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SOUND AND BEHAVIORAL CORRELATIONS

IN CAPTIVE ORCINUS ORCA

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INTRODUCTION

The relationship between cetacean sounds and behaviors has been a topic of interest, frustration and confusion. The traditional approach attempted to correlate the occurrence of a sound with a specific behavior, e.g., as in the case of obvious behavioral stress and the emission of a "distress whistle" (Busnell and Dziedzic, 1968; Caldwell and Caldwell, 1971; Wood, 1954). While the results have been positive they have also been inconclusive. A sound might be highly correlated with a particular activity but it might also be evinced in apparently unrelated activities. Thus with this method no definite pattern is ascertained.

In this study we looked at the percentage emission rather than the absolute occurrence of sounds. Instead of concentrating on one or two individual sounds we took a

broad look at the overall usage of sound in different behavioral activities of Orcinus orca. With this approach a relationship was found between sounds and behavioral states, i.e., "tranquility," "play" and "distress."

METHODS

The killer whales observed in this study were an adult male (Orky) and an adult female (Corky). They have been maintained at Marineland in Palos Verdes, California. The male was captured in 1968 and the female in 1969, both from Pender Harbor, British Columbia, Canada. Corky is from the A5-pod (Michael Bigg, personal communication).

Observations were made on a monthly basis. Alternate night and day samples were gathered. The first recording was made in August, 1978 and the last to be included in this report in June, 1980. During the observational periods all vocal activity was recorded, the bouts of which were separated by several minutes of silence. No recording was made during commercial performances. As the female's most recent pregnancy approached full-term, observations were increased to twice a month. Following the second and third births, observational periods encompassed 24 hr a day for several days.

The sounds were recorded on one of two channels of a Uher 4200 tape recorder, through a TR-225 Transducer Sonar Hydrophone. Observer notes detailing the behavior of the whales were recorded simultaneously on the Uher's second channel. The voice notes described the behavior of both whales. No attempt was made to identify the sound emittor, as such designations were considered unreliable.

Sound Classification

Before data analyses could proceed, a method of cataloging the sounds had to be devised. Alphanumeric labels were assigned to each sound that was distinguishable to the author's ear. Orca sounds often vary at their beginning and end. This characteristic became the first parameter in the sound classification. Similar sounds, having the same body but different beginnings or endings, were classified under the same

letter but assigned a distinct number. Dissimilar sounds were assigned both a different letter and number. The second parameter involved the number of continuous repetitions of a unit sound. The third parameter addressed sounds that were part of the same sequence. Using these three parameters, 11 types (Plates 13.1-13.11) of sounds were isolated with 40 individual variations.

Behavior Classification

The behaviors of the whales were classified into 22 prolonged duration activity states (Table 13.1). Each activity state was composed of shorter events such as Breaches, Squirting and Fluke Slaps (Table 13.2). The shorter events corresponded to the observer's voice notes on the tape. Each event was defined and given a two letter behavioral code.

Data Files

A microcomputer (Apple II Plus) was programmed to accept and store the alphanumeric sound codes and the two letter behavioral codes. The program preserved all temporal and sequential information.

First the observer's notes were encoded. Each occurrence of each behavior was entered into the computer along with the mode of locomotion following each blow by the whales. The file was closed when the activity state changed or the recording ended due to vocalization termination. For example, if during a recording the activity state changed from Tusseling to Floating the first file was closed and a second opened. While some overlap must be assumed, transition periods between activity states were found to be short. After a file was closed a label was assigned indicating which activity state had occurred and how many times that state had been entered into the computer. Each occurrence of the 22 activity states (see Table 13.1) was given a unique address within the computer to allow for comparisons between the same activity states and between different activity states.

Table 13.1. Captive and wild activity states. These activity states are defined by the discreet behaviors in Table 13.2. The captive activity states represent an ethogram of the whales Orky and Corky at Marineland in Palos Verdes, California. The wild activity states represent a preliminary ethogram for the A5-pod. Note that for the wild activities all the states are listed as interactive.

WILD

INTERACTIVE

Sexual Activity
Bull and Cow Swim Close, Fast Separate from Pod
Milling Cow/Calf Subgroup with Cavorting Calves
Subgroup Hugging the Shore
Directive Travel, Widespread Subgroups None on Shore
Slow Travel In and Out Along Shore
Milling, Zigzagging, Breaches, Salmon Jumping
Cow/Calf Subgroup Traveling in Fog
Entire Pod Fast, Tight, Directive Travel
Loose Subgroups Meandering but Generally Directive
Rubbing on Gravel
"Silent Running"
Bulls, A4 and A5, Unison Swim
Breach by Boats Preceded by 'J7' Sound
Loose Subgroups Mill in Tidal Rip
Milling at Mouth of Seine Net
Subgroup Begin Unison Swim after Milling
Unison Swim
Direction Change, Pod Tightens and Accelerates
Turnaround
Milling with Fast Swims along Kelp Beds
Subgoups Spread Linearily along Shore
Entire Pod Rapidly Changes Direction Several Times
Widespread, Some Center Straits, Some on Shore
Thrashing in Kelp
Repeated Deep Dives in One Location
Tight, Slow Swim
Post Calf Swim, Unison Blows, Tight, Long Submergences, Spyhops
New Calf Alone on Surface Pod Silent
Steller Sea Lion Attack
Orcinus and Phocaenoides dalli Swim together
Spyhopping at Sunset
Birth

CAPTIVE

INTERACTIVE

Tussling
Unison Swimming
Sexual Activity
Playing "Tag" with Human
Feeding without Show
Begging at Platform
Play (general) with Trainers
Dawn Wall Squirting

NON-INTERACTIVE

Parallel Floating
Floating at Different Sites
Floating Watching the Public
Corky Resting on the Ledge
Orky Playing with the Gate
Non-Synchronized Swimming
Orky Floats, Corky Active
Corky "Performing" Orky's Show Behaviors
Corky "Silent Running"

ENVIRONMENTAL

Water-Lowering
Calf-Removal
With Calf
Show Music Immediately Prior to Show

MISCELLANEOUS

Orky Floats, Corky Vocalizing
Alone on Bottom

Table 13.2. Part 1. Captive and wild behaviors. This table represents all captive behaviors of the whales Corky and Orky observed from August 1978 to June 1980 and all the wild behaviors of the A5-pod observed during the summers of 1979-1981.

WILD

NON-DIRECTED

AI - Spyhop
AJ - Headstand
AM - Pectoral slap
AN - Fluke slap
AO - Inverted fluke slap
AP - Thrash
AS - Submerged backflip
AT - Dorsal fin slap
AU - Snap at water
AW - Stand
AX - Rollover
AZ - Squirm on surface
BA - Mouth open
BB - Dorsal fin quiver
BC - Submerged stationary
BD - Submerged milling
BE - High bob
BH - Highrise
BK - Float with pectoral fin in air
BL - Fluke wave
BM - Lateral head jerk on surface
BN - New calf on surface alone

LOCOMOTION

EA - Float
EB - Drift
EC - Steady swim
EE - Swim on side
EG - Cruise
EH - Fast swim
EI - Plowing a large wake
EL - Swim backwards
EM - Push off cliff
EN - Leap (headfirst re-entry)
EO - Breach
EP - Swim in opposite directions
EQ - Sink
EX - Sink, surface, sink, etc.
EY - Chase (another whale)
EZ - Porpoise
FA - Fluke-up dive
FB - Bob-dive
FC - Float with head against cliff
FD - Constant accelerated swim
FE - Milling
FF - Cavorting calf
FG - Slant dorsal dive
FH - Repeated dives same place
FI - Turnaround (individual whale)
FJ - Squirm on surface
FK - Side-swipe with flukes
FL - Drift towards our boat
FN - Surfing seiner wake
FO - Thrashing in kelp
FP - Pulling kelp with dorsal fin
FR - Cartwheel
FS - Dorsal slice
FT - Tight milling

CAPTIVE

NON-DIRECTED

AA - Blow by Orky
AB - Blow by Corky
AC - Blow by Baby
AD - Bottom sitting
AE - Ledge sitting
AF - Looking through the windows
AG - Rubbing
AH - Grinding teeth
AI - Spyhop
AJ - Headstand
AK - Regurgitate
AL - Sitting on Jet
AM - Pectoral slap
AN - Fluke slap
AO - Inverted fluke slap
AP - Thrash
AQ - Clockwise spin
AR - Counterclockwise spin
AS - Backflip (submerged)
AT - Dorsal fin slap
AU - Snap at water
AV - Submerged air release
AW - Stand (flukes on bottom)
AX - Back arch
AY - Roll over
AZ - Squirm on surface
BA - Mouth open
BB - Dorsal fin quiver
BC - Submerged, stationary
BD - Submerged milling
BE - High bob
BF - Head shake
BG - "Walrus scare"
BH - High rise
BI - Spontaneous "Mammary presentation"

LOCOMOTION

EA - Float
EB - Drift
EC - Steady swim
ED - Counterclockwise swim
EE - Upside down swim
EF - Swim on side
EG - Swim on surface
EH - Fast swim
EI - Plowing a large wake
EK - Swimming deep
EL - Swimming backwards
EM - Push off wall with rostrum
EN - Leap
EO - Breach
EP - Swimming in opposite directions
EQ - Sink
EW - Waves in the tank
EX - Surface, sink, surface etc.
EY - Chase
EZ - Porpoise
FA - Fluke up before dive
FB - Bob dive
FC - Float with head against wall
FD - Constant, accelerated swim

Table 13.2. Part 2. Captive and wild behaviors. This table represents all captive behaviors of the whales Corky and Orky observed from August 1978 to June 1980 and all the wild behaviors of the A5-pod observed during the summers of 1979-1981.

WILD

DIRECTED

CB - Squirt
CH - Touch with pectoral fin
CI - Swimover
CJ - Stroke with flukes
CK - Ram
CL - Touch with dorsal fin
CM - Hit
CN - Erection
CP - Squirting cliff
CQ - Licking cliff
CR - Nose
CS - Head off
CT - Rub against whale
CU - A floats above B
CV - Cut off
CS - Air release with vocal
XB - Push up whale
DC - Given fish by person
DG - Dorsal fin biting
DH - Face to face
DI - Diver in water
DJ - Rub on cliff
DK - Rub on gravel
DL - Calf rolls over female
DM - Calf approaches boat
DN - Whale to whale belly orientation
DO - Nose against rocks
DP - Calf circles boat
DQ - Submerged air release
DR - Splashing

UNISON

XA - Blow
XC - With calf
XD - Steady swim
XE - Ventral swim
XF - Float
XI - Spyhop
XJ - Thrash
XK - Breach
XM - Submerge
XN - Drift
XO - Tandem swim
XP - Wall/Cliff squirt
XQ - Wall/Cliff lick
XR - Pod blow

CAPTIVE

DIRECTED

CA - Watching people
CB - Squirt
CC - Push toy
CD - Play with tire
CE - Play with gate
CF - Banging
CG - Beg
CH - Touch with pectoral fin
CI - Swim over
CJ - Stroke with flukes
CK - Ram
CL - Touch with dorsal fin
CM - Hit
CN - Erection
CO - Tag with humans
CP - Squirting wall
CQ - Licking wall
CR - Nose
CS - Head off
CT - Rub against another whale
CU - Motionless one above the other
CV - Cut off
CW - Closely watching submerged object
CX - Air release during vocalization
CY - Prior to show
CZ - Play with hose
DA - Large air release, long submergence
DB - Push up another whale
DC - Given fish
DD - Play with trainer
DE - Observer stroking whales
DG - Dorsal fin biting

UNISON

XA - Blow
XC - Blow by adults and calf
XD - Steady swim
XE - Ventral swim
XF - Float
XI - Spyhop
XJ - Thrash
XK - Breach
XL - Watch people
XM - Submerged
XN - Drift
XO - Tandem swim
XP - Wall squirt
XQ - Wall lick

Table 13.2. Part 3. Wild behaviors continued from Table 13.2 (parts 1 and 2). Note that there were no comparative captive behaviors for these categories.

WILD

GROUP LOCOMOTION

GA - Shore hugging
GB - Center waters
GC - Head in towards Rubbing Rocks
GD - Slow dive
GE - Subgroup float
GF - All whales float
GH - Slow swim
GJ - Milling in kelp
GK - Milling around cliff face
GN - Whales in tidal rip
GO - Kelp hugging
GP - One pod moves towards another
GQ - Whales swim abreast
GR - Several breathes, long dives

POD FORMATION

HA - Loose
HB - Tight
HC - Lone whale
HD - 2-3 subgroup
HE - Bull/cow
HO - Bull/bull
HN - Bull/calf
HI - Cow/cow
HF - Cow/calf
HG - Calf/calf
HN - Several tight subgroups
HO - Spread across the strait

OTHER CREATURES

MA - Salmon jumping
MB - High seiner density
MC - Whales under seiner
MD - Zodiacs with pod
MF - Seiner sets net between hydrophone and whales
MG - Many jumping fish
MH - Milling at seine net mouth
MI - Rowing zodiac
MJ - Whale approaches gill net
ML - Gulls circling
MK - Humans making sounds underwater
MM - Gulls diving
MN - Salmon swim ahead of whales
MO - Steller sea lions near
MP - Dalls porpoise

After entering the voice notes the tape was rewound and the whales sounds were then encoded. Each behavioral file had a corresponding sound file. Every time a sound was heard its designated code was entered. The program was outfitted with a pause mode in the event that the identity of a sound was temporarily in question.

RESULTS

A total of 14,892 sounds were entered into the computer for analysis. (See the sonograms in Plates 13.1-13.11 for the more frequently emitted sounds.) Five sounds comprised 65 percent of the total sounds produced. These sounds were 'F1' (Plate 13.6, top; 23 percent), 'D1' (Plate 13.4, top; 15 percent), 'A1' (Plate 13.1, top; 10 percent), 'B1' (Plate 13.2, top; 9 percent) and 'C1' (Plate 13.3, top; 8 percent). The remaining 35 percent of the sounds produced consisted of 35 different types. These varied in usage from five percent to less than one percent (Fig. 13.1).

Each activity state was typified by a characteristic usage of sound, although it is important to note there was no one-to-one correlation between the occurrence of a sound and a particular event. In fact, most sounds occurred in a wide variety of activity states. It was the relative frequency of sound usage that was specific to the activities.

For example, in Figure 13.2 the usage of sound in two different activity states is shown. The activity state represented at the top of the figure, Non-Synchronized Swimming, was typified by slow, wandering, independent movement by the whales. During this activity there was no Side-by-Side Swimming, Unison Swimming or Unison Blows. The second activity state, called Dawn Wall Squirting (Fig. 13.3), occurred regularly at dawn and was characterized by licking and squirting the area on the tank wall first hit by sunlight. (It is interesting to note that the choice of the specific spot on the wall that was used as a target was made prior to sunrise. Unerringly this spot was the first spot to be hit by the sun's rays.) Physically this was a very different state

than Non-Synchronized Swimming. Rather than slow independent movement, the whales actively engaged in touching and rolling over one another, in addition to their attention to the tank wall.

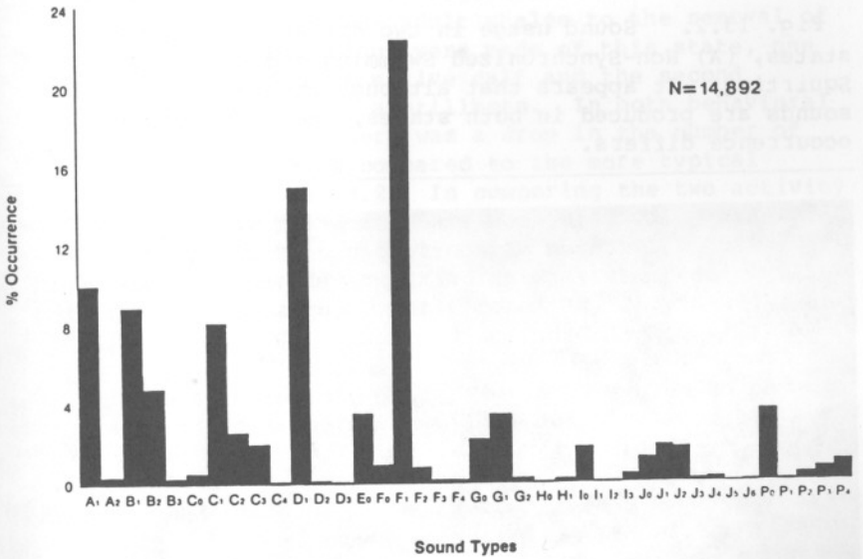


Fig. 13.1. Sound type distribution for all sounds recorded from August 1978 to June 1980. The sample includes the sound production of an adult pair of whales and a calf, which was present for two weeks.

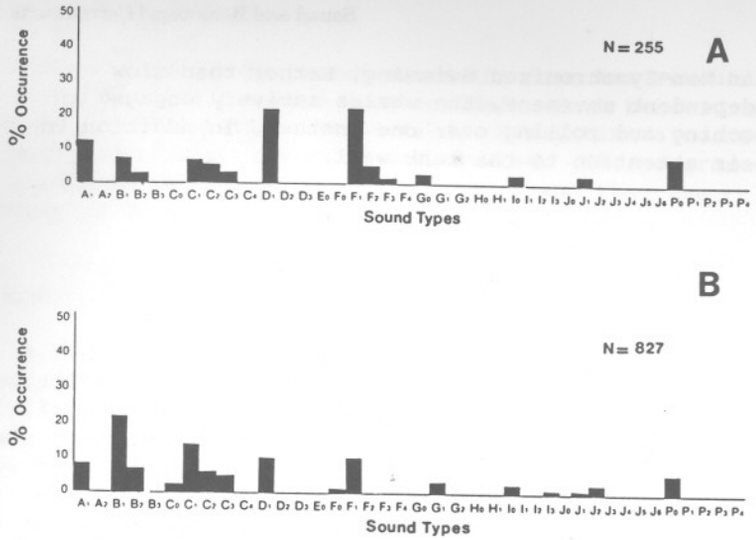


Fig. 13.2. Sound usage in two different activity states, (A) Non-Synchronized Swimming and (B) Dawn Wall Squirting. It appears that although the majority of sounds are produced in both states, their frequency of occurrence differs.

Fig. 13.3. Dawn Wall Squirting. On sunny mornings the whales would frequently orient towards the first bright spot in the tank, flicking their tongues, gently squirting at and sometimes even licking the wall. Photograph by R. Morton).

While most of the sounds occurred in both activity states, there was a difference in their frequency of usage in the two activities. In Non-Synchronized Swimming there was a marked increase in the sounds 'A1,' 'D1,' 'F1' and 'F2' (Plate 13.6, bottom) while in Dawn Wall Squirting there was an increase in 'B1,' 'B2' (Plate 13.2, bottom) and 'C1.'

As illustrated in Figure 13.4, during several other activity states, sound usage by the whales was dramatically characteristic. Unison Swimming, at the top of the figure, was the most commonly observed activity state. As the name indicates, it is characterized by synchronous movements and simultaneous breaths. Note the drop in pulse production, 'P0' (Plate 13.11, part 1, top), as compared with Non-Synchronized Swimming (Fig. 13.2). The second activity state in Figure 13.4 was the behavioral reaction of the adult whales to the removal of the calves. Two recordings were made of this state, one following the removal of a live calf and the second following the removal of a stillborn. In both behavioral states of Figure 13.4 there was a drop in the number of sound types produced as compared to the more typical usages seen in Figure 13.2. In comparing the two activity states (Unison Swimming and Calf Removal), Chi Square analysis revealed that significantly more 'A1,' 'D1' and 'F1' sounds were produced during Unison Swimming ($p < 0.001$), while significantly more 'B2,' 'C1' and 'G1' (Plate 13.7, top) were produced during Calf Removal.

Unison Swimming and Calf Removal have been compared because they represent extremes in levels of arousal. Unison Swimming has been categorized as a low arousal state based on the extended periods of time spent by the whales in this activity. Calf Removal, on the other hand, has been labeled as a high arousal and stressful state by trainers and researchers alike, based on the specific behaviors exhibited by the whales.

In Figure 13.5 the proportion of 'F1,' 'B1' and 'G1' sounds produced in seven activity states are shown. During the analysis of sound usage in the various activities, a particularly interesting relationship was revealed between the general state of arousal and the usage of these three sounds.

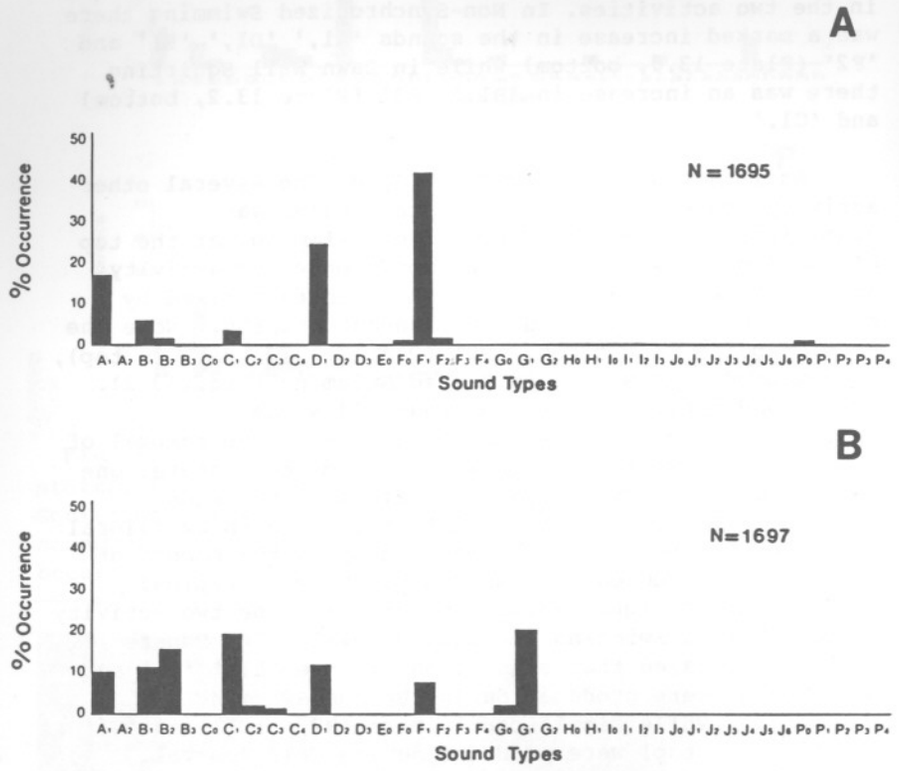


Fig. 13.4. Sound usage in two activity states representing two extremes in levels of arousal, (A) Unison Swimming, a calm state, and (B) Calf Removal, a stressful state. Note the variation in the production of sounds 'F1' and 'G1.'

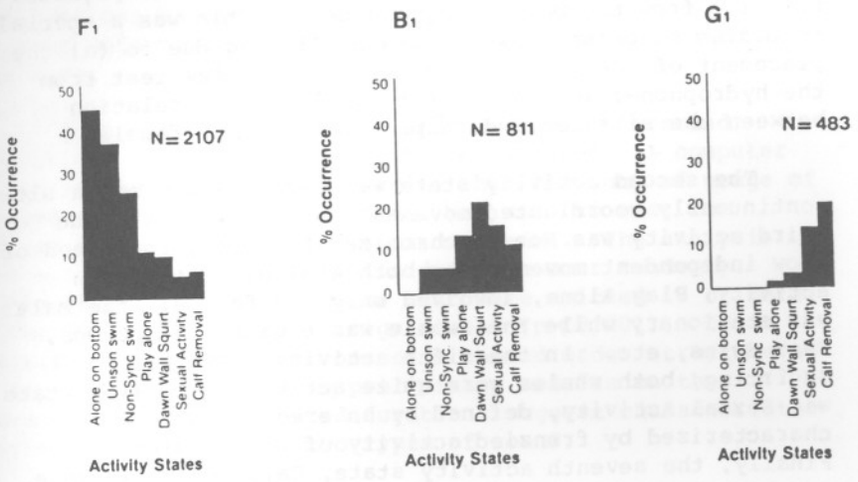


Fig. 13.5. The relationship of three sounds, 'F1,' 'B1' and 'G1,' to each other and seven activity states spanning a variety of arousal levels. Note the domination of the sound 'F1' during calm states, 'B1' during play and 'G1' during periods of stress.

The first activity state (Alone on Bottom) was observed and recorded only once. Three days following the stillbirth, the female spent two hours vocalizing on the tank bottom, while the male floated motionlessly on the surface in his typical night resting behavior. While the female was on the bottom she vocalized slowly and continuously. There was no apparent acoustic or physical reaction from the male (very unusual). This was a special recording since we knew who was vocalizing due to (a) the placement of the whales (the female was a few feet from the hydrophone) and due to (b) the direct correlation between the silences and respirations of the female.

The second activity state was Unison Swimming, a slow continuously coordinated movement by both whales. The third activity was Non-Synchronized Swimming, comprised of slow independent movement by both whales. The fourth activity, Play Alone, involved only the female; the male was stationary while the female was engaged in Spyhops, Fast Swims, etc. In the fifth activity, Dawn Wall Squirting, both whales were quite active. The sixth state was Sexual Activity, defined by an erection and characterized by frenzied activity of both whales. Finally, the seventh activity state, Calf Removal, was a reaction by both whales to an event presumed negative.

The three sounds of interest have a unique relationship to each other and to the level and type of arousal displayed by both whales. The occurrence of 'F1' was highest in a very tranquil state in which the bull was still and the female only moved to surface. Its usage dropped slightly when the movements of the whales became synchronized; they would blow and dive in unison. In periods of Unsynchronized Swimming the frequency of 'F1' dropped even more. During these three activity states the sounds 'G1' and 'B1' were absent or infrequent.

In the next state Play Alone, defined by boisterous activity, 'B1' passed 'F1' in usage and 'G1' occurred. When both whales were quite active in Dawn Wall Squirting, 'B1' peaked and 'G1' increased slightly. During Sexual Activity 'B1' dropped while 'G1' continued to increase. Finally, in the recording made following the removal of the calves the sound 'G1' peaked.

In the case of these three sounds and their accompanying activities, each sound peaked in its frequency of usage during a different type of activity. In other cases, the emission of one sound was directly related to the emission of a second sound, for example, 'D1' and 'A1.' As more sounds and activities were analyzed not only did general relationships among them become evident but subtleties started to emerge. However, a longer data base is required before further comments can be made.

Sound sequences as well as sound and intersound durations are also beginning to be examined. A computer program was written to determine the frequency of usage of sound pairs. A Chi Square test was used to test for goodness of fit, assuming a random model. The analysis revealed that the sound pairs did not occur randomly. Some 76 percent of the pairs that were emitted 10 or more times were statistically significant ($p < 0.001$). These results support indications of a second order structure to the vocalizations. Also preliminary results on the measurement of intersound durations suggest characteristic durations between any two types of sound.

DISCUSSION

From these data it would seem that Orcinus orca possesses a complex and precise system of communication. A high degree of order has been evinced in preliminary analysis of such parameters as sound sequencing and intersound duration, in addition to the correlations found between sounds and behavioral states.

In any initial attempt to piece together a functional picture of communication among killer whales, a closer examination of their vocal patterns appears to be essential. For instance, in studying the vocalization 'F1' we found that 70 percent of 176 consecutive recordings of Orky and Corky were initialized or terminated by repeated emission of that sound (Table 13.3A). Furthermore, on several separate occasions when each whale exhibited periods of decreased sound production

(during periods of illness in the male and in the last two weeks of pregnancy in the female), single 'F1' sounds were emitted and not repeated. It is possible that the 'F1' sound was functioning as an invitation to "converse" and if rejected, no further sounds were produced. Moreover, it may have also served at times to terminate a "conversation." If an uninterrupted string of 'F1' sounds was produced in the course of a sound sequence, the vocalizations ceased. On the other hand sound production continued, if the 'F1' string was interrupted. For example, immediately following the removal of the second calf the whales were producing a high percentage of stress correlated sounds ('G1' and 'C1'). Some emission of 'F1' sounds was occurring, but not consistently, and sound production was not terminated (Table 13.3B). It may be that at that time one of the whales was not interested in closing the vocal interaction. Another possible feature of the sound 'F1' was revealed in a preliminary analysis of recordings made of different wild orca populations. From the data it seemed that the occurrence of 'F1' may be independent of the geographical location of the whales, although its usage and function may vary with the particular pod and locale.

Work with wild killer whales was begun in 1979 (Tables 13.1 and 13.2). Corky's pod (A5) was recorded over the course of three summers. Sixty sound types were isolated and 27 of these sounds (which occurred at greater than 1 percent of the time) are illustrated in Figure 13.6. The wild sound usage was in some cases different from the captive data. In captivity, 'F1' appeared to be associated with Tranquility. The wild data, however, showed a stronger relationship (Fig. 13.7) with synchrony of movement, i.e. Turning Around (an entire pod reversing its course) and Post Birth Swim (Tight Swimming, Unison Blowing and Spyhopping) recorded 23 hr after the birth of a calf. The sound 'B1' (Plate 13.2) maintained its relationship (Fig. 13.8) with relaxed "pleasurable" activity states, i.e., Rubbing on Gravel. (The whales generally mill and float in the vicinity of specific beaches while members of the pod rub their bodies in the gravel.) These differences in sound usage indicated the importance of vocalization studies in the field as well as in oceanariums.

A

F1 F1 F1 F1 D1 A1 D1 D1 A1 J2 C1 C1 D1 B1 C1 C1 A1 D1 A1
C1 C1 B1 C1 D1 C1 C1 D1 D1 D1 A1 D1 A1 D1 A1 D1 A1 F1 D1
A1 F1 D1 F1 F1 F1 F1 F1 F1

B

...C1 F1 G1 G1 C1 G1 C1 G1 G1 C1 G1 C1 G1 G1 G1 J2 C1 C1
C1 J1 G1 C1 C1 C1 G1 G1 G1 G1 G1 C1 G1 C1 C1 D1 A1 C1 F1
C1 F1 G1 F1 F1 G1 F1 F1 C1 F1 G1 B1 B1 G1 C1 G1 G1 C1 G1
C1 C1 G1 D1 C1 D1 G1 C1 G1 G1 C1 G1 C1 C1 G1 C1 G1 G1 C1
B1 G1 C1 G1 C1 G1 C1

Table 13.3. (A) A typical vocal exchange between Orky and Corky. Each alphanumeric code represents a sound type. Note that the exchange begins and ends with an 'F1' train. (B) A vocal exchange during an activity state with a high stress level. These sounds were recorded during the removal of a calf. 'G1' and 'C1' are considered stress indicators. Note that there is no 'F1' train terminating this exchange.

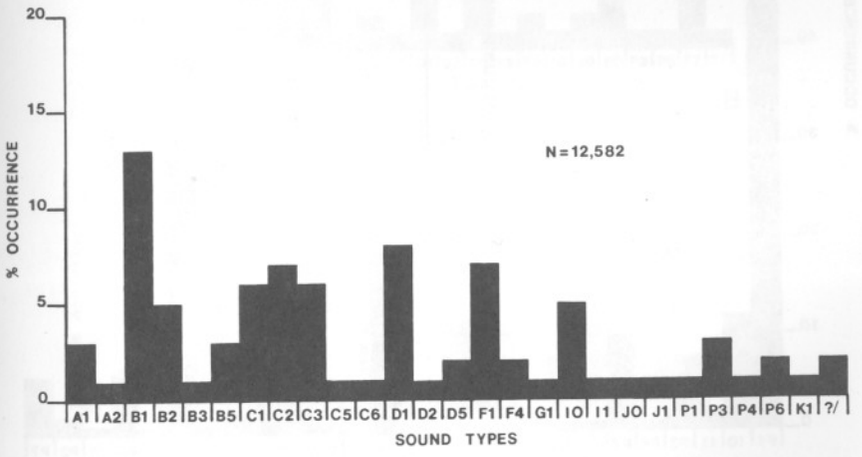


Fig. 13.6. Wild sound type distribution. This is the overall distribution of the 27 most common sounds used by the pods A1, A4 and A5 during the summers of 1979-1981. The computer code / indicates a sound too distant to recognize.

Finally, an orca recording made in the field during an attack on a colony of Steller sea lions, Eumetopias jubatus, is worth mentioning. Sound usage during this activity was dramatic (Fig. 13.9) although very few sound types were produced. A sound 'K1' (sonogram not included here) occurred but it may not have been an actual vocalization. It was an explosive sound probably produced by the quick fluke thrusts of the fast moving whales cavitating in the water. It is likely, therefore, that 'G5' (sonogram not included here) dominated sound

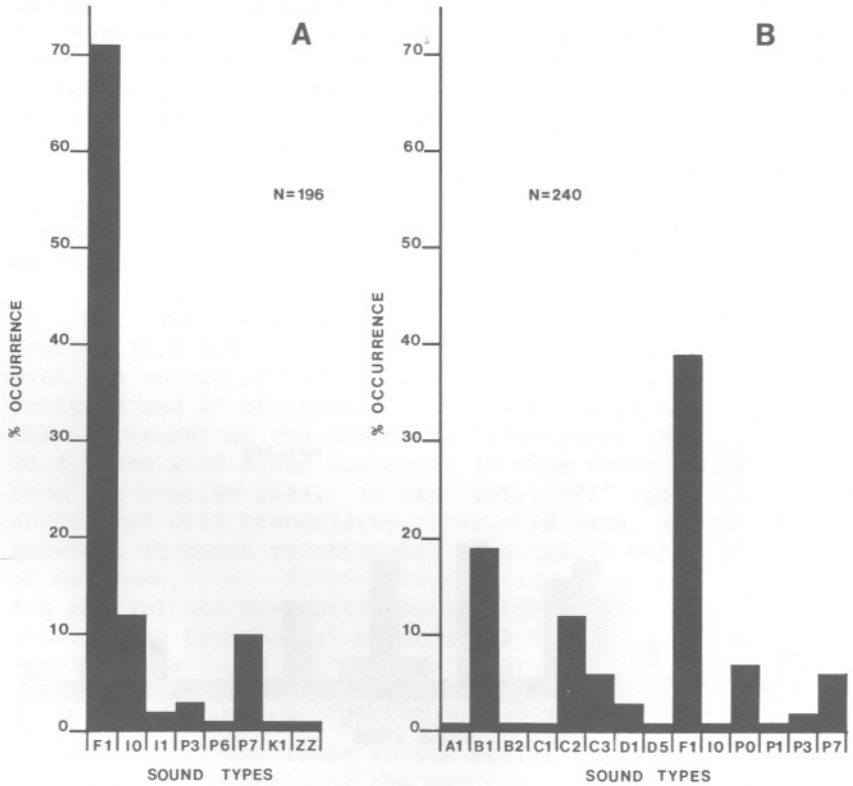


Fig. 13.7. Turning Around (A) and Post Birth Swim (B) are two activity states where the sound 'F1' is produced more often than any other sounds. Note that both of these activity states are characterized by behavioral synchrony.

production in the wild even more than is indicated from the data (Fig. 13.9). In the captive data the 'G' series was associated with the loss of a calf. The difference in the activity state between that situation and a Steller sea lion attack is appreciable. The only obvious parallel between them was the high level of excitement manifested by the whales.

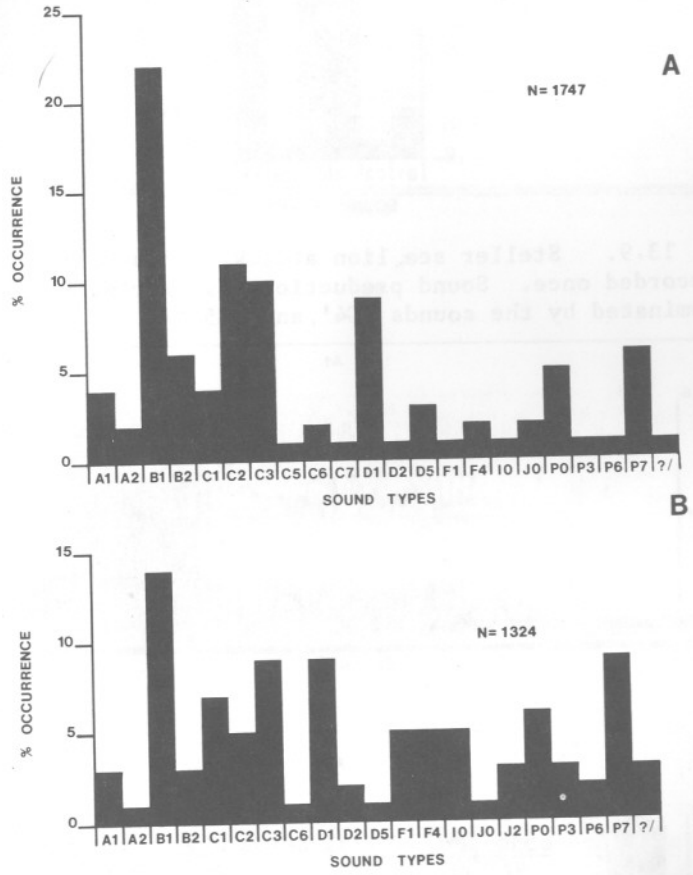


Fig. 13.8. Two activity states (A) Milling; Slow, and Long Submergences and (B) Rubbing on Gravel in which the sound 'B1' is the most frequently occurring. Both are considered "pleasurable" activities, where Milling is associated with feeding and Rubbing on Gravel presumably feels good.

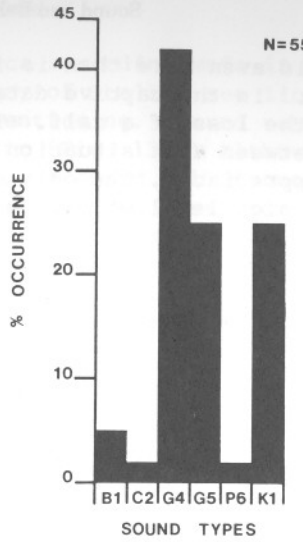


Fig. 13.9. Steller sea lion attack. This activity state was recorded once. Sound production was extremely specific, and dominated by the sounds 'G4' and 'G5.'

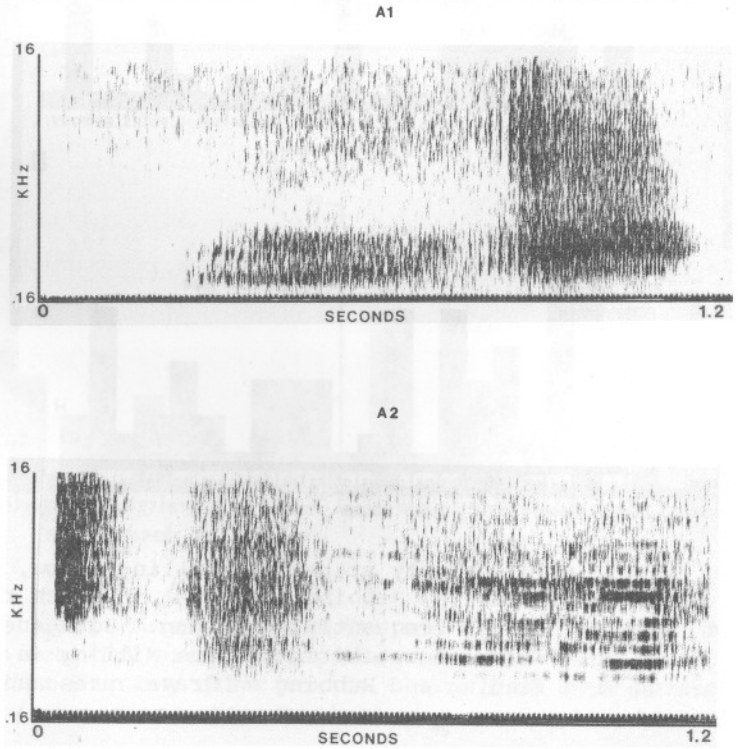


Plate 13.1. Sonograms for Orcinus orca vocalizations 'A1' and 'A2.'

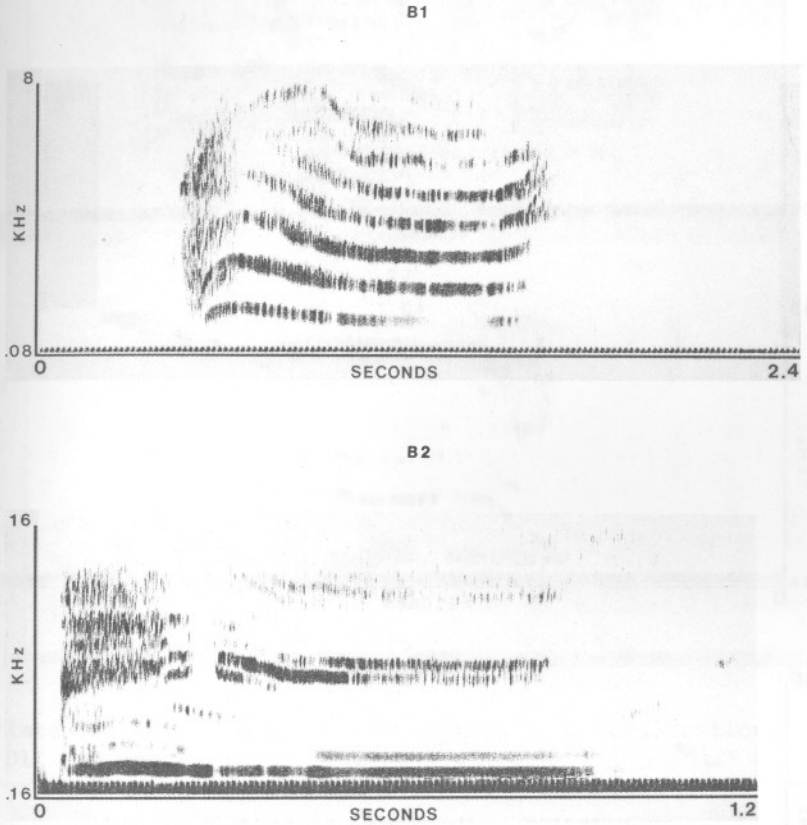
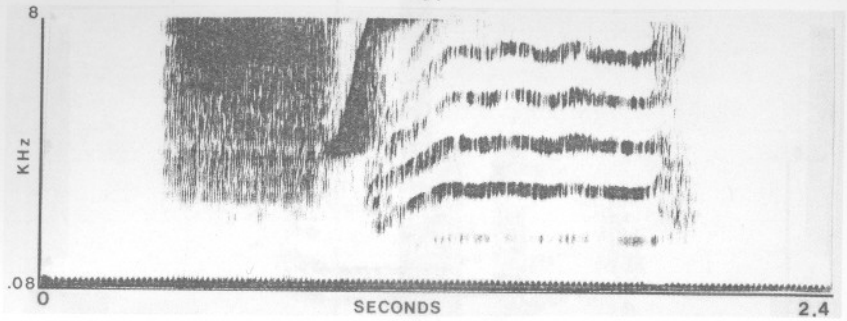
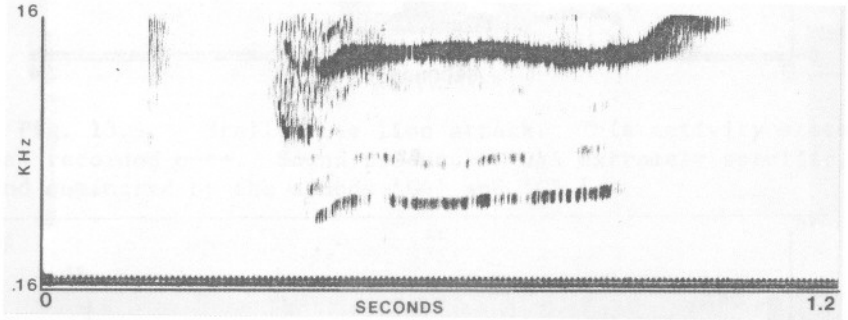


Plate 13.2. Sonograms for Orcinus orca vocalizations 'B1' and 'B2.'

C1



C2



C3

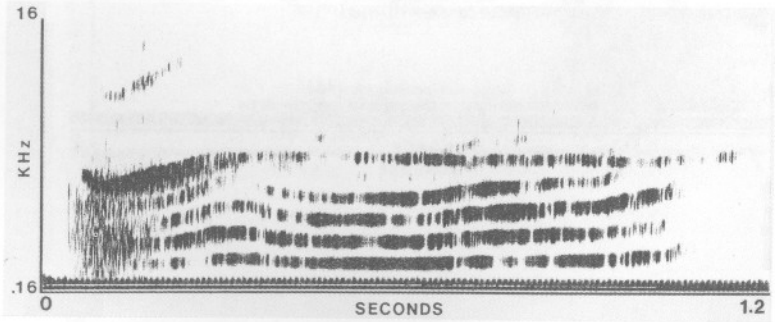
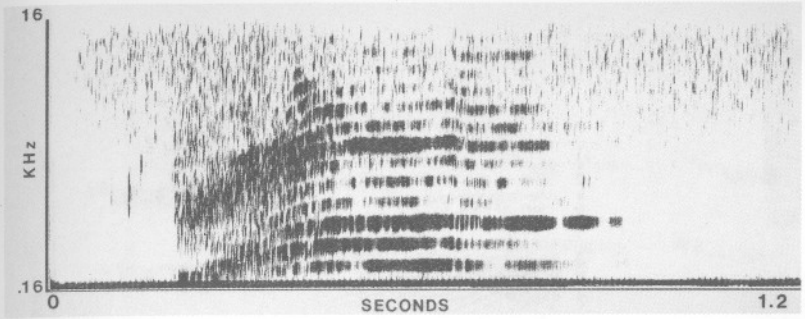


Plate 13.3. Sonograms for Orcinus orca vocalizations 'C1,' 'C2' and 'C3.'

D1



D3

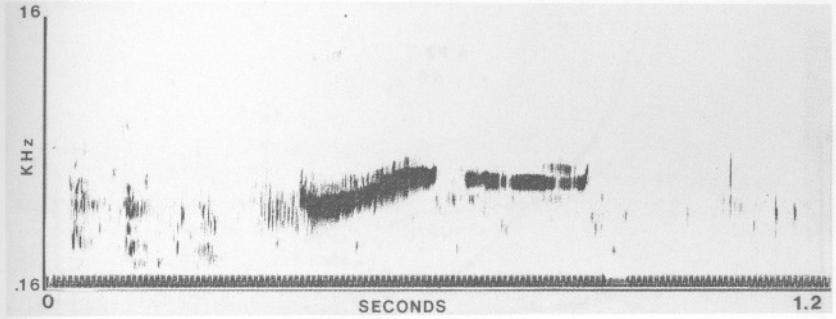


Plate 13.4. Sonograms for Orcinus orca vocalizations 'D1' and 'D2.'

E0

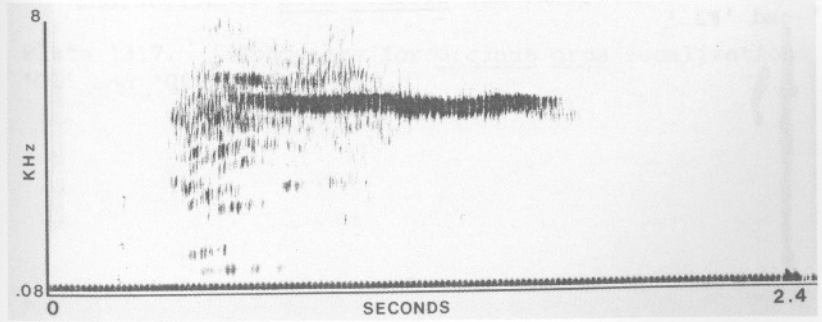
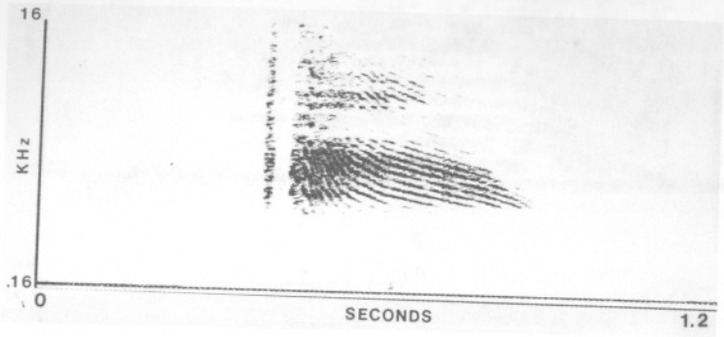


Plate 13.5. Sonogram for Orcinus orca vocalization 'E0.'

F1



F2

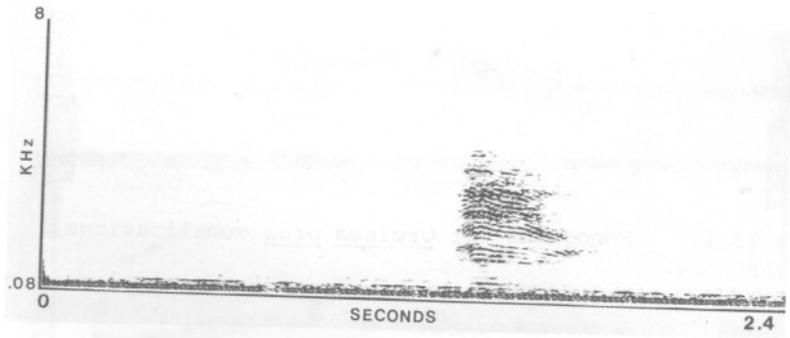
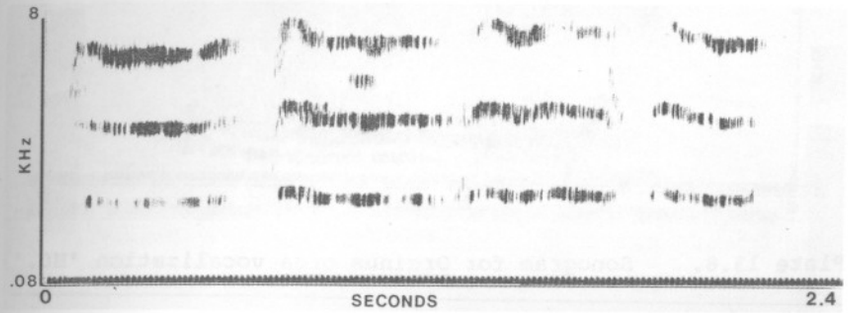


Plate 13.6. Sonograms for Orcinus orca vocalizations 'F1' and 'F2.'

G1



G2

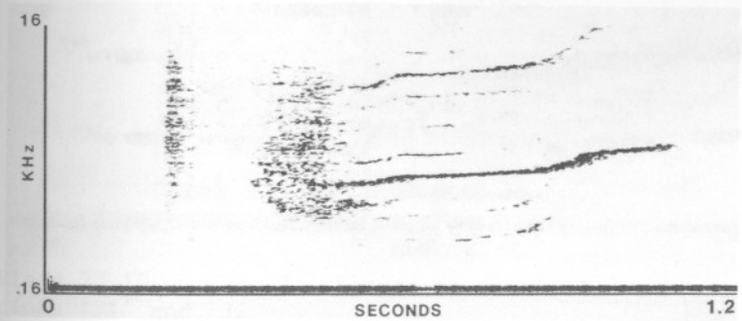


Plate 13.7. Sonograms for Orcinus orca vocalizations 'G1' and 'G2.'

H0

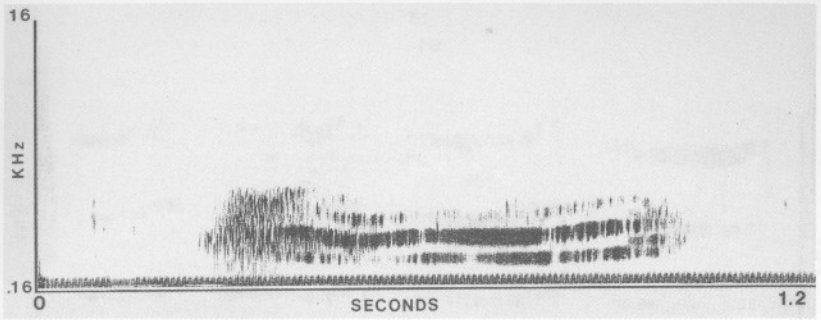
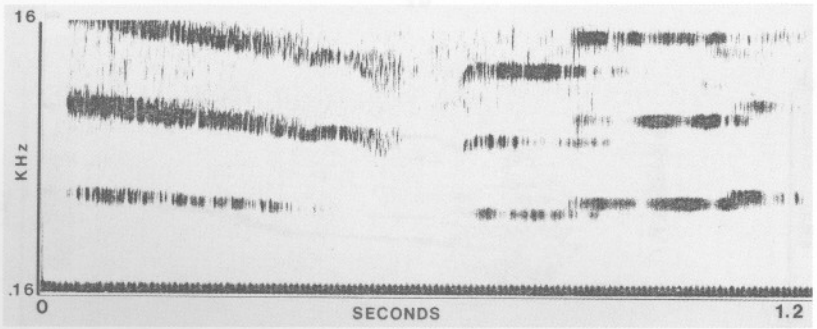


Plate 13.8. Sonogram for Orcinus orca vocalization 'H0.'

I0



I1

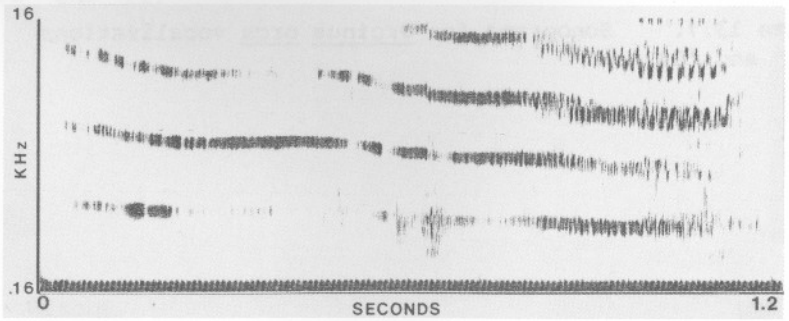
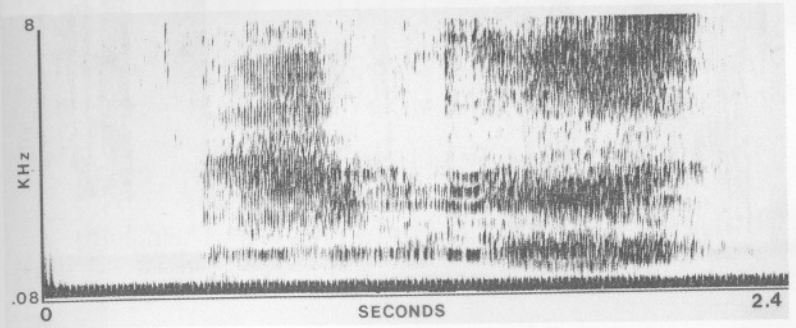


Plate 13.9. Sonograms for Orcinus orca vocalizations 'Iθ' and 'I1.'

J1



J2

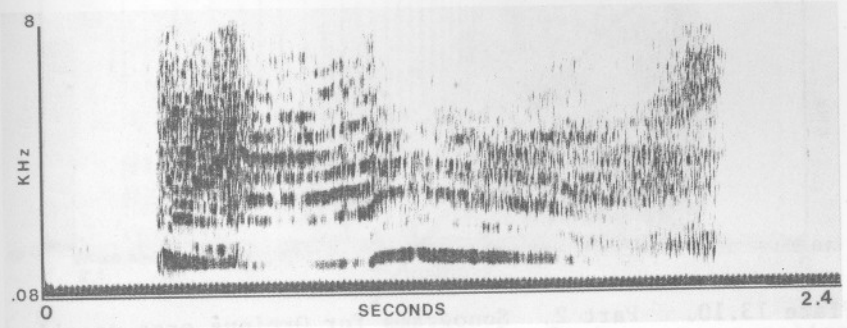
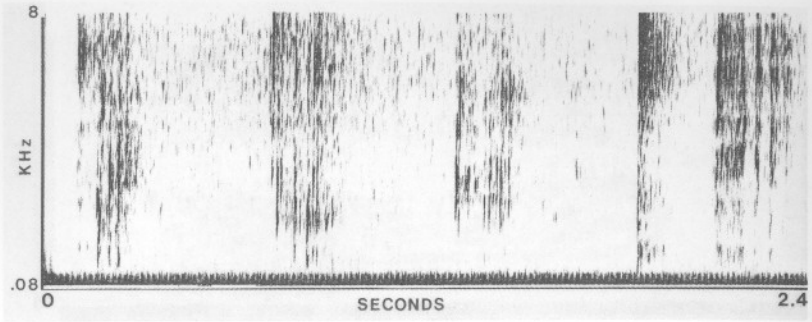


Plate 13.10. Part 1. Sonograms for Orcinus orca vocalizations 'J1' and 'J2.'

J3



J4

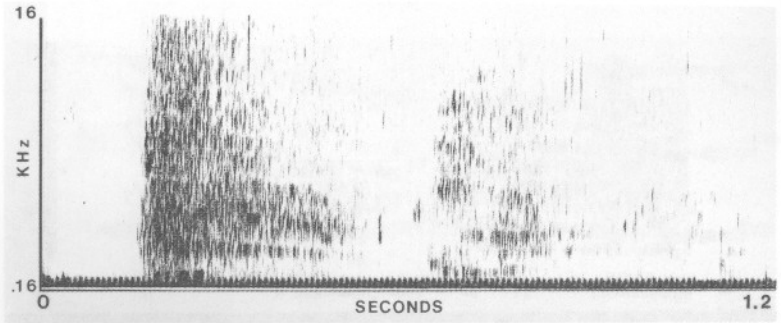
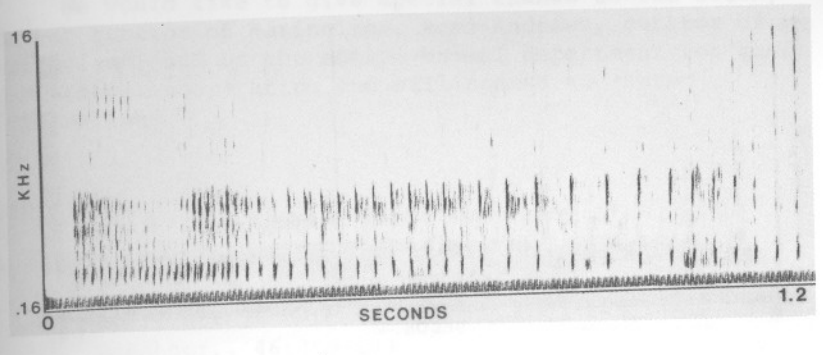


Plate 13.10. Part 2. Sonograms for Orcinus orca vocalizations 'J3' and 'J4.'

P0



P1

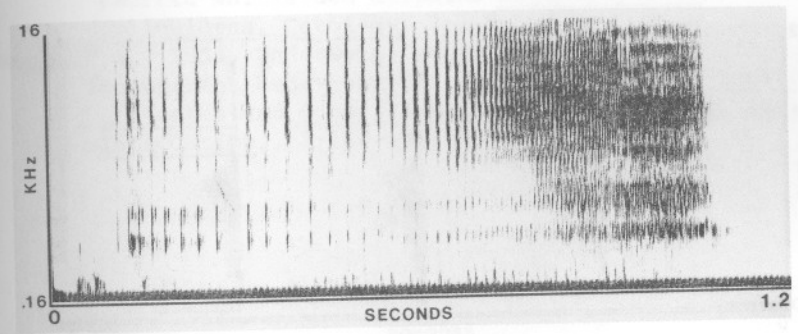


Plate 13.11. Part 1. Sonograms for Orcinus orca vocalizations 'P0' and 'P1.'

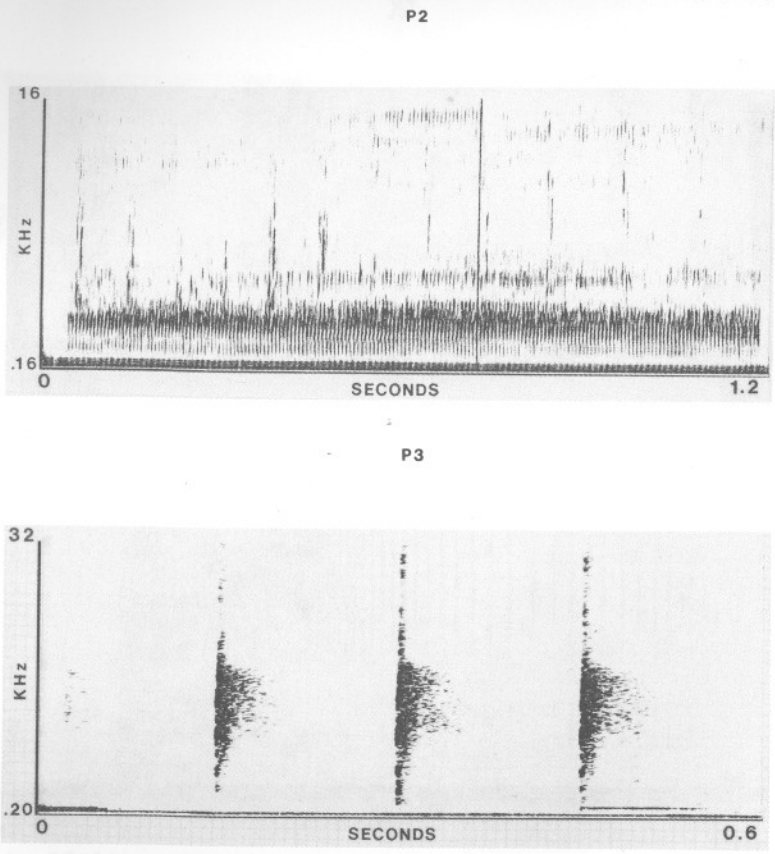


Plate 13.11. Part 2. Sonograms for Orcinus orca vocalizations 'P2' and 'P3.'

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