (*Pagophilus groenlandicus*) hunt. The Marine Mammal Regulations (MMR) of the Fisheries Act of Canada (Anonymous 2010), designed primarily for the commercial hunt for harp seal beaters, allow the use of a club, a hakapik, or a high-power rifle to kill these animals with a strike to the head.

There is a need to better understand how each of the tools currently allowed by the MMR, when properly used, functions to achieve rapid death of the animal in a manner compatible with sound principles of animal welfare. In particular, based on field observations, the skull of grey seal beaters is thought to be substantially thicker than that of harp seal beaters, which may decrease the efficacy of blows from a club or a hakapik to crush their skull and achieve a rapid death.

The aim of the present study was to describe and compare the actual thickness of the calvarium (defined as the dome-like superior portion of the skull covering the cerebral hemispheres) of grey and harp seal beaters in order to verify field observations.

MATERIALS AND METHODS

The intact heads of four harp seal beaters and four grey seal beaters were obtained through other projects carried out at the Maurice-Lamontagne Institute, Fisheries and Oceans Canada, Mont-Joli, Québec. The sex of these seals was not recorded. For each skull, skin, blubber and soft tissues were removed. A transverse section of each skull, approximately 1 cm wide, was taken midway between the caudal border of the orbits and the occipital foramen. Digital pictures of the rostral and caudal views were taken of each section, using a caliper opened to a width of 1 mm as a reference scale (Figure 1). For each picture, a straight line (in red) was drawn between the dorsal portions of the petrosal part of each temporal bone as a horizontal reference. Subsequently, additional lines (in black) were drawn from the center of the horizontal line at angles of 10°, 30°, 60°, 90°, 120°, 150° and 170°, and the thickness of the calvarium was measured where these seven lines intersected the bone (Figure 1). Line drawings and thickness measurements were made using the Image J program (Abramoff et al. 2004).

A cross- structured, mixed, linear regression model was built to investigate the effect of species, section view (rostral vs caudal), and angle of measurement on the thickness of the calvarium. Random effects for individual seals, views within individuals, and angles within individuals were included in the model to account for the fact that measurements within a cluster are expected to be more alike than across clusters (i.e. lack of independency of measurements). The deviation from the axis of symmetry (i.e., 90°) of the angles of measurement was included in the model as fixed effects (e.g., the deviations of the angles 30° and 150° from the 90° angle were the same: 60°). An autoregressive correlation matrix for residuals was used to account for measurements being more alike when they were close by. The model assumed symmetry (providing the same deviation angles from 90°) and non-symmetry (providing unique deviation angles from 0°). Based on preliminary descriptive statistics, the variability of the thickness of the calvarium was anticipated to be higher within a grey seal than within a harp seal. Therefore, separate variance residual for each species was included in the model. The analysis was conducted using the

statistical package Stata IC 11.0 (StataCorp, College Station, TX, USA, 2009). The dataset and commands are available for consultation upon request to the corresponding author.

RESULTS

The model assuming symmetry provided a better fit (i.e. maximum likelihood). Right and Left were then included as fixed effect to further investigate any side effect. Average difference between Right and Left was not significant and therefore side was excluded from further analysis.

Figure 2 compares the average thickness of the calvarium of the two seal species for the different angles of measurement. On average, the calvarium of young grey seals was 1.21 mm thicker than that of young harp seals (3.60 mm, SE= 0.22, and 2.39 mm, SE= 0.25, respectively) ($P = 0.0003$). At the median axis (mid-dorsal region of the calvarium, 90°), the calvarium of young grey seals was on average almost twice as thick as that of young harp seals (4.88 mm, SE= 0.464, and 2.64 mm, SE= 0.318, respectively) ($P \leq 0.001$). For harp seals, the thickness of the skull was homogeneous regardless of the angle of measurement ($P \geq 0.05$). The coefficient of variation (CV) of the thickness of the calcarium of a young harp seal was 0.30 (SD= .72). By comparison, the CV of the calvarium of a young grey seal was 0.45 (SD= 1.62) (ie. 50% more variation in the thickness of the calvarium of young grey seals). The calvarium of a grey seal skull was thinner, the further away from the axis of symmetry (Figure 2). The angles 60° and 120° (30° from the median axis) were slightly thinner by 0.45 mm (not significant, $P = 0.39$). The angles 30° and 150° (60° from the median axis) were on average thinner by 1.34 mm (significant, $P = 0.009$). Finally, the angles 10° and 170° (80° from the median axis) were on average thinner by 2.72 mm (significant, $P < 0.0001$). Harp seal beaters have a thinner calvarium with a uniform inner surface, whereas the mid section of the calvarium of grey seal beaters is almost twice as thick with a more complex, irregular inner surface that becomes thinner laterally (Figure 1).

DISCUSSION

It is difficult to know whether the four specimens collected were representative of each species. In particular, the sex of the seals from which the heads originated was not recorded. Harp seals are monomorphic and it is unlikely that there are differences in the structure of the skull between sexes. However, grey seals are sexually dimorphic, and size differences are observed at weaning between the two sexes (Baker et al. 1995). Therefore, potential sex differences in structure and thickness of the skull in this species should be considered in future tests. Notwithstanding this caveat, there is good evidence that young grey seals have, on average, a thicker calvarium than young harp seals. A thicker calvarium would presumably require a stronger impact in order to be completely crushed (step one of the three-step killing process, as recommended by IVWG [2005] and as currently required by MMR [Anonymous 2010]), thus ensuring destruction of the underlying cerebral hemispheres which are responsible for pain perception.

Structurally, the calvarium of a grey seal beater is thicker near the center (mid-dorsal region) and thinner towards the lateral sides (Figure 1A and B). It is therefore expected that, following a blow with strong vertical pressure from top to bottom on the calvarium, the junctions with the temporal bones would fracture first and more easily than the dorsal region of the calvarium. More likely to sustain linear fractures than to be crushed, as occurs with the skull of a harp seal beater, the thicker dorsal region may feel firm by palpation through skin and blubber. Palpation

of the skull to verify that it is completely crushed represents the second step of the three-step killing process (IVWG 2005) and is used to confirm that both underlying cerebral hemispheres have been destroyed. This step may be more difficult to interpret in young grey seals than in young harp seals since larger and thicker bone fragments would not reflect as well the actual damage incurred by the brain. This may result in unnecessary additional blows by the hunter to the head of an otherwise cerebrally dead animal and be perceived as hunter eagerness.

In conclusion, the significant difference in the anatomical structure of the calvarium between grey seal and harp seal beaters needs to be considered when using the hakapik or the club in order to efficiently stun these animals and when checking by palpation the degree of damage to the calvarium. A thicker calvarium in grey seal beaters may result in less efficient stunning with the use of a hakapik or a club as compared to harp seal beaters and may thus lead to an increased risk for poor welfare outcome. This should be evaluated further with a larger sample of skulls. However, collapse of the dorsal region of the calvarium, with production of only large bone fragments, can still inflict significant damage to the cerebral hemispheres and brainstem, sufficient to induce irreversible unconsciousness or death. This would still result in a good animal welfare outcome, but obviously would be more difficult to detect. A larger sample size would improve statistical comparisons and would address concerns of whether differences exist between male and female grey seal skull thickness. However, the results to date are sufficient to indicate that alternative stunning tools should be investigated and validated in order to provide a killing method that would be better adapted to the specific characteristics of the skull anatomy of grey seal beaters.

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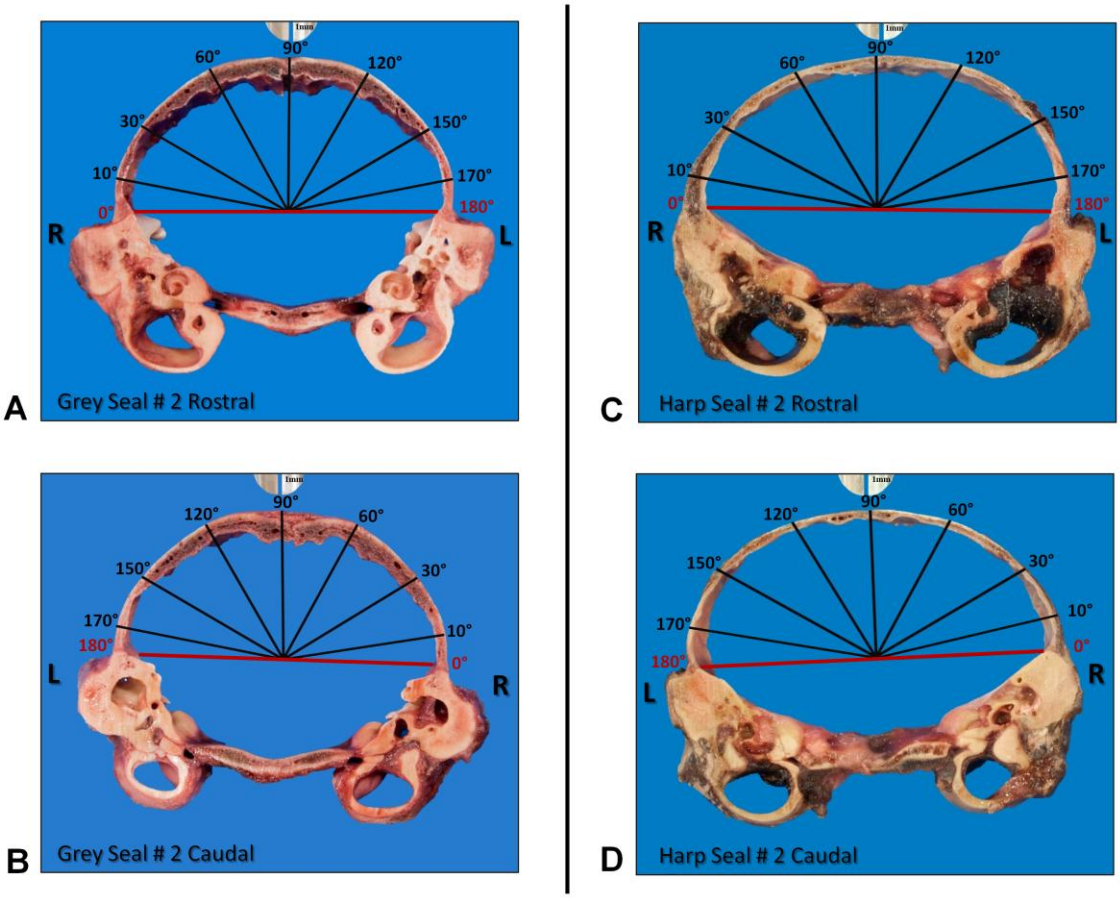

Figure 1. Rostral (top row) and caudal (bottom row) views of a transverse section of the calvarium of a young grey seal (left column) and a young harp seal (right column). The thickness of the calvarium was measured in mm at seven set angles: 10°, 30°, 60°, 90°, 120°, 150° and 170°. For reference, the angle 0° corresponds to the right side (R) of the animal and the angle 180° to the left side (L). Therefore, the order of angles is reversed between the rostral and caudal views. The caliper used as a reference scale at the top of each photo is opened to a width of 1 mm.

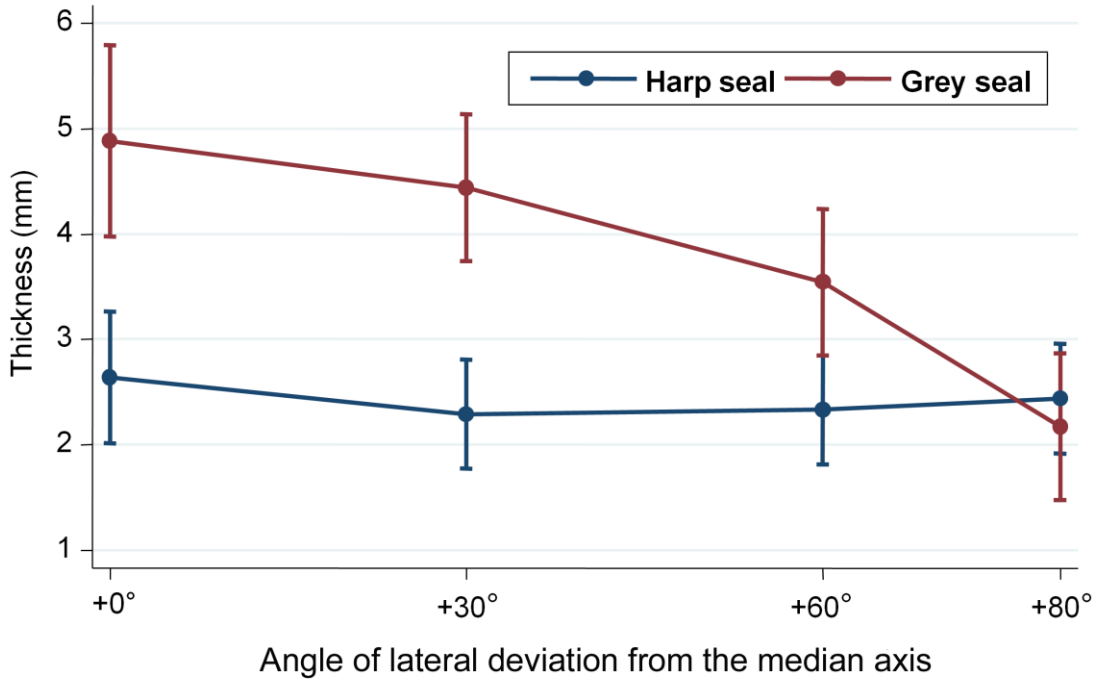

Figure 2. Comparison of the average thickness of the calvarium of young grey seals and young harp seals for different angles of measurement relative to the median axis (90°) (see Figure 1). Whereas the thickness of the calvarium of young harp seals varies minimally, the thickness of the calvarium of young grey seals becomes thinner when measured further away from the median axis.