SHORT COMMUNICATIONS
КРАТКИЕ СООБЩЕНИЯ

ODOBENUS ROSMARUS DIVERGENS (ODOBENIDAE) GROUPS IN THE WATERS ADJACENT TO COASTAL HAULOUTS (CHUKCHI PENINSULA, RUSSIA)

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The distance between individuals is one of the key characteristics of the spatial structure of a group. Here, we investigated inter-individual distances in *Odobenus rosmarus divergens* (hereinafter – walrus) aggregations in waters adjacent to four coastal haulouts in the Chukchi Sea, Russia. The analysis of aerial images showed that the majority of the individuals in water were in tight groups (binomial $z > 11.37$, $p < 0.001$), in which the distances between walruses were significantly shorter than those outside such groups (LMM coefficient ± SE: 0.14 ± 0.03; $p < 0.001$). The number of individuals within the groups did not influence the inter-individual distances (LMM coefficient ± SE: 0.05 ± 0.05; $p = 0.376$) and the density of them was similar across haulouts studied (omnibus $\chi2(3) = 7.78$, $p = 0.051$). The water areas adjacent to haulouts may provide optimal conditions for social interactions of walruses and potentially play an important role in their social life. The investigation of walrus aggregations in water may become increasingly important in the context of the reducing Arctic ice cover.

Key words: aggregation, Chukchi Sea, inter-individual distance, Pacific walrus, pinnipeds, social behaviour

Introduction

The spatial proximity between individuals of the same species depends on a variety of factors, such as the risk of predation, the spatial distribution of resources, intraspecific relationships, and the type of animal activity (Muroyama, 2017). External threats, such as predators, contribute to the mutual attraction of individuals, as this reduces individual risks (Hamilton, 1971). At the same time, a high density of individuals increases competition for food and other resources, so their scarcity leads to an increase in the distance between individuals (Janson & Goldsmith, 1995). The balance of these effects, depending on the set of external conditions (e.g. predator pressure and the availability of resources), determines the spatial structure of the groups; one of their key parameters is the distance between individuals (Mogilner et al., 2003).

Odobenus rosmarus Linnaeus, 1758 (hereafter – walrus) tends to maintain a close proximity between individuals regardless of the group size (Krushinskaya & Lisitsyna, 1983), aiming to maintain constant visual and tactile contact with conspecifics (Miller & Kochnev, 2021). Walruses are probably the most social pinnipeds (Pinnipedia), as they form large aggregations and are gregarious throughout the year, both when in water and on land, regardless of the activity type (Fay, 1982; Miller & Kochnev, 2021). Walruses aggregate on sea ice and come ashore at hauling-out sites, both on islands and on mainland capes (Fay, 1982). On land, walruses form aggregations that reach hundreds of thousands of individuals (Chakilev & Kochnev, 2014). The composition and number of haulouts change constantly, with some animals coming ashore and others leaving to sea. Some individuals can stay near the haulout for a long time, leaving it for feeding and coming back, while others only stop for a short rest and move to other areas (Jay et al., 2002; Kochnev et al., 2008). As a result, a large number of walruses are constantly in the water area close to the hauling-out sites. The average number of walruses in water near the coastal haulouts of the Chukchi Peninsula can range from 9% to 13% of the total number of walruses hauling out (Kryukova, 2012). The probability of a walrus being in water and not hauling out increases with wind speed, decreases with air temperature, and is related to a diurnal cycle, the reasons for which are not fully understood. However, energy conservation has been proposed to play a major role (Jay et al., 2017).

Walruses display various behavioural types in the waters adjacent to haulouts, namely resting, grooming, playing, as well as suckling in case of young animals (Kryukova, 2016). During resting in the water, individuals of various sexes and age form groups, in which they maintain close physical contact with each other. It is assumed that this helps walruses not to lose contact with each other and better stabilise their location during strong waves (Kryukova, 2016). The need for thigmotactic thermoregulation (due to the warmth of neighbours' bodies) may also play an important role in cold waters (Miller & Kochnev, 2021). In general, little is known about the social behaviour of walruses in the waters near haulouts in addition to certain aspects of mother-infant interactions (Miller & Boness, 1983; Giljov et al., 2018; Kryukova, 2018).

Compared to tightly packed haulouts, in water, walruses can much more freely control the distance to conspecifics. Therefore, aggregations in the water near haulouts provide a unique opportunity to investigate walrus group behaviour. The aim of this study was to study the spatial relationships between individuals in water near coastal haulouts in *Odobenus rosmarus divergens*. In particular, we investigated the cohesion of individuals by comparing inter-individual distances in groups and outside them.

Material and Methods

For the analysis of the spatial relationships between individuals in the water aggregations, we used drone photo-images taken during walrus population counts in the coastal haulout areas of the Chukchi Peninsula (Altukhov et al., 2020; Kozlov et al., 2020; Pereverzev et al., 2020). The age-sex structure of walrus aggregations at these haulouts is mixed and includes males and females of various ages, females with a dependent calf and juveniles. Aerial photography at the haulouts and adjacent waters was carried out using a small DJI Phantom or Phantom 4 Pro (Da-Jiang Innovations Science and Technology Co., China) unmanned aerial vehicle at an altitude of about 60 m a.s.l., depending on the weather conditions. During the trial flights at these operating altitudes, the animals showed no visible signs of disturbance.

We used the footage obtained during one flight per haulout on four study sites (see Fig. 1). Photographs from Kolyuchin Island (part of the Beringia National Park, Russia) and natural monuments of regional level «Vankarem Cape» and «Kozhevnikov Cape» (Kozhevnikov Cliffs of the Schmidt Cape) were made in September 2017. Images from a proposed natural monument of regional level «Serdtse–Kamen Cape» were obtained in September – October 2019. From the footage, we analysed orthomosaics compiled with AgiSoft Metashape (Agisoft LLC, Russia) or individual frames (in the case of non-overlapping images) of water areas adjacent to haulouts.

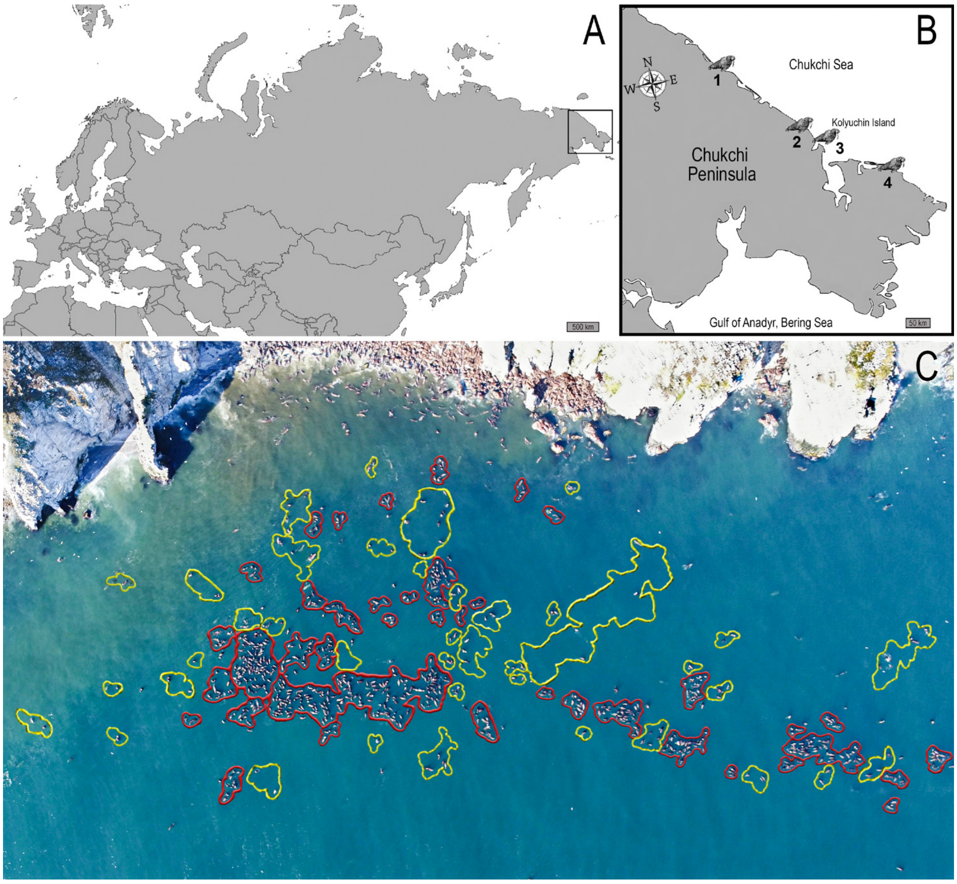

Fig. 1. Study area location at the Chukchi Peninsula, Russia. Designations: A – general view; B – map of the Chukchi Peninsula with four studied haulout sites indicated, namely Kozhevnikov Cape (1), Vankarem Cape (2), Kolyuchin Island (3), Serdtse-Kamen Cape (4); C – aggregation of *Odobenus rosmarus* individuals in waters near the haulout at Kolyuchin Island with group (red line) and non-group (yellow line) areas outlined along the boundary.

The images were analysed using photogrammetric methods in the ImageJ program (National Institutes of Health, USA). Each image was scaled according to the longitudinal length of an adult walrus on each photo, which was fully visible on the surface and stretched out. Given the average length of a walrus (Kastelein, 2009), this roughly corresponds to 2.7–3.2 m.

The inter-individual distances were investigated in groups (Fig. 2) and outside them. A group was defined as an aggregation of three or more walruses, where each individual had two or more neighbours at a distance of one length from the adult walrus body. Pairs of animals, which are usually a female and its dependent calf (Kryukova, 2018), were excluded because they represent long-term social units rather than short-term aggregations of individuals studied in the present study. On each image, all the groups are outlined (red line in Fig. 1C). The total number of individuals in the groups was scored.

The distances between each walrus and all other individuals in the group were measured. The distance between the centres of the walrus backs was considered the inter-individual distance. An additional simple script specially written for the automatic measurement of the distances between individuals was used (see Fig S1). The subsample of three groups per study site was analysed both by the program and by the human rater. The measurements were further compared with the Mann-Whitney test and Spearman rank correlation. High program-rater reliability was revealed ($p < 0.001$) with both approaches.

To investigate the inter-individual distances between walruses in water outside the groups, on each image, the outlined group contours were transferred to the parts of the water area on the image where the groups were absent (yellow line in Fig. 1C), and the distances were measured within these contours («non-groups»). Thus, inter-individual distances for walruses in groups and outside groups were measured within equal water areas.

In the analysis, each outlined group (or «non-group») was a sampling unit, for which we computed a median value of inter-individual distances by pooling the data from all individuals. This approach was successfully applied previously in a study on group cohesion in *Dama dama* Linnaeus, 1758 (Focardi & Pecchioli, 2005). We performed a mixed linear model (LMM) that generalises an ANOVA with the use of random-effects parameters, which may impact the variability of the data (Table S1). To model the data, the median distances were used as a variable, group/non-group was used as a factor, the haulout site as a cluster variable, the number of individuals and the area occupied by the group/non-group as covariates. The areas occupied by the groups/non-groups were measured in «square walrus lengths» with the ROI (regions of interest) tool in ImageJ (National Institutes of Health, USA). Log transformation of the data was applied for normalisation of the residuals.

Fig. 2. A typical group of the *Odobenus rosmarus* individuals in water off Kolyuchin Island haulout (Chukchi Sea, Russia).

The density of walruses in water was estimated using the index, calculated as the area occupied by the group divided by the number of animals in the group. The same index was calculated for the «non-groups» (Table S2, Table S3). The areas occupied by the groups and their corresponding «non-groups» were equal (Fig 1C), and the index scores represented the density of individuals within the groups and outside them. For these data, we used a binomial logistic regression with aggregation type (group/non-group) as a variable. The walrus/area index was used as a covariate and the study site (haulout area) was used as a factor. Data processing and statistical analysis were performed in Jamovi v. 2.3 software (Jamovi project, 2022).

Ethical statement

All applicable international, national, and institutional guidelines for the care and use of animals were followed. All procedures performed in the study were in accordance with the ethical standards of the Saint Petersburg State University ethical committee (Permit №131-03-3).

Results

The analysis of aerial photographs revealed that on all four study sites, the majority of individuals (n = 2755) in the waters adjacent to the haulouts were aggregated in groups (77–85% per haulout site; binomial $z > 11.37$, $p < 0.001$). In total, inter-individual distances were obtained for 115 groups and corresponding 115 «non-groups». The largest group scored consisted of 418 animals. The LMM was used to test the effects of the median inter-individual distance on the aggregation metrics (group/non-group, area occupied by it, number of associates) and accounted for the haulout variation (Table S1, Table S2, Table S3). The model explained 65% of the variance in the data (R-squared = 0.65). On all the haulout sites, the inter-individual distances were related to whether the animals were in groups or outside them, with significantly shorter distances in groups (groups: median = 1.63, IQR = 1.10; non-groups: median = 2.44, IQR = 2.15; LMM coefficient ± SE: 0.14 ± 0.03; $p < 0.001$).

Larger inter-individual distances were associated with larger areas occupied by the group/non-group (LMM coefficient ± SE: 0.47 ± 0.04; $p < 0.001$), whereas there was no effect of the number of individuals in the group/non-group on the median inter-individual distance (LMM coefficient ± SE: 0.05 ± 0.05; $p = 0.376$). There was no relationship between the median inter-individual distance and the haulout site ($p > 0.05$).

The density of walruses in water was examined with binomial logistic regression. The overall model was significant ($\chi 2(4) = 79.3$, $p < 0.001$; Table S2 in Electronic Supplement 1). Unsurprisingly, the density of walruses in the groups was greater than that in the non-groups (groups: median = 0.82, IQR = 0.43; non-groups: median = 1.59, IQR = 1.92; omnibus $\chi 2(1) = 79.34$ $p < 0.001$). The walrus density did not differ significantly between the haulout sites (omnibus $\chi 2(3) = 7.78$ $p = 0.051$).

Discussion

The analysis of the spatial relationships between walruses in the waters adjacent to coastal haulouts showed that the majority of individuals (up to 85%) were aggregated in groups. The distance between individuals was significantly shorter and their density in the groups was greater than within the water areas of the same size outside such groups. Our results are in line with the previous knowledge about strong tendency for social aggregation in walruses (Fay, 1982; Miller & Kochnev, 2021). However, it should be noted that we studied a specific state of walruses aggregating near the coast, while aggregations on ice, which are more typical for these mammals, play a more important role in their social behaviour (Miller & Kochnev, 2021).

The distance between individuals is one of the key characteristics of the group spatial structure (Mogilner et al., 2003). A certain distance between animals in a group can be species-specific, but only under stable conditions. In the natural environment, typical inter-individual distance can be influenced by a set of intrinsic and external factors (Muroyama, 2017). For instance, walruses attacked by *Orcinus orca* Linnaeus, 1758 are united in more dense groups (Kryukova et al., 2012). Therefore, it can be assumed that the distance between individuals in walrus groups in water can vary under various conditions. However, our results did not show any significant difference among the four studied haulout sites. It is important to note though that the weather conditions on all study sites were similarly calm and animals were resting. A different result may be observed during walrus migration off shore, near ice haulouts, when animals are disturbed, for example by a predator, or when fast ice is present near the shore. Thus, multiple factors may influence the distance between individuals in walrus groups. Therefore, the results obtained in this study may be not applicable to different study conditions.

A study of walruses resting in water showed that the occurrence of various resting poses depended on the size of the group (Kryukova, 2016). It might be that the larger the group, the more relaxed the walruses are, and therefore the animals adopt a more comfortable horizontal posture but have less control over the environment in comparison with vertical one. The distance between individuals, as it is shown in the present study, was not affected by the group size. In line with this, it has been previously suggested that walruses form tight groups regardless of the number of individuals (Krushinskaya & Lisitsyna, 1983). This result also agrees with studies on birds (Miller & Stephen, 1966) and fish (Breder, 1951), which showed that the distance between individuals is independent of the flock size.

The formation of tight groups (Fig. 2) suggests that the aggregations of walruses in the waters near the haulouts (Kryukova, 2012) are not just the individuals approaching and leaving the haulout. Grouping may help walruses stabilise themselves in waters during strong waves (Kryukova, 2016). Moreover, within a group, particularly in its centre, animals face less risk of predation (Morrell & Romey, 2008). However, it is widely assumed that the formation of tight groups in walruses is primarily associated with social attraction (Miller & Kochnev, 2021). The maintenance of close contact with conspecifics, particularly tactile contact, known as thigmotaxis, is an inherent feature of this species. It was indicated that being in such rafting groups close to the haulout provide walruses the greatest opportunity for repeated and prolonged social interactions (Miller & Boness, 1983). We hypothesise that the water areas adjacent to haulouts may play the role of so-called «social arenas» described for other mammals (e.g. Fishlock & Lee, 2013; Giljov & Karenina, 2024), where a large number of various social interactions among walruses occur. However, to test this hypothesis it is important to study walrus behaviour near ice haulouts where these animals spend a considerable part of their life cycle.

In waters away from haulouts, the probability of meeting conspecifics of various sex and age is considerably lower. A shallow bay protected from strong waves and winds where the haulout forms, with warmer water, also facilitate more comfort behaviour, including positive social engagement. On land, walruses have limited mobility, and the variety and intensity of social contacts are limited. Thus, the water areas near haulouts provide optimal conditions for social interactions of walruses. The formation of tight groups in water suggests that water aggregations may be as important for walrus social behaviour as terrestrial haulouts. In addition, a major reduction in Arctic ice cover, along with prolonged periods of open water in the Chukchi Sea (Wang & Overland, 2015), may increase the importance of social aggregations in water for the walrus.

Conclusions

Our study has highlighted the importance of water aggregations for walruses in waters adjacent to coastal haulouts. Walruses display a strong tendency for social aggregation observed in water, with tight group formations and absence of agonistic competition for a piece of land. This may suggest that these water areas potentially serve as crucial areas for various social interactions among individuals. The stability of inter-individual distances across various group sizes and haulout sites emphasises the robustness of these aggregations in walruses. As the Arctic environment continues to change, with reduced ice cover and extended open water periods, the role of water aggregations may become even more important for the species survival and adaptation. Future research should focus on understanding the specific social dynamics within these groups, as well as the potential impacts of changing environmental conditions on walrus social behaviour and overall population health.

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Supporting Information

Additional data to the paper of Giljov et al. (2024) may be found in the **Supporting Information**.

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ГРУППЫ *ODOBENUS ROSMARUS DIVERGENS* (ODOBENIDAE) В АКВАТОРИЯХ, ПРИЛЕГАЮЩИХ К ЛЕЖБИЩАМ (ЧУКОТСКИЙ ПОЛУОСТРОВ, РОССИЯ)

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Расстояние между особями – одна из ключевых характеристик пространственной структуры группы. В данной работе описаны особенности пространственных отношений между особями в скоплениях *Odobenus rosmarus divergens* (далее – морж) в акваториях, прилегающих к четырем прибрежным лежбищам в Чукотском море (Россия). Анализ аэрофотоснимков показал, что большинство моржами в воде находилось в плотных группах (binomial $z > 11.37$, $p < 0.001$), в которых расстояния между особями были значительно меньше, чем вне таких групп (LMM coefficient ± SE: 0.14 ± 0.03; $p < 0.001$). Количество особей в группах не влияло на расстояния между ними (LMM coefficient ± SE: 0.05 ± 0.05; $p = 0.376$), и плотность групп особей была сходна на всех исследованных лежбищах (omnibus $\chi2(3) = 7.78$, $p = 0.051$). Акватории, прилегающие к лежбищам, могут обеспечивать оптимальные условия для социальных взаимодействий моржей и играть важную роль в их общественной жизни. Исследование скоплений моржей в воде приобретает все большее значение в условиях сокращения ледового покрова Арктики.

Ключевые слова: ластоногие, межиндивидуальное расстояние, скопление, социальное поведение, тихоокеанский морж, Чукотское море