with another goal object present usually followed an extensive amount of opportunity to display the initial behavior pattern. We found that the more opportunity an animal has to exhibit a specific "stimulus-bound" behavior, the longer it may take for a new pattern to emerge.

A number of experiments demonstrated that animals exhibiting "stimulus-bound" eating, drinking, or gnawing have much in common with animals under the influence of natural drives such as those induced by deprivation. Animals will work to obtain appropriate goal objects and appear willing to tolerate aversive stimulation, such as shock or quinine additives, in order to obtain the desired objects (*2*). However, the fact that in our experiment animals that were "stimulus-bound" drinkers appear just as motivated to obtain food, for example, raises the question of whether thirst and hunger motives are involved at all (*5*). Apparently, there is considerably more plasticity in establishing connections between hypothalamic circuits and motivated behavior than commonly advanced interpretations of "stimulus-bound" behavior suggest.

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4. The electrode tips were located in neural sites previously reported to yield "stimulus-bound" behavior. The electrode tips of animals 60S and 61S were located in the zona incerta dorsal to the fornix, and the electrode tips of animals 74S, 80S, and 89S were located in the dorsal part of the lateral hypothalamus. No histology is available for 63S due to dislodgement of its electrode pedestal.
5. Animals that were switched from "stimulus-bound" drinkers to "stimulus-bound" eaters have been observed to eat the dry pellets in the absence of water almost to the point where they appeared to be choking.
6. Supported by NIH grants M-4529, career scientist award MH-4947, and research grant NsG-437 from NASA. We thank Laura Lande and Debra Singer for assistance.

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# Vocalization of Naive Captive Dolphins in Small Groups

Abstract. *Pure-tone whistles (2403) by four individual dolphins* (Delphinus delphis bairdi) *were analyzed for duration and the elapse of time before either response by another animal or a repeat whistle by the same animal. Only five major types of whistle emissions were recorded, all stereotyped and each characteristic of the animal emitting it. Only one of the four animals emitted two different whistles, one of which was rare and both of which were stereotyped. A pure-tone chirp and pulsed sounds are discussed. We found no evidence of a dolphin "language," but we present evidence of social response to acoustic signals.*

Many of the small toothed whales have two types of sound emission or phonation (*1*): a pulsed or broad-band "click" type that is emitted in both echo-ranging and emotional contexts, and a narrow-band or pure-tone "whistle" type that is emitted characteristically only in emotional contexts.

There are strong indications that the Atlantic bottlenosed dolphin *Tursiops truncatus* (Montagu) has a primary "signature" whistle, characteristic of the individual emitting it, that constitutes at least 90 percent—occasionally almost 100 percent—of any individual's whistle repertoire (*2*). We postulate that this signature whistle may serve primarily to identify its source for the other members of the community.

Many *Tursiops* with which we have worked for as long as 3 years have never changed this basic whistle contour in any major way other than by repetition of the same whistle without a pause in time. A few, however, have at least one different but stereotyped whistle. Thus we believe that any study of cetacean communication that deals with the transfer of information by way of the whistle should begin with this important individualized signature whistle and its minor variants. This and other whistle contours (if any) may then be investigated in straightforward biological terms of age, sex, and physiological condition of the animal, rather than by initial efforts to construct a dolphin "language." Hitherto the latter approach has been commonly pursued with *Tursiops* (*3*) and currently is being used by other workers in studies of different odontocete cetacean species.

Analysis of the pure-tone whistles from a group of common dolphins indicates that this species also has a mechanism of a primary signature whistle characteristic of the individual. We report primarily a time-and-contour analysis (*4*) of 2403 whistles emitted by four common dolphins [*Delphinus delphis bairdi* (Dall)] captured together off Los Angeles, California. Recordings (*5*) and observations of the small, brightly-colored, possibly immature individuals, one male and three females, were begun 2 days after capture. Initially the animals whistled loudly and in frequent bouts. After 34-day captivity and removal of a female, both the loudness and frequency of occurrence of sound emissions were reduced; recordings were discontinued on day 34.

Among the 1424 whistles of the initial four-animal group, only five whistle contours were recorded (Fig. 1, A–E); all whistles were virtually constant within themselves in contour shape, duration, and frequency modulation (*5*). Contours 2 and 5 (Table 1) were apparently emitted by the same animal, as they were the only two whistles that never were emitted simultaneously; all other animals showed a strong tendency to "chorus" (*6*) or to the elicitation of a whistle from a second animal before cessation of the whistle by the first. We have therefore designated contour 5 a secondary whistle of what is arbitrarily termed animal 2; it constituted only 6 percent of all whistles emitted by this animal. We interpret the faint indication of

Table 1. Analysis of 2403 whistles by two groups of captive eastern Pacific common dolphins (*Delphinus delphis bairdi*). Group 1 comprised four dolphins; group 2, three of the same four. Percentages appear in parentheses.

| Contour | Average duration (sec) | Whistles (No.) by: Group 1 | Whistles (No.) by: Group 2 |
|---|---|---|---|
| 1 | 0.87 | 544 (38.2) | 0 |
| 2 | .79 | 626 (44.0) | 295 (30.1) |
| 3 | .87 | 95 (6.7) | 448 (45.8) |
| 4 | .85 | 139 (9.8) | 199 (20.3) |
| 5 | .83 | 20 (1.4) | 37 (3.8) |

contour 5 (which shows slightly in Fig. 1B although it was completely inaudible) as further evidence that these two contours were emitted by the same animal. We postulate that the animal either did not or could not completely repress its secondary whistle when it emitted its primary whistle. The whistles were recorded at various hours of the day under various conditions. This secondary whistle was recorded only once apart from several times during a competitive-feeding episode, and a number of times after several minutes of exposure to strange objects. This whistle cannot be regarded as aberrant, because it was also nearly constant within itself.

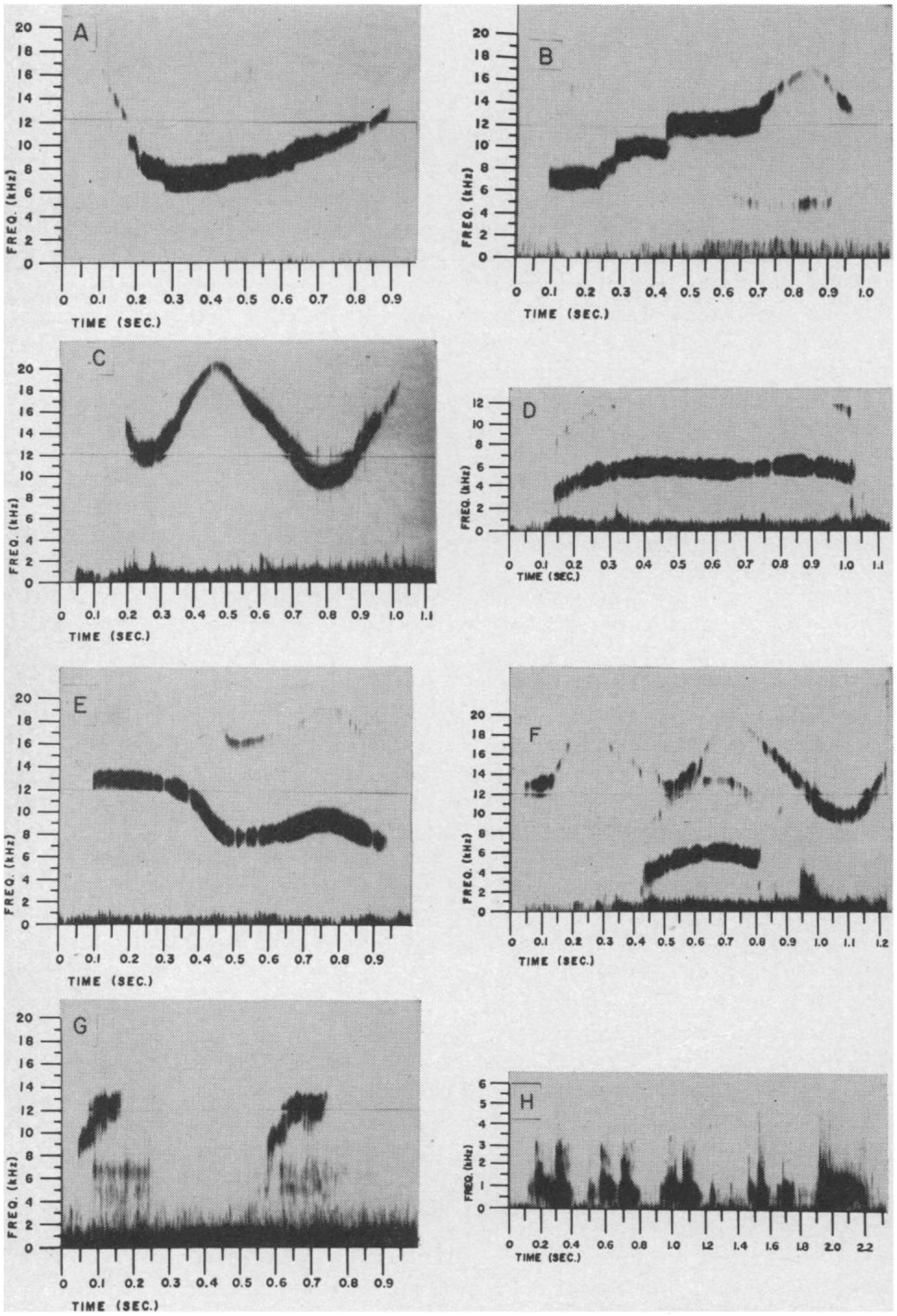

Fig. 1. Captive common dolphins: Sound spectrograms (sonagrams) of pure-tone whistles and chirps and of pulsed sounds emitted in apparent emotional contexts. (A) Whistle contour 1; (B) whistle contour 2; (C) whistle contour 3; (D) whistle contour 4; (E) whistle contour 5 (secondary whistle contour of animal emitting contour 2); (F) example of inhibition of production of contour 4 (0.41 to 0.8 second) by simultaneous whistle of animal making contour 3 (0.41 to 1.2 seconds), both apparently responding to whistle of individual making contour 2 (last portion shown, from 0 to 0.4 second); (G) chirp overlaid by pulsed emissions; (H) burst-pulse "barks." Horizontal lines in sonagrams A–C and E–G at 12 khz are artifacts.

After a female was removed from the group, the prominent contour 1 was eliminated, although 979 later whistles were analyzed (Table 1). As the female was a vocal animal the overall number of whistles was expected to diminish. Moreover, the responses to the female's whistles were eliminated, so that some insight was provided into the observation that "as the size of the group increases, the number of phonations per animal per hour tends to increase geometrically rather than arithmetically" (*5*).

Two opposing tendencies in whistling are demonstrated in analyses of the data on time versus contour: The most obvious is excitation of a whistle, or response, by one or more animals after another animal's whistle (*1*); the second is a strong tendency toward inhibition of the response until after termination of the first animal's vocalization. Figure 2, A and B, shows the interval between the onset of a given whistle and the onset of a whistle by a different animal; because the number of whistle responses decreased so rapidly after the 4 seconds that followed onset of the first animal's emission, only whistles during these 4 seconds are shown. Ninety-four percent of all whistles by a second animal occurred within the 2 seconds following onset of the first animal's vocalization. Close coincidence of the strong peak at 0.8 and 0.9 second with the 0.84-second average duration of all five types of whistle emissions indicates the frequent onset of the second animal's whistle on termination of that of the first animal.

Response to the stimulus of another animal's emission may be frequent, however, before termination of the first animal's emission. A response during the interval between 0.8 and 0.9 second frequently resulted in chorusing. However, there was also inhibition of one animal's whistle by the simultaneous, or nearly simultaneous, initiation of a whistle by a different animal. When in the three-animal group whistles were initiated within 0.3 second of each other, one or other of the animals always became silent; when initiations were separated by between 0.4 and 0.5 second, one or other became silent 44 percent of the time (Fig. 2B); but, with separations varying between 0.6 and 0.7 second, one animal was silenced only 4 percent of the time. Thus it was between 0.6 and 0.7 second after initiation of a whistle that chorusing became most evident.

The two animals emitting contours 3 and 4 (Fig. 1F) responded simultaneously to termination of another's whistle (contour 2); the simultaneous response began at 0.41 second, and at 0.8 second contour 4 abruptly terminated, rather than extending the normal duration. Two percent (46) of all analyzed whistles showed this abrupt cutoff; all but one occurred when two animals responded almost simultaneously to a known outside stimulus.

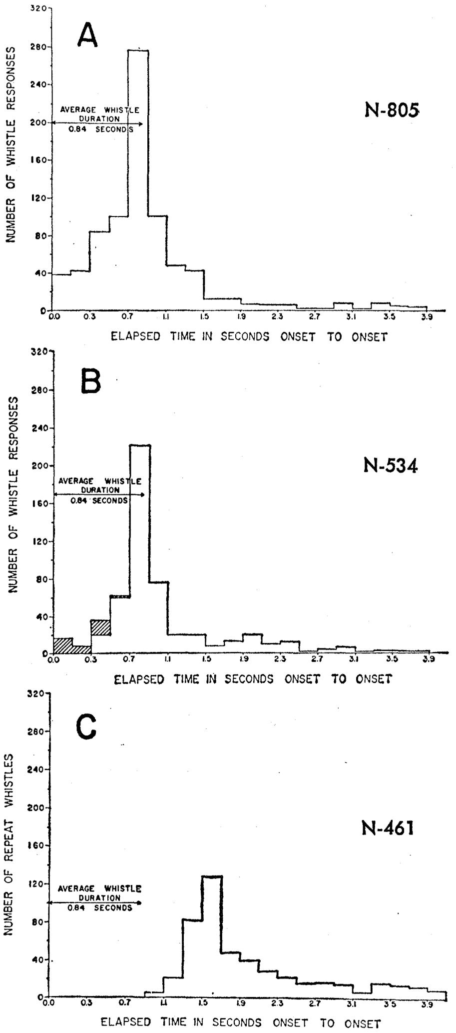

Fig. 2. Captive common dolphins. (A) Time intervals between initiation of a whistle by one individual and elicitation of a whistle from a second individual; taken from analyses of whistles by a group of four. (B) Same; taken from analyses of whistles made by a group of three of the original four; each crosshatched area indicates number of times that one of the two remaining animals abruptly terminated its normal (fully contoured) whistle. (C) Time intervals between signature whistles repeated by same animal; graph represents only whistles that either were repeated or had not elicited an intervening response within 4.1 seconds.

The animal emitting contour 3 accounted for 61 percent of the cutoffs, while the two highly vocal animals emitting contours 1 and 2 accounted for only 9 percent each. Thus differences appear in this aspect also of *Delphinus* vocal behavior: some individuals tend to defer more readily than others.

Whistles were frequently repeated without an intervening response by another animal. A mode is apparent between 1.6 and 1.7 seconds from onset of a whistle to onset of a repeat emission (Fig. 2C). This finding signifies a modal value of about 0.8-second delay before a whistle is repeated, because the average duration was about 0.84 second. Seventy-nine percent of all repeat whistles occurred within 1.7 seconds of termination of the preceding one.

Almost all small toothed whales that we have investigated emit in addition to contoured whistles a brief pure-tone chirping sound, usually with a short, sharp upsweep. This sound was emitted in frequent bouts by the *Delphinus* when first captured; it was usually accompanied by emission of a pulsed sound of a soft, grating quality (Fig. 1G). At times the chirp was omitted and rapid "barking" bouts ensued (Fig. 1H). Each "bark" was a burst-pulse sound similar to those made in emotional contexts by other odontocetes (*5*). All these sound emissions became most constant prior to feeding and ceased completely after feeding—usually for about 1 hour. Pulsed sounds of the click-train type, shown to be used for echolocation by two other species of small odontocetes (*1*), accompanied feeding.

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4. The continuous analyses of time versus whistle contour were based on several episodes ranging from 15 minutes to 2 hours in duration. Recorded time (real time) was expanded by reduction of the tape speed to either 1/8 or 1/16 the recorded speed, depending on complexity of the vocal activity. Durations of whistles and intervals between them were then measured with a stopwatch and reconverted to real time. Contour analyses were done by ear at 1/8 real time and periodically checked by sound spectrograms. Whistle durations are averages based on a random sample of 40 of each of the five types of whistle.
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## Enforcing Insecticide-Content Water Quality Standards

In his recent article (*1*), Nicholson proposed the establishment of (i) "minimum detectable limits for selected chlorinated hydrocarbon insecticides" and (ii) "10-percent depression in acetylcholinesterase concentration in fish brain" as water quality standards for "point source discharges."

The analytical methods suggested for enforcing these standards are unsuitable. The effective and equitable enforcement of the suggested criteria would be most difficult.

In acetylcholinesterase inhibition studies, values of less than 20-percent inhibition are considered unreliable. As Nicholson reports, the threshold lethal value is 40-percent inhibition. An inhibition range of 20 to 40 percent would be too narrow for monitoring purposes. More important, however, no suitable source of *control* fish brain (0-percent inhibition) is suggested.

As to the chlorinated insecticides, the minimum detectable limits of these compounds are, by definition, at the limit of sensitivity of the method. This screening technique could lead to many false "positive" results, especially from pesticide-manufacturing plants, since the "electron capture" detector is so nonspecific and so highly sensitive. Perhaps Nicholson does not realize how restrictive the proposed standards would be: a plant, for instance, produc-