

VOCALIZATIONS OF A CAPTIVE JUVENILE
AND FREE-RANGING ADULT-CALF
PAIRS OF BRYDE'S WHALES,
BALAENOPTERA EDENI

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ABSTRACT

Vocalizations were recorded from a captive juvenile Bryde's whale, *Balaenoptera edeni*, that stranded off the gulf coast of Florida (Pinellas Co.) and was held at Sea World of Florida. The most common vocalization was a pulsed moan with durations of 0.5–5.1 sec and acoustic energy from 200–900 Hz. Although these sounds are unlike any reported previously from this species, there are similarities to moans recorded opportunistically during a feeding study of free-ranging *B. edeni* in the Gulf of California (GOC). The pulsed moans recorded from Bryde's whale adults in the GOC were shorter in duration (0.7–1.4 sec) than those recorded from the captive juvenile, but the frequencies were similar (165–875 Hz). In addition, a series of discrete, regularly spaced pulses (interpulse interval = 0.5–1.0 sec, 700–950 Hz) were recorded only in the presence of Bryde's whale calves in the GOC.

Pulse rates produced by the captive juvenile (20–70 pulses/sec) were intermediate between those recorded in the presence of GOC adults (60–130/sec) and calves (10–20/sec). With these limited data it is not possible to determine to what extent the intermediate qualities of the juvenile call reflect maturational differences in the sound production apparatus, a phase of learning to vocalize like an adult, or the characteristics of a context-dependent call not recorded in the GOC.

Key words: acoustic communication, baleen whales, captive behavior, Gulf of California, *Balaenoptera edeni*, Bryde's whale.

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Only one description of vocal activity from Bryde's whales, *Balaenoptera edeni*, appears in the literature (Cummings *et al.* 1986). Data from two recording sessions in the Gulf of California were reported by Cummings *et al.*: one from a pair of animals confirmed to be Bryde's whales; the second from a whale believed to be *B. edeni* based on the similarity of the sounds to those recorded in the first session.

In this paper we present descriptions of the vocalizations from a captive juvenile and from free-ranging Bryde's whales. The captive juvenile stranded off the Gulf Coast of Florida (Pinellas Co., 28°04'45"N, 82°49'33"W), was rescued on 25 November 1988, and maintained by Sea World of Florida (SWF) until her release into the Gulf of Mexico on 5 January 1989. Although it is likely that some of the animal's behavior was the product of the abnormal conditions of confinement, there were consistent vocalizations that may be part of the normal repertoire of this species.

For comparison, we have examined previously unreported recordings of sounds from adults and adult-calf pairs of Bryde's whales in the Gulf of California (GOC). These recordings were made during a study that was primarily concerned with feeding behavior (Tershy *et al.* 1990). Although the acoustical system was not calibrated and the recordings were made opportunistically, the contexts for the recordings and the identities of all marine mammals and birds were documented carefully. We include these data because the recordings contain pulsed sounds similar to those recorded from the captive animal, and unpulsed sounds similar to those previously described by Cummings *et al.* (1986). We compare the three data sets (previous recordings, the captive animal, and the free-ranging adults, adult-calf pairs) and consider potential contextual and/or age-related variations in Bryde's whale vocalizations.

MATERIALS AND METHODS

Captive juvenile—The Bryde's whale (field no. SWF-BE-8876-B) was a young female (6.9 m) approximately 1–2 yr of age, based on her size. She was kept in a pool 20 m in diameter and 4 m in depth. She was fed a fish gruel (ground bonito and a high caloric dietary supplement, see Walsh *et al.* 1991) through a feeding tube three times daily. Her abrasions were treated with antibiotics and her back was covered with zinc oxide to prevent sunburn (Fig. 1a). Coincident with weight gain and a general improvement in her condition was an increase in the occurrence of vocalizations.

The sounds from the captive Bryde's whale were recorded in three regimes. The earliest recordings were made periodically (by DKO) during handling of the captive juvenile by the SWF Animal Care staff (28 November; 14, 15 December). The second set of recordings was made every two hours, day and night, with concurrent observations (by PLE) from 21 to 24 December. Observation sessions consisted of simultaneous acoustical recordings and behavioral descriptions for 30–60 min. The duration of the observation period was dictated by the whale's activity: data were collected for a minimum of five "circuits" of the tank. A circuit was defined as a complete circling of the tank beginning at

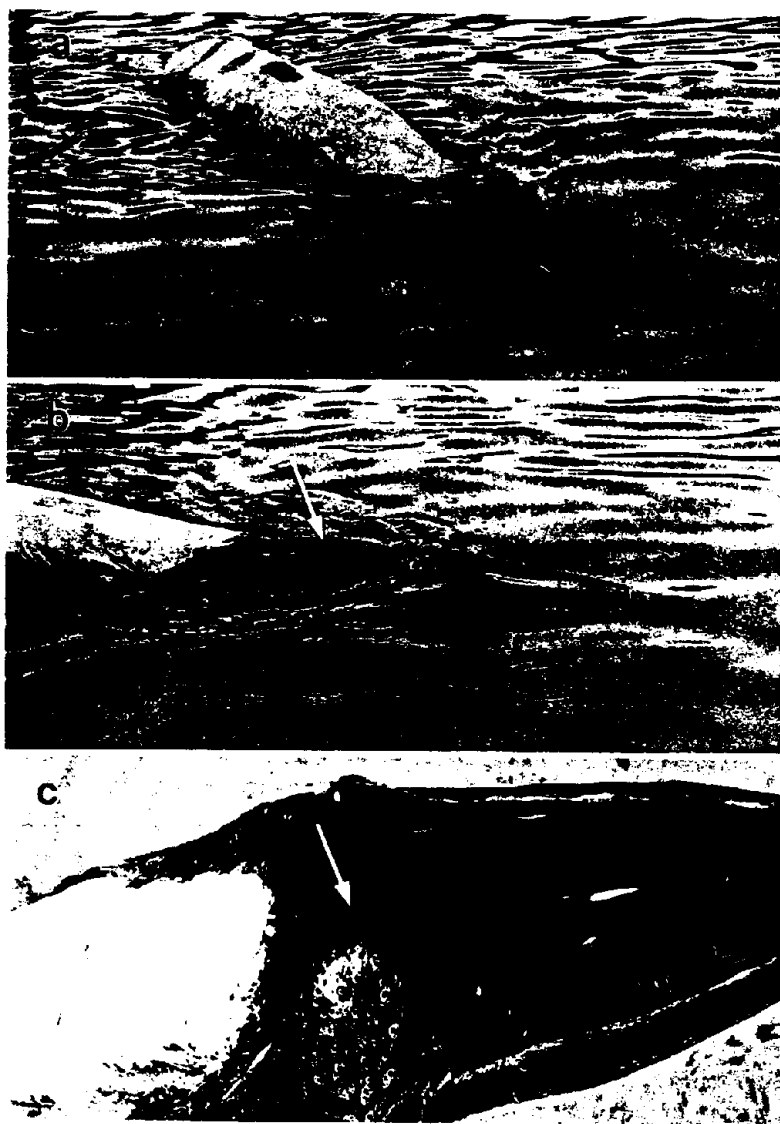


Figure 1. Captive Bryde's whale, *Balaenoptera edeni*. a. Swimming toward the hydrophone: note that she was not vocalizing and both blowholes were closed. b. Inhalation (arrow points to open left blowhole). c. Bubble production during vocalization. Bubbles were only released from the right blowhole (arrow points to closed left blowhole) (photos by PLE).

the location of the hydrophone. Any changes in the surroundings that may have affected the whale's behavior were noted, *e.g.*, increases in noise during dolphin and diver recreation in the adjacent tank or when the spotlights over her tank were turned off. The majority of the sounds analyzed (48%) are from those recordings, including two sessions prior to and following a feeding. The third

set of recordings was obtained (by DKO) from 29–31 December using a timer-activated tape recorder (every two hours) without concurrent observations.

Recordings at SWF were made using a Gould CH-17U hydrophone with 10 m of shielded cable input directly to a Uher 4400 Report IC tape recorder at tape speeds of 2.4, 4.8, or 19 cm/sec. No intensity measurements were made because roll-off levels of the system were not measured. The frequency response of the hydrophone was 100–18,000 Hz (–2 dB); the upper frequency response of the recording system was limited to approximately 8 kHz by the tape recorder at 4.8 cm/sec and to 5 kHz at 2.4 cm/sec. The fastest tape speed was used initially to include any higher frequency vocalizations; since none were heard during the initial tapings, the slower tape speeds were used to conserve tape. Background noise was highest below 125 Hz.

The hydrophone was suspended from a wooden dowel to a depth of 1–2 m, approximately 1 m from the edge of the pool. The input to channel 1 of the tape recorder was monitored with headphones during all recordings (except those made using the timer), and behavioral descriptions were recorded on channel 2 or on data sheets.

Gulf of California whales (GOC)—The study area was in the Canal de Ballenas over a 20×45 -km area (approximately 29°00'N, 113°20'W; Tershy *et al.* 1990). Bryde's whales were seen frequently during the four year study (1983–1986), and 160 of them were individually identifiable based on dorsal fin shape and condition, pigmentation patterns, and scars (Tershy *et al.* 1990). The primary objective of the study was to document feeding activity by balaenopterid whales in the GOC. The acoustical recording system was employed opportunistically to investigate the occurrence of vocalizations rather than to sample systematically for detailed signal processing.

Recordings were made using a modified Navy sonobuoy and a portable Sanyo cassette recorder (model TRC 1500). The frequency response of the system was not determined, but sound analyses indicated that the frequency range was at least 30–5,000 Hz. Most of the sounds analyzed had the majority of their acoustic energy in the 50–1,000 Hz range, where it is likely that the system was not significantly nonlinear. Our analyses of these tapes were conducted primarily to compare general call characteristics to those of the captive juvenile.

The sonobuoy was deployed over the side of a 4.5-m skiff. A description of the context of the recordings was made on the tape preceding or following the recording sessions. These included the species present, number of individuals, general behavior of the whales, and their location relative to the hydrophone.

The recordings included in our analyses were made only when Bryde's whales were seen in the study area and no other species of mysticetes were present. Twelve cassette tapes recorded in the GOC during the Tershy *et al.* study were examined to get an overview of the variety in the data, but only relevant portions will be presented. The total tape time analyzed in detail was 70 min from uninterrupted recording sessions 2–20 min in length.

Sound analyses—All the tapes described above were analyzed with a Kay 5500 Digital Signal Processor with the hamming function and without averaging. The sampling rate was $2.56 \times$ the frequency range. The SWF tapes were played

back on the same Uher on which they had been recorded; the GOC cassette tapes were played back on a Marantz (PMD420) tape recorder. Initial reviews of the tapes from both the captive animal and from the GOC were conducted between DC and 2,000 Hz with 29 Hz filter bandwidth and 42 dB dynamic range represented on the screen of the Kay monitor. All analyses were conducted by observing the calls on the screen while listening to the tapes through headphones to ensure that no calls above 2,000 Hz were missed.

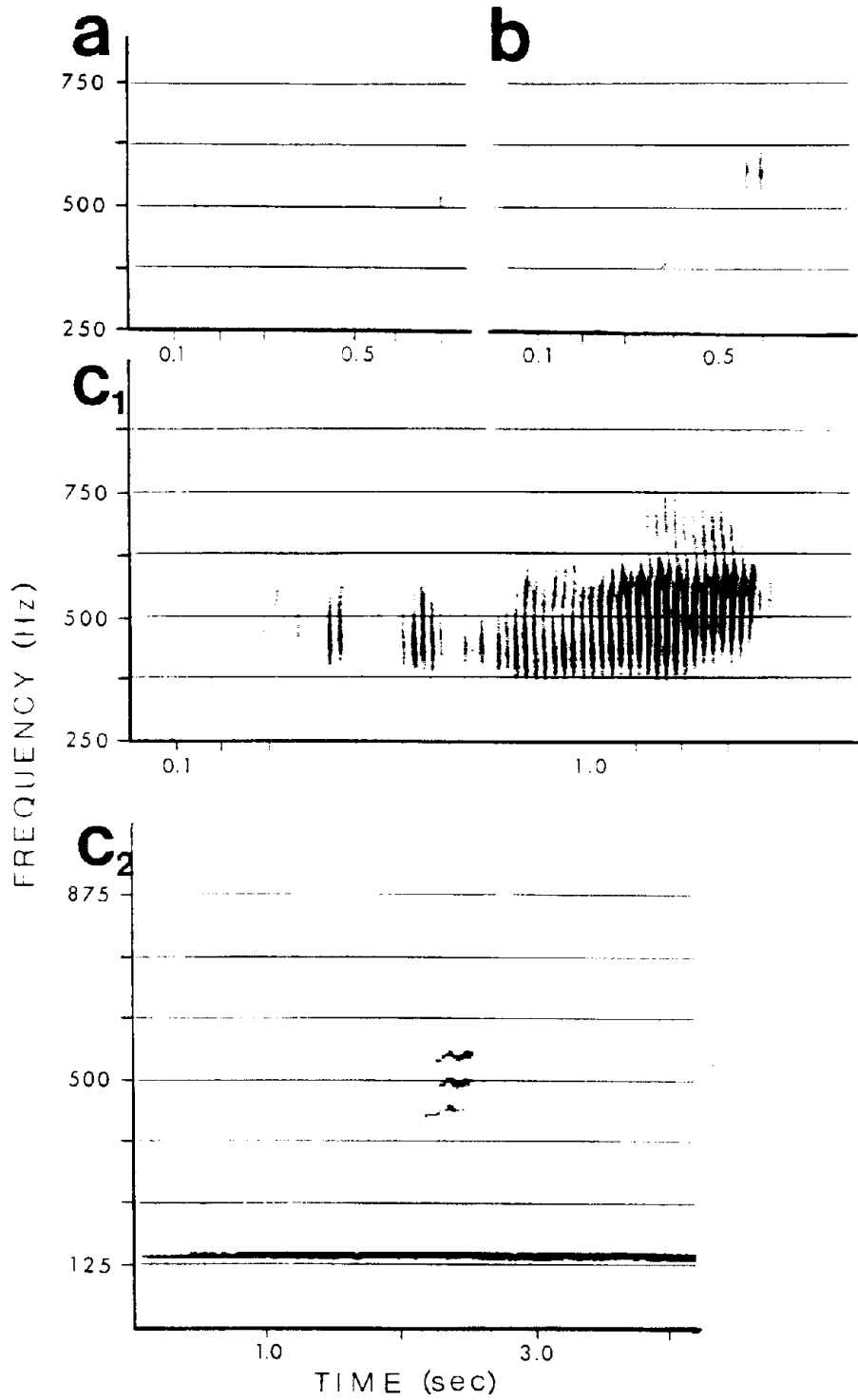
Narrower filter bandwidths (7, 15 Hz) were used when measuring frequency off the screen. All measurements were done using the 0–1,000 Hz or 0–500 Hz scale. The amount of analysis overlap for the various fast fourier transforms (FFT) and time axes used was 3–8, meaning that each sample point was analyzed at least three times. The vertical amplitude cursor was used to determine relative amplitude and the frequency was measured with the horizontal frequency cursors (Fig. 5a) at the point of greatest relative amplitude in the power spectrum that was displayed simultaneously. Changes in frequency within a call were calculated by the Kay "difference frequency" program using the two horizontal frequency cursors.

Wideband filter representations (75–150 Hz) were used to emphasize the temporal characteristics of the vocalizations to measure durations and to determine if the sounds were pulsed. Call durations were measured on the screen using the vertical cursors to mark the location (in sec) at which the call was first visible above background noise and the location at which the call ended. The duration measurement was then read as the difference in time (in sec) from the first to the second cursor location. Pulse rates were determined by counting the pulses per second off the screen of a waveform display or directly from a wideband representation of the call (as illustrated in Fig. 2a, b, 3b). Intercall intervals were calculated from the beginning of one call to the beginning of the next.

RESULTS

Vocal behavior of the captive juvenile—Initially, the whale vocalized primarily when handled by the divers prior to feeding and during antibiotic administration. The underwater vocalizations in this context were comparatively short "moans" (Thompson *et al.* 1979), and, more rarely, discrete pulses (Fig. 2). Bubbles were produced continuously through the right blowhole as vocalizations began, but the underwater sounds were not audible above the surface. Bubbles were not observed in the absence of vocalizations; they were also not seen prior to exhalation. Occasionally, when the animal was positioned in the sling above the water surface, the divers felt vibrations along the body wall that were similar to those produced when the whale vocalized underwater, but no vocalizations were audible.

Over the next week an increase in the whale's vocalizations was noted, and an intensive acoustical study was initiated. During the 21–24 December period of observation, the whale vocalized throughout the day and night in the absence of divers. Moans were produced predictably at one or two positions at the periphery of the pool as she swam in a very consistent pattern (Edds and Odell,



in prep.). These moans were "growl-like" in quality, with greater durations than recorded earlier (up to 51 sec, Fig. 3, 4). She ceased her periodic vocalizations only when the surface sprinkler system was turned off prior to a feeding or for repair. There were no apparent responses to trainer or dolphin activities in the adjacent tank, and no obvious responses to observers.

During all vocalizations the head was lowered slightly and bubbles were emitted from the right blowhole only (Fig. 1c). We observed that the whale was able to open both blowholes during respiration and to keep them both closed between respirations (Fig. 1a, b). Because no air leakage was visible just prior to exhalations that were not preceded by vocalization, it seems unlikely that the blowhole was damaged or the musculature weakened. Another possibility is that the act of vocalizing affected only one side of the blowholes. As in the case of the shorter vocalizations described above, bubble production always began as vocalization was initiated and continued until vocalization ceased. On several occasions a moan was produced continuously between blows and was resumed following respiration. No sounds were audible above the water surface.

The total number of vocalizations analyzed from the three different recording regimes was 233 (Fig. 4). The majority of vocalizations were pulsed moans with amplitude and frequency modulation (Fig. 3). Pulse rate varied within and among moans (range: 20–70 pulses/sec). Some of the moans "faded away", gradually losing intensity until no longer audible; more common was an abrupt ending (38%), or declining frequencies with the same harmonic structure (37%) as the major portion of the call. "Up" endings and extreme "up-down" frequency shifts were less common (17% and 8%, respectively). Durations of the moans were variable during all recording sessions (0.3–51 sec, Fig. 4). There appeared to be a shift to longer vocalizations during the bihourly recordings of 21–24 December, but there was no apparent diurnal correlation for call durations. Shorter calls continued to be more common around feeding time.

Individual pulses occurred relatively rarely ($n = 13$, Fig. 2) but could also immediately precede a moan ($n = 7$), occur during a moan ($n = 2$, Fig. 3), or occur as a single pulse at the end of a moan ($n = 2$). One series of pulses not associated with a moan occurred during the first few days of captivity (Fig. 2a).

Figure 2. Sonograms of vocalizations of the captive juvenile Bryde's whale (*Balaenoptera edeni*). a. Discrete pulses with very low repetition rates (10/sec) that did not immediately precede a "growl"; these were the rarest of the vocalizations. b. Pulses produced with higher repetition rates (e.g., 30–40 pulses/sec) that did not immediately precede a "growl"; c. Increasing pulse rates occurred in longer sounds with a "growl" quality, as shown in C₁. C₂ shows the frequency bands from the same sound reproduced with a narrower filter. [The 0–1000 Hz range was used for all figures shown; filter bandwidth for a, b, c₁ was 75 Hz (fast fourier transform (FFT) size = 50 pts; transform time = 0.02 sec; analysis overlap = 6.25×); filter for c₂ was 15 Hz (FFT size = 256 pts; transform time = 0.10 sec; analysis overlap = 8×). Noise around 125 Hz on c₂ was due to the water pump and sprinklers, and was present on all tapes recorded at Sea World of Florida.]

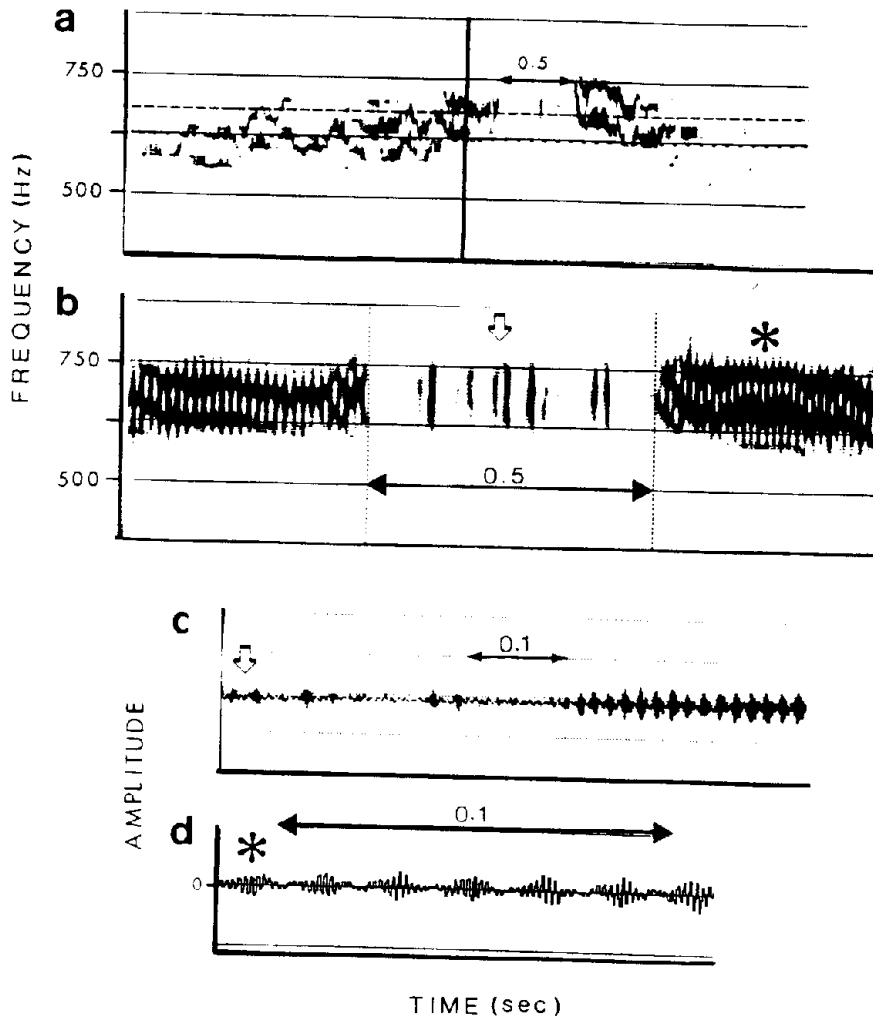


Figure 3. Sonogram of early portion of a long "growl-like moan" of the captive Bryde's whale, showing a section of discrete pulses within the pulse train. Apparent in this call are both frequency changes and variations in pulse rate (tank noise was concentrated below 250 Hz). a. Sonogram to illustrate frequency bands with energy maxima: dashed line = 680 Hz; dotted line = 625 Hz; pulse rate in first half of call approximately 55 pulses/sec (filter bandwidth = 29 Hz; FFT size = 128 pts; transform time = 0.05 sec; analysis overlap = 4 \times). b. Time expansion with broader filter bandwidth of beginning portion of call marked with horizontal bar in (a) to illustrate pulse rates, as described in Watkins (1967a). Note that after the section with discrete pulses, the pulse rate increases (filter bandwidth = 75 Hz; FFT size = 50 pts; transform time = 0.02 sec; analysis overlap = 3 \times). c. Waveform representation of portion of the same call. Open arrow in (b) corresponds with open arrow in (c); pulse rate in second half of call = 5.5 pulses/0.1 sec = 55 pulses/sec. d. Expanded waveform of portion of the same call labelled with asterisk in (b) to illustrate amplitude modulation.

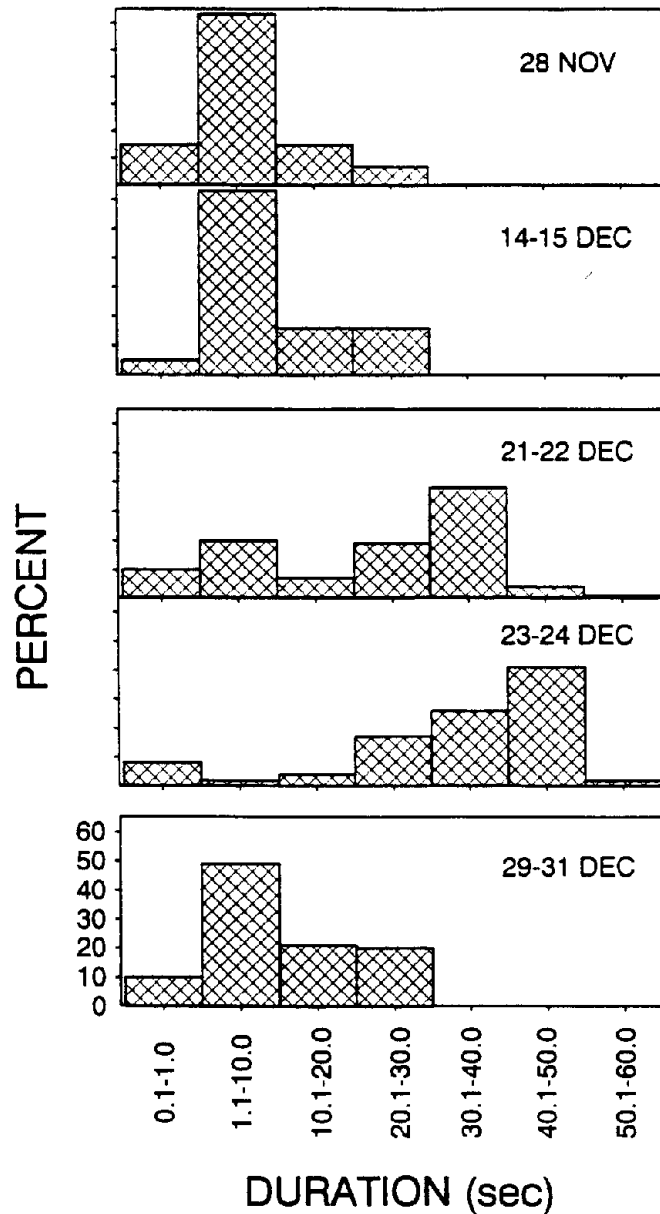


Figure 4. Percentage of the captive Bryde's (*B. edeni*) calls in specific duration categories recorded during different dates. The shortest calls (<20 sec, see Fig. 2) were primarily produced during handling or following a feeding, as illustrated in the recordings done on 28 November and 14–15 December. The longest calls were produced during the bihourly recordings over 24 hr between 21 and 24 December; n (28 November) = 41; n (14–15 December) = 19; n (21–22 December) = 69; n (23–24 December) = 65; n (29–31 December) = 39; total n = 233.

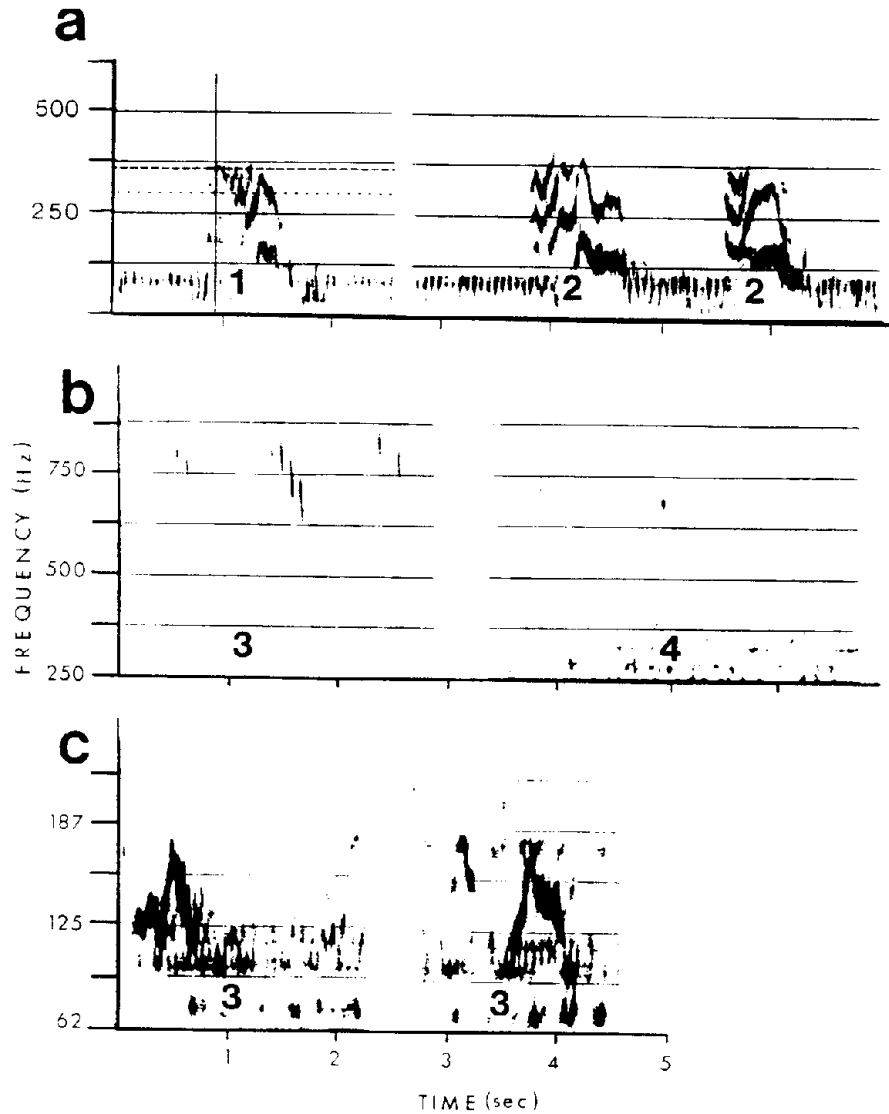


Figure 5. Call types recorded in the Gulf of California. a. Sonograms of three moans recorded on 24 July 1983. Adult-calf pairs were present with other adults in the area. (1) was produced alone, duration: 0.79 sec. The solid vertical line indicates the cursor position for a power spectrum analysis of the major frequencies represented; the dashed cursor line = 360 Hz, the dotted cursor line = 300 Hz; moans (2) were produced as a pair later during the same recording session, durations: 0.90 and 0.74 sec, respectively. All three calls appear to be complex moans with pulsed and nonpulsed components (filter bandwidth = 29 Hz; FFT size = 128 pts; transform time = 0.05 sec; analysis overlap = 4 \times). b. Sonograms of discrete pulse series recorded during observations of adult-calf pairs when the adult was diving without the calf. Two recording sessions are represented (3 and 4) from different times on 24 August 1985. Interpulse intervals were 0.08–0.1 sec. [Signal:noise was worse in session (4), requiring a narrower filter bandwidth to

The majority of acoustic energy was between 400 and 610 Hz, with pulse durations of 10 msec and interpulse intervals of 50–130 msec.

Vocal behavior of free-ranging cows and calves—Seventy-three calls were analyzed from the Gulf of California tapes. These included pulsed ($n = 27$) and nonpulsed moans ($n = 10$) recorded in the presence of groups and adult-calf pairs (Fig. 5a, c), and a previously undescribed call, consisting of series of discrete pulses, recorded only when calves were present ($n = 36$, Fig. 5b). The characteristics of these calls are summarized in Table 1.

Frequencies for the moans recorded in the GOC were generally between 100 Hz and 500 Hz, but sidebands from pulsed moans were as high as 930 Hz. In most recordings pulsed and nonpulsed moans were frequency modulated with increases and decreases in frequency throughout the call. No consistent patterns of frequency modulation within the calls were apparent, nor did they end in a consistent increase or decrease in frequency. Frequency modulations within a call varied from 10 to 65 Hz.

The nonpulsed calls were present on two tape recordings (21 July and 24 August) made during observations of adult-calf behavior, when no other Bryde's whales were present. Nonpulsed moans were recorded when an adult accompanying a calf was diving without the calf and were louder when the adult was near the surface and closer to the hydrophone. These nonpulsed moans (Fig. 5c) were of shorter duration (0.1–0.6 sec) than the pulsed moans recorded when a group of Bryde's whales was in the area (durations 0.7–1.4 sec, Fig. 5a).

On 21 July series of discrete pulses were produced repeatedly while a calf was alone near the surface and were loudest when the calf was nearest to the hydrophone. The discrete pulses recorded on the two occasions when only calves were present had short durations (25–40 msec) and consistent interpulse intervals of 50 msec (± 2 msec SE, $n = 30$) or 90 msec (± 1 msec, $n = 82$). The number of pulses per series varied (4–11), and the duration of the call was dependent on the number of pulses due to consistent interpulse intervals. In general, the first pulse had a frequency maximum around 900 Hz, and the last pulse was near 700 Hz. Bandwidth of the pulses was around 100 Hz. In all of the pulse series recorded, the final pulse was of lower frequency than the initial one, but pulses of higher and lower frequency could occur within the pulse series (Fig. 5b). Intervals between pulse series were very variable (range: 1–64 sec), but mostly 1–2 sec.

distinguish the calls from the noise in the sonogram. Session (3): filter bandwidth = 29 Hz; FFT size = 128 pts; transform time = 0.05 sec; analysis overlap = 4 \times . Session (4): filter bandwidth = 15 Hz; FFT size = 256 pts; transform time = 0.10 sec; analysis overlap = 8 \times .] c. Sonograms of two nonpulsed moans that alternated with discrete pulses recorded during session (3). Similar moans were apparent during session (4), but were not retrievable from the noise (0–500 Hz scale used; filter bandwidth = 12.8 Hz; FFT size = 75 pts; transform time = 0.06 sec; analysis overlap = 4.7 \times).

Table 1. Comparison of call characteristics for free-ranging adult-calf pairs and a captive juvenile Bryde's whale, *Balaenoptera edeni*.

Call type	GOC ^a	Captive juvenile
Discrete pulses		
Freq. range (Hz) ^b	700-900	400-600
Duration (msec) ^c	25-40	10
Pulse intervals (msec)	50-100	50-130
Pulsed moans		
Freq. range (Hz) ^d	100-500	200-900
Duration (sec)	0.7-1.4	0.5-5.1
Rate (pulses per sec)	60-160	20-70
Nonpulsed moans		
Freq. range (Hz)	90-180	
Duration (sec)	0.1-0.6	
Intra-call F (Hz) ^e	10-65	

^a GOC = Gulf of California; the discrete pulses were only recorded when a calf was alone at the surface while the adult companion was diving. The discrete pulses were loudest when the calf was close to the hydrophone. The pulsed moans were recorded in the presence of adult-calf pairs after a feeding aggregation separated. The nonpulsed moans were loudest when the adult of an adult-calf pair was closest to the hydrophone.

^b Frequency range denotes the lowest and highest frequency components of the sounds using the frequency cursor on the viewing screen of the Kay 5500 Digital Signal Processor. Frequencies were measured with the bandwidth setting at 7 or 15 Hz on 0-1,000 Hz scale.

^c Duration was measured using the two time cursors and the power-at-cursors function to determine where the sound began and ended with a 6 dB increase above background used as the criterion for the presence of the sound. Duration measurements were conducted with bandwidths of 29 or 75 Hz on the screen.

^d Includes major sideband frequencies.

^e Intracall change in frequency indicates the frequency increases and/or decreases within a call. Frequency was measured as described above.

DISCUSSION

Comparisons of vocal activities—The simple frequency modulated sounds reported here (Fig. 5c) from the Gulf of California are similar to those reported by Cummings *et al.* (1986) from the same area. The durations and frequencies present also are within the same range for both studies. The major differences in the data are the pulsed moans and the pulse series reported here. These differences may be attributed to differences in the context of the recordings, as Cummings *et al.* (1986) did not record in the presence of adult-calf pairs.

Some pulsed moans we report from the Gulf of California were similar in structure to those of the captive juvenile. However, none of the calls from free-ranging Bryde's whales, including those of Cummings *et al.* (1986), contained calls with durations as long as those from the captive juvenile.

Although discrete pulses have not been reported from Bryde's whales pre-

viously, pulse series have been reported from other baleen whale species. Among the balaenopterids, pulses have been reported from humpbacks, *Megaptera novaeangliae* (Beamish 1979), minke, *B. acutorostrata* (Winn and Perkins 1976), finback, *B. physalus* (Thompson *et al.* 1979), and blue, *B. musculus* (Beamish 1979). Of those reports the recordings from an entrapped humpback are of interest because the animal was a potentially stressed juvenile that produced pulse series ("ratchet sounds") while exhaling underwater (Beamish 1979). Although the pulse repetition rate was not reported, the estimated rate from Beamish's figure 6a is 38–40 pulses/sec, a value within the range of the juvenile Bryde's whale (20–70 pulses/sec). Possibly, the co-occurrence of underwater exhalation and pulse production in these two juveniles is a result of similar mechanisms for producing the pulses. However, pulse production by a captive juvenile gray whale (*Eschrichtius robustus*) was accompanied by exhalation only rarely (Fish *et al.* 1974).

Functional speculations—The long moan of the captive Bryde's whale may belong to a category of sounds produced when the animals are distressed by other individuals or circumstances. Similar, relatively harsh, sounds with relatively long durations (up to 26 sec) have been recorded by Clark (1983) from southern right whales that were disturbed by conspecifics or another species. The longest call reported from finbacks, similar structurally to the captive juvenile's moan, was recorded in potentially agonistic contexts (Watkins 1981; Edds 1988, see fig. 6). Calls peculiar to stressful situations also have been reported from some terrestrial mammals.

Kiley (1972) discussed the vocalizations of various ungulate species in situations of "isolation" (conspecifics out of view) and "frustration" (individual was thwarted from obtaining something desired, such as food). In general, the calls produced under both conditions were similar, and both amplitude and duration increased with an increase in arousal. In horses, a contact call produced by females and their young when in close proximity became louder and longer, with higher frequencies and more repetitions, when the distance between the two was increased (Kiley 1972). Also, in several primate species (*e.g.*, Rhesus monkeys, *Macaca mulatta*, Bayart *et al.* 1990), isolation calls produced by infants have longer durations with higher intensities and greater frequency fluctuations than "separation" calls that are produced when the mother is in view. With these data in mind, it is possible that the long moans of the juvenile were stimulated by her captivity and may be a form of isolation call not recorded previously.

Further, the increase and then decrease in average moan duration may have been indicative of her condition. Initially, she may have been too weak to vocalize for extended periods. The fact that her vocal activity increased as she gained weight supports this hypothesis (DKO, PLE, personal observations). Also, the shorter durations and decreased calling rate over 29–31 December coincided with a decline in the rate of weight gain. However, those recordings were made using a timer, without an observer present, and no data were taken on her swimming speed or general activity. Clearly, we cannot correlate any one variable

with the variation in call durations recorded from the captive Bryde's whale, but vocal activity may be a useful behavior to monitor in cetaceans acclimating to captivity.

Significance of bubble release during vocalization by captive juvenile—We will discuss three potential reasons for bubble release: abnormal release due to illness; purposeful release as a visual display; and release as a normal consequence of vocalization. The Bryde's whale may have produced the bubbles due to physical damage to the blowhole muscles or tissues incurred during stranding. However, both blowholes were open during inhalation and completely closed when vocalizations were not being produced. There was no apparent difference in the timing of air release from the left *vs.* the right blowhole as the whale raised the rostrum for exhalation. Undoubtedly, there is a pressure increase at the blowholes just prior to exhalation. The fact that exhalation appeared to be simultaneous on both sides suggests that the left and right blowholes were functioning normally. Bubbles were released from the right blowhole only during vocalizations (Fig. 1c). Therefore, we believe it is unlikely that bubble release was the result of muscular problems or injury around the blowhole.

Bubbles may constitute part of a behavioral display. Although bubble release during vocalization is not common in two baleen whale species that have been observed closely (humpbacks, Silber, personal communication; Watkins 1967b; southern right whales, Clark, personal communication), bubble production has been observed in specific behavioral contexts. Clark (1983) observed bubble release concurrent with southern right whale "blow sounds" only, indicating that bubble release can occur during some vocalizations and not during others. Humpback whales released bubbles during agonistic encounters in their breeding areas (Baker and Herman 1984); however, no accompanying vocalizations were described. Silber (1986) also observed bubble streams from the blowholes or mouths of adult humpback whales during low-level aggressive encounters. Although vocalizations occurred during those encounters, Silber could not determine which whales were vocalizing. Further support for an agonistic display function comes from the observation that a juvenile Bryde's whale in the Gulf of California released bubbles as it repeatedly swam by a stationary diver (Tershy, personal observations).

Lastly, bubble release may have been the normal consequence of "growl" production by the juvenile Bryde's whale. Particular sound types by other species ("ratchet" sounds by humpbacks, "blow sounds" of southern right whales) are accompanied by bubble production while others are not. The age of the animal may also be a consideration. Ridgway (personal communication) observed that young bottlenosed dolphins (*Tursiops truncatus*) often release bubbles during vocalization, but adults do so rarely, and he suggested that dolphins learn to recycle air. Singing humpbacks do not produce bubbles (Silber, personal communication) during the 7–30 min that they are submerged (Payne and McVay 1971); therefore, recycling of air is likely in that species. Clark (personal communication) noted that the songs of bowhead whales, which may be produced continuously for 154 sec, have alternating louder and softer portions that may represent recycling of air. If recycling of air is common during repeated or extended vocalizations by baleen whales, it is possible that the skill is learned.

and had not been mastered by the captive juvenile Bryde's whale. Alternatively, the recycling mechanism may not be functional in young animals for developmental or maturational reasons. The observation that air escaped from only one blowhole may indicate that the whale had independent control of the two blowholes and perhaps only one side was required for vocalization.

Clearly, we cannot determine which of the above possibilities is the correct reason for bubble production by the juvenile Bryde's whale: none can be eliminated based on our captive study. The existence of many possibilities emphasizes the need for additional observations.

Potential age-related differences in Bryde's vocalizations—The series of pulses with consistent repetition rates that may have been produced by the free-ranging calf is very different qualitatively from the higher pulse rate calls believed to be from free-ranging adults. It is possible that both the individual pulses and moans can be produced by both adult and calf; however, the pulse series were heard only when calves were present (Tershy, personal observation). In addition, juveniles in the Gulf of California (defined by their small size and consistent lack of an adult companion) did not produce the slow pulsed call (Tershy, personal observations).

The recordings from the captive animal illustrate that the female juvenile could produce pulses with high pulse rates, similar to those of the adult, as well as discrete pulses. It is possible that the female juvenile calls are intermediates between a calf call and an adult call. If so, the intermediate nature of the calls may be due to a maturational process, whereby the capability to produce more rapid pulse rates improves with age as the sound production apparatus changes or as the animal "practices" pulsing. However, the differences in the pulse rates may simply reflect the different contexts for the recordings: adult-calf interactions, *vs.* adults interacting vocally, *vs.* the calls of an isolated individual.

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