

## Short Note

# The Effect of Group Composition on the Social Behaviors of Beluga Whales (*Delphinapterus leucas*) in an Artificial Environment

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Social groups are important in the lives of odontocetes, which frequently migrate together, influencing many activities, including reproduction, foraging, and defense (Connor et al., 1998). Odontocetes frequently travel in groups that consist of many conspecifics, although the composition may vary. Beluga whales (*Delphinapterus leucas*) have a northern circumpolar distribution. Like many other cetaceans, most of their aggregations migrate between summer and winter locations (Kleinenberg et al., 1969; Huntington et al., 1999). Belugas primarily follow the edge of retreating polar ice, moving north in the spring and summer and south in the fall. A study of seasonal distribution and foraging behavior of belugas in Cook Inlet, Alaska, found that the number of belugas detected and the observed level of foraging were highest in the upper inlet during the summer months, with fewer detections at these same locations in the winter (Castellote et al., 2016). For most of the year, females and calves travel in small, tight groups separate from adult males, which travel in groups numbering up to a few hundred individuals. In the spring, adult males intermix with groups of females and calves during a presumed mating period that ranges from mid-May to the end of September (Brodie, 1971; Sergeant, 1973; Glabicky et al., 2010). During mating periods, groups can range from two up to several hundred individuals (Hobbs et al., 2000).

Scientists originally considered all beluga populations to be nomadic. However, long-term studies have identified a strong resident population in the White Sea, providing an ideal setting to study the population dynamics of these animals (Andrianov et al., 2009). There are two main groups of belugas in the White Sea—one comprising sexually mature males, and the other comprising multiple, smaller families of females and their offspring. In the summer, these smaller groups of females and calves

follow a sedentary lifestyle in strictly defined habitats. Once sexually mature, males leave their families to form separate groups, migrating and mixing with female and calf groups during the reproductive season (Krasnova et al., 2014). Reported ages of sexual maturation varies by sex, ranging from 4 to 10 years for females and 8 to 15 years for males (Lomac-MacNair et al., 2016). Male and female groups come together around the second half of May to form an aggregation of approximately 100 individuals that persists until late September. Typically, this group is about half mature individuals and half juveniles. Daily dynamics of this large aggregation are influenced greatly by both time of day and tides (Krasnova et al., 2012).

Social behaviors have not been well studied in beluga whales, mainly due to difficulties with constant surveillance of target groups in the wild and the small numbers of individuals in captivity. Detailed studies on captive beluga whales are scarce, focusing mainly on physiological and biological characteristics. In an analysis of nine databases containing publications involving cetaceans, only 29% of the 1,628 articles were conducted with captive cetaceans (Hill & Lackups, 2010). However, research with captive animals and wild animals can be used to complement each other since both approaches will have their advantages in different situations. For example, a recent study on captive belugas at Marineland of Canada documented a social pattern similar to what has been observed in wild beluga whales. When mixed sexes were present, male beluga whales were found in the proximity of other adult males seven times more often than they were found in the proximity of females, who were generally found alone. These findings suggest that male belugas frequently travel with the same sex not only due to migratory tendencies but from social preferences (Hill et al., 2018).

Generally, development in beluga calves seems to be consistent with the development of other odontocetes that have been more thoroughly studied. In beluga calves born in captivity, mother–calf swims were the most common behavior of newborn calves. Contact during these close swims can regulate the calf’s swim patterns, offer proximity to milk, and provide protection from predators. As calves mature, time apart and the average distance between mothers and calves increase. When separated from their mothers, calves tend to initiate independent swims and object play with items found in the nearby environment, sometimes with other individuals. Object play emerges during the first month of life and remains constant throughout their development (Hill, 2009; Hill et al., 2017). Social interactions with other adults and calves, such as playing chase or initiating contact, increase as calves separate from their mothers more frequently (Hill, 2009). The early development of these behaviors points to the strong role played by social behaviors among odontocetes. Additional evidence is provided by the observation of female belugas performing alloparental care—that is, caring for offspring not their own. Alloparental behavior has been observed in multiple species of marine mammals, allowing greater foraging freedom for the mother while providing protection for the calves (Whitehead, 1996). Groups that display alloparental behavior achieve higher reproductive success than groups that do not (Riedman, 1982; Gero et al., 2009). Alloparental care is observed much more in captive animals—where nursing mothers and unrelated females are housed more closely together—than in wild populations (Leung et al., 2010).

While odontocetes interact using visual and tactile gestures, their acoustic signals play a major role in communication, whether in captivity or in the wild. In general, vocalizing seems to be more important in more social species or populations (Belikov & Bel’kovich, 2007). A common nickname for the beluga whale is the “Canary of the Sea” due to its high-pitched chatter, which includes sequences of whistles and squeaks used for vocalizing and echolocation. In beluga whales, calls can be divided into a variety of categories, each with a general purpose. For example, whistles with a small frequency range usually occur between individual whales and are used mainly for group coordination, whereas echolocation clicks are used strictly for navigation and prey detection (Vergara et al., 2010; Chmelnsky & Ferguson, 2012). Vocalizations can occur alone or specific sounds can be associated with some behavioral activities such as social behaviors, exploration, and swimming, with specific sounds occurring during each activity (Panova et al.,

2012). Juvenile beluga whales are generally more vocal than adults in their first few years of life when they are learning to make more complex calls (Vergara & Barrett-Lennard, 2008).

Studies in other odontocetes have found correlations among specific behaviors, with no behaviors occurring in complete isolation. In Hector’s dolphins (*Cephalorhynchus hectori*), for example, bites correlated very closely with other aggressive behaviors but not with sexual behaviors (Slooten, 1994). Behaviors may also be influenced by additional contextual cues. For instance, in a study of ten belugas of varying ages housed at SeaWorld San Antonio, solitary swimming by adult whales decreased when calves and juveniles were introduced into the group. The modified swimming behavior of the adult beluga whales in this study suggests that the change in group composition provided the content for the behavioral change (Hill et al., 2015).

Diving activities were included in this study as an activity unlikely to reflect social interactions given that diving supports feeding and predator evasion rather than contributing to group structure. In the wild, belugas have varying diving patterns depending on the vertical distribution of their prey, and this causes dive behavior to vary among regions and sometimes even between different populations in the same region (Hauser et al., 2015). Because beluga whales are fully aquatic mammals, they require stored oxygen while diving to forage. Marine mammals have a few key adaptations that allow them to stay submerged longer and dive deeper, including expanded oxygen storage capacity and modifications in metabolism and blood flow. Marine mammals typically rely on aerobic metabolism and function within their aerobic dive limit, although they can exceed this limit at the cost of significant lactate accumulation (Helbo & Fago, 2012). Blood and muscle of marine mammals have increased oxygen storage capabilities attributed to increased hemoglobin and myoglobin concentrations. This enables individuals with larger bodies to store more oxygen and dive for longer periods than smaller individuals (Kooyman & Ponganis, 1998). Although adult body size varies geographically, male beluga whales are generally larger than females, weighing up to 1,500 kg (Stewart & Stewart, 1989). In addition to body size and sex, respiration rates vary based on season, increasing from fall to winter due to the higher metabolic demands of maintaining body temperature in colder temperatures. Maturity is another variable impacting respiration rates as calves demonstrate an initial elevated respiration rate that declines over the following 3 years, finally reaching the respiration rate of adults (George & Noonan, 2014).

This study encompassed the observation of social behaviors and diving activities of beluga whales at Mystic Aquarium over a 4-year period, during which time the number of whales varied between three and four individuals. Within this context, the effects of changing group composition on the frequency of vocalization and social behaviors, including biting, touching, chasing, and jaw popping, along with the submersion duration of captive beluga whales were examined. Given the commonplace social structure and tendency to travel in groups seen frequently in wild beluga whales, the hypothesis was that there would be greater frequency of social behaviors with more individuals present. It was also expected that vocalizations would be similarly affected by group size since they are frequently paired with specific social behaviors and also represent an important component of intraspecific communication. In contrast, the duration of submersion was treated as a largely physiological characteristic that was not expected to be influenced by group composition. It was consequently used as a reference point in this study, with the expectation that it would not vary with group configuration. The data generated from observing the response of these animals to changes in their social group was expected to provide insights about belugas in general, and more specifically how changes in group configuration may or may not affect their social behaviors and diving activities, thus filling gaps in our knowledge from the limited data collected from studies of wild beluga whales.

Beluga whales were observed at Mystic Aquarium in Mystic, Connecticut (USA), from March 2011 through December 2014. The whales reside in the outdoor Arctic exhibit, with water temperature maintained at approximately 10°C throughout the year. Observers tallied certain behavioral data on a paper ethogram over the course of a day during the aquarium's public hours on a schedule of approximately once every 4 to 6 weeks. Observers were visible to the beluga whales frequently throughout the study as were members of the public visiting the aquarium. Observers recorded the number of behaviors performed by each whale during 5-min focal intervals, rotating from one individual to another throughout the day, resulting in each whale being observed two to four times each hour. Over the 4 years of the study, many different observers contributed to this project. Observers were oriented to the behavior and use of the ethogram, and then they were trained on-site to recognize individual animals and specific behaviors prior to collecting data. In addition, observers worked in pairs to improve the accuracy and consistency of data recorded throughout the study. All behaviors,

including vocalizations, were recorded without instrumentation, such as a hydrophone, which would have been potentially distracting (for the whales). The animal that emitted a vocalization was determined by the direction from which the sound originated. The data analyzed for this study excluded data collected with a trainer present to evaluate only behaviors initiated by the whales and not those executed at the request of a staff person.

Observers also collected submersion data during three time intervals per day for each whale: first when the aquarium opened at 0900 h, then around 1200 h, and shortly before the aquarium closed at 1700 h. A submersion event began when an animal's blowhole went below the surface of the water and ended when the blowhole broke the surface again. When possible, observers recorded three to five submersion events of at least 5 s duration for each animal during each time interval. These data were then used to determine the maximum submersion times for each individual whale, for each time of day, and for each time frame, which were then analyzed (Table 1).

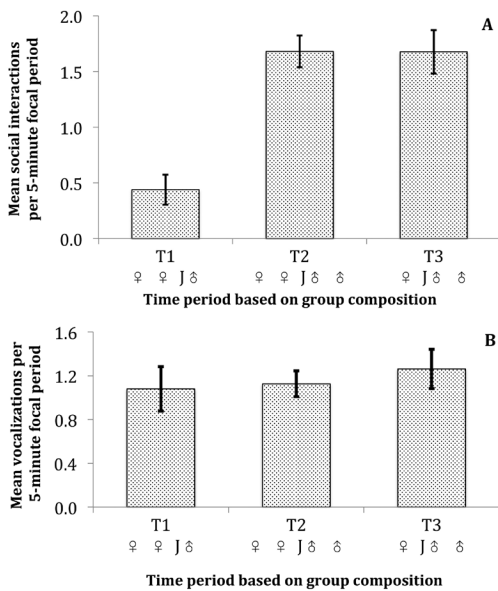
Over the 4-year course of this project, the number of beluga whales present in the Arctic exhibit changed, so the data were subdivided into three time frames for analysis to reflect these differences in group composition. Time 1 (T1) includes data gathered from March to September 2011 when the group included three animals: Adult Females 1 and 2 and the Juvenile Male. Time 2 (T2) is the longest time frame, from November 2011 to January 2014, and includes four individuals: Adult Females 1 and 2, the Juvenile Male, and the newly added Adult Male. The final time period (T3) includes the data collected from March until December 2014, with three individuals present: Adult Female 1, the Juvenile Male, and the Adult Male.

Separate one-way ANOVA analyses were run on data pooled by time frame, individual, and sex. Follow-up two-sample *t* tests assuming unequal variances were used to determine the source of differences when they were indicated. This allowed the significance of group composition on social behaviors and diving activity to be evaluated.

The variation in the average frequency of social behaviors among the whales increased between T1 and T2 and then remained fairly constant into T3, even after the group size returned to three individuals at the start of T3 (Figure 1A). Although visually there seemed to be little change, the differences in average social behaviors were statistically significant between T1 and T2 and T1 and T3, among individuals, and between male and female individuals (Table 1). While the number of average vocalizations per 5-min focal period followed a somewhat similar trend among the

**Table 1.** Single factor ANOVAs evaluating social interactions, vocalizations, and maximum submersion times between time intervals, individual whales, and males vs females. Data for each comparison were pooled within time intervals, individuals, or sex of the animals as appropriate for the specific analysis. A noteworthy difference occurs in the vocalizations, for which a significant difference occurs at all levels except between the time frames.

Comparison	Social interactions	Significant?	Vocalizations	Significant?	Submersion times	Significant?
T1-T3	$F_{(2, 1108)} = 10.604$ $p < 0.001$	Yes	$F_{(2, 1108)} = 0.219$ $p = 0.803$	No	$F_{(2, 324)} = 4.582$ $p = 0.011$	Yes
Individuals	$F_{(3, 1107)} = 66.029$ $p < 0.001$	Yes	$F_{(3, 1107)} = 48.929$ $p < 0.001$	Yes	$F_{(2, 321)} = 12.348$ $p < 0.001$	Yes
Male/female	$F_{(1, 1109)} = 132.858$ $p < 0.001$	Yes	$F_{(1, 1109)} = 39.339$ $p < 0.001$	Yes	$F_{(3, 323)} = 24.277$ $p < 0.001$	Yes



**Figure 1.** Average social behaviors (A) or vocalizations (B) for all individual whales per 5-min focal period during T1 through T3. Error bars represent  $\pm 1$  SE. Using a single factor ANOVA, there was a significant difference in the average frequency of social interactions throughout this study (A:  $F_{(2, 1108)} = 10.61$ ,  $p \leq 0.001$ ), while there was no significant difference in the average frequency of vocalizations (B:  $F_{(2, 1108)} = 0.219$ ,  $p = 0.80$ ). Symbols indicate group composition: ♀ = mature female, J♂ = juvenile male, and ♂ = mature male.

time periods, the differences were not statistically significant (Figure 1B). However, further analysis showed that the average number of vocalizations did vary significantly among individuals and between males and females (Table 1).

The average maximum submersion time increased between T1 and T2, and then remained fairly constant into T3, in a pattern similar to that

of the social behaviors (Figures 1A & 2). And as with the social behaviors, the differences in maximum submersion times were significant between T1 and T2 and T2 and T3, as well as between individuals and males vs females (Table 1).

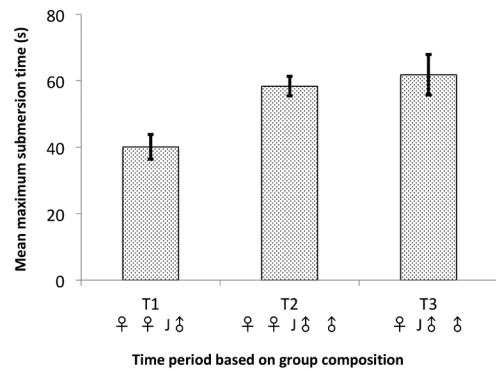
While the use of vocal, visual, and physical signals are important for communication among these whales, the latter two can be used as alternatives to acoustic communication, which is particularly beneficial under conditions wherein vocalizations may inadvertently alert predators or prey to their location (Myrberg, 1981; Würsig et al., 1990). Sensory systems serve cetaceans both in their physical world as well as in their social world, with social behavior constituting a great deal of communication (Pryor, 1990). As hypothesized, the social behaviors among the whales varied based on group composition. Specifically, the average frequency of social behaviors among the whales increased significantly following the introduction of the mature male beluga from T1 to T2. Adding a mature male to a group previously composed of a juvenile and females, as occurred during T2, might mimic the seasonal blending of mixed female and juvenile with mature male groups and stimulate more behaviors among the whales, potentially linked to attempts at mating (Glabicky et al., 2010). However, proximity alone might explain the increased social behaviors as there were more whales in the same amount of space during T2 than there were during the other time periods. So, while differences in social behaviors as group composition changed were documented, the explanation for why these differences occurred remains unclear.

The hypothesis that the frequency of vocalizations would change with changes in group composition was not supported. Changes in group composition are a type of stressor, and a previous study showed that both transporting whales and introducing harbor seals into their habitat, also stressors, caused vocalizations of the captive

beluga whales to decrease or even stop (Castellote & Fossa, 2006). It is difficult to determine whether or how much stress influenced the frequencies of vocalization during the three time frames in this study.

Despite not varying with group composition and time, the average number of vocalizations were different in other comparisons—that is, between individuals and sexes (Table 1). However, the significant differences in the number of vocalizations between males and females may be skewed by the much higher number of vocalizations by the single juvenile male as compared to the adult whales. During a 5-min focal interval, adults vocalized an average of 0.5 times with a standard deviation (SD) of 2.7, while the juvenile vocalized 2.8 times with an SD of 22.1. The need for juveniles to “learn” how to vocalize was documented in a study at the Vancouver Aquarium, where the acquisition and increasing complexity of calls were documented for one male beluga throughout his first years (Vergara & Barrett-Lennard, 2008). While the juvenile whale in the present study was older than that individual, he may still have been developing as suggested by the high frequency and large variation in his vocalization data. Another explanation for the increased number of vocalizations from the juvenile whale may have been that he was much more responsive to the environment, including guests and observers who were visible throughout this study.

Surprisingly, maximum submersion times varied significantly with changing group composition (Figure 2), with the difference being significant except between T2 and T3 (Table 1). However, in contrast to the results for social behaviors and vocalizations, maturity of the whales may have been less of a factor in this case than the sex of the whales (Table 1) as the mean submersion time was smaller when the sex ratio favored females—that is, during T1 (Figure 2). Male beluga whales dive for longer periods than females (Helbo & Fago, 2012), in part because males are generally heavier, weighing around 1,500 kg, while females weigh a maximum of 1,360 kg (Stewart & Stewart, 1989), and larger individuals have greater oxygen storage capacities. Females are also used to swimming with calves, which have an even lower oxygen storage capacity due to their much smaller size, so that even in the absence of calves, they may demonstrate shorter dive durations. In addition, males generally dive at the same rate throughout the day, while females dive more often between 2300 and 0500 h (Martin & Smith, 1999)—times not observed during this study—making it possible that the shorter submersion times recorded for the female whales reflected the time of day that data were collected as well as body size effects.



**Figure 2.** The mean maximum submersion time for each time interval T1 through T3, showing a noticeable increase in duration from T1 to T2. Error bars represent  $\pm 1$  SE. The results of a single factor ANOVA indicate a significant difference in the average maximum submersion time as the group composition changed ( $F_{(2,324)} = 4.582, p = 0.011$ ). Symbols indicate group composition: ♀ = mature female, J♂ = juvenile male, and ♂ = mature male.

The juvenile male in this study may have been an outlier because of his age. When looking through the data, his contributions to both vocalization and social behavior were greater in frequency than the other three individuals and may have skewed comparisons between the sexes. For instance, during the 5-min focal interval, adults exhibited an average of 0.7 social behaviors with an SD of 4.7, while the juvenile exhibited an average of 3.5 social behaviors with an SD of 24.6. As a consequence, the statistically greater number of both social interactions and vocalizations of the male whales in this study compared to the females may be distorted by the much higher frequencies exhibited by the juvenile male. In fact, the contributions of the juvenile to the dataset were higher than the other whales almost all of the time. Since juveniles are usually more vocal (Vergara & Barrett-Lennard, 2008) and socially interactive (Hill, 2009) than mature individuals, this is perhaps not surprising. The submersion data acted as a reference parameter for this project (i.e., it is a non-social behavior that depends strictly on physiological constraints and not social parameters), and the maximum submersion times did not differ substantially between the juvenile and the adults. This further supports the inference that the contributions of the juvenile male skewed the number of vocalizations and behaviors; however, a larger sample of juvenile whales would be needed to confirm this.

Some of the observers in this study participated on only two collection dates, while others participated for more than a year. Kavanagh et al.

(2016) examined the reliability and validity of field-collected behavioral data using observers with varying degrees of experience. They found no difference in the data collected by experienced vs inexperienced observers, although their study standardized training and time on project, which was not the case for this study. They also found that misclassifications of behaviors did occur due to unclear definitions of behaviors, and this was probably a factor in the current study as well. However, the large sample size of observations in this study should help mitigate the impact of such mistakes, leaving the general trends and conclusions represented herein intact. The number of focal periods sampled ranged from 189 to 153 among the three time frames, respectively, with T2 representing the high end of the range for these counts since it represented more than 50% of our collection timespan. Overall, submersion data had a smaller sample size due to the fact that these data were only collected during discrete time periods each day, with 54, 222, and 51 data points recorded for each of the three time frames, respectively.

In summary, the results of this study supported the hypothesis that group composition influences social behaviors among beluga whales, even within the constraints of a structured habitat. The data also suggest that the age and sex of individuals in a group may play a role in their social behaviors given the similarity in frequencies between T2 and T3 (Figure 1); however, the introduction of a new whale may be seen as a novelty by the resident belugas, which may elicit a greater response than the removal of an individual from the group. As a result, the manner in which group composition changed, addition vs removal, may in and of itself have influenced the activities of the whales. And while the submersion activity did not reflect changes in group size as expected, it did vary with group composition, most likely due to the changing sex ratio of the animals present. Although the focus of this study was on captive beluga whales, the findings support previously documented trends in group behaviors for these animals. These results may also provide useful insights for the husbandry and care of these whales with respect to the potential behavioral impact of changes in group membership on the established residents.

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