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Underwater Barking by Male Sea Lions (*Zalophus californianus*)

THE incessant, raucous barking in air by the California sea lion (*Zalophus californianus*) is well known. Wenz[1] presented sonograms of barks from *Zalophus* which were recorded during the breeding season by an underwater hydrophone at a depth of 360 feet, about 2 miles off the shore of San Clemente Island (60 miles from the coast of Southern California). These barks (like those recorded in air) were characterized by a rich harmonic structure, and an up–down–up frequency modulation, and sometimes terminated in a high upward sweep. Wenz thought that it was unlikely that these barks originated entirely in air and suggested that they were transmitted into the water by vibration of the submerged throat area while the sea lion's nose and mouth were in air.

Since the report by Wenz, several investigators have reported underwater barking by *Zalophus*[2–5] both in captivity and in the wild. Schevill *et al.*[4], in support of Wenz, noted that a single sea lion simultaneously emitted an airborne and a waterborne component of a series of barks while its head was in air and its body was submerged. Schusterman *et al.*[5] have occasionally recorded underwater barks while their animal was completely submerged with its mouth closed.

It had previously been suggested that underwater clicking sounds by *Zalophus* (hitherto thought to be their most prevalent underwater vocalization)[6] were related to locating food, which was accomplished by means of an active sonar system[7–10]. Whether the underwater acoustic signalling of *Zalophus* is primarily used for the detection and discrimination of food prey is still debatable[11–13]. On the other hand, there is a good deal of laboratory evidence indicating that the vocal repertoire of these animals under water is related to social communicative processes. For example, in one experiment the amount of underwater click vocalizations was as much as fifty-fold larger even in clear water when two sea lions swam together and interacted than when one sea lion swam alone[14].

During the breeding season (June and July) aerial barking is used extensively by *Zalophus* during episodes of territorial and sexual behaviour[15,16]. Such field observations along with laboratory experiments strongly suggest that the amount and types of aerial vocalizations are determined by age, sex and dominance status within the social hierarchy.

Table 1. AGE AND WEIGHT OF MALE CALIFORNIA SEA LIONS CONSTITUTING SOCIAL GROUP

Animal	Age (yr)	Weight (pounds)
G	6·5–7·5	434
M	6·5–7·5	401
W	4·5	220
N	4·5	195
P	4·5	192
S	3·5	156

During the breeding season of 1967 the social structure of a group of captive immature male *Zalophus* was manipulated[17]. Measures of aerial vocalization and attack behaviour were taken. Results showed that barking by larger males inhibited barking by smaller ones. Dominant males directed their barks and attacks at individuals next in line in the social hierarchy.

Barking by breeding males is at least partly a territorial vocalization in air and, because large areas of a bull's territory are submerged during high tide[15], the male *Zalophus* may produce barks more frequently than any other type of underwater vocalization, especially when interacting with other males. This hypothesis is also consistent with previous reports that the dominant males usually barked from a position within the pool[18]. Experiments to study this were begun in October 1968.

Two compounds were enclosed and separated from each other by a wire fence. Compound 1 was 7·6 × 13·7 m and contained a $3{\cdot}4^2$ m pool; compound 2 was approximately 10·7 × 13·7 m. The experimental technique was to modify group composition by removing and reintroducing individual animals into compound 1 and recording the number of vocalizations and attacks by 10 s or 20 s intervals on a time-ruled check sheet. Data were obtained from a group of six male *Zalophus* (see Table 1). Aerial and underwater vocalizations were continuously monitored and the signals were periodically recorded on a Uher 4000 tape recorder.

Throughout the 4 months of observations (October 1968–February 1969), both aerial and underwater vocalizations consisted almost exclusively of a series of barks: underwater clicks were recorded infrequently from three of the sea lions. The underwater barking of individual members of the group was compared with their aerial barking. No analysis of the acoustic structure of these aerial signals (Fig. 1) has yet been performed, but spectrographs suggest individual differences in the structure of the barks. These individual differences can also be identified by humans familiar with the signals. Older males emit signals of a more clearly defined harmonic structure than the younger ones. These signals are repetitive, have a rapid onset and often have a frequency range greater than 4 kHz. A series of barks in air can be

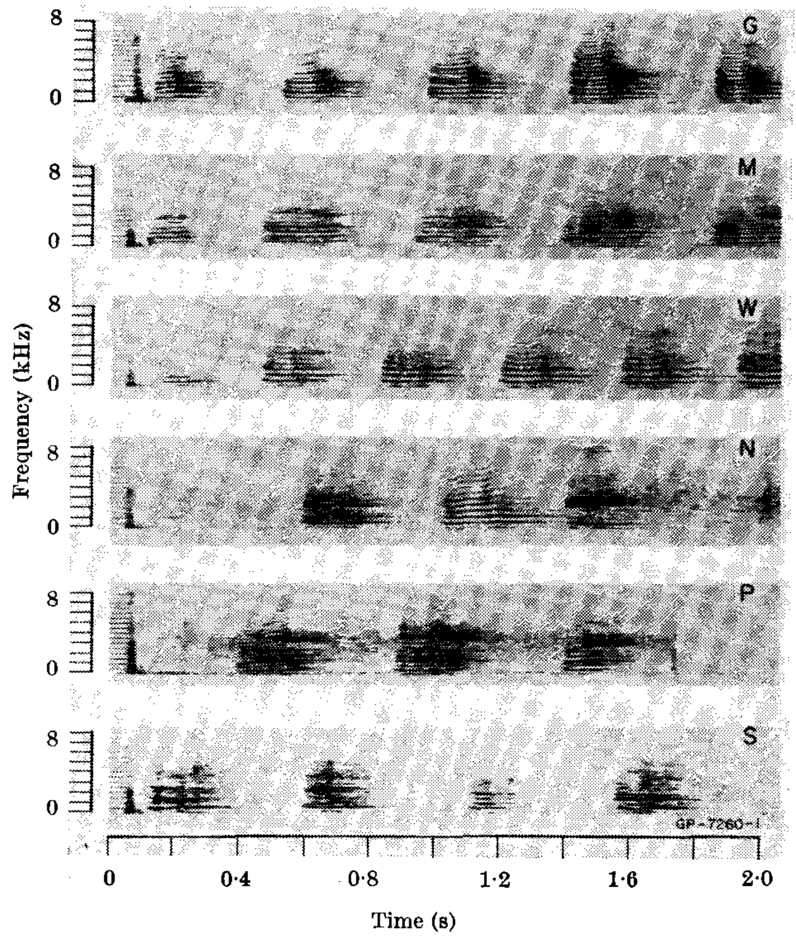

Fig. 1. Spectrographs of aerial barking by six male California sea lions during social interaction. The signals are extended in time because of reverberation.

readily localized in space by binaural detection of differences of intensity, phase and time of arrival, and contain information which may be related to individual recognition and most probably to class recognition.

As noted previously, the animals frequently barked with their heads in air and their bodies in the pool. We refer to these barks as "amphibious", because they can be heard simultaneously in air and under water. Fig. 2 contains spectrographs of barks emitted by each of the animals while they were positioned with body and neck in the pool and head in air. The recordings were made under water. No great difference is apparent between the structure of the barks emitted with the throat in water and that of barks recorded when the animal's head is in air.

Fig. 3 shows spectrographs of barks recorded under water when the animal was completely submerged. These underwater barks are not very different in structure from

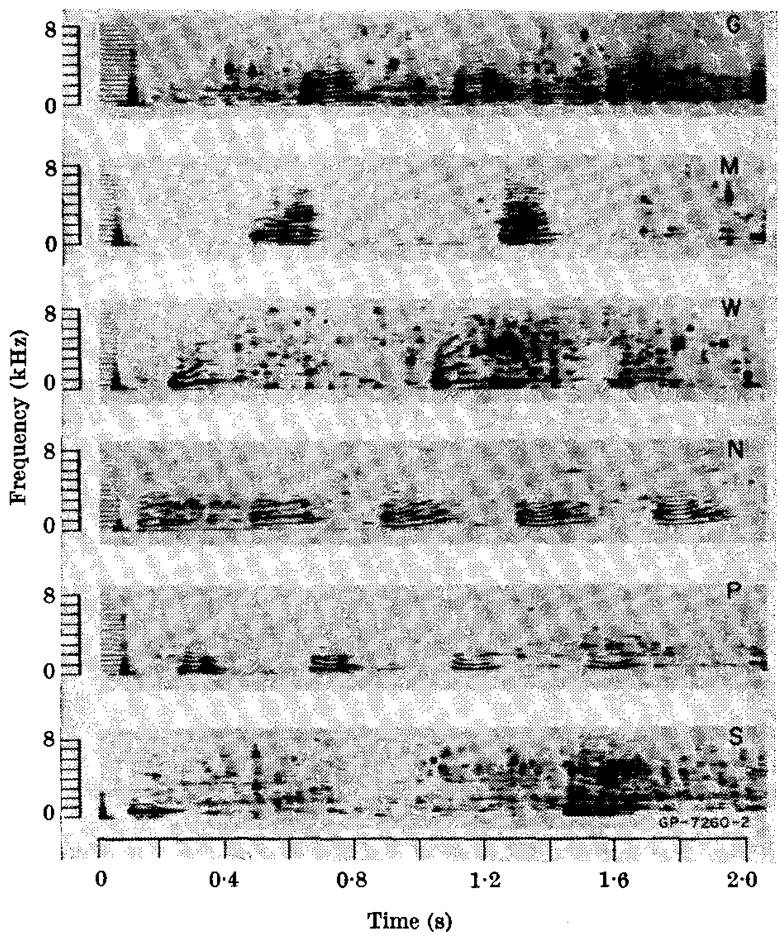

Fig. 2. Spectrographs of amphibious barking by six male California sea lions during social interaction. Recordings were made under water while the animals barked with their heads in air and their bodies submerged. The dark spots are produced by water turbulence.

those heard in air. Sea lion *W* shows a very definite sweep frequency in the two underwater barks. It is perhaps surprising that the structural characteristics of these acoustical signals are very nearly the same even though the sounds made in air are produced when the animal's mouth is open, while under water the animal's mouth is closed. Moreover, a series of barks under water can be localized just as readily as those in air, and they contain information related to individual and class recognition.

To determine to what extent these sea lions bark with their heads submerged, we computed the total number of 10 s or 20 s intervals from four 2 h observation sessions—chosen at random—in which each individual barked with its head submerged, and divided that figure by the total number of intervals during which the animal barked amphibiously. We also computed a total barking score: the number of intervals during which the animal barked

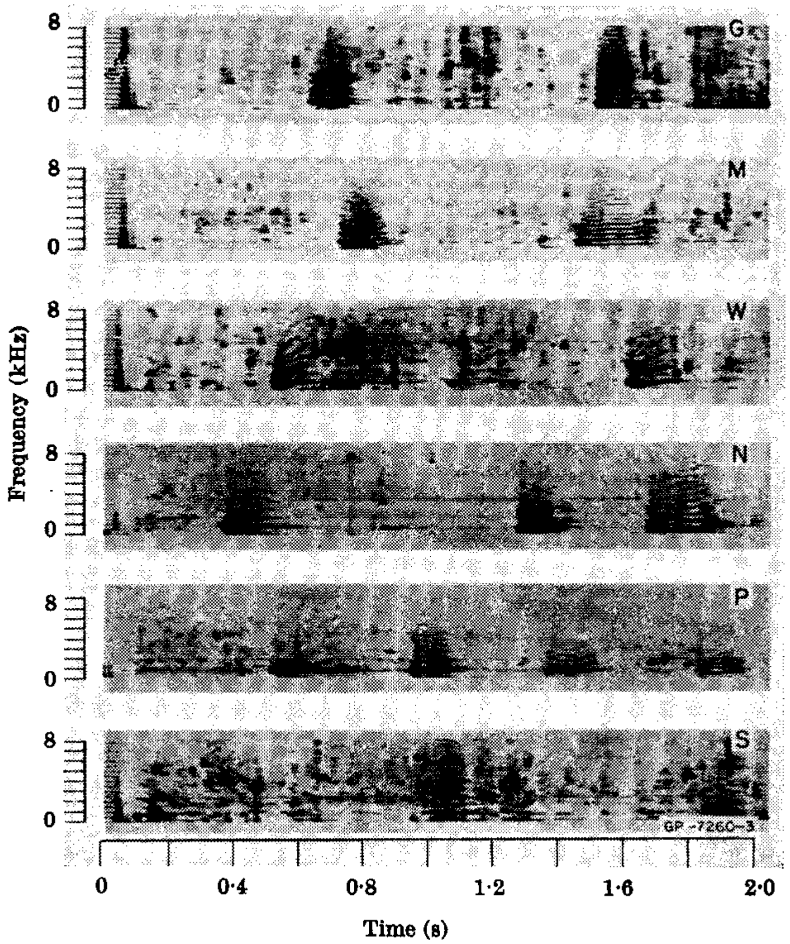

Fig. 3. Spectrographs of underwater barking by six male California sea lions during social interaction. The barks were emitted with the heads submerged.

whether or not it was in the pool. All these figures were obtained without considering the nature of the group composition. The following points emerge from this analysis (Fig. 4). First, in terms of total barking (aerial barking in or out of the pool—only rarely did an animal bark continuously while it was submerged), the animals fall into two distinct groups: the three largest males barked between 60 and 70 per cent of the time; the three smallest males barked between 20 and 25 per cent of the time. Second, five of the six sea lions barked mainly while they were in the pool, emitting amphibious signals much of the time. Third, approximately one-third of the total amphibious barking was underwater barking (average value for the six animals). When an animal submerged its head it would usually bark only a few times and then resurface. The typical situation was for the animal to bark amphibiously, then submerge and bark under water, resurface and bark amphibiously, and so on.

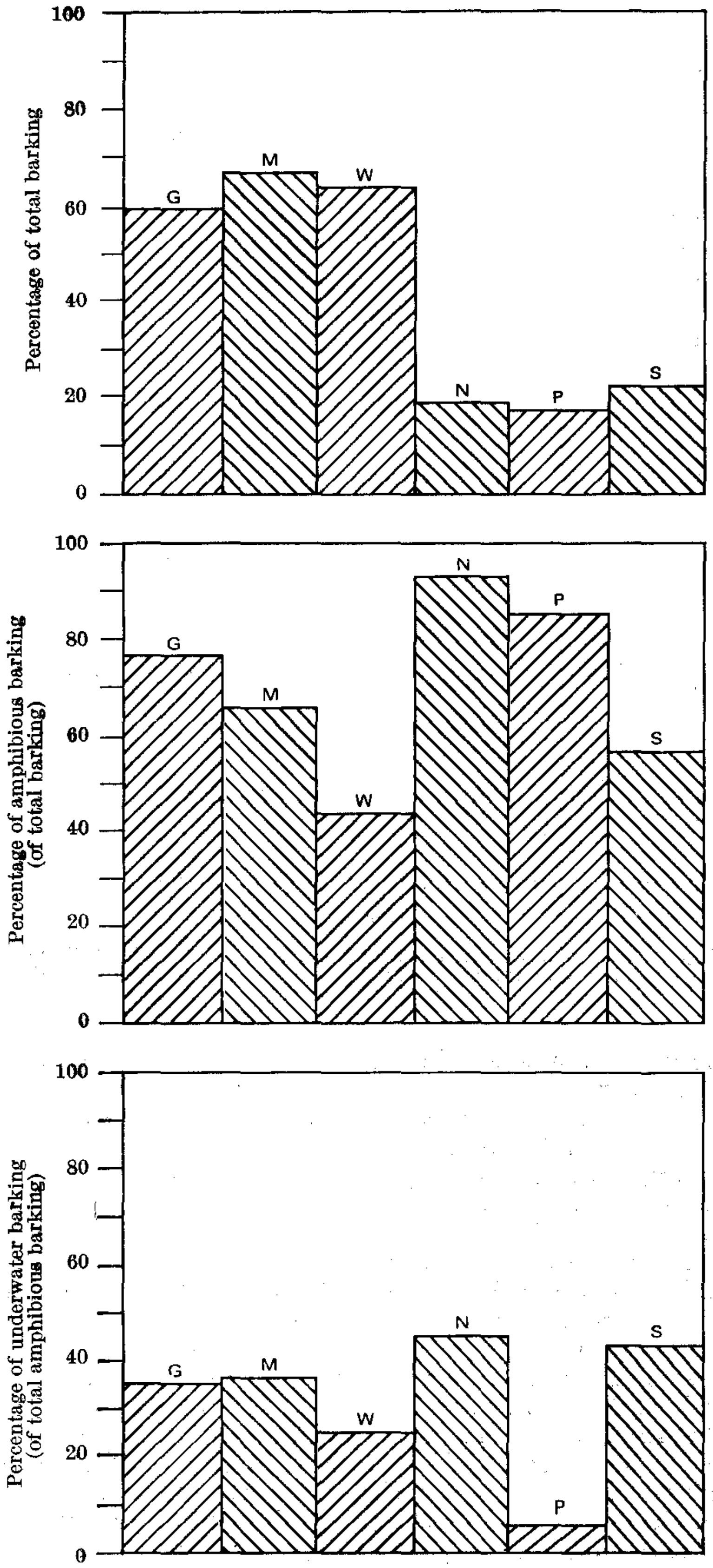

Fig. 4. **Amount of aerial, amphibious and underwater barking by six male California sea lions in a social group.**

The present results taken in conjunction with both field[15,16] and laboratory observations[17,18] support the hypothesis that barking by *Zalophus* is probably the most widespread underwater vocalization by the male of this species and that these signals serve the same function under water as they do in air, namely, as territorial and dominance displays which tend to decrease overt physical aggression.

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