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Beluga (*Delphinapterus leucas*) Bubble Bursts: Surprise, Protection, or Play?

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Cetaceans produce a variety of bubble displays, ranging from bubble streams to very large bursts of air. Previous research has indicated that different types of bubbles serve different functions. Using archival video data, we investigated the frequency and function of bubble behavior for four beluga mother-calf pairs housed at Sea World San Antonio (SWSA, 2007-2010). Bubble bursts, large, forceful bursts of air released underwater, were the most frequent form of bubbles produced. The mothers primarily produced bubble bursts while swimming with their calves whereas the calves produced the majority of their bubble bursts during solitary activities. These results suggest that mothers may use their bubble bursts as a protective behavior or warning to threatening stimuli (e.g., other belugas) whereas when threatening stimuli are not present calves may produce bubble bursts as a form of play. Additional research is necessary to better understand if these bubble displays are under the intentional control of the animals producing them.

Cetaceans often release air underwater as they move about and interact with their environments. Multiple researchers have speculated and investigated the meaning behind various bubble types (Delfour & Aulagnier, 1997; Dudzinski, 1998; Kaufman & Forestell, 1986; Marten, Shariff, Psarakos, & White, 1996; McCowan, Marino, Vance, Walke, & Reiss, 2000; Reidenberg & Laitman, 2007). One form of bubble produced during surprising or threatening situations are large forceful bursts of air released while underwater (Delfour & Marten, 2001; Marten & Psarakos, 1995; Sarko, Marino, & Reiss, 2002). The speed and stereotyped nature of these bubble bursts imply a reflexive-like response. Interestingly, bubble burst displays do not occur with every surprising or threatening stimulus, suggesting that they may be under intentional control.

One study conducted with five juvenile and adult belugas investigated the context in which bubble bursts (i.e., bubble blows) occurred (Delfour & Aulagnier, 1997). The authors found that bubble bursts were produced primarily during solitary play. They also found that the time of day and individual beluga influenced the frequency of bubble burst production.

In an attempt to extend the previous study regarding bubble blow behavior in belugas, we examined the production of bubbles in a sample of mother-calf beluga pairs in the care of humans. This sample of mother-calf pairs provided an

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opportunity to observe bubble bursts within a unique social dynamic. Personal observation had suggested that the bubble burst behavior did not always occur during play activities but rather during interactions in which both the mothers and calves were present. We expected that belugas would produce a variety of bubbles, including bubble bursts. Given the presence of the calf, we did not expect the mother to produce bubble bursts as frequently during solitary swims as seen during the previous study (Delfour & Aulagnier, 1997). Finally, the role of calf age and environmental complexity in maternal bubble burst production was also examined. We did not develop hypotheses for these factors as they have not been examined within the bubble burst context previously.

Method

Subjects and Housing

Eight belugas, four mother-calf pairs, comprised the sample for the current study. Two male calves, OLI and GRA, were born in June 2007 at Sea World San Antonio (SWSA). We examined data collected between 2 months and 18 months of age. Their mothers, TIN and MAR, were approximately 25 years at the time of their births. Two female calves, QIN and BEL, were born a year apart in July 2008 and June 2009, respectively. Their mothers, SIK and CRI, were approximately 23 and 25 at the time of their births, respectively. We examined video data collected between the females' births and 18 months.

The two male calves were housed in two separate locations during the course of the study. The first four months of the study included observations made at their housing facility in the zoological area, consisting of one pool, 17.1 m x 10.7 m x 6.1 m (56 ft x 35 ft x 20 ft). The remaining months of the study included observations conducted at their birthing facility and SWSA's main beluga facility, which was composed of five large interconnected pools. The two female calves were housed solely at SWSA's main beluga facility.

Procedure

Archived video data were coded by five research assistants for the current study. The data collected were part of a longitudinal study documenting the development of beluga calves and their relationships with their mothers located at SWSA. A Sony Handycam Hybrid hard disk recorder was used to record two sessions for each mother-calf pair per week. Sessions ranged between 5 and 15 minutes in length. We used videos recorded between January 2008 and July 2010 for a total of 32.81 hours of behavior.

All video sessions were coded for bubble behavior and the context in which the behavior occurred. Operational definitions are provided in Table 1. Examples of bubble bursts are provided in Figures 1 and 2. Information coded included date, time, subject (beluga), and context of each bubble. All analyses used context categories that were mutually exclusive and followed a hierarchical arrangement. Bubble bursts that occurred in a clear reactive context were considered reactive even if they occurred while the mother and calf were in a pair swim or involved in an interaction or play context. For the current study, pair swims only occurred between the mother and her calf. Social interactions and play included any interaction in which one member of the mother-calf pair was engaged.

Figure 1. The beginning of a bubble burst by a mother while swimming with her calf. Picture taken by H. M. Hill.

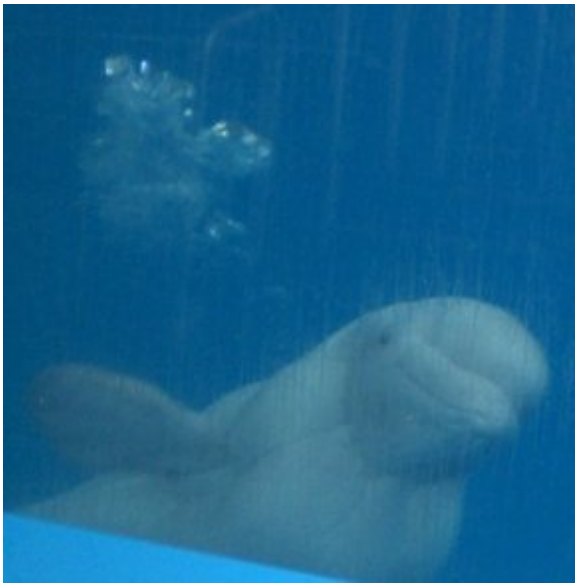

Figure 2. The visual display of a completed bubble burst by a female during a solitary activity. Picture taken by H. M. Hill.

Data Analyses

Analyses were performed with all animals. Two exclusionary criteria were used for the analyses: 1) If the context or beluga could not be determined, the bubble observation was excluded, and 2) If bubble behaviors occurred within 3 s of each other during mother–calf interactions, calf-calf interactions, adult-calf interactions, or adult-adult interactions, these bubble events were excluded as they may have been related. A series of chi square goodness of fit tests and tests of independence were conducted to examine the expected hypotheses and to explore behavioral trends.

Table 1
Operational definitions of bubble types and contexts.

Categories	*Operational Definition*
Types of Bubbles	
Bubble Bursts	Large purposeful release of air below the surface of the water that creates a visible ripple effect on the surface of the water. A release of air immediately prior to surfacing for a respiration is not included.
Other Bubbles	Bubble streams- continuous release of small bubbles, that may co-occur with sounds. Bubble rings- column of water in the shape of a donut. Small to medium bubbles-bubbles that are released and interacted with during play activity.
Contexts	
Play	The situation in which the animal is individually, or in a group, interacting with an object within the environment.
Reactive	The situation in which the belugas react with a startle or flight response (e.g., body jerks, sinking to the bottom, swim away from stimulus). This context can include, but is not limited to, situations of loud noises, separation, or novelty.
Pair Swim	The situation in which two of the belugas were within 3 m of each other and in synchrony for at least 3 s. Pair swim can include echelon and infant position.
Interaction	The situation in which an animal comes within proximity of another animal and a behavioral response occurs. Responses may be affiliative or aggressive.

Note: All bubble definitions were adapted from McCowan et al. (2000). Bubble bursts were coded for only one context. Thus, contexts are mutually exclusive.

Results

Bubble Types

In approximately 33 hours of data, we observed 814 bubble bursts and 42 other bubbles for the four mother-calf pairs. The frequencies for each type of bubble observed are displayed in Figure 3. Bubble bursts were produced at a rate of 24.81 bursts per hour. A chi square goodness-of-fit test indicated that the distribution of type of bubble varied significantly across the categories, $\chi^2(3, 856) = 2{,}246.70$, $p < 0.001$. There were more bursts than bubble streams, bubble play, and bubble rings. When the types of bubbles were examined for mothers and calves, separately, the two chi square goodness-of-fit tests suggested that mothers and calves produced more bubble bursts than expected by chance alone and fewer bubble streams than expected by chance alone, $\chi^2(1, 370) = 366.01$, $p < 0.001$ and $\chi^2(3, 486) = 1{,}154.61$, $p < 0.001$, respectively.

A chi square test-of-independence was conducted to investigate whether or not the type of bubbles produced differed by age category (i.e., mother or calf).

The results indicated that mothers produced significantly more bubble bursts than the calves as expected by chance alone (adjusted residual = 5.5), and the calves produced significantly more bubble streams than their mothers as expected by chance alone (adjusted residual = 5.1), $\chi^2(3, 856) = 30.04$, $p < 0.001$, $V = 0.187$.

When bubble bursts were examined independently of other types of bubbles, a chi square goodness-of-fit test indicated that the context in which bubble bursts occurred differed significantly from chance, $\chi^2(3, 810) = 330.28$, $p < 0.001$. Reactive contexts (4.07%, n = 33) occurred the least often followed by social interactions involving one of the mothers or calves (15.06%, n = 122). Pair swims between the mothers and their calves (42.10%, n = 342) and solitary activities (38.64%, n = 313) were the most frequently occurring events.

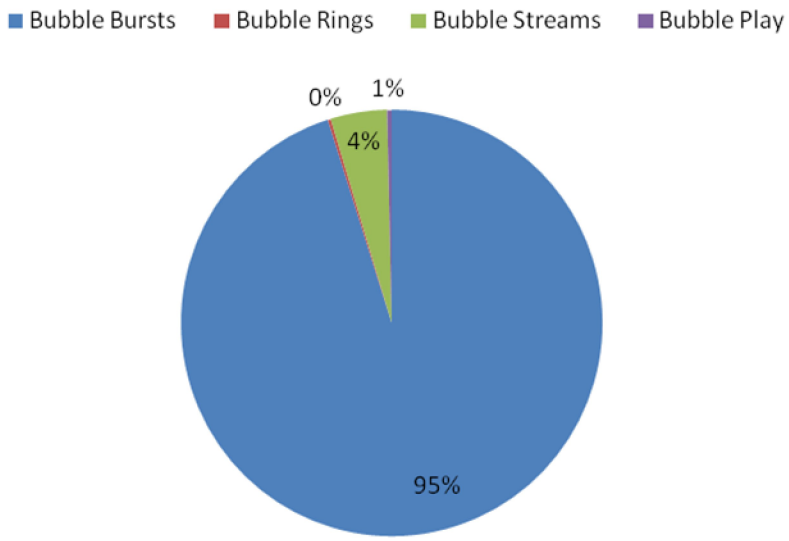

Figure 3. The frequency of bubble types observed for four beluga mother-calf pairs.

Bubble Bursts, Context, and Age Category

A chi square test-of-independence indicated a significant relationship between the animal producing the bubble burst and the context in which the bubble burst occurred, $\chi^2(3, 810) = 102.70$, $p < 0.001$, $V = 0.356$. Mothers produced significantly more bubble bursts than expected by chance during pair swims with their calves (59.7%, n = 219, adjusted residual = 9.2) and within contexts eliciting reactive responses (5.7%, n = 21, adjusted residual = 2.2) than during solitary activities (27.5%, n = 101, adjusted residual = -5.9) and social interactions (7.1%, n = 26, adjusted residual = -5.8). Calves produced significantly more bubble bursts during solitary activities (47.9%, n = 212, adjusted residual = 5.9) and social interactions (21.7%, n = 96, adjusted residual = 5.8) than pair swims (27.8%, n = 123, adjusted residual = -9.2) and reactive situations (2.7%, n = 12, adjusted residuals = -2.2). See Figure 4.

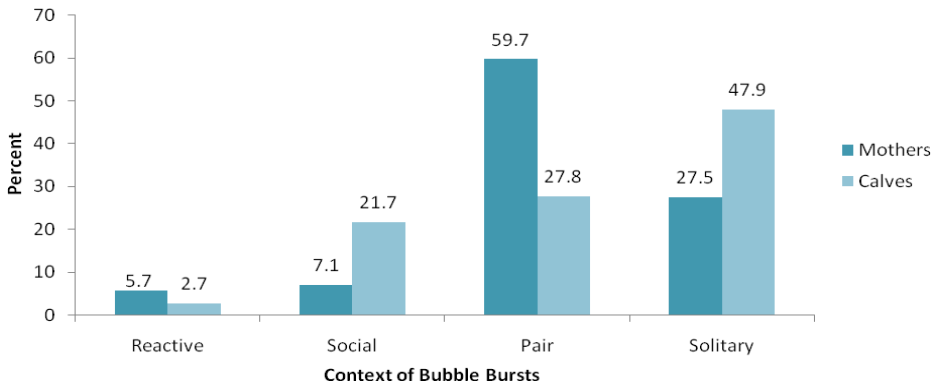

Figure 4. The frequency of bubble bursts by context and mother-calf status.

Bubble Bursts, Environmental Complexity, and Age Category

A chi square test-of-independence indicated that a significant relationship existed between the environmental complexity of the mothers and calves, as indicated by housing location, and the age category (i.e., mother or calf) for the production of bubble bursts, $\chi^2(1, 814) = 30.26$, $p < 0.001$, $V = .193$. Although, the beluga mothers produced more bubble bursts at the primary beluga facility (78.0%, $n = 288$) than at the zoological facility (22.0%, $n = 81$), they produced relatively more bubbles bursts at the zoological facility (68.6%, $n = 81$, adjusted residual = 5.5) as compared to the primary beluga facility (41.4%, $n = 288$, adjusted residual = -5.5). In contrast, the calves produced significantly more bubble bursts at the primary beluga facility (58.6%, $n = 408$, adjusted residual = 5.5) than at the zoological facility (31.4%, $n = 37$, adjusted residual = -5.5).

Discussion

The purpose of the current study was to investigate the differences in the production of bubble bursts by beluga mother-calf pairs in the care of humans. The results indicated that the composition of animals moderated the production of bubble bursts. Previous research had suggested that bubble blow production, which is synonymous with bubble bursts, occurred during solitary play (a non-interactive behavior) using a composition of adult and young adult belugas in a display exhibit (Delfour & Aulagnier, 1997). While this interpretation may be true for a composition of adult belugas, it does not seem to be valid for beluga mothers monitoring their calves.

Unlike the adults in the previous study (Delfour & Aulagnier, 1997), our adult females exhibited different behavioral trends in their bubble burst production. First, bubble bursts were exhibited significantly more often than any other bubble type observed (e.g., bubble stream, bubble play, bubble ring). In fact, bubble bursts occurred 40 times more often per hour than observed by Delfour and Aulagnier (1997). Of all the bubble types, bubble bursts are the most easily observed from the surface as compared to bubble streams, bubble rings, or other forms of bubble

play. Thus, bubbles of other types may be under-reported in comparison to bubble bursts. However, underwater footage did not produce substantively more types of bubbles than overhead footage. As seen in previous research, belugas produce these other bubble types, but perhaps not as frequently as bubble bursts (Delfour & Aulagnier, 1997). It is also possible that the current sample of belugas may not be representative in their production of underwater bubble activity. Research with additional belugas is necessary to evaluate this possibility.

As anticipated, the belugas in the current sample displayed significantly more bubble bursts while swimming with their calves as compared to any other context. The four females produced slightly more bubble bursts during their solitary activities (n = 101) as compared to the five belugas in the previous study (n = 90; Delfour & Aulagnier, 1997). Bubble bursts during solitary activities constituted approximately half the bubble bursts produced when swimming with their calves. In contrast, the calves produced twice as many bubble bursts during solitary activities as compared to their mothers, providing support for the interpretation that bubble bursts may be a form of play (Delfour & Aulagnier, 1997). The calves also exhibited significantly more bubble bursts while engaged in social interactions with others (i.e., usually another calf).

These trends suggest that bubble burst behavior may have multiple functions for belugas depending on the social context or the presence of a calf. Delfour and Aulagnier (1997) suggested that the bubble blow behavior was very rare. This conclusion seems to be valid for facilities with only adult and juvenile belugas. When the presence of calves is considered, the mothers appeared to use bubble bursts as a protective display or threat. This supposition was supported by the observations that the mothers primarily produced bubble bursts during social interactions involving their calves (e.g., another calf approached the mother-calf pair or the calf swam too far away) and not as they simply swam together.

Similar to the previous study, both calves produced more bubble bursts during solitary activities. Unlike adult belugas, the calves regularly engaged in affiliative social interactions that included bubble bursts. These data corroborate findings observed in bottlenose dolphin calves in which calves exhibited both solitary and interactive bubble play (Kuczaj, Makecha, Trone, Paulos, & Ramos, 2006). It is possible that the beluga calves may have produced bubble bursts as a form of interactive play. However, another interpretation may be that the calves produced the bubble bursts as a warning directed toward their interaction partner. Additional evaluations of calf-calf social interactions should be conducted to elucidate the function of bubble bursts in calf social interactions.

Finally, due to an unexpected housing change, we were able to evaluate the effect of environmental complexity on bubble burst production. The first two mother-calf pairs were housed in a separate pool with less environmental complexity from two weeks to ten months. The last two mother-calf pairs stayed at the birthing facility the entire length of the study. Despite the difference in time spent at the two locations by the four mother-calf pairs, the mothers produced significantly more bubble bursts at the pool with less environmental complexity than the pool with more environmental complexity. In contrast, the calves produced significantly more bubble bursts at the pool with more environmental complexity than at the pool with less complexity. These findings are most likely

due to the developmental age of the calves. When the first two mother-calf pairs were housed at this facility the calves were less than a year old. This developmental period is characterized by increases in independence but consistent reliance on mothers for protection and nutrition (Hill, 2009; Krasnova, Bel'kovich, & Chernetsky, 2006). Thus, the mothers may have been more vigilant and sensitive to changes in their environment and increased their bubble burst production as a display of protective behavior.

In summary, bubble bursts are produced by belugas in a variety of contexts, ranging from startling events to anticipated interactions. Future studies should continue to explore the function of bubble bursts within belugas at various stages of development and social contexts. The current study was unable to directly examine the level of control belugas display in their bubble bursts. Some contexts (e.g., surprising sounds or events) would appear to elicit a reflexive response, such as a startle response, whereas other contexts (e.g., play or visible approaches of other animals that could be perceived as threatening) would suggest the presence of intentional control. When we compare the current findings to the previous study (Delfour & Auglanier, 1997), the presence of calves clearly altered the display of bubble bursts. Specifically, the function of bubble burst production seems to be dependent upon the context and presence of calves. Additional studies in which the bubble burst behavior is examined for additional mother-calf pairs, other social groupings of various ages, and varied environmental situations and complexities should be conducted. These studies would offer insight into the function of bubble bursts and the degree of control belugas may have over them.

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