Evaluating New Zealand fur seal (*Arctocephalus forsteri*) pups' response to conspecific adult aggression and earthquake-driven habitat displacement

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Abstract: Attacks from conspecific adults are among the most frequent causes of New Zealand fur seal (*Arctocephalus forsteri*) pup mortality, but pups are often able to flee from these adults in tidal pools. However, the 2016 Kaikoura earthquake buried a large portion of the Ohau Point seal colony, substantially altering the tidal pools where pups could seek shelter and potentially resulting in an increase in pup deaths by adult antagonism. Therefore, this study sought to investigate pups' responses to adult aggression in pre-earthquake tidal pools and determine if the post-earthquake areas allowed for the same behavior. This was achieved via analysis of videos of pups playing at Ohau Point, Kaikoura in January 2015 and at Kean Point, Kaikoura in April 2018. The adults' aggressive behaviors were categorized, the pups' responses were characterized, and retreats were measured. The results showed that pups retreated from the antagonistic adult in 29 of the 32 observed aggressive interactions, and the average distance of retreat was 1.42 body lengths. The post-earthquake play spaces allowed for this distance of retreat, but presented possible challenges in size, jaggedness of surrounding rocks, and proximity to open ocean. While this study provided insight into pre-earthquake responses, a larger amount of post-earthquake footage would aid in more fully understanding the impacts of earthquake-driven spatial change.

Keywords: behavior; pinniped; pup mortality; Kaikoura; coloniality

Introduction

Among the most frequent causes of New Zealand fur seal (*Arctocephalus forsteri*) pup mortality are abduction and attacks by conspecific adults, particularly by sub-dominant males and non-filial females (Mattlin 1978). Pups in turn can seek shelter in tidal pools, which are critical areas that provide space for pups to play, practice their swimming, and avoid aggression from adult conspecifics (Harcourt 1991). However, in November of 2016, a 7.8 M_w earthquake occurred in Kaikoura, burying a large portion of the renowned Ohau Point Seal Colony and yielding substantial variations in habitat and number of tidal pools neighboring the colony (Bai et al. 2017). Initial reports do not suggest a notable population decrease, but fur seal species are largely philopatric and females reach sexual maturity between age 4-5, suggesting that the long-term impact of the colony damage will likely not be evident for another 5-6 pupping seasons (Lento et al. 1997; Gentry 1987; McKenzie 2006). Nonetheless, if pups lack shelter and are unable to retreat from the aggressors in their new spaces, the changes in tidal pools and habitat displacement caused by the earthquake may ultimately result in increased pup mortality within the colony.

Work on New Zealand fur seals is relatively scare, and there is even less research concerning their aggression in particular (Lalas & Bradshaw 2001; Kim 2016). Also, while preliminary population surveys were conducted following the earthquake, to the researcher's knowledge, there are no published studies that address the potential effects of earthquake-driven habitat changes on the species in general, much less on the pups' behavior. The present paper sought to fill these gaps by examining fur seal pups' potential change in response to aggression by conspecific males and non-filial females due to the spatial impacts of the 2016

Kaikoura earthquake. Specifically, it aimed to answer the following questions: In the pups' play spaces before the occurrence of the earthquake, how do they respond to different agonistic behaviors by adult males and non-filial females? Do pups retreat from the approaching conspecific, and if so, what is the average distance of retreat? Do post-earthquake habitats allow for the same behavior observed in pre-earthquake conditions, or is there a change in the pups' response to adult aggression in their new areas? These data could contribute to the current scientific literature, as well as help to inform management decisions in the wake of earthquake-driven habitat displacement.

Methods

Study area

The New Zealand fur seals in this study were observed at the Ohau Point seal colony in January of 2015 (before the occurrence of the 2016 earthquake), as well as the Kean Point seal colony in May of 2018. The sites are located on the East coast of New Zealand's South Island, approximately 26 km north and 4 km south of Kaikoura, respectively (Figure 1). At Ohau Point, four pre-earthquake tidal pools were observed (Figure 2), referred to as "Triangle Pool," "A-Pool," "C-Stick Pool," and "Fence Pool" (Gooday 2015). At Kean Point, two post-earthquake tidal pools were observed (Figure 3), and were called "Large Pool" and "Open Pool" (Gooday 2018).

Both seal colonies included in the study are rookeries, or breeding areas, and as of 2015, Ohau Point seal colony was the largest fur seal breeding colony in the area, with an estimated 3000 individuals (Boren *et al.* 2008). Kean Point is a sizable colony as well, and estimates for both sites following the earthquake are still occurring and to be published. The colonies have also been notable tourist attractions, though the 2016 earthquake significantly altered the accessibility of each area. While Ohau Point was largely buried and is no longer available to the public, the colony at Kean Point is now more accessible than previously. However, the tidal pools used to collect post-earthquake data are located in a Department of Conservation (DOC) restricted area, and therefore are largely unaffected by the presence of tourists.

Figure 1. Left: map of New Zealand with a pin demarking Kaikoura. Top right: Google Earth image of a bird's eye view of Ohau Point seal colony pre-earthquake (Kim 2016). Bottom right: Google Earth image depicting a bird's eye view of Kean Point post-earthquake (2018).

Figure 2. Pre-earthquake tidal pools at Ohau Point. Top left: "Triangle Pool;" top right: "A-Pool;" bottom left: "C-shift pool;" bottom right "Fence Pool." Sourced from Gooday (2015).

Figure 3. Post-earthquake tidal pools at Kean Point. Left: "Large Pool;" right: "Open Pool." Sourced from Gooday (2018).

Sampling methods

Pre-earthquake behavioral data were collected using video captured in 2015 for a thesis study examining pup behavior and non-invasive population survey techniques (Gooday 2016). Sampling occurred over five days in January (7, 10, 12, 13, 14) and comprised of three one-hour filming periods per day at 7 am, 12 pm, and 6 pm, to account for possible differences in seal behavior throughout the day.

Behavioral data following the earthquake were gathered using video captured on the 5th and 6th of May 2018. Though the original intent was to duplicate the pre-earthquake three one-hour filming periods over these days, due to issues with the camera SD card, only 20 minutes of footage was able to be collected on each day.

The seals involved in aggressive interactions (the indicators of which to be discussed in the following section) were categorized into different demographic groups using characteristics from previous work (Kim 2016; Goldstien, personal communication, 2018; Crawley & Wilson 1976). Given that the footage was originally captured for different purposes, there was no scale able to be utilized for measurements. Though this was worked around when taking pup response measurements (as described in the following section), identification of seals by age and sex had to be accomplished using only qualitative traits and relative body lengths.

I. Pups (born in the current breeding season): Approximately 40 – 70 cm long; dark coat until molting around age 5-6 months
II. Yearlings and juveniles: Less than 1 m long; grey or brown adult coats
III. Females (adults): Approximately 1 to 1.5 m long; dark brown coat and slender neck

IV. Sub-dominant males (adults): Approximately 1 to 1.5 m long; neck larger than that of females but not as obvious as that of dominant males

V. Dominant males (adults): Approximately 1.5 to 2 m long; distinctively large neck and able to defend territories from other males

Given that the study sought to analyze pups' response to aggression from conspecific adults, antagonistic behavior toward yearlings and juveniles were not included in analysis. Location, time of day, tide state (low, mid, high), approximate temperature, cloudiness, rain, wind speed, and wave action were also noted at the start of each filming period.

Quantification of aggression and responses

The collected video footage was first reviewed for frequency and intensity of adult aggression towards pups using a method modeled after work performed by Juliet Kim in 2016. The sex and age group of the individuals involved in the interactions were noted using the groupings outlined above, and the intensities of aggression exhibited by the adult were categorized within six categories of behavior (Figure 4), expounding upon the four categories defined by Kim (2016).

I. Threat: A behavior where the adult opens its mouth and shows its teeth while facing in the direction of the 'opponent,' or pup, in this work.

II. Threat Exaggeration: A behavior that includes the elements of a threat and is accompanied by an extension of the neck in the direction of the opponent. Kim notes that this behavior has been characterized as 'threat' or 'lunge' in previous studies (Carey 1992; Francis 1987), but decided to distinguish between the two as ‘lunges’ occurred more often when the opponent was within reach, whereas ‘threat exaggerations’ were performed when the opponent was out of reach. This statement is concurrent with the behaviors observed in the present study.

III. Lunge: A behavior that again includes the threat behavior, but is characterized by quick extension of the neck in the direction of the opponent and a snapping motion of the jaw. Contact is not made between aggressor and opponent.

IV. Bite: A behavior that includes all aspects of the lunge behavior, but is distinguished by contact being made between aggressor’s open mouth and the opponent’s body.

V. Advance: A behavior in which the aggressive adult moves quickly in the direction of the opponent.

VI. Combination: This category includes instances in which an aggressor displayed a series of antagonistic behaviors towards the same pup(s) within a single interaction.

The responses of the pups in each of these interactions were then grouped into one of two observed categories: 1) retreat, in which the pup scurried quickly away from the aggressor following the antagonistic behavior; and 2) no response. The pups’ retreats were measured using an on-screen ruler tool called Ondesoft (Figure 5) at each onset of aggressive behavior. As mentioned above, there was no object utilized for scale during filming sessions. Therefore, retreats were measured in body lengths, rather than meters. This was achieved by measuring the pup of interest’s length (from nose to tail) in screen pixels, and also measuring the retreat in pixels. The unit of ‘body length’ was calculated using a ratio of those two measurements (Equation 1) to account for differences in camera height during filming, depth perception, and size of computer window used in analysis.

$$\textit{Equation 1}: \text{Body length} = \frac{\text{Length of pup retreat (pixels)}}{\text{Pup length from nose to tail (pixels)}}$$

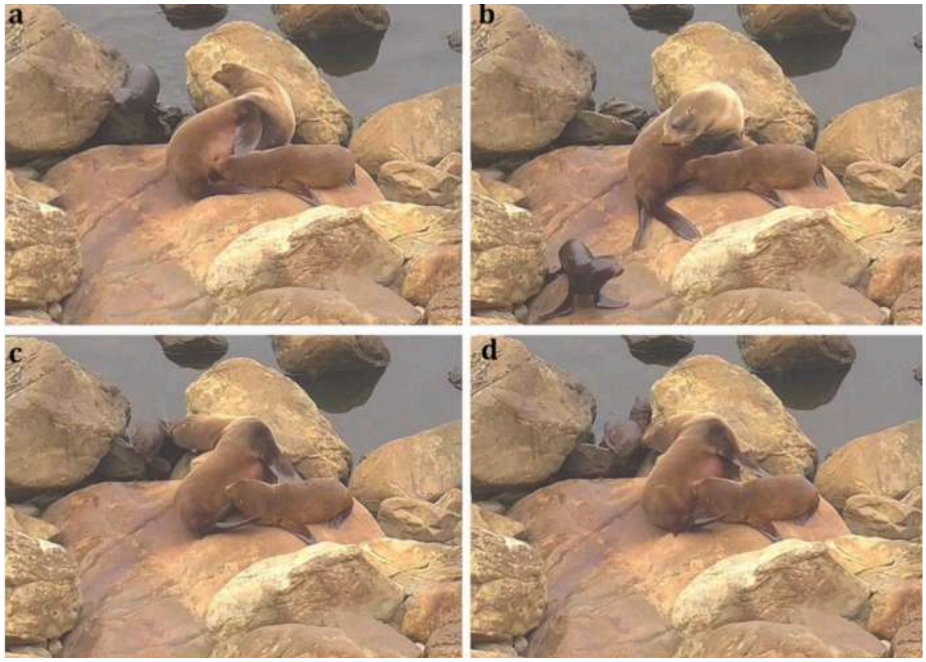

Figure 4. Four different aggressive behaviors shown by an adult female (center of image) with her pup (dry pup suckling from female) towards a non-filial pup (wet pup left of female). a.) threat behavior; b.) threat-exaggeration behavior; c.) lunge behavior; d.) bite behavior. Sourced from Kim (2016).

Figure 5. Screenshot of Ondesoft screen ruler software overlaying pre-earthquake tidal pool footage at Ohau Point. Sourced from Gooday (2015) and Ondesoft (2018).

Data analysis

The statistical analyses performed for this project were univariate and therefore able to be conducted in Excel 16.13 (Microsoft Office 2018). In pre-earthquake videos, pup length, sex of aggressive adult, size of pool, and category of aggressive behavior were analyzed to test for potential influence on retreat length using simple linear regression and ANOVA tests ($p < 0.05$). These variables were chosen to investigate if smaller pups may retreat further, if pups would retreat further from dominant males than females, if pups would retreat further in larger pools, and if certain aggressive behaviors triggered further retreats. The mean length of pup retreat for each category of aggressive behavior was calculated, as was the overall average length of retreat.

At the post-earthquake site, given the small amount of footage that was able to be gathered, observations were noted and data were primarily analyzed qualitatively. In addition, pre-earthquake average retreat length and observed behaviors were extrapolated to the new tidal pools to test if they allowed for the same responses to aggressive conspecifics.

Results

In the 15 hours of pre-earthquake footage, 32 interactions were observed ($n = 32$) in which a conspecific adult displayed aggressive behavior(s) towards at least one pup. In the 0.66 hours of post-earthquake footage, no aggressive interactions were observed ($n = 0$). 29 out of 32 (90.6%) aggressive interactions resulted in the pup(s) retreating from the antagonistic adult (Figure 6), and the overall average pup retreat length was calculated to be 1.42 body lengths.

In the pre-earthquake conditions, the average pup length was found to be 72.83 pixels, but pup length did not correlate significantly with retreat length (R^2 = 0.045) (Figure 7). As for the sex of adult aggressors, of the 32 interactions, 2 of the aggressors were classified as sub-dominant males, 3 as dominant males, and the remaining 27 antagonists were found to be females. Though the sex ratio was biased, the sex of the aggressor was not found to have an impact on average pup retreat length (df = 2, f = 0.022, p = 0.979) (Figure 8). Moreover, the average retreat length per pool did not differ significantly (Figure 9). Lastly, 12 threats, 1 threat exaggeration, 9 advances, 2 lunges, 1 bite, and 7 combinations of aggressive behaviors were identified (Figure 10), but again the average retreat length was not found to differ significantly per category of behavior (df = 5, f = 0.62, p = 0.684) (Figure 11).

In the post-earthquake conditions, the two tidal pools observed would allow for the average retreat of 1.42 body lengths, but the video was taken from too far a distance to observe behavior (Figure 3). One of the pools, Large Pool, was approximately three times larger than any of the four pre-earthquake tidal pools and was surrounded by tall, jagged rocks. The other, Open Pool, was close to the open ocean, with only a thin strip of rock sheltering the pups from wave action.

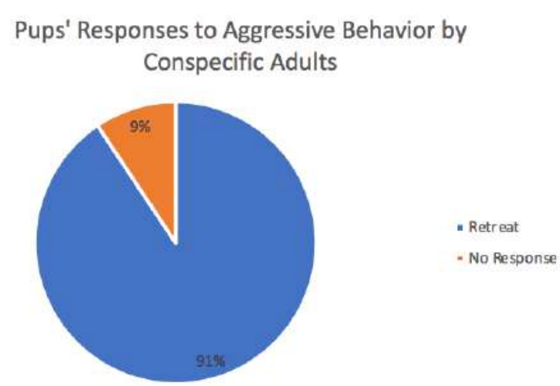

Figure 6. Pups' responses to aggressive behavior by conspecific adults. (n = 32).

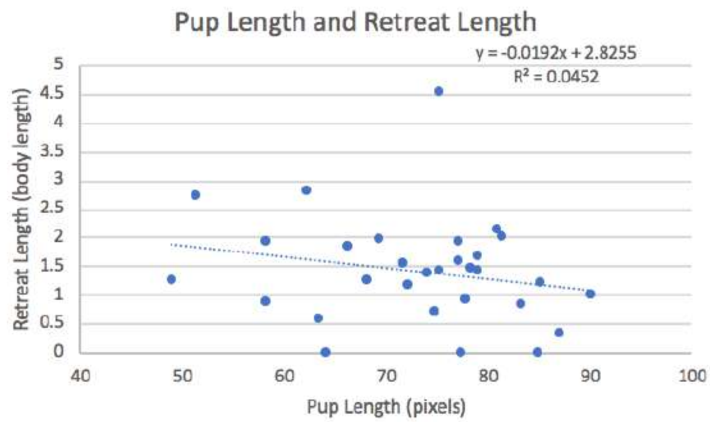

Figure 7. Pup length and retreat length (body length). (R^2 = 0.0452)

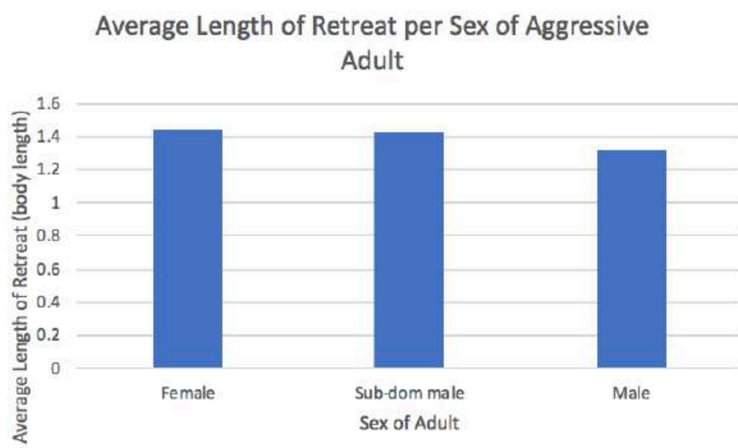

Figure 8. Retreat length by sex of aggressive adult. (df = 2, p = 0.979)

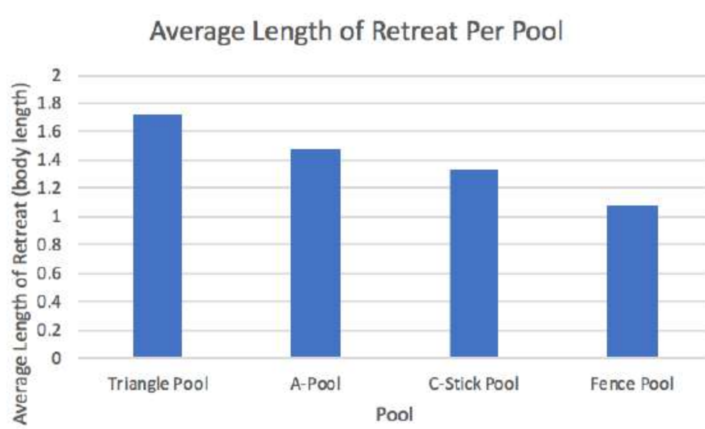

Figure 9. Retreat length by pool. (df = 3, p = 0.718)

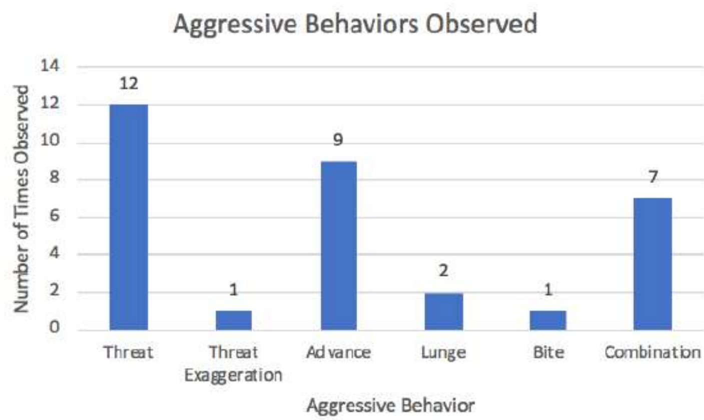

Figure 10. Number of observations per category of aggressive behavior. (n = 32)

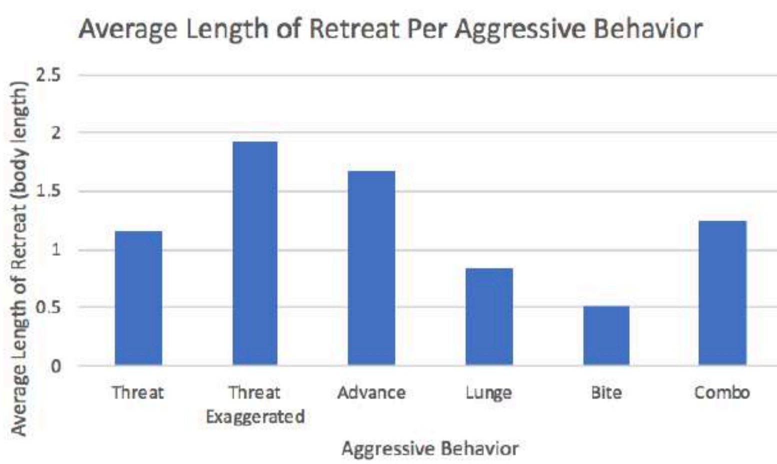

Figure 11. Average length of retreat per category of behavior. (df = 5, p = 0.68)

Discussion

The quantitative results from these data support the notion that, in pre-earthquake conditions, New Zealand fur seal pups primarily (90.6%) respond to aggressive behavior by conspecific adults by retreating (Figure 6), with an average retreat length of 1.42 body lengths. Neither the pup length, sex of aggressive adult, size of tidal pool, or category of behavior impacted the length of retreat. However, it is necessary to note that the adult sex ratio was largely biased in favor of females (27 females: 5 males), which was expected due to the area and point in the breeding season at which the study took place. Also, several categories of behavior (i.e. threat exaggeration, lunge, and bite) were only observed on 1 or 2 occasions (Figure 10), and more data points are necessary to reliably determine if type of aggressive behavior significantly affects pups' retreat length.

The qualitative results from these data support that the post-earthquake play spaces included in analysis do allow for the same average distance of retreat observed by pups in the pre-earthquake tidal pools. However, one of these pools was considerably larger than previously, and the other was closer to the open ocean (Figure 3), either of which could potentially impact pups' learning to swim. Additionally, both post-earthquake pools were surrounded by jagged rocks (Figure 3), as compared to the rounded rocks enclosing the pre-earthquake play spaces (Figure 2), which could present difficulty in terms of mobility and fleeing from aggressive adults. Given the small amount of footage and the large distance between the camera and the pups, very little post-earthquake behavior in general was able to be analyzed, and no aggressive interactions were observed, presenting great opportunity for further research.

In this way, the present study can serve as a set of methods and pre-earthquake behavioral data to suggest future work. Firstly, it could be beneficial to use Google Earth footage to quantify the number and size of tidal pools at both Ohau Point and Kean Point pre- and post-earthquake, as this study primarily compares pre-earthquake Ohau Point to post-earthquake Kean Point. Based on the current analyses, it would be useful to gather a larger amount of footage (15 hours or more) in the new play spaces from a closer distance to observe antagonistic interactions and pups' responses. In this way, one could assess whether the larger pool, jagged rocks, and proximity to open ocean affect pups' usage of the pools or ability to respond to aggression within them. The additional post-earthquake footage would ideally be collected in January, to keep the point in the breeding season consistent. However, it could also be valuable to obtain supplementary pre- and post-earthquake footage at different points of the year to account for likely changes in adult behavior throughout the breeding process. While the present data offer insight into New Zealand fur seal pups' responses to aggression by adult conspecifics, expansion of the research could aid in more fully understanding the impacts of earthquake-driven spatial displacement.

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