

Behavioral Responses and Habituation of Pinnipeds and Small Cetaceans to Novel Objects and Simulated Fishing Gear With and Without a Pinger

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Abstract

Marine mammals are vulnerable to entanglement in nets and lines. To quantify their interactions with fishing gear, pinnipeds and small cetaceans were exposed to novel objects and simulated fishing gear in a zoological environment at SeaWorld San Diego. The objects included a line, a frame covered with gillnetting, and a pinger. Exposures were delivered using a baseline-exposure protocol, documenting naïve responses and using repeated trials to measure habituation or sensitization. Responses to objects paired with the pinger differed strikingly from others, stimulating behaviors consistent with aversion in all species. Among pinnipeds, harbor seals (*Phoca vitulina*) left the test pool or touched the pinger-associated object less often, although some eventually manipulated it extensively. California sea lions (*Zalophus californianus*) reacted initially with avoidance, defensive, and agonistic behaviors. However, they quickly returned to baseline activities and readily took fish from pingered nets. Northern elephant seals (*Mirounga angustirostris*) reacted the least. Among the cetaceans, bottlenose dolphins (*Tursiops truncatus*) and a Pacific white-sided dolphin (*Lagenorhynchus obliquidens*) did not manipulate the objects but made fast investigative or agonistic passes near them. Jaw claps and surface-active behaviors were most common during pinger trials. Commerson's dolphins (*Cephalorhynchus commersonii*) responded particularly strongly. Counts of some defensive or agonistic behaviors differed dramatically in the presence vs absence of the pinger, including bows (70 vs 0), roostertailing (117 vs 0), and fluke slaps (76 vs 2). Across seven trials, avoidance time in a refuge pool rose to > 90%, indicating sensitization. However, pinnipeds startled through gillnetting, and Commerson's dolphins charged it deliberately in spite of the pinger. Based on these

experiments, it is more likely that pingers reduce entanglement by arousing aversion than by warning marine mammals to avoid a hazard.

Key Words: net alarm, pinger, fishing gear, entanglement, gillnet, behavior, neophobia, aversion, habituation, sensitization, agonistic behaviors, pinnipeds, small cetaceans

Introduction

Entanglement of cetaceans and pinnipeds in fishing gear and marine debris has become a significant cause of mortality worldwide (Žydelis et al., 2009). The most recent effort to estimate global marine mammal losses was based on bycatch data from U.S. fisheries, estimating a take of over 650,000 marine mammals annually, split roughly equally between pinnipeds and cetaceans (Read et al., 2006). In U.S. waters, gillnets were the greatest cause of bycatch for both taxa (Carretta et al., 2004; Read, 2005), but they were also commonly entangled in lines (e.g., float lines). California sea lions (*Zalophus californianus*), the Pacific harbor seal (*Phoca vitulina richardii*), and harbor porpoises (*Phocoena phocoena*) were identified as vulnerable.

A number of gear modifications to reduce bycatch have been tested in the last two decades, including acoustic net alarms or "pingers" (Kraus et al., 1997). However, the use of pingers has been controversial (Dawson et al., 1998; Kraus, 1999), and there is little information about the details of interactions between marine mammals and fishing-gear generally. There is some consensus that small cetaceans are capable of detecting nets as long as they are alert, within echolocation range, and actively emitting clicks (Hatakeyama & Soeda, 1990; Au & Jones, 1991; Au, 1994; Hatakeyama et al., 1994). However, small cetaceans often become entangled. Phocoenids and

small delphinids specialized for high-frequency echolocation appear to be particularly vulnerable (Dawson et al., 1998). Failures may occur in darkness or when not echolocating (Akamatsu et al., 1994), but there are other possibilities (Cockcroft, 1994). They may detect nets but fail to recognize them as a barrier; they may become entangled while engaged in other distracting activities; or they may deliberately interact with nets.

Little is known about the neurophysiology of response to novelty in marine mammals. In terrestrial mammals, a novel or unexpected stimulus triggers the defensive cascade, a series of neuroendocrine and behavioral events (Lang et al., 1997) adapted for short-latency defense and information gathering. Animals focus their attention on the source (orienting response), with concurrent physiological changes (e.g., arousal, release of catecholamines). They often experience wariness or mild fear, leading to precautionary avoidance (neophobia). If the onset of the stimulus is acute, they may experience a startle or other intense defensive response (Turpin, 1986), which can be triggered at latencies too short (~50 to 300 ms) for significant cognitive involvement (Ekman et al., 1985). These short latency reactions are aversive and habituate poorly at high stimulus amplitudes (Scourse & Hinde, 1973; Thompson et al., 1973; Davis, 1997).

Behaviors in the defensive cascade can indicate the intensity of an animal's initial perception of danger, but they are poor predictors of outcome over longer periods. Cortical involvement is initiated in the first few hundred milliseconds as animals attempt to obtain more information. Whether they approach or investigate from a distance depends on species-typical sensory-motor strategies (Petrinovich, 1973). Frightening, novel, or unexpected stimuli can stimulate close-range investigation (Wong & Bowles, 1976; Cooper, 2008), often with defensive agonistic gestures such as threats or simulated attack (Caro, 1995, 2005). Following investigation and cognitive evaluation of the stimulus, animals can choose many possible strategic responses such as escape, attack, playing dead, habituation, sensitization, or persistent avoidance. The strategy they adopt is often intelligent and flexible depending on context. For example, pinnipeds are known to ignore intense deterrents to take food from fishing nets (Shaughnessy et al., 1981). Observations of interactions with gear are needed to determine which behaviors are most likely to result in entanglements.

Studies under controlled conditions can provide detailed information about interactions with fishing gear unavailable under free-ranging conditions (Jefferson et al., 1992; Perrin et al., 1994; Jefferson & Curry, 1996). The program described here exposed naïve pinnipeds and small cetaceans at SeaWorld San Diego to novel enrichment objects

and simulated fishing gear with or without pingers to obtain detailed observations of behavior.

Materials and Methods

In Phase I of the study, February to August of 1995, naïve marine mammal subjects were exposed to a variety of novel enrichment devices (*novel object trials*). Trials began with single exposures to observe naïve responses (*naïve trials*). Some objects were then presented repeatedly to observe change over time (*habituation trials*). The results of Phase I trials were used to design Phase II experiments, February 1997 through July 1998, using simulated fishing gear more like real lines and nets (*simulated fishing gear trials*). Pingers were attached to test objects in both phases.

Because motivation to feed was likely to be an important modulator of response, supplemental trials exposed California sea lions to fish in nets during Phase II (*motivational state trials*). California sea lions were selected as subjects for these experiments because the species is known to become entangled frequently (Read et al., 2006), and it preys on nets in the presence of deterrents (Shaughnessy et al., 1981; Mate & Harvey, 1987). Also, a relatively large group of potential subjects was available at SeaWorld.

Subjects

The subjects were pinnipeds and cetaceans in SeaWorld's permanent collection and stranded pinnipeds in the last stages of rehabilitation. Dolphin calves less than 1 y of age and pinnipeds less than 6 mo of age were not included in the design due to concerns about handling in the event of an experimental entanglement.

Novel Object Trials—The subjects (Table 1) were three stranded, rehabilitated juvenile female Pacific harbor seals; four juvenile to subadult California sea lions; three bottlenose dolphins (*Tursiops truncatus*); and three Commerson's dolphins (*Cephalorhynchus commersonii*). The bottlenose dolphins were wild-born, long-term SeaWorld residents older than 20 y (2 females, 1 male). All three Commerson's dolphins were males—two collected as subadults a decade earlier and one subadult born at SeaWorld.

The first three species are representative pinnipeds and small cetaceans, and they are susceptible to entanglement in their own right (e.g., Read et al., 2006; Stolen et al., 2007). However, bottlenose dolphins are large enough to escape entanglement reasonably often. Therefore, a smaller, more vulnerable species was tested as well. Commerson's dolphins were the smallest cetaceans available and shared characteristics with other species known to be especially susceptible to fatal entanglement, the Hector's dolphin

Table 1. Summary of pinniped and cetacean subjects in Phase I novel object trials

Species (trial type)	Subject groups	Trial blocks	Trial type (experiment day)					Animal/ trials
			Buoy	Buoy/pinger	Net	Board	Barrel	
Harbor seal	PV1* ♀ j, st	3	2	3	3	2	1	11
	PV2 ♀ j, st	3	3	3	3	2	2	13
	PV3 ♀ j, st	3	3	3	2	2	1	11
California sea lion	ZC1* ♀ j, st (focal)	2	2	2	2	2	--	8
	ZC/CU2 ♂ sa, st [‡]							
	ZC3 ♂ j, st							
	ZC4 ♀ j, st	2	2	2	2	2	--	8
Commerson's dolphin	CC1 ♂, a, w, sw	3	3	3	3	--	--	9
	CC2 ♂, a, b, sw (focal)							
	CC3 ♂, a, b, sw (focal)	3	3	3	3	--	--	9
Bottlenose dolphin (TT1, TT3 & TT6 were tested together)	TT1 ♂, oa, w, sw (focal)	3	3	3	--	--	--	6
	TT3 ♀, oa, w, sw (focal)	3	--	--	3	1	--	4
	TT6 ♂, oa, w, sw (focal)	1	1	--	--	--	--	1

Notes: Species codes: CC = *Cephalorhynchus commersonii*, TT = *Tursiops truncatus*, PV = *Phoca vitulina*, ZC = *Zalophus californianus*, and ZC/CU = *Z. californianus/Callorhinus ursinus* hybrid. Codes for age/sex class and animal origin: j = juvenile, sa = subadult, a = adult, oa = old adult, st = stranded, w = collected from wild, sw = long-term collection at SeaWorld, and b = bred at SeaWorld. In the listing for a group, "focal" refers to the subject of detailed behavioral observations. [‡] One of the group members was a California sea lion/northern fur seal hybrid that could not be separated from the other subjects; this animal was not treated as a focal subject.

(*C. hectori*) and the harbor porpoise (Dawson, 1994; Kastelein et al., 1995), including small size, vulnerability to predators, and high-frequency echolocation (Evans et al., 1988; Kastelein et al., 1993).

Simulated Fishing Gear Trials—The six harbor seal subjects (Table 2) were stranded, rehabilitated juveniles (4 males, 2 females) and were naïve to the experimental protocol. Four had been at SeaWorld for at least 6 mo, and two were recently rehabilitated. The five focal California sea lions were part of a pool of 17 drawn from the communal beached animal exhibit at SeaWorld and were tested with other sea lions in groups of one to three. Composition of trial groups was not randomized due to dominance relationships among individuals, but group composition was changed between blocks of trials, with a focal animal selected for each block.

The eight northern elephant seal (*Mirounga angustirostris*) subjects were recently stranded, rehabilitated juveniles. They were tested in four groups: a male and female tested singly in a smaller quarantine pool and two groups of three to four seals of mixed sex tested in holding pools at the beached animal exhibit.

Seven bottlenose dolphins and one Pacific white-sided dolphin were tested. They were long-term residents at SeaWorld ranging in age from 9 to approximately 40 y of age. Three were born at SeaWorld, and the rest had been collected or rehabilitated several decades previously. All were naïve to the experimental protocol.

Motivational State Trials—Twelve California sea lions that had not been focal subjects were tested. Of the 12, three were males (0.5 to 15 y) and nine were females (0.75 to 24 y). All but one were born in an oceanarium, and all had been housed together for months to years.

Test Objects

Gillnet pingers (Dukane/Seacom Netmark 1000 net alarms) were used for the experiments, with nominal specifications of 130 dB re: 1 μ Pa RMS sound pressure level (SPL), 10 to 80 kHz, and 400 ms duration pings every 4 s. One was a production model and the other a test model that had been configured for delayed ping onset. Marine mammals at SeaWorld do not receive sounds for enrichment, but they are familiar with tones used as training signals, and they hear a variety of human-made sounds incidental to park operations.

Table 2. Summary of pinniped and cetacean subjects in Phase II simulated fishing gear and motivational state trials

Species (trial type)	Groups exposed	Animal trials			Total animal trials (groups)
		Net	Net/pinger	Buoy line	
Harbor seal (naïve/habituation)	4 ♀ j, st (single) 2 ♂ j, st, sw (pair)	30	30	19	79 (5)
California sea lion (naïve) [†]	1 ♂ a, b, sw; 1 ♀ oa, w, sw; 7 ♀ j, st, 4 ♂ j, st ; 1 ♂ j, st, 1 ♀ j, st; 2 ♀ j, st	15	14	2	27 (5)
(motivational state) [‡]	1 ♀ oa, w, sw; 8 ♀ a, b, sw ; 1 ♂ oa, b, sw; 1 ♂ j b, sw; 1 ♂ a, b, sw	29	34	1	64 ([†])
Northern elephant seal (naïve/habituation)	1 ♂ j, st; 1 ♀ j, st, 3 ♂ j, st; 2 ♀ j, st, 1 ♂ j, st; 1 ♀ j, st	9	9	0	18 (4)
Commerson's dolphin (habituation)	1 ♀ a, w, sw, 1 ♂ a, w, sw, 1 ♂ j, b, sw	17	16	11	44 (1)
Pacific white-sided dolphin (naïve)	1 ♀ a, st, sw	1	1	1	3 (1)
Bottlenose dolphin (naïve)	PWS ^{††} ♀ a, st, sw, 2 ♀ a, w, sw; 2 ♂ a, b, sw; 3 ♂ a, b, sw	8	8	2	18 (3)

Notes: PWS = Pacific white-sided dolphin (*Lagenorhynchus obliquidens*). Codes for age/sex class and animal origin: j = juvenile, sa = subadult, a = adult, oa = old adult, st = stranded, w = collected from wild, sw = long-term collection at SeaWorld, and b = bred at SeaWorld. [†]Compositions of individual groups for sea lion naïve and motivational state trials are not broken out by group because groups were changed for every trial block; codes indicate the age/sex composition of the subjects only. ^{††}The Pacific white-sided dolphin was always tested with the first bottlenose dolphin (*Tursiops truncatus*) group; she is included as a nonfocal subject in this row.

Two classes of objects were tested. In Phase I, subjects were exposed to objects like those normally used for environmental enrichment at SeaWorld, consisting of a barrel, a piece of plastic construction netting on a frame, a plastic cutting board with 5-cm holes drilled through it, and a lobster-pot float with a short section of line (Figure 1). The float was tested with and without an attached pinger.

For the simulated fishing gear trials, investigators collaborated with SeaWorld staff to design two objects that were more realistic models of fishing gear: (1) a line with a float and anchor and (2) a length of gillnet on a frame (Figures 2a & 2b). These objects allowed subjects to engage in behaviors very similar to those that would cause entanglement in the wild. Gillnetting was weakened with a pair of dykes to make it part easily in the event of contact, while the line was cut to the core to ensure that it would break if an animal became wrapped in it. These measures were effective. No pinnipeds or cetaceans experienced injuries in the course of the experiments, despite occasional brief entanglements.

For simplicity, the plastic net was used during motivational state trials. It was paired with the

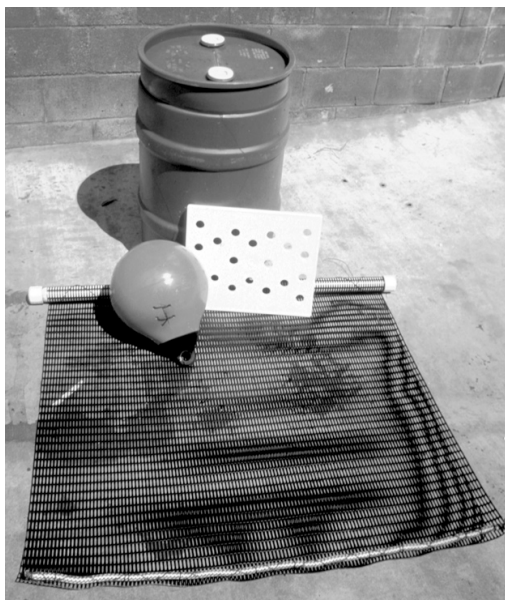


Figure 1. Net, float, board, and barrel objects used for novel object trials

test model pinger, modified with a switch that activated in seawater with a 14-min delay. This allowed behaviors in the presence of the silent pinger to be observed before ping onset.

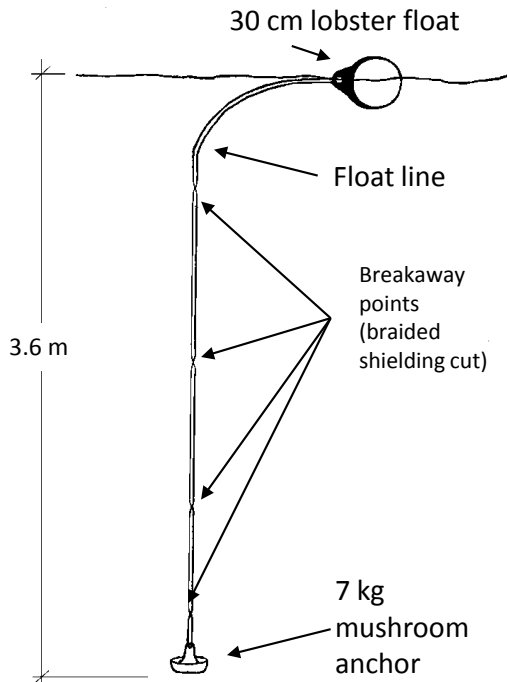


Figure 2a. Design of float line object for simulated fishing gear trials (model for pinniped experiments)

Test Spaces

Experimental subjects were familiar with the test pools, and all had access to a refuge during trials. Cetaceans were given access to a small refuge pool, while pinnipeds were tested where there was ample hauling-out space. Pinnipeds were tested in off-exhibit and beached-animal holding pools of varying size, but all were big enough to allow subjects to swim around the 1.5 m × 1.5 m pinniped gillnet easily. The primary test space for California sea lions in simulated fishing gear and motivational state trials was an off-exhibit holding pool at SeaWorld's beached animal exhibit, 7 m × 4 m × 3 m deep. Bottlenose and Pacific white-sided dolphins were tested in groups in two off-exhibit holding pools (~11 m × 11 m × 3 m deep) with access to a refuge pool 4 m × 4 m × 2 m deep. The Commerson's dolphins were tested in an exhibit pool with underwater viewing, 13 m × 13 m × 4 m deep. They had access to a refuge pool 5 m on its longest side × 1.5 m deep.

Acoustic Measurements

Quantitative measurements of ping characteristics were collected from the production model pinger at three stations in the largest pool available, the exhibit pool in the Commerson's Theatre. Data were collected 1 m from the pinger, 2 m from the pool wall, and in the refuge pool. Pings were collected with a B&K 8103 hydrophone and 2635 charge amplifier on a Racal Store 4D recorder running at 30 ips (system bandwidth 20 Hz to 200 kHz). For comparison, a few measurements

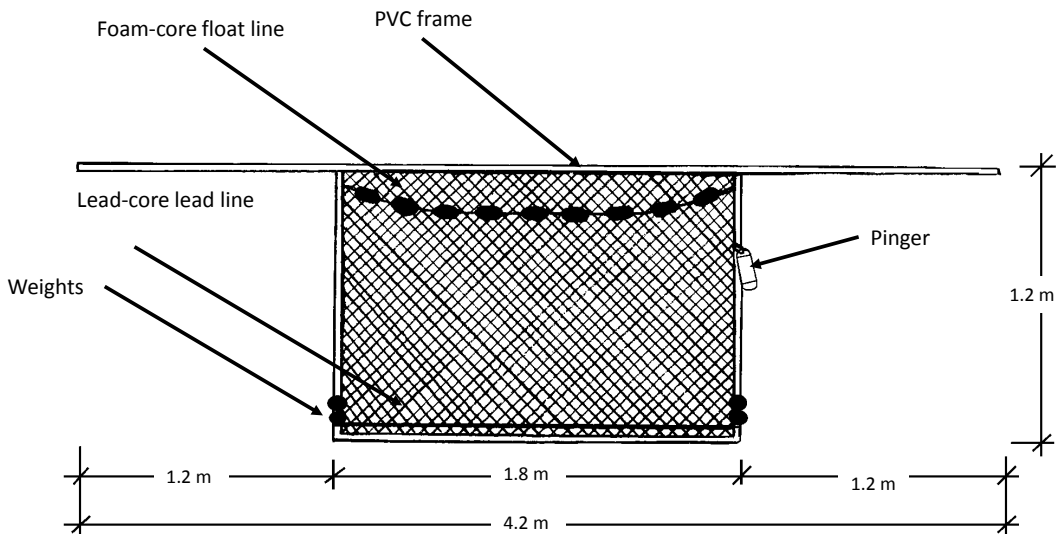


Figure 2b. Design of gillnet object for simulated fishing gear trials (the object for the Commerson's dolphin [*Cephalorhynchus commersonii*] trials is used as an example)

were also collected in smaller pools 1 m from the pinger.

To monitor vocal responses and ensure that pingers were functioning correctly, underwater audio recordings were also collected during pinniped pinger trials and for all trials with cetaceans. They were made using an ITC 6050C hydrophone with a custom-built amplifier connected to a Nagra IV-SJ tape recorder (system bandwidth 50 Hz to 45 kHz) or a Sony TCD-7 DAT recorder (system bandwidth 50 Hz to 20 kHz). Ultrasonic signals were recorded on a second channel with the B&K 8103 signal passed through an ultrasonic "bat" detector (Westec) to make the signals audible to the human ear.

When collecting quantitative acoustic measurements, the hydrophone was introduced directly into the pool on a pole at least 2 m from the wall and midway down in the water column. For monitoring during trials, hydrophones were introduced in 20-cm diameter Lexan tubes anchored to the poolside. Quantitative acoustic analyses were made with a Spectral Dynamics SD380 spectrum analyzer.

Experimental Procedures

All experimental trials were conducted using a baseline-exposure protocol. Objects were grouped into blocks within each trial series, with a single presentation of all objects constituting one block. Presentation order was balanced across blocks during the initial novel object trials, but when it became clear that the naïve response to the pinger could be substantially different and potentially negative, subjects with little experience in human environments were sometimes exposed to objects without the pinger first (these cases are indicated in the results).

Temporary separations are a normal husbandry practice at SeaWorld. When pinniped subjects were tolerant of isolation, they were tested alone. Otherwise, they were tested in small groups. Cetaceans were always tested in familiar social groups. They were allowed to move freely throughout the baseline period. During object introduction, subjects were distracted by SeaWorld Animal Care staff by calling them to the poolside for a brief feeding. After the object was introduced, subjects were allowed to move freely again for the remainder of the exposure period. In the event of a serious entanglement, SeaWorld Animal Care staff were always available to rescue the subject according to a pre-arranged plan.

During both baseline and exposure periods, behaviors of a focal individual were recorded on audio or video and observed in real time by at least one person. Overhead video was used to monitor the relative positions of all animal(s) and the test

object. Another one to two observers collected supplementary observations, managed equipment, coordinated interactions with SeaWorld Animal Care staff, and controlled deployment of objects.

Novel Object Trials—Novel object trial blocks began with exposures to all objects. However, responses to the board, barrel, and float without the pinger proved to be relatively similar. Therefore, the trial series was later simplified to focus on the float, float/pinger, and net, the objects most like fishing gear. One naïve trial with each object was planned, followed by two habituation trials. During each trial, subjects were observed for a 1-h baseline and 3-h exposure period. The long exposure periods were designed to allow animals to become familiar with the objects. The results were used to determine optimal trial length for Phase II.

Pinnipeds: To minimize disturbance, no humans came into the test area during pinniped trials except briefly when the test object was introduced. All on-site monitoring was conducted on video or from a location where observers were not visible to the subjects (ethogram in Appendix A1). Pinnipeds were monitored with a Canon L-1 camera mounted over the test pool to allow both behaviors and the relative positions of animals and object to be determined, with data recorded on a Panasonic 6024AG battery-operated video recorder at 5 frames per second (fps). During a number of these trials, a second channel of video was added using a Deep Sea Power and Light color underwater camera mounted in a protective housing. These data were used to obtain more detailed descriptions of interactions with objects.

Commerson's Dolphins: Commerson's dolphin trials were conducted in an exhibit pool with underwater viewing. Those individuals not in the test pool during experiments were kept in adjoining holding pools where they could see and hear some activities in the test pool, but they were not exposed directly. Test objects were introduced into the pool on a rope from overhead.

Video was collected with an overhead camera suspended 8 m above the pool. It was a high-resolution CCD that covered over 90% of the pool surface. Video was collected on a 400-line Toshiba time-lapse video recorder at 5 fps. A grid of bright yellow ropes was suspended between the camera and the pool, producing a grid on video. The Commerson's dolphin behaviors were also recorded through the underwater viewing windows using a handheld Sony TR101 Hi-8 video camera. Spoken observations and the mixed audio track from the hydrophones were recorded on this camera.

Bottlenose and Pacific White-Sided Dolphins: Dolphin behaviors were also collected from

overhead using the CCD camera and Toshiba time-lapse recorder, but there was no underwater viewing. Two poolside observers were positioned on opposite sides of the pool. One described behaviors onto the voice track of the DAT recorder, while the second monitored equipment and recorded behaviors as a backup for the primary observer. They were stationed far enough from the pool to eliminate disturbance but were able to detect behaviors selected for the project ethogram reliably (Appendix A2). One focal individual was selected for each trial block.

Simulated Fishing Gear Trials—The simulated fishing gear trials were conducted after a hiatus of 6 mo. Most subjects had not previously been exposed to the study protocol (Table 2). Based on the novel object trials, the majority of responses could be characterized in the first 30 min of exposure. Therefore, nearly all simulated fishing gear trials were shortened to 30 min of baseline and 30 min of exposure.

All subjects were tested in naïve trials, but habituation trials were conducted as availability of subjects and pools allowed. During habituation trials, subjects were exposed until responses became constant. Note that this definition of “habituation” does not require a return to the baseline condition. Subjects could retain some responsiveness or even become sensitized. A series of habituation trials was terminated when (1) responses ceased to change for two or more trials, (2) when animals were moved for husbandry reasons, or (3) when project and SeaWorld Animal Care staff stopped the trials for the subjects’ well-being. Trials were conducted in blocks, and every effort was made to finish a block once started. For a subset of trials (e.g., harbor seal habituation trials, northern elephant seal trials, California sea lion motivational state trials, bottlenose/Pacific white-sided dolphin trials), the delayed-onset pinger was used.

Stranded and rehabilitated northern elephant seals were only available for simulated fishing gear trials and were only tested with the gillnet and gillnet/pinger (Table 2). None had ever been exposed to novel objects as enrichment devices. As a precautionary measure, elephant seal groups were presented with the gillnet alone during the first trial. Also, because they were not included in initial novel object trials, simulated gear trials with elephant seals were extended to 1 h.

California Sea Lion Motivational State Trials—The motivational state trials represented a refinement of simulated fishing gear trials. They were conducted with 12 California sea lion subjects from the same pool of 17 animals from November 1996 to June 1997 (Table 2). These experiments were designed to clarify the influence of activity and social grouping on interactions with the pinger. The subjects included

eight sea lions selected because they were tolerant of isolation (group size = 1).

An in-depth description of the experiments can be found in Anderson (2000). Effects on behavior resulting from exposure to the pinger are summarized here. Procedures were generally the same as for simulated fishing gear trials. The underwater color camera was used to collect details of responses under water.

The net and net/pinger were always presented in consecutive trials, balanced so that half the subjects received the net the first day, and half received the net/pinger (14-min delayed-onset). The net was deployed from a box by triggering a door remotely, removing the distraction of human intrusion. Trials consisted of a 30-min baseline period and 30-min exposure. In net/pinger trials, total trial duration was 75 min to allow for 30 min of data to be recorded after the pinger with the onset delay activated.

Group trials were conducted in the morning for logistic reasons (availability of staff to manage multiple animals). The order of conditions was randomized across animals and every effort was made to replicate each block of trials six times. The interval between trials for any given sea lion varied due to logistic and husbandry constraints, ranging between 3 and 8 d.

Eight trials were conducted using a net with fish attached, four with the pinger, and four without the pinger. Fish were taken from the sea lions’ daily food supply (*Clupeia* spp. and small scombrids) and attached loosely to the plastic net immediately before the trial.

Data Reduction, Management, and Analysis

Data Reduction and Management—Videotapes were scored by four trained observers using the ethograms given in Appendix A. The ethogram was limited to behaviors that could be identified reliably by multiple observers. The lead observer (RCA) supervised all trials and was responsible for training inter-observer reliability. Agreement was high—90% or better after training.

Quantitative analysis was primarily based on focal animal samples. Data were scored during trials and from videotape using *The Observer*, Version 2 (Noldus) and the ethograms in Appendix A. Observers collected counts of brief behavioral events, such as jaw claps, and durations of states such as synchronous swimming. Observers scored event times, beginning and end times of states, and modifiers (e.g., the quadrant of the pool where an event took place). Detailed observations were taken of the times that the focal animal oriented, approached, and contacted an object; entered or left the test pool; and interacted with other animals. Video and audio recordings

were scored to obtain counts of a few important behaviors from all nonfocal subjects (e.g., agonistic and acoustic behaviors).

Pinniped vocalizations were too rare to warrant scoring, but acoustic behaviors were collected for cetacean trials. They fell within broad categories (e.g., tonal and pulsed calls, click trains, jaw claps). The jaw claps were usually easy to differentiate, but they were not common. Most acoustic behaviors overlapped and graded into one another. Thus, they were lumped and scored as bouts from which rates and total bout duration could be calculated.

Data Analysis—Novel object and simulated fishing gear trials yielded similar responses. The novel object trials were only analyzed descriptively, but results are included because an independent set of subjects was tested; some rare, informative incidents occurred; and exposure periods were long enough to show changes within exposure. Data from the larger sample of simulated fishing gear and motivational state trials were graphed and analyzed using *Statistica 5.5* (StatSoft, Inc., Tulsa, OK, USA) and custom *Excel '98* macros (Microsoft, Inc., Redmond, WA, USA).

Statistical tests of the simulated gear data were processed using parametric Analysis of Variance (ANOVA). ANOVA was selected because it had greater power than nonparametric equivalents, facilitated *post hoc* comparisons, and yielded robust results even when assumptions were violated to some degree. The best fit possible was ensured by applying the log-normal transformation to latencies and durations and the arcsine transformation to rates and percentages (Zar, 1996).

A different approach was used for the motivational state trial data. The sample of sea lions was small relative to the complexity of the experimental design and the data were less regular, making violations of ANOVA assumptions problematic. Sea lion motivational state data were analyzed using the nonparametric Wilcoxon matched-pairs test for dependent samples. The test has low power (Zar, 1996), and corrections must be made to compensate for multiple pairwise testing. Therefore, the analysis was supplemented with a nonparametric resampling procedure (bootstrapping). For a given comparison (e.g., transformed proportion of resting time in net vs net/pinger trials), the difference of medians was calculated. The two datasets were then pooled, randomized, and resampled with replacement 1,000 times. The frequency distribution of the resampled median differences was compared with the original observed median difference and the probability (p) of obtaining the result calculated. If $p < 0.05$, the difference between the two conditions was significant (additional detail in Anderson, 2000).

Results

Acoustic Characteristics of the Pinger

The source level of pings from the production model NetMark 1000 in the 10 to 80 kHz band (Figure 3) averaged 131 dB re: 1 μ Pa @ 1 m (RMS SPL) in the Commerson's exhibit pool. It dropped to 124 dB re: 1 μ Pa in the center of the refuge pool. Average sound exposure level (SEL) was 110 dB re: 1 μ Pa²/Hz @ 1 m in the exhibit pool and 102 dB re: 1 μ Pa²/Hz in the refuge pool. The level of the test model pinger was slightly lower, averaging 126 dB re: 1 μ Pa @ 1 m RMS SPL and 105 dB re: 1 μ Pa²/Hz SEL. Most of the energy was at 10 kHz, with harmonic peaks 10 to 30 dB lower. The peak was around 50 to 60 dB above the background level at the same frequency in the absence of pings. Due to reflections from multiple surfaces, the received level was only 2 to 3 dB lower 2 m from the wall (Stothard et al., 1997). Levels in the pinniped and bottlenose dolphin test pools were within the range of error of measurements made in the Commerson's dolphin pool.

Behavioral Responses of the Subjects

The repertoires of behaviors aroused by the objects were broadly species-typical despite large inter-individual differences. Responses to an object/pinger combination differed qualitatively, characterized by (1) avoidance beyond the neophobic response to objects without the pinger, (2) agonistic gestures and interactions, and, in cetaceans, (3) potentiation of negative responses across trials. The differences did not prevent contact with the gillnet, however. Results are summarized below by species and trial series.

Harbor Seals—Novel object trials showed that in harbor seals the latency to first approach and contact varied greatly by individual and object, ranging from a few seconds after introduction to no contacts during the 3 h of the trial. However, once contact occurred, harbor seals manipulated some objects extensively, mouthing them; touching them with their nose, body, and flippers; pushing them around the pool; pushing their noses into apertures; and in the case of the plastic net, wrapping themselves by spinning with the edge of the net held in the mouth. Summed for all three harbor seals, contact time with the net in naïve trials exceeded 110 min, over twice the contact time with the familiar float.

Behaviors during pinger trials were substantially different. The three harbor seals never touched the float/pinger during the naïve trial, and one never contacted it at all (Figure 4). The float/pinger remained untouched in five of nine trials. Among the other objects, only the familiar float was untouched, and then only in a single trial (one

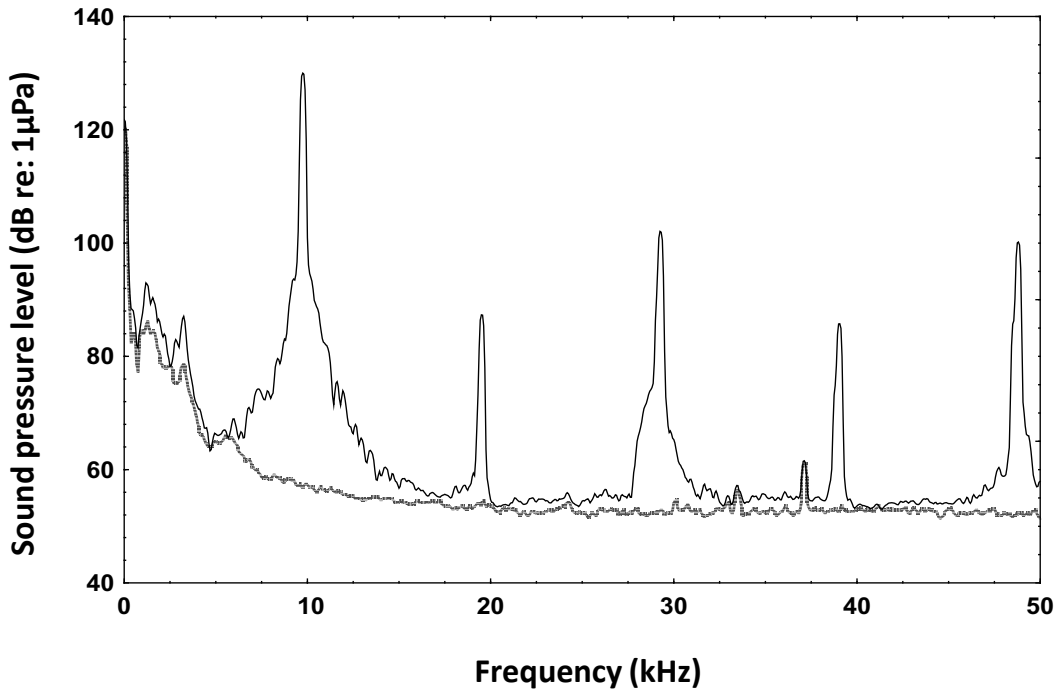


Figure 3. Spectrum of ping from Dukane/Seacom NetMark 1000 net alarm (black line) and background noise (gray line) in the Commerson's dolphin pool

of a possible 15 trials). Total time in contact with the float/pinger was less than 20% of the time spent in contact with the familiar float. There was clear evidence of declining contact with the net and float over successive trials, consistent with habituation, but number of contacts and time spent in contact with the net/pinger *increased* with repeated exposure, suggestive of initial aversion followed by investigation (Figure 4). There was no obvious difference in time spent out of the pool with vs without the pinger, but variance in hauling-out time was high (range 0 to 174 min).

During simulated fishing gear trials, the six harbor seals were tested three to seven times with all three objects for a total of 79 animal trials (Table 2). During the naïve trial, neophobic responses were common, usually consisting of very brief approaches or contacts followed by abrupt avoidance. However, individuals differed greatly in their initial responses, ranging from none (one seal slept throughout the naïve trial) to prolonged, active manipulation of the gillnet, float, float line, and lead line. Harbor seals did not orient agonistic behaviors toward any of the objects.

The details of their manipulation methods were revealing. Harbor seals often thrust their noses through the gillnetting or clawed it apart with their foreflippers. Having torn a hole in the net, they forced their heads through and continued

manipulating, steadying themselves against the hole while they mouthed or chewed the netting or lines from the other side. Similar steadying behaviors were observed with the float line. Harbor seals grasped and held the float line with their foreflippers or wrapped a twist around one flipper while manipulating the line with the mouth and other flipper. These behaviors produced the only entanglements observed in pinnipeds. Two harbor seals caught a tooth or nail on gillnetting while manipulating, using forceful yanks to free themselves. Neither subject experienced injury due to the precautions taken to weaken the netting.

Harbor seal responses to the net with the pinger were very different. After an initial, brief examination, the seals avoided it for most or all of the trial, often by jumping out of the pool. Based on their orienting behavior, they monitored the pinger while hauled out on the poolside. Some seals got back in the water as soon as the pinger was removed.

Three of four single females never touched the gillnet/pinger. The fourth waited a cumulative 40 min before contacting it. All four approached it < 5 times vs 5 to 24 approaches to the gillnet alone. Bout duration in the pool was similar among baseline trials for all three objects without the pinger (ANOVA, $p = 0.716$). By comparison, bout duration was significantly shorter during gillnet/pinger trials ($n = 328$ bouts, $df_{3,324}$, $F = 3.948$, $p = 0.009$). The

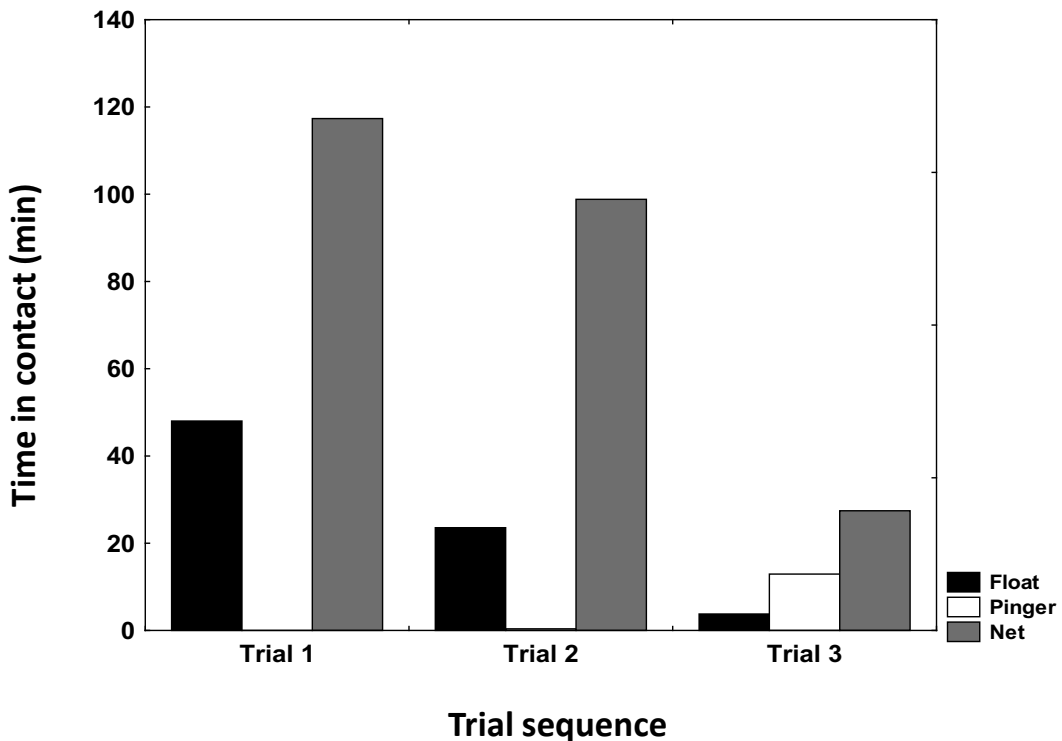


Figure 4. Harbor seal time in contact with float, net, and net/pinger during Phase I novel object habituation trials

difference was not large (averaging 1.53 min vs 3.48 and 3.37 min in baseline and gillnet trials; Scheffé *post-hoc* test, $p < 0.05$), but cumulatively the harbor seals spent only 12.1% of their time in the pool with the pinger vs 30.0% during baseline, 33.2% with the float line, and 25.6% with the gillnet.

For the females, approaches and contacts with the gillnet/pinger were intermediate between the gillnet alone, which was contacted the most, and the float line. Duration of individual approaches was significantly different among the objects (ANOVA, $df_{2,296}$, $F = 21.090$, $p < 0.005$), with longer durations within a body length of the gillnet (172 bouts in 174 min) and the gillnet/pinger (56 bouts in 41 min) vs the familiar float line (71 bouts in 19 min) (Scheffé *post-hoc* test, $p < 0.05$). The harbor seals spent significantly more time in contact with the gillnet per bout (188 bouts in 144 min) vs the gillnet/pinger (53 bouts in 21 min) and float line (63 bouts in 14 min; ANOVA, $df_{2,301}$, $F = 16.960$, $p < 0.005$; Scheffé *post-hoc* test, $p < 0.05$).

Even though they spent more time in the pool, the pair of male harbor seals spent less time in the pool with the gillnet/pinger (77.1% vs 90.1% and 96.2% of trials with the gillnet and float). There were fewer approaches in the presence of the gillnet/pinger vs the gillnet (592 bouts vs 751), and

a large difference in total approach time (8.4% vs 23.8% of trial time). Bout duration in the pool with the gillnet was significantly longer than with the gillnet/pinger (ANOVA, $df_{1,120}$, $F = 43.898$, $p < 0.005$) as was bout duration of approaches (ANOVA, $df_{1,1341}$, $F = 11.962$, $p < 0.005$), which averaged over twice as long (0.26 min vs 0.12 min). These harbor seals contacted the gillnet alone more than twice as often as the gillnet/pinger (446 bouts in 73.7 min [8.8% of time] vs 274 bouts in 32.55 min [3.9% of time]).

Even though they spent less time in the pool or close to the pinger, harbor seals still contacted the gillnet regardless of the pinger. In 21 of 29 trials with the gillnet/pinger, the seals eventually contacted and manipulated it. Two of the six showed significant increases in number of contacts over the course of habituation trials (2 to 20 contacts and 18 to 75 contacts, respectively). The median difference in latency to first touch was small, under 200 s for all three objects, with the median difference in latency less than 50 s between the gillnet and gillnet/pinger. The longest bouts of contact with both objects were in excess of 10 min.

In addition to contacts that involved deliberate manipulation, harbor seals swam into or through the gillnet incidentally on several occasions. First,

they ran into it when they were swimming around the pool as though they expected to swim through the PVC frame without obstruction (3 incidents; one male did it twice). In these cases, they were moving slowly and bounced off the net, turning to stare at it afterwards. Second, they were surprised into it on two occasions. In the first, a juvenile female got in the water after the object was introduced, heard the pinger for the first time, and abruptly turned away, running through the net. In the other, a juvenile male had been manipulating the net before delayed onset of pinging. At the sudden onset, he plunged through the net. In both cases, the seals jerked sharply upon feeling the entangling mesh, suggesting they did not expect to be constrained. They extricated themselves quickly because the net parted as intended.

California Sea Lions—During novel object trials, naïve responses by the California sea lion were more short-lived and aggressive than those of harbor seals. Although more subjects left the pool during gillnet/pinger trials than during gillnet trials, time out of the water was short and objects were contacted and manipulated frequently. Contacts included mouthing and chewing the object, swimming tight circles around it, pushing it, rubbing the back and flippers along it, and thrusting the nose and head into any available aperture.

The group of three California sea lions contacted objects less often than the single juvenile male, spending correspondingly more time in social interactions. The group of sea lions touched the float/pinger much less than other objects, but individuals often rushed at it and touched it briefly when it was introduced. Despite strong initial responses, California sea lions in novel object trials began to swim in a manner indistinguishable from the baseline period within 30 to 60 min of exposure. Some exhibited detectable responses for only 5 min.

In social groupings across all trial series, reactions were characteristic of the group as a whole rather than individuals separately. Individuals that had avoided the pinger when isolated swam close to it during group trials. In one case, a subadult female started to leave the pool as soon as the pinger activated. However, when her two companions did not leave the pool, she immediately turned and rejoined them.

During the Phase II simulated gear trials, behaviors could be documented in greater detail using underwater video. Initial responses to the gillnet were short-lived startles (4 of 6 subjects) or defensive/agonistic gestures (2 bouts, 3 subjects), but none of the California sea lions left the pool in the first minute after the object was introduced. Responses to the gillnet/pinger were substantially stronger. When the pinger activated, they jerked away (6 of 6

and jumped out of the pool within the first minute (5 of 6 subjects). However, the response was transitory. Mean time out of the pool during gillnet/pinger trials was 24 s; the longest time was 330 s.

A few California sea lions exhibited potentially agonistic behaviors oriented at the gillnet and gillnet/pinger. They porpoised rapidly around the pool, shook their heads at the object, and emitted bubble clouds. Porpoising bouts and charging/fast swimming were only seen in the presence of the pinger (15 events). Often, the subjects swam up to the object quickly and turned with an abrupt flip, raising a cloud of bubbles that obscured the head and/or body, then swam away rapidly with the head and neck extended. Sea lions also gaped at the objects, sometimes while releasing bubbles, although no sound was detected. Bubble clouds were only observed in the presence of test objects. Interestingly, the incidence of bubble clouds in gillnet/pinger trials was substantially lower regardless of group size. Bubble clouds were most common in the presence of the gillnet without the pinger (23 of 30 events).

Although California sea lions typically had shorter approach and contact latencies than harbor seals, they were substantially less prone to manipulate the gillnet for long periods regardless of age, sex, and social grouping. Only five of the total of 12 sea lions in simulated fishing gear trials (42%) began manipulating the gillnet or net within the first trial. The addition of the pinger reduced contact further, with only one animal of 12 (8%) contacting the net/pinger, and then only during the second trial with the object. The only animal that manipulated it extensively was an adult male.

California sea lions were presented with the float line once in the simulated fishing gear trials. The single animal in this trial manipulated the line, mouthing it and pulling the object around the pool.

In total, 56 motivational state trials were completed, with six trials per focal subject (3 net and 3 net/pinger trials). Results of the Wilcoxon matched-pairs and bootstrap analyses of percent time, bout rates, and latencies are shown in Table 3. The results of the bootstrapping procedure were consistent with the results of the Wilcoxon matched-pairs test but were more sensitive. Therefore, results of the bootstrapping procedure are reported preferentially (significant $p < 0.05$).

Differences in behavior in the two exposure conditions (net vs net/pinger) were compared to one another and to the baseline condition. Behaviors that typically consumed a high proportion of the trial time, such as resting and swimming, did not distinguish the two conditions. California sea lions did not stay out of the pool significantly longer in the presence of the net/pinger relative to both the net and baseline trial conditions, but the proportion

of time out of the pool was highly variable (from none to all of a trial).

Contacts and approaches were consistently and significantly lower in trials with the net/pinger vs the net (Table 3). Median latency to first approach and contact were more than an order of magnitude greater in the presence of the net/pinger (approach: 1.1 vs 12.7 min; contact: 2 vs 47 min). However, there was considerable variation in approach latency to the net/pinger, with the shortest under 5 s. The median approach rate was 2.0 bouts/h during net/pinger trials vs 12.5 bouts/h for the net, and the contact rate was close to 0 vs 11 bouts/h (2 total bouts in all net/pinger trials). Altogether, California sea lions spent 1.2% of the time looking, approaching, and contacting the net/pinger as opposed to 18.1% of the time during net trials.

Although they were accustomed to taking dead fish from the water, California sea lions were initially cautious about approaching a fish-laden net, exhibiting all the behaviors typical during naïve trials with other objects. However, within a few minutes, they approached and took fish. The pinger did not deter them. They exhibited behaviors consistent with agonism in experiments with the pinger, such as rapid flips, but took the fish regardless. The sample of trials with fish was too small for statistical comparison, but latencies to

take fish in the two conditions (net vs net/pinger) were so short that any significant difference would have had limited management value (< 10 min). Once sea lions had pulled fish from the net, they were more prone to manipulate it.

Northern Elephant Seals—Northern elephant seals were not tested during novel object trials. During simulated fishing gear trials, they always received the gillnet first. They usually responded to its introduction with orienting and avoidance. A few left the pool. However, when they approached and touched the gillnet, they did so quickly (within 8 min). They investigated it by nosing, chewing, touching, or grasping it with the pectoral flippers, and then pushing it around by both the frame and mesh. They did not dig holes in the net or rest on it, however.

Pinger onset aroused the least intense responses seen in any species. To some extent, the difference was a product of generally lower activity state. Elephant seals spent at least 40% of trial time hauled out on the deck in all experimental conditions and in several cases remained hauled out for the entire 2-h trial. The strongest responses to pinger onset were exhibited by the single female, a sharp jerk and avoidance, and the two juvenile females, which left the pool or avoided the pinger throughout exposure. Two hauled-out elephant seals put their heads in the water after

Table 3. Results of Wilcoxon Matched-Pairs Signed Rank Test and bootstrapping analysis of California sea lion responses to net and net/pinger relative to the baseline in motivational state trials

Behavior	Measure	Comparison	Wilcoxon Z	Wilcoxon p	Bootstrap p
Avoidance	Median duration	Net/pinger vs net †	2.1	0.049 [†]	0.008
Out of pool	Median % trial	Net/pinger vs baseline	1.8	0.070	0.050
	Median % trial	Net/pinger vs net	2.1	0.060	0.050
	Bouts/h	Net/pinger vs baseline	2.2	0.031	0.025
Lap swim	Median % trial	Net/pinger vs baseline	2.0	0.300	0.042
	Bouts/h	Net vs baseline	0.9	0.462	0.091
	Bouts/h	Net/pinger vs baseline	0.3	0.680	0.100
Resting	Median % trial	Net/pinger vs net	1.6	0.110	0.069
	Median % trial	Net/pinger vs baseline	1.6	0.109	0.411
Return to baseline	Latency (s)	Net/pinger vs net	2.0	0.049	0.021
Approach	Latency (s)	Net/pinger vs net	1.8	0.080	0.029
	Median % trial	Net/pinger vs net	2.0	0.041	0.009
	Bouts/h	Net/pinger vs net	2.2	0.033	0.008
Total time investigating*	Median % trial	Net/pinger vs net	2.2	0.038	0.010
	Median bouts/animal	Net/pinger vs net	2.0	0.044	0.039
Close contact object**	Median % trial	Net/pinger vs net	2.2	0.031	0.024
	Median bouts/animal	Net/pinger vs net	2.2	0.032	0.029

[†]In this table, “net” refers to the plastic net. ^{††}Significant differences ($p < 0.05$ criterion) indicated in bold. *Total time investigating the object included looking, approaching, contacting, and manipulating it. **Time within one body length and in contact with the object.

pinger activation as if to listen (it could be heard faintly above water). The group of four mixed-sex elephant seals approached and manipulated the gillnet extensively with an active pinger.

There were no clearly agonistic responses from the elephant seals. During his initial naïve trial with the gillnet, the single male blew bubble clouds and vocalized at close range briefly. However, when the pinger activated during the second trial, his response was minimal (orienting). None of the other elephant seals charged, blew bubbles, swam rapidly, or vocalized at either of the objects.

Despite their subdued responses, there was evidence that elephant seals avoided the gillnet/pinger. The count of touching bouts was considerably lower in gillnet/pinger vs gillnet trials (2 vs 24 bouts), as well as the total time spent touching (19 s vs 356 s) (Table 4). Time per bout out of the pool was the only measure that differed, with elephant seals spending significantly longer periods out of the pool with the active pinger relative to the baseline (ANOVA $F = 3.754$, $p = 0.013$; Scheffé *post-hoc* test, $p = 0.022$) but not with the net alone ($p > 0.10$). However, time spent out of the pool was only marginally greater in the presence of the gillnet/pinger vs net or inactive net/pinger (98% vs 63 to 74% of the time), and differences were confounded by imbalance in the trial presentation order.

Commerson's Dolphins—During novel object trials, Commerson's dolphins were only tested with the float, float/pinger, and plastic net. Their investigative and defensive repertoires differed substantially from those of pinnipeds. Latencies to contact and time spent in approaches or contacts were poor response indicators because the dolphins tended not to contact test objects. They did not touch the pinger or net at all, although they bumped the familiar float for short periods. Instead, highly kinetic behaviors were common. Upon introduction of the novel plastic net and pinger, they suddenly altered direction and swam at high speed around the pool, including high-speed passes within one body-length of the test object. Focal dolphins bowed, swam spinning, and swam

at high speed around the pool, either in isolation or synchronously (Figure 5). Similar behaviors were associated with unusual or surprising events in other contexts—for example, when a hydrophone was placed in the pool for the first time.

Differences in behavior relative to the baseline were obvious in the case of the float/pinger. Some highly kinetic behaviors were common during exposure trials but never seen during baseline periods (Appendix A2), including bows, fluke slaps, roostertailing, and bubble clouds. Spins and chasing were common during exposures but rare during baseline periods. In the first hour of exposure to the float/pinger, but not to the net or float, incidents of spinning, fast swimming, fast synchronous swimming, bubble clouds and trails, bows, roostertailing, spins, and chasing increased dramatically (Figures 5 & 6). The significance of differences in event counts was obvious, with counts of bows 0 vs 70 with the gillnet/pinger, roostertailing 0 vs 117, and fluke slaps 2 vs 76. Time spent chasing increased by almost an order of magnitude in the presence of the pinger but not the float and plastic net. Although surface-active behaviors tended to decay over the course of 3-h exposures (Figure 5), chasing actually increased during the second hour, and none of the behaviors returned to baseline rates (Figure 6).

Increases in defensive movements were infrequent in response to objects without the pinger, but there was a single series of spinning bouts in the presence of the float. This behavior occurred in the trial immediately after a float/pinger trial.

Behaviors thought to be affiliative (Appendix A2) showed an opposite trend. These included slow synchronous swimming, resting within a body length of another dolphin, pectoral flutters, head shakes, and touching or grasping another individual with the jaws. Affiliative behaviors declined in the presence of novel objects, particularly during the first hour of exposure to the float/pinger (Figure 6).

During experiments with simulated fishing gear, Commerson's dolphins resumed baseline-like

Table 4. Behaviors of northern elephant seals (*Mirounga angustirostris*) exposed to simulated fishing gear, including time out of the pool, rates of orienting, and a summary of contacts with the test object

Object/period	Time out & orienting			Touches		
	% time out of pool	Rate orienting (event/min)	N bouts	% time	Total time (s)	Latency to first touch (mean s)
Gillnet only (Baseline)	44.2	--	--	--	--	--
Gillnet only (Trial)	62.6	0.14	24	3.4	356	113.5
Gillnet/pinger (Baseline)	70.7	--	--	--	--	--
Gillnet/pinger (Pinger inactive)	74.1	0.33	2	0.7	19	226.0
Gillnet/pinger (Active)	97.7	0.08	0	0	0	N/A

Note: N/A = The northern elephant seals did not touch the active gillnet/pinger.

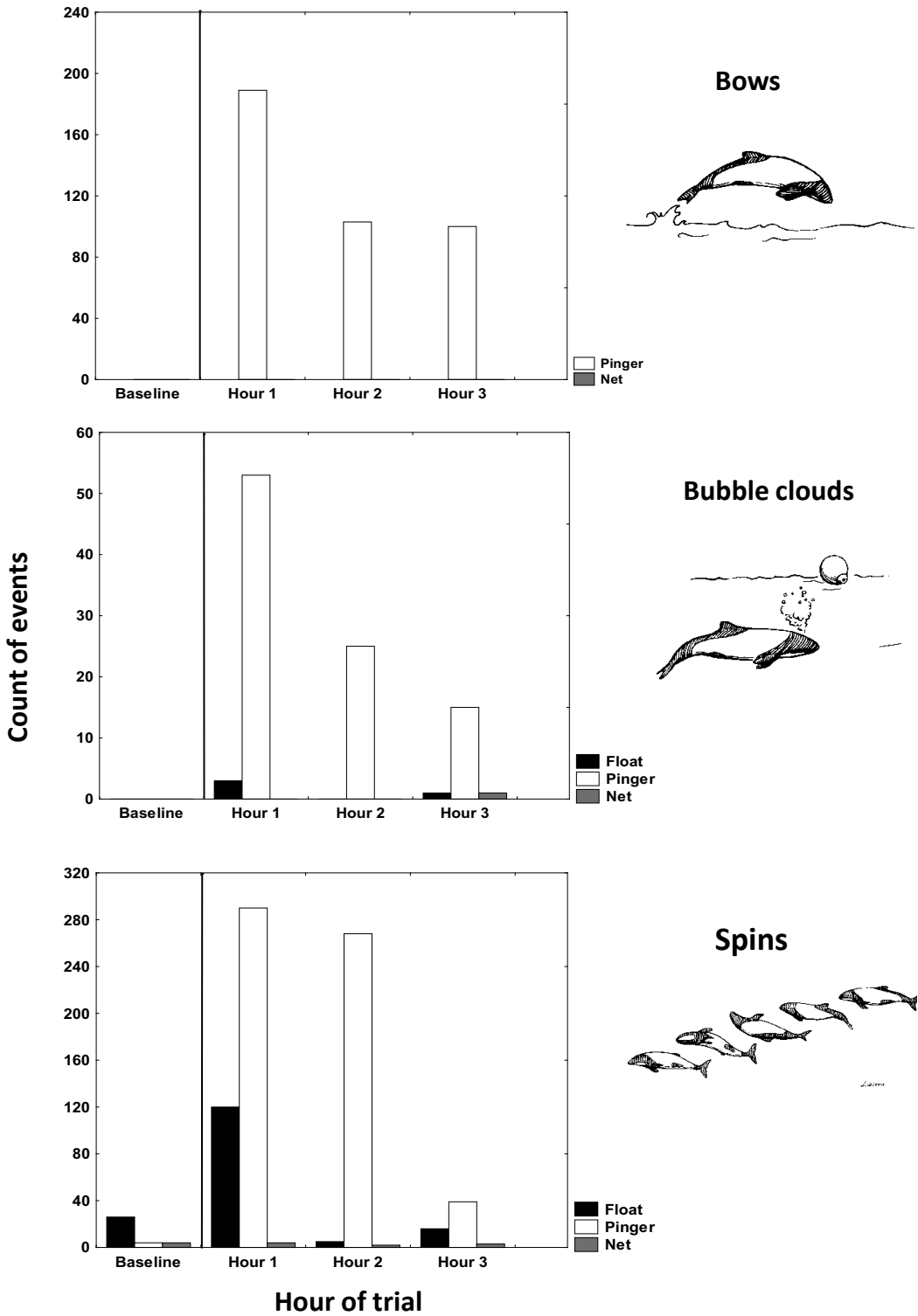


Figure 5. Events exhibited by Commerson’s dolphins during novel object trials with the float, net, and net/pinger objects

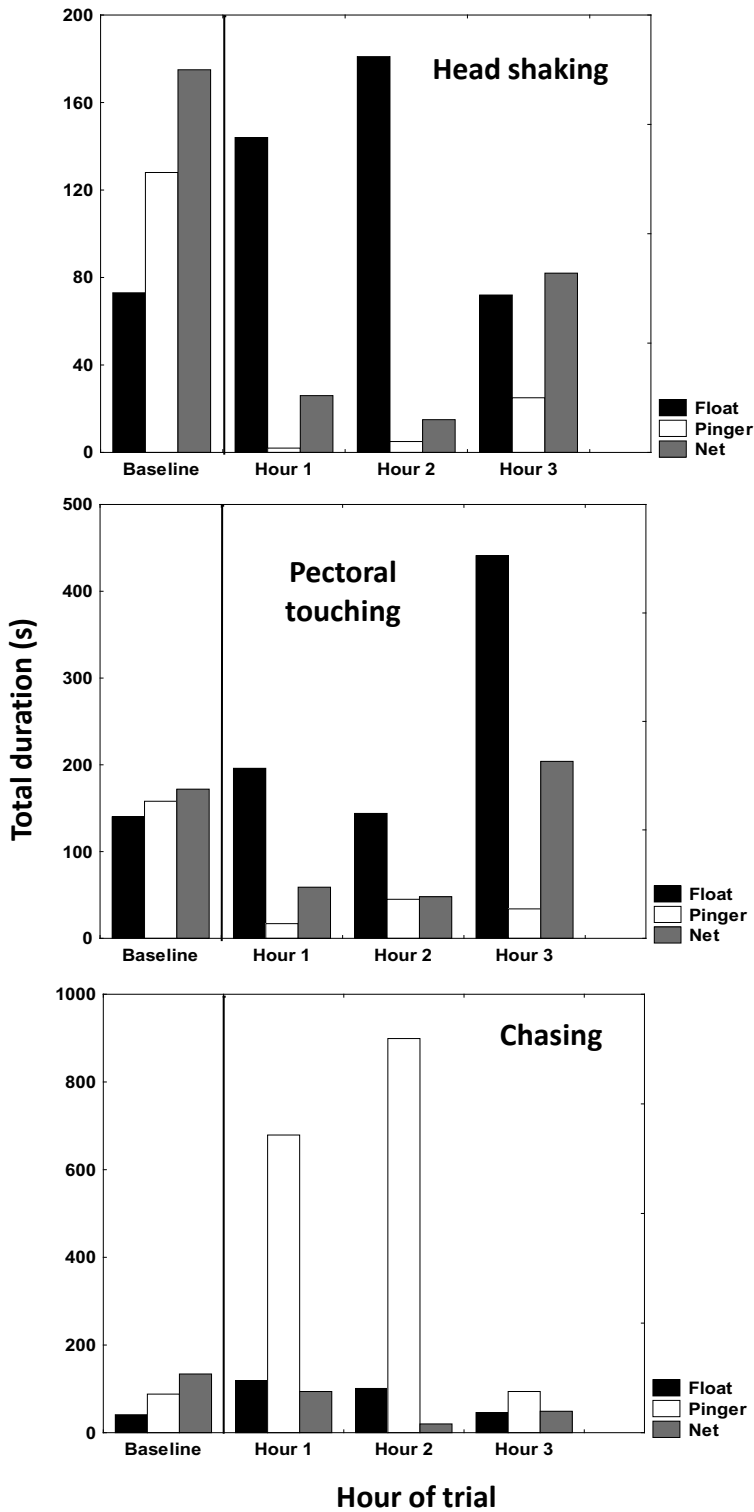


Figure 6. Durations of responses by Commerson’s dolphins during novel object trials. Head shaking (top) and pectoral touching (middle) are affiliative states; chasing (bottom) is an agonistic state.

lap-swimming within an hour of encountering the gillnet for the first time, but they did not manipulate it. Time spent in the refuge pool was variable but showed no obvious trend over the course of seven trials with this object (Figure 7a) and was not statistically different from baseline ($p > 0.10$). Their responses to the gillnet/pinger were dramatically different (Figure 7b & c). During the naïve trial with the object, surface-active behaviors (e.g., bows, roostertailing, fluke-slapping) and bubbling (e.g., trails and clouds) began immediately after introduction. The dolphins swam rapidly around the test pool while exhibiting these behaviors. Surface activity declined in the second and third trials largely because the dolphins retired to the refuge pool except for brief incursions into the test pool (Figure 7b & c). By the fourth trial, the dolphins had begun moving into the refuge pool during the baseline period, apparently anticipating exposure to the pinger in all trials (compare Figure 7a with Figure 7b, Trials 5 through 7). Time in the refuge pool increased to $> 90\%$ of the trial period (Figure 7b) and did not decline. Trials were stopped after seven exposures.

During the first two trials with the gillnet/pinger, the dominant male took possession of the refuge pool, occasionally threatening or nudging the adult female out of it and excluding the subadult male completely. The subadult was eliminated as a subject because he no longer had access to a refuge. This was a reversal of the adult male's typical behavior. When they were housed together, he often chased the subadult out of the exhibit pool.

Adult Commerson's dolphins spent significantly less time in the test pool during gillnet/pinger trials than they did in the presence of either the gillnet or the float line (ANOVA, $df_{2,134}$, $F = 9.688$, $p = 0.002$), averaging 7.4% of the time vs 70% with the net and 64% with the float line (baseline 76%). There was a dramatic increase in agonistic chasing in the presence of the pinger, both in number of bouts (29 of 51 bouts during pinger trials) and in bout duration (mean 3.86 min vs 1.86 min for the gillnet and 1.2 min for the float line). Bout durations were significantly longer (ANOVA, $df_{2,54}$, $F = 7.304$, $p = 0.002$; Scheffé *post-hoc* test, $p < 0.05$).

Bouts of surface-active behaviors were almost unique to the gillnet/pinger trials. Some behaviors (e.g., bows, roostertails) were not observed in other contexts. Fluke slaps were never observed during baseline periods and float line trials and were rare in the presence of the gillnet (2 events). They were common during pinger trials (76 events).

Out of 259 bouts of affiliative behavior during simulated fishing gear exposures, 124 were observed in the presence of the gillnet vs 13 for the gillnet/pinger and 22 for the float line. The rate

during gillnet trials was similar to that observed during the comparable baseline periods (mean 105 bouts; range: 84 to 115).

Observers were convinced that Commerson's dolphins were aware of the gillnet mesh. They turned their heads toward the net and emitted click trains during repeated brief, often close, approaches. They did not charge it until they had investigated by swimming along it, orienting their heads toward it, and clicking. They often stopped short of the mesh during charges, suggesting they knew it was present. In particular, the subadult male repeatedly charged the net, breaking off within 30 cm with an abrupt movement. When they charged, all three dolphins oriented themselves directly at the net (i.e., along a vector 90° to the plane of the net).

However, the adult male charged through the gillnet during the first (naïve) trial, striking it head-on and passing through it thanks to the weakened mesh. The adult female charged through it twice. During the first gillnet/pinger experiment, she had just broken off from a bout of agonistic chasing with the male. She turned, oriented toward it, and charged through it quickly. During the fifth net/pinger experiment, she charged it again when she was fast swimming toward the refuge pool. Pulse trains were detected as she made the turn to approach the net (~3 m away). During this second passage, her left pectoral flipper and rostrum caught in the mesh. She immediately began to jerk and twist in an effort to free the entangled parts of her body. Because the mesh was weakened, she quickly pulled out of it and escaped.

Bottlenose and Pacific White-Sided Dolphins—In novel object experiments, bottlenose dolphins played with the familiar float, pushing it and tossing it around the pool. They did not touch other objects often or for very long. During naïve trials, they rushed past unfamiliar objects at close range or charged and swam quick, tight circles around them (Figure 8, sketch). One individual, the dominant male, oriented agonistic behaviors on test objects, including fluke slaps, jaw claps, and aggressive charging (Appendix A2). Charging at the familiar float was rare. However, the dolphins charged it in the trial after the first exposure to the float/pinger.

During simulated fishing gear experiments, naïve responses were similar. During baseline periods, bottlenose dolphins spent much of their time swimming in synchrony. After object introduction, they swam erratically and separately. For a short time, they charged the unfamiliar objects, swimming quick, tight circles around them. When their arousal level subsided, they returned to synchronous swimming but were more tightly congregated than during baseline periods.

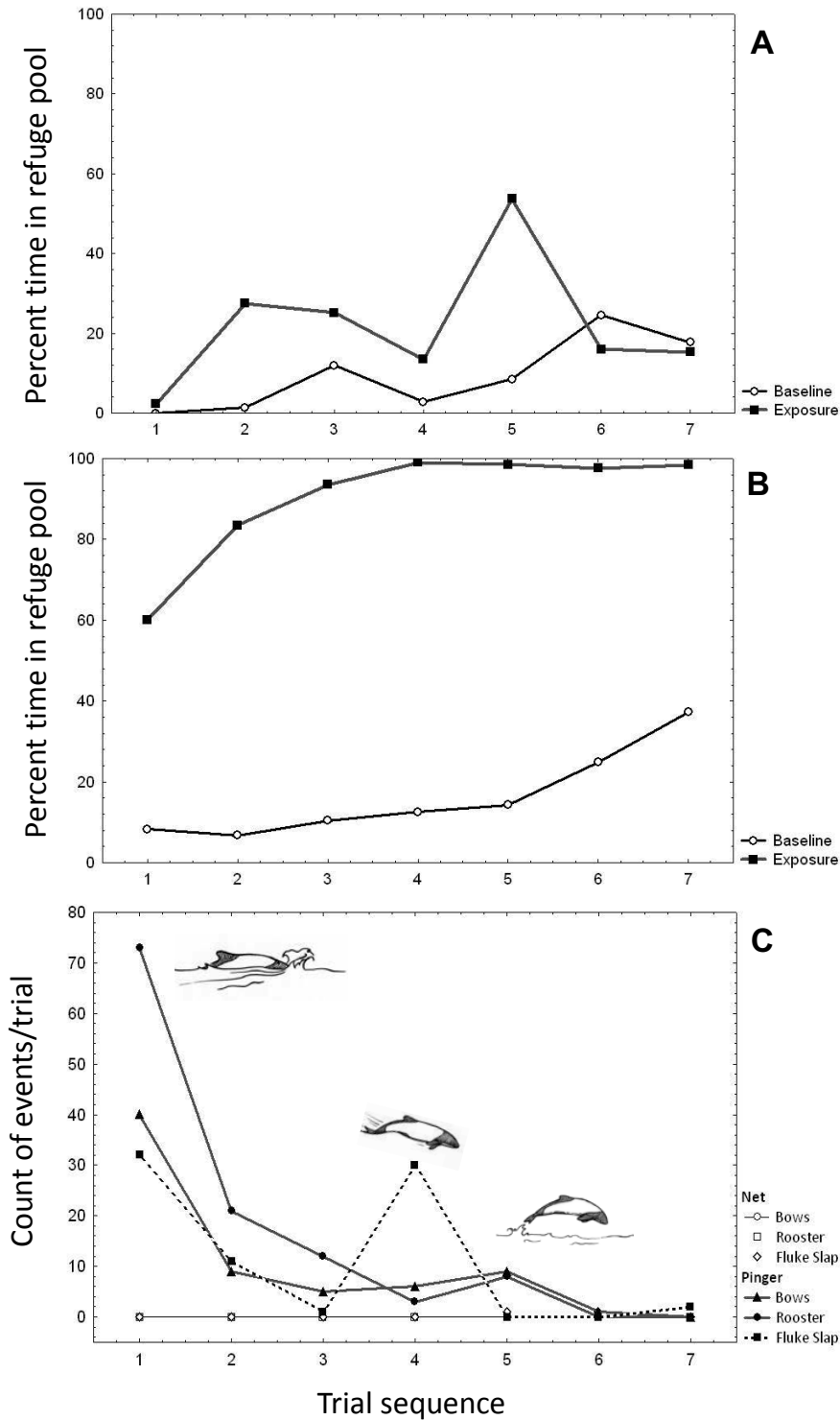


Figure 7. Commerson's dolphin behaviors during habituation trials: (A) Percent time in the refuge pool during gillnet trials, (B) percent time during gillnet/pinger trials, and (C) surface active behaviors during gillnet/pinger trials.

By comparison with the Commerson's dolphins, bottlenose and Pacific white-sided dolphin responses were subdued, and the return to baseline behavioral states was rapid. During naïve exposures, dolphin groups spent significantly less time per bout in the main pool in the presence of the gillnet/pinger (ANOVA on time per bout, $F = 6.693$, $p < 0.005$), although only the difference between baseline and gillnet/pinger periods was significant (Scheffé *post-hoc* test, $p = 0.002$). Bouts of rafting were somewhat longer in the presence of the pinger, but the difference was not significant (ANOVA, $F = 2.091$, $p = 0.084$). There was no significant difference in time per bout of lap swimming or synchronous swimming ($p > 0.05$).

Charging, rushing, porpoising, and fluke slapping at the object were never common and were predominantly behaviors of one male bottlenose dolphin. This was a different individual from the male exhibiting similar behaviors in the novel object trials. Dolphins never tossed or manipulated the gillnet or float line. On several occasions, individuals charged the center of the gillnet but changed direction abruptly before contact. Neither bottlenose dolphins nor the Pacific white-sided dolphin ever swam through it. Approaches were observed most often when the pinger was in the pool but before it had started pinging (Table 5).

The Pacific white-sided dolphin investigated the gillnet when naïve, approaching it repeatedly. In contrast, she did not approach the gillnet/pinger and spent 27% more time in the refuge pool during gillnet/pinger trials than during trials with the gillnet.

Acoustic Behaviors

Cetacean vocalizations could not be attributed to any individual and were therefore tallied by trial and examined qualitatively. Commerson's dolphins increased pulse trains by 67% in the half-hour after introduction of the gillnet/pinger (Figure 9). Pulse trains could be separated into

categories easily by ear based on the signal from the Westec bat detector: (1) series of broadband clicks at about 80 pulses/s and (2) series of clicks with extremely short interpulse intervals that were audible as a "whine." In 36 h of recordings, bouts of whines were only noted four times, always during trials with the pinger.

Sounds produced by the Pacific white-sided and bottlenose dolphin groups were variable click trains, pulse bursts, and tonals that tended to overlap and grade into one another. For the purposes of analysis, they were pooled into bouts. Bottlenose-only groups decreased sound production during gillnet/pinger trials (Table 5). One bottlenose dolphin group produced a high rate of vocalizations (0.66 sounds/min) during the 14-min delay period. However, the dolphins sharply reduced sound production after activation and for the remainder of the trial (0.04 sounds/min). Although the sounds could not be categorized quantitatively, RCA noted no marked difference in the two periods (e.g., a substantially lower number of tonal and pulsed calls or clicks). Instead, the change was the result of a decrease in total sound production.

Discussion

Net alarms like the pingers used in these experiments are effective under at least some conditions (e.g., Lien et al., 1995; Laake et al., 1998; Barlow & Cameron, 2003; Carretta & Barlow, 2011). Unlike current acoustic harassment devices (AHDs), which have source levels in excess of 195 dB re: 1 μPa @ 1 m (Jamieson & Olesiuk, 2001), the Netmark 1000 pingers are in a class of devices with low to moderate source levels, roughly 120 to 160 dB re: 1 μPa @ 1 m (Kastelein et al., 2001). They are intended to warn rather than harass. However, pingers need not be an informative warning simply because they effectively prevent entanglement. Harbor porpoises avoid a wide range of tonal signals at received levels that can be as low as 110 dB re: 1 μPa @ 1 m (Kastelein et al.,

Table 5. Results of bottlenose dolphin and Pacific white-sided dolphin trials with simulated fishing gear, showing the proportion of time spent in the refuge pool and rates and counts of behaviors

Object/period	Behaviors		
	% time refuge pool	Approach rate (behav/min)	Number vocalizations (behav/min)
Gillnet only (Baseline)	0.0	--	0.101
Gillnet only (Trial)	0.15	0.118	0.131
Gillnet/pinger (Baseline)	0.01	--	0.389
Gillnet/pinger (Pinger inactive)	0.16	0.157	0.663
Gillnet/pinger (Active)	0.25	0.088	0.044
Buoy line* (Baseline)	0.20	--	0.000
Buoy line* (Trial)	0.24	0.533	0.029

*The Pacific white-sided dolphin was the focal subject in the single trial with the buoy line.

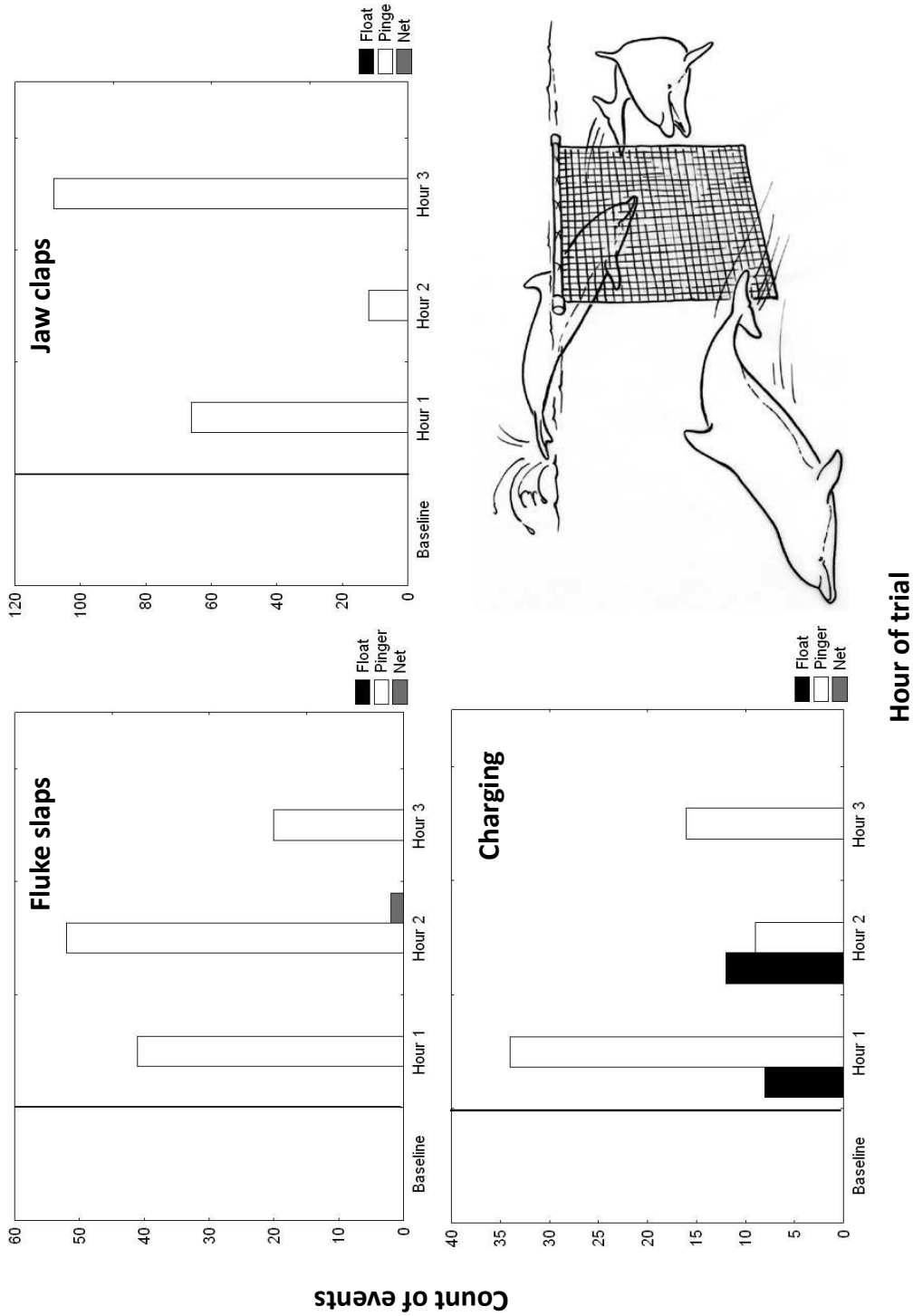


Figure 8. Focal bottlenose dolphin responses to the float, net, and net/pinger during the Phase I novel object trials

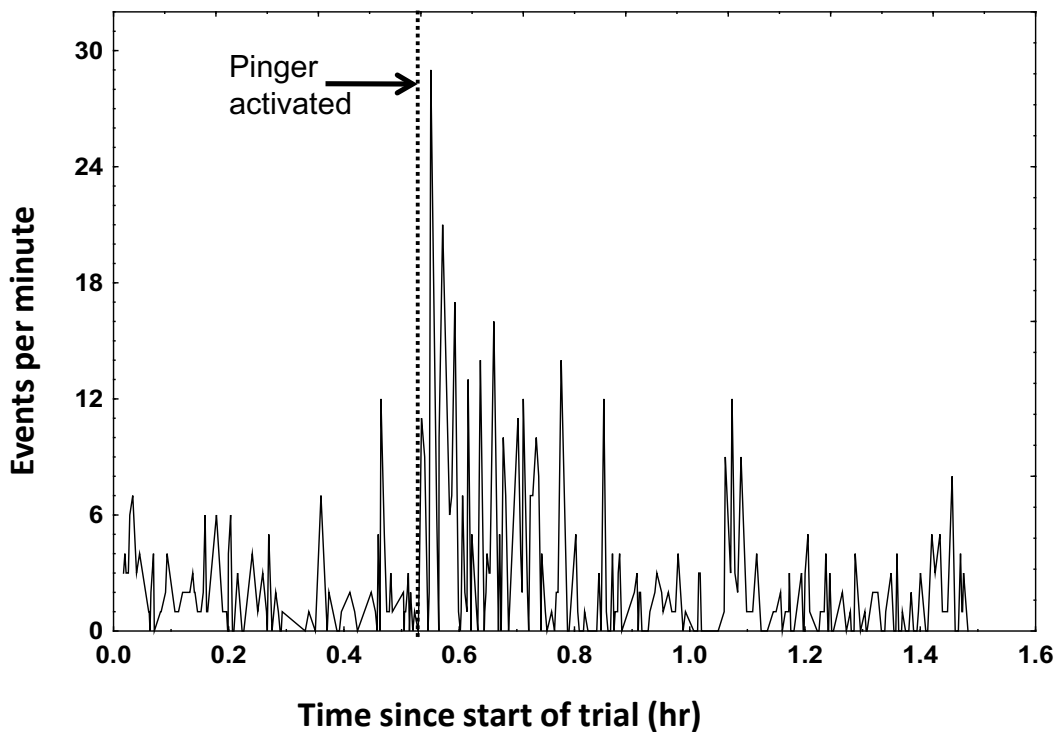


Figure 9. Rate of pulse trains produced by Commerson's dolphins during the initial trial with the gillnet/pinger object

2001, 2006a; Southall et al., 2007), and harbor seals avoid a similar range of devices at slightly higher levels (Kastelein et al., 2005, 2006b). Aversion is a parsimonious explanation for these behaviors.

The results of the present experiments support the hypothesis that pingers are effective because they are aversive. These observations suggest a conceptual model for the effect of pingers. They reduce entanglements by arousing aversion but may not “warn”—that is, stimulate appropriate avoidance responses to netting and lines. Pinger effectiveness depends on (1) species-typical defensive and investigative responses aroused by pings initially and (2) strategic choices made in a given context as animals gain experience with them.

The hypothesis that the pinger was aversive was strongly supported. During naïve trials, neophobia (Turpin, 1986; Lang et al., 1997) was observed, but all species avoided the object/pinger more than they did the object alone. The difference was usually significant. Except for phocids, subject species exhibited agonistic (defensive and aggressive) behaviors more often in the presence of objects with a pinger. California sea lions directed abrupt flips, rushing, bubble clouds, and gaping threats at them. Bottlenose dolphins charged and rushed past them and emitted bubble clouds, jaw claps, and persistent surface-active behaviors. They rarely oriented

these behaviors at the float line and other objects. Cetaceans increased fast swimming and surface active behaviors, both associated with agonistic contexts (Tyack, 2000). Commerson's dolphins also increased chasing and reduced affiliative behaviors. The dominant male Commerson's dolphin displaced a subordinate male out of the refuge pool into the test pool; whereas in baseline trials and experiments with other objects, he did the reverse.

The avoidance and agonistic behaviors were persistent across trials. Both bottlenose dolphins and Commerson's dolphins oriented agonistic behaviors on the familiar float after a trial with the float/pinger, suggesting that the float was negatively associated with the pinger. Commerson's dolphins increasingly avoided the gillnet/pinger, eventually spending 90% of the exposure period in their refuge with no evidence of habituation over seven trials.

Interestingly, there was no evidence of sensitization to the pinger among pinnipeds, despite initial aversion and other studies showing that harbor seals react with aversion to tonal signals (Kastelein et al., 2005, 2006b). During 3-h novel object trials and across habituation trials, harbor seals became somewhat more likely to interact with the object/pinger combination. They may have been predisposed to habituate enough to permit contact with the object. Pinnipeds are adapted to track and catch prey by

touch (Hyvärinen, 1989; Denhardt et al., 1998), and they do not echolocate. Their motivation to explore by touch could overcome at least some aversion to tonal signals. If so, pingers might reduce the odds of contact, but they also might alert pinnipeds to the presence of something to investigate. When pinnipeds discover that high-quality food is present, such as near fish ladders or near aquaculture facilities, even high-amplitude deterrents like AHDs are of limited utility (Yurk & Trites, 2001; Terhune et al., 2002; Nelson et al., 2006). In this context, pingers are unlikely to prevent contact with objects.

Also consistent with the proposed model was failure of the pinger to prevent contact, at least in the limited test spaces available for these experiments. Pinnipeds were most likely to contact objects with pingers, although contact and approach time was significantly lower than for gear without pingers. Individual harbor seals manipulated the gillnet/pinger extensively. California sea lions took fish within 10 min even when the pinger was present, although they directed agonistic behaviors toward it and otherwise avoided it. However, there were large inter-individual and species differences in these interactions. Some of the harbor seals and sea lions manipulated nets extensively, but others did not. Almost all of the juvenile harbor seals manipulated netting eventually, whereas less than half the California sea lions made contact in trials without fish. Northern elephant seals were the least likely to manipulate objects with the pinger.

Cetaceans tended not to touch novel objects, with or without the pinger. Instead, they investigated by echolocating and swimming at high speed past the object at close range. These behaviors could have brought them into contact with nets inadvertently. Entanglements occurred in similar experiments with harbor porpoises. Kastelein and his coworkers reported that subject porpoises became entangled by the flukes or pectoral fins in the course of fast swimming and rushing, even though they had examined the experimental nets visually and with echolocation (Kastelein et al., 1995; Nachtigall et al., 1995).

In the present experiments, accidents or failure to perceive nets as significant barriers also resulted in contact. Harbor seals started through the gillnet when surprised on two occasions. Commerson's dolphins swam directly into the gillnet, either by accident or deliberately. An adult female charged through the gillnet/pinger twice: during an agonistic encounter and while regrouping after a separation.

Although measurements of Commerson's dolphin vocal activity did not permit echolocation clicks to be differentiated from social pulse trains, the dolphins increased sound production by 67% during pinger trials compared to baseline or net-only trials. An unusual "whine" (actually a rapid pulse train) occurred only during pinger trials. Similar sounds

recorded from free-ranging Commerson's dolphins have been described as "distress" calls (Dziedzic & de Buffrenil, 1989). So, while Commerson's dolphins produced more click trains, some of these sounds may not have been useful for examining the net. A group of bottlenose dolphins decreased sound production in the presence of an active pinger, perhaps as a defensive response. In both cases, pingers were not clearly associated with a focused increase in echolocation.

Behaviors during gillnet approaches and contacts suggested that Commerson's dolphins could detect the net, but adults may not have perceived it as a significant barrier. The juvenile Commerson's dolphin rushed at it several times but broke off within a few meters, suggesting detection. Adults directed click trains at the gillnet, but they later broke through it on three separate occasions. In each case, they oriented directly at it, suggesting that they could detect the plane of the net. On the other hand, bottlenose dolphins and the Pacific white-sided dolphin approached and buzzed the gillnet numerous times but never tried to swim through it. One explanation could be differences in high-frequency as opposed to mid-frequency echolocation systems (Au & Jones, 1991; Au, 1994; Kastelein et al., 2000, 2006b), perhaps resulting in different susceptibilities to entanglement. Another possibility is that the Commerson's dolphins, which in the clear test pool could probably see the gillnet as well as receiving at least some echolocation returns, may have assessed the nature of the barrier differently. Repeated efforts to rush through it certainly suggest that they did not perceive it as a high risk.

The experiments described here support a model of pinger function more sophisticated than the simple alarm originally intended by designers. If so, successful use of pingers to protect marine mammals will depend on species-typical defensive and agonistic behaviors, the balance of opposing motivations, and strategies for coping with varying environmental contexts. Unfortunately, this means that unintended consequences are possible. For example, small dolphins and porpoises with high-frequency echolocation could be excluded from critical habitat, at least when large areas are ensouffled. Harbor porpoises avoided feeding habitat at received RMS SPL as low as 110 dB re: 1 μ Pa in the presence of tonal signals from AHDs (Olesiuk et al., 2002; Southall et al., 2007). Dawson et al. (1998) provide suggestive evidence of similar avoidance in Hector's dolphins exposed to widespread deployment of nets with pingers. Strong motivation to avoid pingers in small dolphins specialized for high-frequency echolocation would certainly be predicted based on persistent avoidance observed in Commerson's dolphins in the present study. However, other motivating factors could make pingers less effective, particularly in geographically

confined areas. In the present experiments, social interactions led to encounters with the gillnet despite clear evidence that they were aversive. Applied at high densities and in confined spaces, pingers could drive some species or individuals from favored areas (Dawson et al., 1998; Olesiuk et al., 2002) while raising the chances of entanglement if individuals were sufficiently hungry or distracted (Brotons et al., 2008; Carlström et al., 2009). Observations of interactions with gear and data on the conditions that promote entanglement are needed to determine when pingers will prevent bycatch reliably (e.g., Carretta & Barlow, 2011).

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Appendix A1. Ethogram for Pinniped Observations

Modifiers

A or W – In air or water

DO1, DO2, etc. – Distance (in body lengths) between animal 1 and object, or animal 2 and object, etc.

D12, D13, etc. – Distance (in body lengths) between animal 1 and animal 2, or animal 1 and animal 3, etc.

DIR – Direction or orientation of action/activity: Undirected (U), toward animal 1 (TA1)

I or T – Individual that initiates (I) or terminates (T) an action/activity. Modifies calls, agonistic behaviors, social interactions, etc.

INT – Intensity of action/activity: Intense (I), normal (N), weak (W)

LA – Location of animal (quadrants 1-4)

LO – Location of object (quadrants 1-4)

PAT – Pattern of activity: Variable (V), stereotyped (S)

SD – Swim direction: Clockwise (C), counter-clockwise (CC), directional (D), non-directional (ND)

SS – Swim speed: Fast (F), medium (M), slow (S)

States/Events

Locomotion and Movement

BOB – Bobbing (state). Animal bobs at surface with head above water and body vertical, usually looking at people at the poolside or animals in other pools.

BOW – Bow (event). An energetic leap that clears the surface of the water with considerable height and a characteristic curved trajectory; the jump takes animal much higher than would be needed to breathe. Often associated with a high state of arousal.

BRE – Breach (event). Animal raises part or all of body out of water and slaps downward, creating a splash.

CWL – Crawl (event). In both phocids and otariids, slow forward movement using the foreflippers, dragging hindquarters. Head and neck close to the ground. The speed and direction should be noted.

EW – Enter water (state). For pinnipeds, it is important to distinguish between states/events on land vs in the water. The scorer will note “EW.” All subsequent behaviors will be recorded as taking place in water until the observer notes “animal left water” or “LW.”

EWS – Enter water suddenly (event). Animal enters water abruptly by diving/leaping in. Observers will note the direction/speed of the animal relative to the location of the object.

GAL – Gallop on land (state). In *Z. californianus*, rapid, energetic running; the motion is a lot like the gallop of a horse, with one foreflipper ahead of the other and the rear flippers coming off the ground together.

IN – Investigate (state). Animal directs its sensory organs toward the object or approaches. Specify closest point of approach. Animal may approach the object and manipulate it.

LW – Leave water (state) or haul out.

LWS – Leave water suddenly (event). Animal leaves water by jumping/leaping out. Observers note how far animal goes from edge. For example, does animal remain at water edge or does it run/crawl some distance away?

POR – Porpoising (state). Rapid, energetic swimming where the animal leaps partially or just clear of the surface as it surfaces to breathe. Not a distinct, curved bow.

STR – Stride on land (state). Rapid acceleration, associated with rushing at another animal. Long steps with forelimbs, dragging hindquarters working in unison.

RFT – Rafting (state). Animal floats at surface horizontally (dorsal side up or down). Note whether alert or resting.

SPY – Spy hopping (state). Raising the body vertically out of the water to look around.

SPN – Spin (event). Animal spins or “corkscrews” through the water but does not clear the surface. The animal generally spins several times, returns to normal swimming state, then begins another bout of spinning. This behavior is often associated with aggression.

SW – Swimming (state), with animal not following a repeated path. May be characterized as circle (CIR), synchronous or unison (UNI), horizontal (HOR), or inverted (INV). Note distance between individuals (see above); head above/below water.

UND – Undulatory locomotion (event). In phocids, forward movement by scrunching or undulating the body forward on the belly; the flippers may provide balance but contribute little to forward movement and are often held away from the surface.

WK – Walk on land (state). All four limbs are used alternately, slow short steps, with the front part of the body off the ground.

Comfort Movements

COM – Comfort movements (state). Animal rubs body part against pool, rocks, gently against conspecific.

GRM – Grooming (state). Animal nibbles or rubs own body part to clean or maintain hair or relieve an itch.

Resting

RW – Resting in water, overall inactivity (state). Animal generally floats at the surface, often in a particular area of the pool for several minutes. Not clearly asleep. In water, animal may float with its flippers on one side extended in the air.

RL – Resting on land, overall inactivity (state). Animal may be standing or lying at or near the poolside, but the eyes are open; not clearly asleep.

SLP – Sleeping (state). Animal relaxed with eyes closed (sometimes in short bouts). In air, California sea lions often fold flippers underneath the body. May also sleep standing, propped up on front flippers with head thrown back and resting against the back. Phocids may sleep with the flippers off the surface and the neck contracted.

*Affiliative Behaviors***Positive, “Friendly” Social Behaviors/Interactions**

NUZ – Nuzzling (event), nosing, rubbing, or grooming a conspecific. Use modifier to indicate whether in air or water.

*Agonistic Behaviors***Behaviors Associated with Aggression, Dominance, and Submission to Other Animals**

FS – Flipper slap (event), usually with one of the pectoral flippers, but the rear flippers may be slapped as well. Note contact (C) or no contact (NC).

HT – Head thrust (event). Animal thrusts head toward conspecific. Often accompanied by vocalizations. Note contact (C) or no contact (NC).

GAP – Gape/open-mouthed threat (event). A specifically directed, open-mouthed gesture. Should be distinguished from mouthing objects or conspecifics. Often associated with a growl or bark.

BIT – Bite (event). Animal bites conspecific or object.

CHS – Chase (state). One animal chases conspecific(s). Should be certain that the animal is chasing and not just following another animal; this is most easily distinguished in pinnipeds by noting that the animal follows another vigorously, particularly with the head (i.e., as if trying to get close enough to bite). This event often occurs as part of a sequence which begins with one animal approaching another and initiating contact with a push or bite, then swimming away abruptly (SS event), whereupon the other animal chases. Observers will describe the sequences of behaviors surrounding chases in as much detail as possible.

SS – Sudden swim (event). Animal suddenly begins swimming, often abruptly removing itself from the proximity of a conspecific(s) or object with energetic movements, sometimes with splashing and/or water cavitation.

PSH – Push (event). An animal pushes a conspecific or object. Should be distinguished from exploratory or affiliative behaviors such as nudging. Specify which part of body is used for pushing, and where on body receiving animal is pushed.

RT – Retreat (event). Animal avoids another by running/swimming away in a rapid, smooth way, often with the head lowered and sleeked.

Human Interactions

HUM – Interacting with or directing behavior toward humans (state). Most often occurs during feedings or when people approach the poolside.

Vocalizations

V1, V2, etc. – Vocalizations (event). Number indicates which animal vocalized. May be classified as BK (bark), SQ (squeal), BL (belch), GR (growl), or US (unspecified).

Food Handling

EAT – Eating (state). Animal is fed by Animal Care staff.

PLF – Playing with food (state). Note from where the animal got the food (e.g., bottom of pool, trainer, probably regurgitated, etc.).

Object Play

OBJ – Object play (state). Interacting with or manipulating object other than food item. May be classified as CH (chewing), NG (nudging/rubbing), TS (tossing, batting), or PSH (pushing).

Appendix A2. Ethogram for Cetacean Observations

Modifiers

A or W – In air or water

DO1, DO2, etc. – Distance (in body lengths) between dolphin 1 and object, or dolphin 2 and object, etc.

D12, D13, etc. – Distance (in body lengths) between dolphin 1 and dolphin 2, or dolphin 1 and dolphin 3, etc.

DIR – Direction or orientation of action/activity: Undirected (U), toward animal 1 (TA1)

I or T – Individual that initiates (I) or terminates (T) an action/activity. Modifies calls, agonistic behaviors, social interactions, etc.

INT – Intensity of action/activity: Intense (I), normal (N), weak (W)

LA – Location of dolphin (quadrants 1-4)

LO – Location of object (quadrants 1-4)

PAT – Pattern of activity: Variable (V), stereotyped (S). Stereotyped behavioral states may be associated with swimming alone, social interactions (e.g., social swim pattern), or object interaction.

SD – Swim direction: Clockwise (C), counter-clockwise (CC), directional (D), non-directional (ND)

SS – Swim speed: Fast (F), medium (M), slow (S)

States/Events

Locomotion and Movement

BOB – Bobbing (state). Dolphin bobs at surface with head above water and body vertical, usually looking at people at the poolside or animals in other pools.

BOW – Bow (event). An energetic leap that clears the surface of the water with considerable height and a characteristic curved trajectory; the jump takes the dolphin much higher than would be needed to breathe. Often associated with a high state of arousal. May be an agonistic gesture.

BRE – Breach (event). Dolphin raises part or all of body out of water and slaps downward, creating a splash.

IN – Investigate (state). Dolphin directs its sensory organs toward the object. Dolphin may approach the object, but at greater than one body length.

POR – Porpoising (state). Rapid, energetic swimming during which the dolphin leaps partially or just clear of the surface as it surfaces to breathe. Not a distinct, curved bow.

SPY – Spy hopping (state). Raising the body vertically out of the water to look around.

SPN – Spin (event). Dolphin spins or “corkscrews” through the water but does not clear the surface. The animal generally spins several times, returns to normal swimming state, then begins another bout of spinning. This behavior is often associated with aggression in Commerson’s dolphins.

SW – Swimming (state). May be characterized as circle (CIR), unison (UNI), horizontal (HOR), or inverted (INV). Note distance between individuals (see above); head above/below water.

Comfort Movements

COM – Comfort movements (state). Dolphin rubs body part against pool or other conspecifics.

Resting

RW – Resting in water (state), overall inactivity. Dolphin generally floats at the surface, often in a particular area of the pool for several minutes.

Affiliative Behaviors

Positive, “Friendly” Behaviors/Interactions

GSP – Affiliative grasping (event). Seen most often in Commerson’s dolphins; dolphin gently grasps another with the jaws or touches another with the jaws open. It isn’t clear whether this behavior has agonistic overtones, but it clearly occurs in affiliative contexts.

HDS – Head shaking (state). In Commerson’s dolphins, the head is shaken vigorously from side to side. It seems to be a visual gesture, but it also may be associated with click trains.

NDG – Nudge (event). Like affiliative grasping, but with the mouth closed. Dolphin gently pushes against another or rubs rostrum against another.

PCT – Pectoral touching and flutter (state). Touching another dolphin with the pectoral flipper. In Commerson’s dolphins, this can be a stereotyped pectoral flutter, but it wasn’t scored as a separate behavior here. They swim close together or in contact, vibrating the pectoral fins.

RWA – Resting in water (state) close to another dolphin.

SYN – Synchronous swimming (state). Two dolphins swimming at slow to moderate speeds in the same direction, often in contact, generally surfacing synchronously.

Agonistic Behaviors

Behaviors Associated with Aggression, Dominance, and Submission

Note: Surface active behaviors are associated with agonism and are included in this list, but they can also occur in the context of play. Distinguish context in the notes. The behaviors included in this category were fluke slaps, pectoral slaps, and head slaps. Breaching and bows may also fall into this class.

BIF – Bite (event). Biting and holding a conspecific. Depending on intensity, this could also be an affiliative behavior. Commerson's dolphins grasp one another gently in affiliative contexts. Affiliative grasping could not be differentiated reliably from biting without other contextual information.

CHG – Charge (event). Dolphin charges an object or conspecific by approaching at very high speed, often striking or nearly striking it.

CHS – Chase (state). Dolphin chases conspecific(s). Distinguished from merely following by speed and persistence. Often occurs as a part of a sequence of events (approach, push, abrupt SS, chase); observer should record as much detail as possible when recording these sequences.

FS – Fluke slap (event). Slapping the surface of the water with tail flukes.

GAP – Gape or open-mouthed threat (event). A specifically directed, open-mouthed gesture. Should be distinguished from mouthing objects or conspecifics.

HT – Head thrust (event). Dolphin thrusts head toward conspecific. Often accompanied by vocalizations. Note contact (C) or no contact (NC).

JAW – Abrupt opening of mouth (event) in direction of another animal, object, or person. In audio files, heard as distinct clap.

PSH – Push (event). Dolphin pushes a conspecific. Distinguish from nudging (affiliative) by vigor, such as the movement of the dolphin receiving the push. Specify body parts used for pushing and where on body the push occurs.

RAK – Raking (event). Aggressive contact with open mouth swept across another dolphin. May result in rake marks, although it usually happens so quickly that this is difficult to see.

RST – Roostertail (event). Species-typical behavior of the Commerson's dolphin. Resembles porpoising in that the dolphin breaks the surface but does not clear the water. Instead, the dolphin plows through the water with the head, throwing a splash of water forward in the direction of travel.

RT – Retreat (event). Dolphin avoids another by swimming away in a rapid, smooth way, with no jerky movements.

SLA – Slap (event). Dolphin slaps the surface of the water with a pectoral fin.

SPL – Splashing or spitting (event) not associated with normal swimming.

SS – Sudden swim (event). Dolphin suddenly begins swimming at high speed, usually oriented abruptly away from conspecifics with jerky movements and/or cavitation (bubbles shed from the swimming surfaces, especially the flukes).

VER – Vertical head movement (event). Rapid up and down movements of the head, like nodding.

Human Interactions

HUM – Interacting with or directing behavior toward humans (state).

Vocalizations

V1, V2, etc. – Vocalizations by dolphin 1, 2, etc. (event). Classified as burst (B), whistle (W), or unspecified (US).

Food Handling

EAT – Eating (state). Dolphin is fed by Animal Care staff.

PLF – Playing with food (state). Note where the dolphin got the food (e.g., bottom of pool, trainer, regurgitation, etc.)

Other

AIR – Blow (event) or surfacing as if to blow.

BUB – Bubble cloud or trail (event). Distinguish between clouds and trails to the extent practicable, although they may grade into one another.

OBJ – Object play (state). Interacting with or manipulating object as a toy. May be classified as chewing (CH), nudging/rubbing (NG), or tossing/batting (TS).

PLY – Social play (state). Dolphins roll around in the water in close contact; "horseplay." This behavior can have agonistic overtones and can include agonistic gestures (e.g., jaw claps, slaps, etc.), but it is slower and more prolonged than fights. Because it grades into agonism, treat it as a separate category of affiliative behavior.