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Whistles produced by common dolphins from the Southern California Bight

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Abstract

A total of 5,291 whistles produced by common dolphins, *Delphinus delphis*, from the Southern California Bight were analyzed by digital processing of spectrograms and categorized to eight whistle-types, four of which comprised over 97% of any sample. The eight whistle-types were similar to, but not inclusive of all, whistle contours previously reported for common dolphins offshore California, indicating that the whistle repertoire for the species is larger than that reported here. The authenticity of the whistle-types is supported by their occurrence in each of four recording contexts, although proportions of the dominant four whistles varied among contexts. Because the common dolphin whistles described here were not individual-specific nor context-specific, they seem best characterized as a portion of either a graded series or regional dialect repertoire.

Key words: common dolphins, *Delphinus delphis*, whistles, spectrograms, bioacoustics.

Introduction

The common dolphin, *Delphinus delphis*, is a small (about 2.3 m), widely distributed delphinid (Leatherwood & Reeves, 1983). Although common dolphins are often encountered in temperate and tropical waters, there are few descriptive accounts of the sounds they produce (Watkins & Wartzok, 1985). Busnel & Dziedzic (1966) established five whistle-types in their analysis of 80 signals recorded from common dolphins in the Mediterranean Sea. Their whistle categories were apparently constructed on the basis of behavior accompanying each sound because the sonograms of some whistle contours placed in different categories were very similar, with characteristics that seemingly overlapped. Dreher & Evans (1967) identified 19 different whistle-types recorded from feeding and transiting subgroups of a 'migratory herd of 100–150' common dolphins off the California coast and tabulated contour shape and the rank order of whistle emissions. Caldwell & Caldwell (1968) described whistles produced by four recently-collected common dolphins at Marineland of the Pacific near Los Angeles, California. Five individual-specific whistles were defined (one individual emitted two types) based on an analysis of 2403 whistles, with frequent chorusing bouts among the four animals. Quantitative data on whistle duration and frequencies were not given in these accounts, except as represented on example sonograms.

We recorded whistles produced by two female common dolphins, collected from the Southern California Bight (SCB), during three contexts: (I) while together in a large redwood tank; (II) while in separate enclosures outfitted with an acoustic link, and (III) while in separate enclosures with the acoustic link removed. Whistles recorded in each context were analyzed and compared to one another, and to whistles recorded from wild common dolphins in the SCB, deemed a fourth (IV) recording context. A quantitative account of the whistles recorded and their variability among recording contexts is presented and compared to other published accounts of common dolphin whistles.

Methods

Two female common dolphins (#04, #05), maintained at the Naval Ocean Systems Center (NOSC; now NRaD), San Diego, marine mammal facility between June 1978 and June 1981, were the principal subjects of this study. The animals had been collected in September 1975 near San Diego, California. They were maintained in a large concrete tank at the Sea World Oceanarium with several other dolphins until 16 June 1978 when they were moved to a circular redwood tank (9 m diameter, 1.8 m deep) at the NOSC facility. A calibrated LC-10 hydrophone with a Celesco LG-1364 line driver and 40 dB preamplifier was positioned at mid-tank depth. The signal was filtered by an Ithaco Model 4302 filter set at 3.15 kHz hi-pass, with 24 dB/octave rolloff and 20 dB amplification, then recorded on an Ampex Model FR 1300 instrumentation tape recorded at 38 cm/s (15 ips). Bandwidth of the recording system was 3.15 – 75 kHz ± 2 dB. A one-hour continuous sample of sounds was recorded from the dolphins immediately after their introduction to the circular tank.

On 20 November 1978, the dolphins were moved into separate enclosures (3 m × 0.75 m, 0.75 m deep), which were connected by a 15-cm diameter removable PVC water-filled pipe, which served as an acoustic link between enclosures. Each enclosure contained an LC-10 hydrophone connected to the same amplification and recording system as for the redwood tank. The dolphins appeared calm and were nearly neutrally buoyant; portions of the body not submerged were covered with wet towels (see Hui, 1981). Continuous recordings were made over a 24-hour period while the acoustic link was alternately removed and replaced. When emplaced, the acoustic link proved adequate to record the whistles of both dolphins in either enclosure, although those of the dolphin within each enclosure were obviously louder. The dolphins were subsequently returned to the redwood tank.

Whistles recorded from free-ranging common dolphins in the SCB were analyzed to compare to those produced by the two dolphins at NOSC. The recording was made on 12 July 1976 approximately 15 km west of Dana Point, California, using an LC-10 hydrophone connected, via a Hewlett-Packard 311A amplifier set at 20 dB, to a NAGRA IV-SJ dual-channel tape recorder set at 38 cm/s; system bandwidth was 20 Hz – 30 kHz ± 2 dB. The recording contains sounds of four to five animals that were separated by about 0.5 km from a herd of 200+ common dolphins. These dolphins approached within 5 m of the hydrophone, and whistle and pulsed sounds were distinct.

Recorded sounds were listened to at recorded and one-half recorded speed, and identified as frequency-modulated (FM) whistles or amplitude-modulated (AM) buzzes. Buzzes were often produced simultaneously with whistles. Whistles were chosen for study because they were much easier to classify than buzzes. A Spectral Dynamics Model 350 (SD 350) spectrum analyzer produced a continuous spectral plot of frequency on the abscissa and time on the ordinate. After listening to and examining spectrograms of over 2400 whistles, eight whistle-types were classified based upon contour shape (temporal frequency shift of the fundamental) and duration. The eight whistle-types were: down-up (Dd_1); short-up (Dd_2); up-down (Dd_3); long-up (Dd_4); down-up-down (Dd_5); down (Dd_6); level-piece (Dd_7) and up-piece (Dd_8).

Recordings from the two NOSC dolphins were divided into five samples: (1) both animals in the circular tank; (2) Animal #04, Separate Enclosures: Link-in; (3) Animal #05, Separate Enclosures: Link-in; (4) Animal #04, Separate Enclosures: Link-out; (5) Animal #05, Separate Enclosures: Link-out. The recording of free-ranging common dolphins was the sixth (6) sample. Approximately one thousand whistles from each NOSC sample and nearly two hundred whistles recorded from the free-ranging common dolphins were analyzed on the SD 350 set at a real-time frequency response of 80 kHz and a filter bandwidth of 50 Hz.

Frequency measurements (beginning, end, maximum and minimum) and duration were registered for each whistle and filed by whistle-type. The mean and standard deviation of each whistle-type's frequency and duration measures were calculated to provide a quantitative description of the whistles. Proportions of the dominant four whistle-types were then compared among the six samples by Chi-square analysis (Zar, 1984). Random orientations of the dolphins relative to the receiving hydrophones precluded measurements of sound pressure level.

Results

The first four whistle-types (Dd_1-Dd_4) constituted over 97% of the whistles recorded in each sample (Table 1; Fig. 1). The predominant whistle (Dd_1) was a short down-up contour. Dd_1 whistles began at about 6.6 – 7.2 kHz, fell to a minimum of roughly 6.2 – 6.6 kHz in about 0.065 s, then swept up to end at about 8.7 – 10.2 kHz over an average 0.164 – 0.216 s. Dd_1 whistles comprised 29% to 78% of the sampled whistles. Similar to, and often produced in series with Dd_1 whistles, were short upsweeps called Dd_2 whistles. These short rising contours started at about 6.1 – 6.8 kHz and swept up to end at an average 8.9 – 10.4 kHz in about 0.147 – 0.204 s. Dd_2 whistles constituted 14% to 49% of the sampled whistles. Dd_1 and Dd_2 whistles were often accompanied, either synchronously or in series, by buzzes, i.e., a rapid series of clicks at 20 to 200 per second. Combined, these two whistle-types constituted 67% to 96% of the sampled whistles.

The longest whistle-type (Dd_3) was an up-down contour. Dd_3 whistles rose from an average 7.0 – 7.2 kHz to peak at 19.0 – 19.8 kHz, then fell to end at 9.7 – 11.4 kHz in roughly 1.482 – 1.622 s. Some Dd_3 whistles (35%, $n=719$) dropped by ≤ 1 kHz within the first 0.05 s resulting in an average minimum frequency of 6.4 – 6.7 kHz. Dd_3 whistles constituted 6% to 31% of the sampled whistles and had a very distinct sound due to their duration and

Table 1. Occurrence and averaged measures of duration and frequencies (begin, end, max, min) for eight whistle-types produced by *Delphinus delphis* from the SCB, by recording context (sample). Duration is in seconds; frequency in kHz.

Recording Context (sample)	Measured Paramter	Whistle Types								Total
		Dd_1	Dd_2	Dd_3	Dd_4	Dd_5	Dd_6	Dd_7	Dd_8	
Circular	No.(%)	760(74)	141(14)	72(7)	47(4)	9(0.8)	-	1(0.2)	-	1030
Tank	duration	0.196	0.204	1.622	1.243	0.220		0.045		
(1)	begin	6.8	6.3	7.1	6.9	6.9		6.5		
	end	10.2	10.2	10.3	18.8	9.6		6.5		
	max	10.2	10.2	19.2	19.1	10.1		6.5		
	min	6.2	6.3	6.4	6.9	6.2		6.5		
Separate	No.(%)	332(33)	389(39)	62(6)	204(20)		1(0.1)	5(0.5)	4(0.5)	997
Enclosures	duration	0.190	0.147	1.537	1.069	-	0.066	0.068	0.032	
Animal #04	begin	6.7	6.5	7.1	7.1		6.9	6.3	7.3	
(Link-in)	end	8.7	8.9	11.4	18.2		6.7	6.3	8.1	
(2)	max	8.7	8.9	19.2	18.2		6.9	6.3	8.1	
	min	6.2	6.5	6.6	6.7		6.7	6.3	7.3	
Animal #05	No.(%)	582(58)	224(22)	169(17)	10(1)	4(0.4)	10(1)	1(0.1)	1(0.1)	1001
(Link-in)	duration	0.193	0.163	1.482	0.881	0.179	0.173	0.039	0.026	
(3)	begin	6.8	6.8	7.2	6.9	6.8	11.3	5.8	6.2	
	end	9.1	9.0	10.1	17.4	8.4	8.6	5.8	6.5	
	max	9.1	9.0	19.7	17.4	8.6	11.3	5.8	6.5	
	min	6.2	6.8	6.4	6.4	6.2	8.6	5.8	6.2	
Animal #04	No.(%)	311(29)	526(49)	107(10)	111(11)	3(0.2)	7(0.7)	2(0.2)	-	1067
(Link-out)	duration	0.205	0.203	1.571	1.091	0.214	0.353	0.065		
(4)	begin	7.2	6.6	7.0	6.9	6.9	17.0	6.9		
	end	10.2	10.4	11.0	18.4	9.8	11.6	6.9		
	max	10.2	10.4	19.0	18.7	10.1	17.0	6.9		
	min	6.6	6.6	6.7	6.7	6.7	11.6	6.9		
Animal #05	No.(%)	483(48)	193(19)	309(31)	16(2)	7(0.7)	2(0.2)	-	-	1010
(Link-out)	duration	0.216	0.201	1.553	1.041	0.223	0.318			
(5)	begin	6.8	6.4	7.2	6.8	6.9	13.8			
	end	9.7	9.6	9.7	18.1	9.5	10.0			
	max	9.7	9.6	19.8	18.2	9.8	13.8			
	min	6.3	6.4	6.5	6.4	6.4	10.0			
Wild Delphinus	No.(%)	146(78)	34(18)	-	1(0.5)	4(2)	1(0.5)	-	-	186
(6)	duration	0.164	0.160		0.793	0.208	0.254			
	begin	6.6	6.1		6.6	6.6	5.1			
	end	9.7	10.1		15.0	10.7	4.8			
	max	9.7	10.1		15.0	10.8	5.1			
	min	6.2	6.1		6.2	6.2	4.8			

sweeping frequency range. Dd_3 were often given in series and were sometimes accompanied by buzzes. Dd_4 whistles were long rising contours that started at about 6.6 – 7.1 kHz and ended at 15.0 – 18.8 kHz in about 0.793 – 1.243 s. Variations to this long up-swept contour included initial frequency drops (of ≤ 2 kHz within the first 0.1 s) and/or short segments of falling frequency (of ≤ 1 kHz within the last 0.1 s) at the end of the sound, resulting in mean frequency maxima and minima of 15.0 – 19.1 kHz and 6.2–6.9 kHz, respectively. Dd_4 whistles constituted 0.5% to 20% of our sample. They were sometimes produced in series with or overlapping Dd_3 whistles, or in overlapping pairs (Fig. 2).

Whistles that did not fit into the dominant four categories were classified into four types (Dd_5-Dd_8) that constituted less than 3% of any whistle

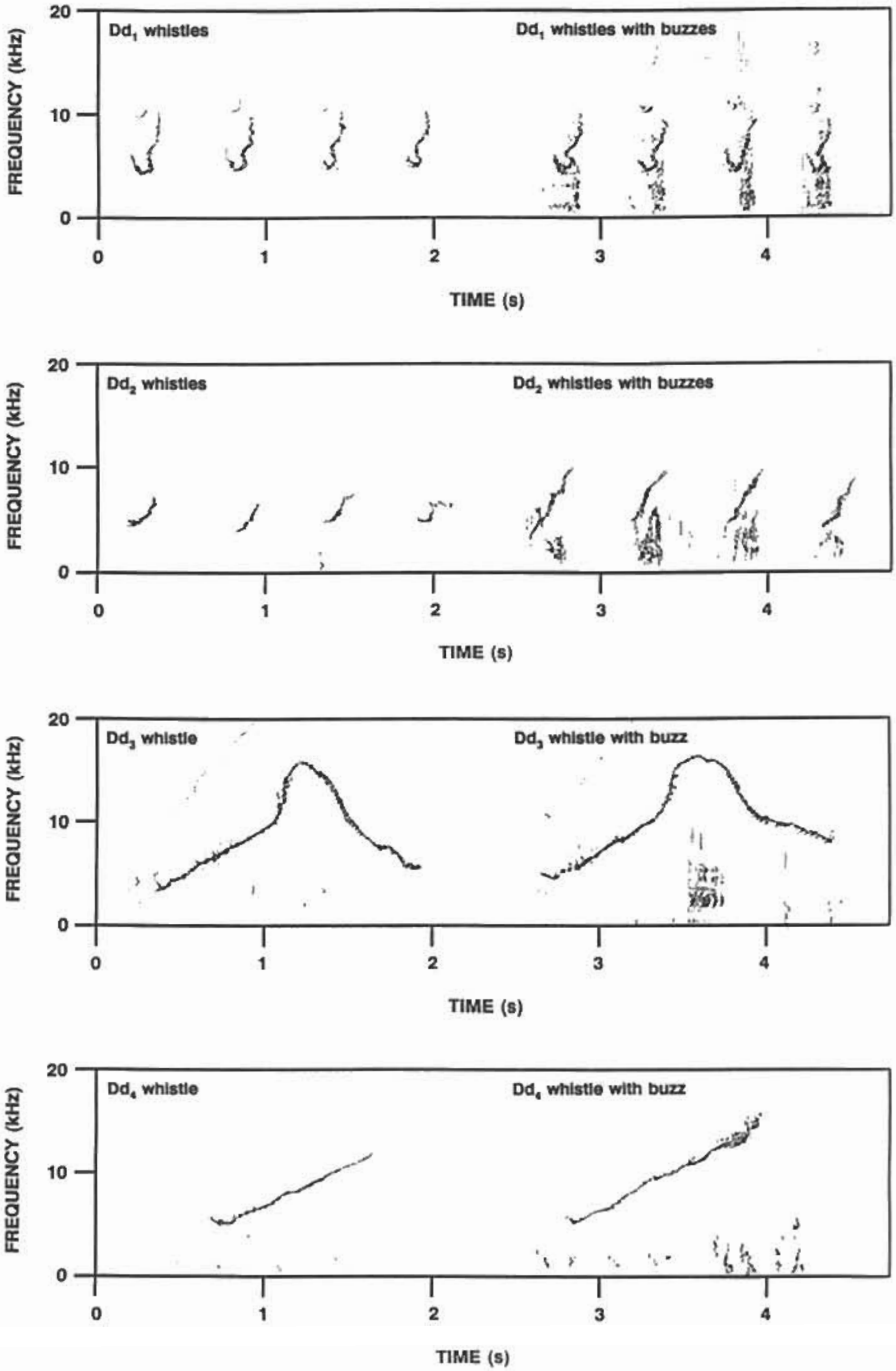

Figure 1. Spectrograms of the dominant four whistle-types (Dd$_1$–Dd$_4$) recorded from common dolphins collected from the SCB. Sample spectrograms are of whistles recorded from the two NOSC dolphins while in the circular tank.

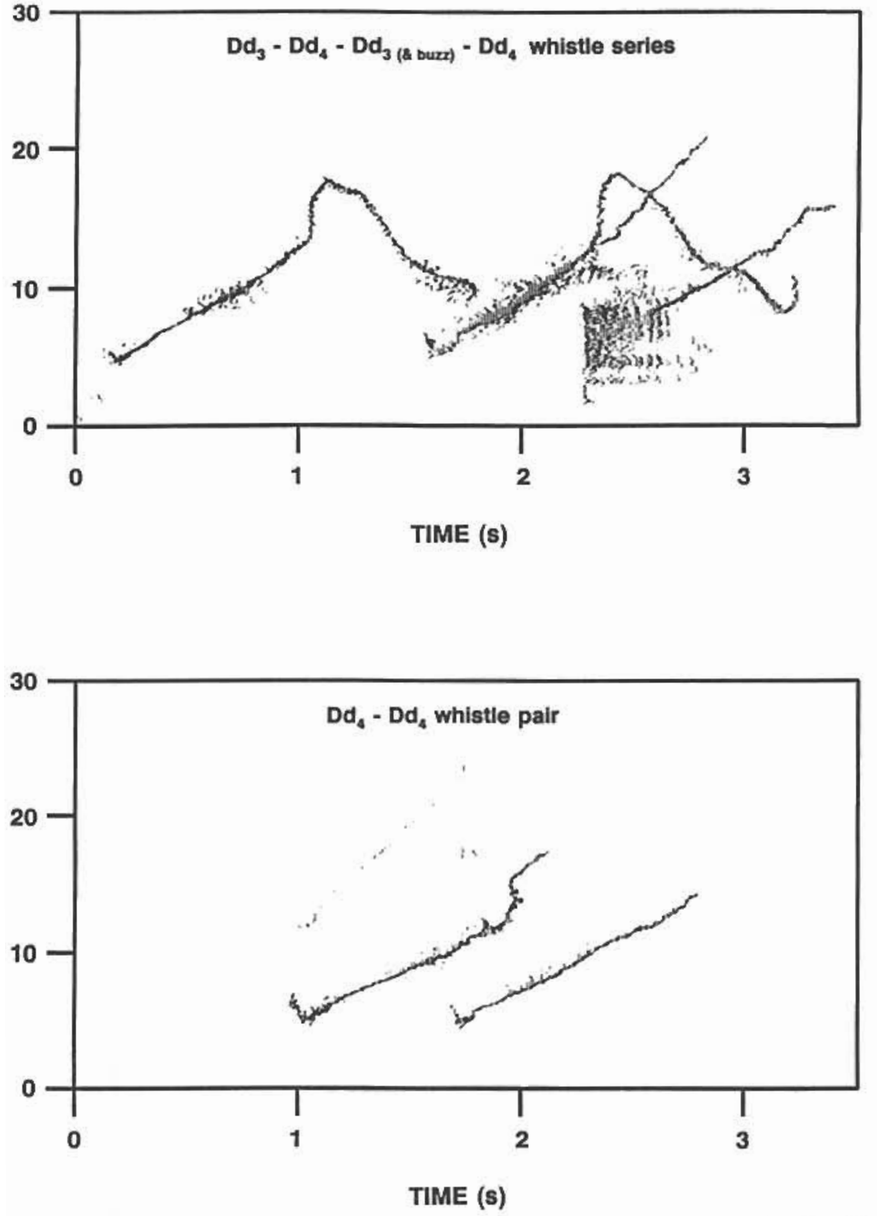

Figure 2. Spectrogram of a Dd_3-Dd_4 whistle series and a Dd_4-Dd_4 whistle pair. Sample spectrograms are whistles recorded from the two NOSC dolphins while in the circular tank.

samples (Table 1). The most common of these were down-up-down contours (Dd_5) that began at about 6.6 – 6.9 kHz, fell to roughly 6.2 – 6.7 kHz, rose to peak at about 8.6 – 10.1 kHz and ended at roughly 8.4 – 10.7 kHz in about 0.179 – 0.223 s. These whistles constituted 0.2% to 2% of the sampled whistles and were rarely accompanied by buzzes. Falling contours, classified as Dd_6, started at 5.1 – 17.0 kHz and fell to 4.8 – 11.6 kHz in about 0.066 – 0.353 s. These whistles constituted 0.1% to 1% of the sampled whistles. Dd_7 whistles were extremely short (0.039 – 0.068 s) level contours at about 5.8 –6.9 kHz and occurred nearly as infrequently (0.1% –0.5%) as Dd_8 whistles, which rose from 6.2 – 7.3 kHz to 6.5 – 8.1 kHz in 0.026 – 0.032 s. These last two whistle categories were so short and produced so infrequently that we assume they may be incomplete whistles, or 'pieces' of the other whistle types.

The authenticity of the whistle-types was demonstrated by their repeated occurrence in different recording contexts (Table 1). The dominant four whistle-types (Dd_1-Dd_4) were recorded in all contexts, with the exception of the Dd_3 type from the wild dolphins. The less common whistle-types (Dd_5-Dd_8) were recorded intermittently. Dd_5 and Dd_6 whistles were recorded in all but one context, and Dd_7 whistles occurred in all but two contexts. Dd_8 whistles occurred only during the Separate Enclosures: Link-in context, but were recorded from both dolphins. Animal #05 made all eight whistle-types while in the separate enclosure with the acoustic-link in place.

Proportions of the dominant four whistle-types (Dd_1-Dd_4) varied among recording contexts (Fig. 3). Paired comparisons of the proportions of Dd_1-Dd_4 whistles produced by each dolphin during Separate Enclosures: Link-in with those recorded from the same animals together in the circular tank were the most different (animal #04: $\chi^2=131.5$, $P \leq 0.001$; animal #05: $\chi^2=24.6$, $P \leq 0.001$). Similarly, the proportions of Dd_1-Dd_4 whistles recorded from the two dolphins in the circular tank were significantly different from those recorded from the wild dolphins ($\chi^2=14.5$, $P \leq 0.01$). Significant intra-individual differences were also found when Dd_1-Dd_4 proportions from each dolphin during Separate Enclosures: Link-in and Separate Enclosures: Link-out conditions were compared (animal #04: $\chi^2=9.8$, $P \leq 0.05$; animal #05: $\chi^2=14.7$, $P \leq 0.01$).

Discussion

Eight distinct whistle-types were recorded from common dolphins from the SCB. Four of them constituted over 97% of the whistles in all recorded samples. The authenticity of the whistle-types is supported by their repeatability among recording contexts. Each of the NOSC dolphins produced the same whistle-types in varied recording contexts. These whistles were similar to those recorded from wild dolphins in the SCB, which is not surprising as the NOSC dolphins may have come from the population of free-ranging dolphins that were recorded.

The eight whistle-types described here are similar to, but not inclusive of all, whistle contours previously reported for common dolphins from California waters. Although comparison to the hand-drawn whistle contours of Dreher & Evans (1967) is speculative, whistles similar to all but Dd_1 and Dd_5 are represented in their list of 19 common dolphin whistle-types. Similarly, sonograms of four 'signature whistles' described in Caldwell & Caldwell (1968: whistles A-D) look like the spectrograms for whistles reported here (i.e., A=Dd_1, B=Dd_4, C=Dd_5, D=Dd_7), but appear to be of somewhat longer duration. The fifth 'secondary' contour (Caldwell & Caldwell, 1968: whistle E) is different from any described here, or by Dreher & Evans (1967). Reports of whistle contours other than the eight described here (Dreher & Evans, 1967, Caldwell & Caldwell, 1968) indicate that common dolphins offshore California likely have a larger repertoire of whistles than we have described.

The whistle repertoires of several dolphin species, including common dolphins, have been described as an amalgam of individual-specific 'signature whistles' (Caldwell & Caldwell, 1965, 1968, 1971, 1979). In this paradigm, each dolphin produces an individually distinctive and stereotyped whistle, the acoustic components of which may be modified with behavioral context (Caldwell *et al.* 1990; Tyack 1986). Conversely, Bastian (1967), Taruski (1979), and Sjare & Smith (1986) described the whistle and tonal call repertoires of *Tursiops truncatus*, *Globicephala melaena*, and *Delphinapterus leucas*, respectively, as a graded series. In this model, multiple whistle-types are identified that inter-grade into one another. Finally, Ford (1989) described the discrete tonal pulsed-calls of *Orcinus orca*, recorded offshore British Columbia, Canada, as pod-specific regional dialects and suggested that variability in calls within pods may be due to individual differences in call rendition. Pods that socialize or travel together shared some calls, but there was no call overlap among sympatric pods that did not associate. Similarly, Hoelzel & Osborne (1986) identified 38 discrete pulsed-call types from three pods resident in the Puget Sound area, with the 10 most common calls representing 85% of the phonations for killer whales in that region.

Because the common dolphin whistles described here were not individual-specific nor context-specific, the repertoire seems best characterized by either the graded series or regional dialect paradigm. Each NOSC dolphin produced all eight whistle-types, and five of the eight whistle-types were recorded from free-ranging dolphins in waters near where the NOSC animals were collected. Further, changes in recording context generally resulted in a shift from the predominant Dd_1 whistle to a combination of the dominant four whistle-types, suggesting a graded response to changing recording contexts. However, the description of only eight whistle-types seems few when compared to 19 contours described by Dreher & Evans (1967), and to the variety of whistles recorded from common dolphins in the eastern tropical Pacific (Hohn & Benson, 1990) and in Atlantic waters (Tyack, pers. comm.). Perhaps the limited repertoire described here represents only a sample of a regional whistle

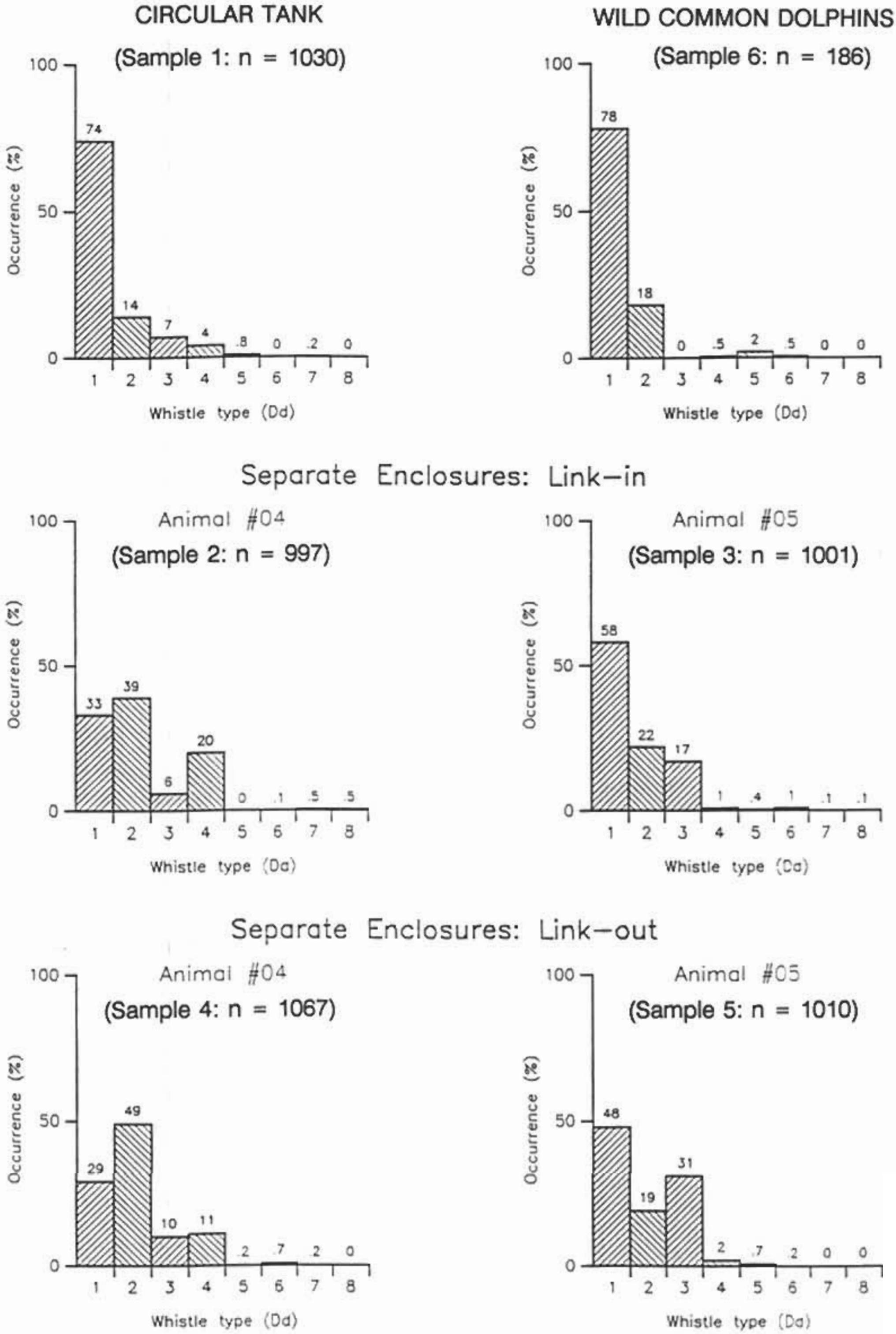

Figure 3. Frequency of occurrence of eight whistle-types (Dd_1–Dd_8) from six whistle samples.

dialect produced by a herd of common dolphins that ranges through SCB waters.

Conversely, mimicry of 'signature whistles' by the NOSC dolphins could account for the limited repertoire and similarity of their whistles. Spontaneous mimicry of whistles and whistle-like sounds has been documented for confined *Tursiops truncatus* (Richards, 1986, Tyack, 1986) and, though not described, could be expected in common dolphins. Mimicry cannot account for the occurrence of the whistle contours in the sample recorded from the wild common dolphins, however. The similarity of whistles recorded from the wild animals to those produced by the NOSC dolphins suggests that the contours recorded at NOSC are representative, at least for one herd of common dolphins in SCB waters. Although not described here, experienced listeners could reliably recognize differences in the whistles of the two NOSC dolphins, indicating that individuals could be so identified. Individual differences in call-type characteristics have been described using multi-variate statistical techniques for several cetacean species (e.g. *Orcinus orca*; Dahlheim & Awbrey 1982). While such differences may be useful for conspecific identification, they do not represent an individual stereotype.

The function of the whistle-types described here is unknown. We note that Dd_1 and Dd_2 were often produced in series and frequently accompanied by buzzes. Series of Dd_3-Dd_3, Dd_4-Dd_3, and Dd_4-Dd_4 whistles were also common, sometimes with whistles that overlapped (Fig. 2). Caldwell & Caldwell (1968) reported that newly captured common dolphins frequently 'chorused', whereby the whistle of one animal seemingly elicited a whistle from another animal, usually after the termination of the first animal's whistle. However, they also noted that 'whistles were frequently repeated without an intervening response by another animal' (Caldwell & Caldwell, 1968: 1123). A herd of common dolphins generally produces such a cacophony of whistles and buzzes that it is often impossible to sort out individual signals (eg. Hohn & Benson, 1990), which further confounds attempts to draw inferences regarding whistle function from samples recorded from individual or small groups of dolphins.

Finally, common dolphins, like bottlenose dolphins, produce sounds other than whistles, including echolocation clicks and burst-pulse sounds such as the buzzes we have already mentioned. Wood (1953) characterized his impression of bottlenose dolphins sounds to include 'barking, yelping, mewing and rasping, jaw clap, snorts, squeals', and others. Our impression is that the common dolphin repertoire of non-whistle sounds is similar though somewhat less varied than that of bottlenose dolphins (Ridgway 1983).

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