Song of the Indian Ocean Blue Whale, *Balaenoptera musculus* spp.

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ABSTRACT

Vocalizations of two blue whales (Balaenoptera musculus) recorded in nearshore waters of Sri Lanka in April 1984 and May 1985 are described. Both animals repeatedly sang the same song consisting of four distinct units. Three of the four units were pulsive while the fourth was a strong, relatively pure tone sustained for 28.6 seconds on average at a frequency between 110 and 131 Hz (usually 120 Hz).

Sounds such as these have not previously been described for the blue whale. The fact that this song remained constant for a year suggests that blue whales have song dialects -- of potential usefulness for determining the boundaries of blue whale stocks.

INTRODUCTION

Blue whale, Balaenoptera musculus, vocalizations have been described as low "moans" lasting from 16 to 36.5 seconds with the principal energy in a 1/3 octave band centered between 18.5 and 22 Hz (Cummings and Thompson, 1971; and Edds, 1982). (The source level reported by Cummings and Thompson in a 14-222 Hz band averaged 188 dB re 1$\mu N/m^2$ at 1 meter; sample size equal to four.) Beamish and Mitchell (1971) suggest that blue whales also may use ultrasonic (21-31 kHz) echolocation pulses which have an intensity of 59.2 ± 1.0 dB at 1m. Likewise, Winn and Perkins (1976) supported the contention that blue whales may produce such sounds (which would presumably be useful for echolocation), but it remains unclear whether recordings of these clicklike sounds were actually emitted by blue whales.

This paper describes the vocalizations of blue whales which were recorded in the Indian Ocean along the coast of Sri Lanka in two areas in which they are frequently encountered. One recording was made off the Northeast

RESULTS

Analysis of the blue whale vocalizations indicated that the whales repeated sequences of sounds of four different types in a rhythmic, fixed pattern. These utterances are therefore properly referred to as songs (see Payne and McVay, 1971, for a discussion of the term song). Payne and McVay (1971) define humpback whale songs as being composed of different themes which are themselves divisible into phrases, the phrases being composed of units. A unit is defined as the shortest sound that is continuous to human ears when heard in real time. When an animal generates units that are composed of pulse trains, we call each pulse a subunit. If the singer modulates the pulsing rate during the unit so that the beginning or end of the unit starts to break up into discrete subunits, it blurs the distinction between the terms unit and subunit. In the case of songs as slow and at frequencies as low as those produced by blue whales, the beginning and end of pulsive units often trail off into pulses that are discrete to the human ear as the sound intensity increases or dies away. It has seemed to us to be less confusing to refer to the whole pulse train including its beginning and end as one unit even when it breaks up at the start and/or finish. With this in mind, we have considered that the blue whale song that we recorded in Sri Lanka were the same in 1984 and 1985. In both years, the song is divided into four units (see Figure 1).

Since we do not know where in this repeated sequence of units the blue whale begins its song, we arbitrarily chose to call one of the pulsive units Unit 1. As shown in Figure 1, this unit is followed by a second pulsed unit, Unit 2, a 122 Hz pure tone (Unit 3) and, after about 48 seconds, a third pulsed series (Unit 4).

Unit 1 is a complex pulsed sound which though higher in fundamental frequency bears a similarity to what Watkins (1981) has described for finback whales (Balaenoptera physalus) as a "low-frequency rumble". Unit 1 appears to be pulsed at a rate of 3.6 pulses/second with principal pulse frequencies ranging from 27 to 120 Hz. The sound in Unit 2 is pulsed at about 13 pulses/second. The principal frequency rises from 50 Hz to 70 Hz with harmonics between 26 and 120 Hz. At the end of Unit 2, the sound rises sharply to a maximum frequency of 150 Hz and abruptly stops for one second prior to the onset of Unit 3. Unit 3 consists of a relatively pure tone, ranging from 110 to 130 Hz. It bears some similarities to the "moan" described by Cummings and Thompson (1971) and by Edds (1982). Unit 4 (Figure 1C) is similar to Unit 1 in that it is pulsive. However, the pulse repetition rate is less clear. Oscillograms of Units 1 to 4 are given in Figure 1.

The harmonic bands which are separated by about 3.5 Hz in Unit 1 and by about 10.5 Hz in Unit 2, indicate a pulse repetition rate of about 3.5 pulses/second and about 10.5 pulses/second.

Table 1 lists the minimum and maximum frequencies, and the average duration of each unit. Table 2 gives the average time between units. On occasion our recordings lacked 1 and 4. It appears, however, that they were not necessarily omitted from the song. These units are of lesser intensity than Units 2 and 3 and are therefore more easily lost in background noise. It should be pointed out that the average pause between songs is probably about 76 seconds. In one instance, 153 seconds lapsed between the end of Unit 4 and the start of Unit 1 -- almost exactly twice the average pause.

DISCUSSION

The blue whale sounds reported by Edds (1982) in the Gulf of St. Lawrence while showing patterns superficially similar to those we report here are shorter in duration (mean 16 seconds) and much lower in frequency (18.5-19.4 Hz) than ours and show other consistent differences in pattern as well.

The blue whale sounds recorded by Cummings and Thompson (1971) near Chile appear to be somewhat more similar in form to ours in that they span a similar frequency range (12.5-200 Hz). However, their principal energy is around 30 Hz. The Chilean songs last longer (on average 36.5 seconds) than the sounds described by Edds and have three repeated units. They also show strong amplitude modulation at a rate of 3.85 modulations per second (our Unit 4 is amplitude modulated at 2.66 modulations/second). The most obvious similarity between what we have recorded and the sounds ascribed to blue whales by others is that the blue whales' song consists of only 2-4 units and one of the units present in all instances is a long, sustained note of constant frequency. However, the fundamental frequencies reported by others have always been much lower than those recorded in both years near Sri Lanka.

It seems most unlikely that the whales we recorded in 1984 and 1985 are the same individual. A more likely possibility is that they were different individuals (we have heard two whales at the same time near Sri Lanka singing songs that were identical). We conclude that the blue whales near Sri Lanka sing the same song, and that they maintain it for at least one year.

The fact that blue whales coming from the same area sing the same song, coupled with the fact that songs from different areas are peculiar to their particular area is reminiscent of the situation with humpback whales and suggests that blue whales may make slow changes to their songs and thus develop local song dialects. If this is the case, the songs of blue whales may prove to be helpful for determining the boundaries of the

stocks of blue whales. However, before that can be demonstrated we need more recordings from more areas.

Payne and Guinee (1983) and Whitehead (1985) have proposed that humpback songs can be used to differentiate between humpback whale "stocks". Consistent differences in vocalizations between different pods of killer whales (Orcinus orca) appear to reflect the degree of isolation of pods (Ford and Fisher, 1983). Comparisons of blue whale vocalizations recorded in different oceans may shed light on questions of the relatedness of different populations as well as whether these are potentially distinct races of blue whales.

The blue whales which we recorded are found right close to the coast of Sri Lanka between January and May, as is explained elsewhere in this volume. One blue whale was seen in Sri Lankan waters in November as well. Their migratory destinations are not known, but it is possible that these blue whales remain in the Northern Indian Ocean. In fact, the Sri Lankan whales may be the "pygmy" blue whale (Balaenoptera musculus brevicauda). Inasmuch as there has been no effort to make yearly or seasonal recordings of blue whales in different oceans, we encourage researchers to collaborate and record blue whale songs for comparison. With such acoustic studies, perhaps the range of a population or its identity can be determined.

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UNIT #	# OF UNITS ANALYZED	MEAN DURATION (s)	FREQUENCY SPAN (Hz)
1	12	12.08	27-120
2	18	11.1	26-150
3	18	28.6	110-131
4	12	9.1	35- 93

TABLE 1. Duration of units and the frequencies spanned by each unit.

SUBJECT	MEAN DURATION OF INTER-UNIT INTERVALS (s)	NUMBER OF INTER-UNIT INTERVALS
Unit 1 - Unit 2	12.09	11
Unit 2 - Unit 3	1	17
Unit 3 - Unit 4	48.7	11
Unit 4 - Unit 1	85.6	8

TABLE 2. Inter-unit intervals.

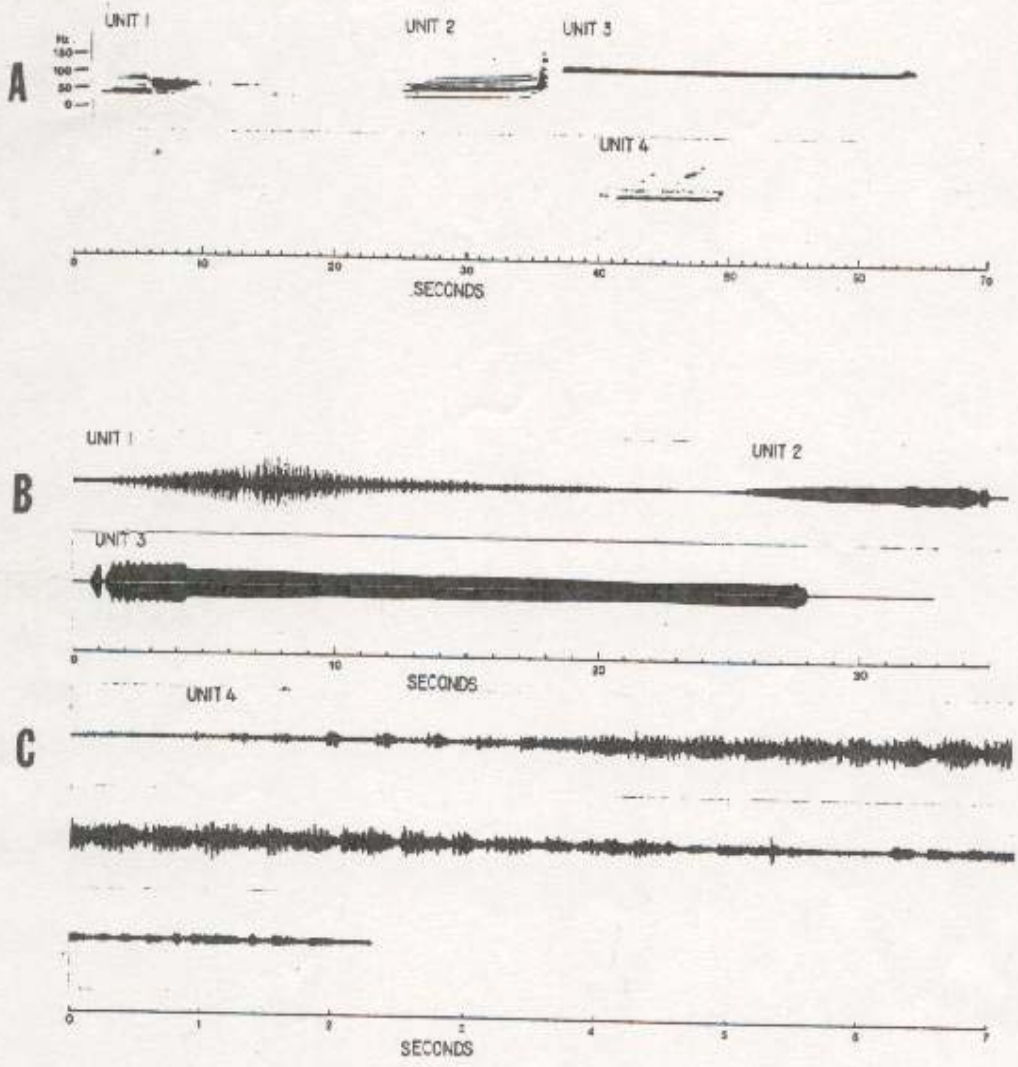
A
UNIT 1
UNIT 2
UNIT 3
UNIT 4
Hz
150
100
50
0
0
10
20
30
40
50
60
70
SECONDS
B
UNIT 1
UNIT 2
UNIT 3
0
10
20
30
SECONDS
C
UNIT 4
0
1
2
3
4
5
6
7
SECONDS

FIGURE 1. A single, complete song [4 units] of a blue whale recorded April 19, 1984 near Trincomalee, Sri Lanka, Northern Indian Ocean.

A. Sonogram: the analysis range is 0-150 Hz and the analyzing bandwidth is 0.3 Hz.

B. Oscillogram of Units 1-3.

C. Oscillogram of Unit 4 (at a more expanded scale than in B). The pulse repetition rate is 19 pulses per second and is amplitude modulated at 2.66 modulation cycles per second.