SHORT COMMUNICATIONS

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Use of Acoustic Transmitter-Equipped Remote Sedation to Aid in Tracking and Capture of Entangled California Sea Lions (*Zalophus Californianus*)

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ABSTRACT: Free-ranging California sea lions (*Zalophus californianus*) with marine debris entanglements were darted with a combination of medetomidine, butorphanol, and midazolam by using acoustic transmitter-equipped darts. Of the 15 animals sedated, 13 (87%) reentered the water and were tracked by using a unidirectional hydrophone. Sea lions that entered the water continued to surface and breathe postsedation. There were three mortalities (20%) during the course of this study due to the following: suspected drowning caused by entrapment under a dock, overdose due to inaccurate weight estimation, and trauma caused by a dart puncturing the animal's abdomen. The drug combination, new dart design, and tracking techniques allowed for successful remote sedation and capture of California sea lions in high-risk situations and improved our ability to determine the final outcome for all cases. These methods allow targeting and capture of individual animals, while minimizing disturbance to other animals.

Key words: Acoustic tracking, California sea lion (*Zalophus californianus*), darting, disentanglement, entanglement, marine debris, pinniped, remote sedation.

Capture of free-ranging pinnipeds is often necessary for the management, rehabilitation, and research efforts of these ecologically important marine predators. A variety of techniques, including nets, traps, and noose poles, have been used to capture pinnipeds. However, these techniques only allow minimal selectivity for sex and age classes and do not allow targeting of specific individuals. Recently, remote sedation (darting) has improved capture success of specific individuals (Haulena 2014; Baylis et al. 2015).

Pinnipeds that enter the water after being darted are at risk of drowning or may escape capture (Heath et al. 1996; Baylis et al. 2015). Consequently, darting has been restricted to use when the distance from water or species' behavior reduces concern for the animal escaping to the water (Geschke and Chilvers 2010). However, darting animals near the water may be unavoidable during rescues attempts, or target research animals may be near the water.

A darted animal may enter the water before it is effectively sedated (Heath et al. 1996; McKenzie et al. 2013). In regions with high wave action, decreased visibility, or high numbers of conspecifics, it may be difficult to follow darted individuals. To aid in recovery of sedated individuals and to reduce the risk of mortality, we developed a method for tracking pinnipeds by using an acoustic transmitter housed in a drug delivery dart.

We investigated the use of a boat-based, unidirectional hydrophone to track California sea lions (CSL; *Zalophus californianus*) darted with an integrated acoustic transmitter to increase capture success and to ascertain the safety and efficacy of a medetomidine (Med), midazolam (Mid), butorphanol (But) drug combination in a variety of age classes and both sexes of CSL. The animals darted in this study were all fishing gear entanglement cases.

California sea lions were darted from land, when possible, or from boats moving parallel to the animals. The animals were darted with Med 0.03 mg/kg, Mid 0.2 mg/kg, and But 0.2 mg/kg, based on the animal's estimated weight. This combination was shown to provide effective sedation of otariids without inhibiting normal respiratory functions (Melin et al. 2013; Haulena 2014). This combination has also been used successfully at lower doses in captive CSL (Spelman 2004); however, in

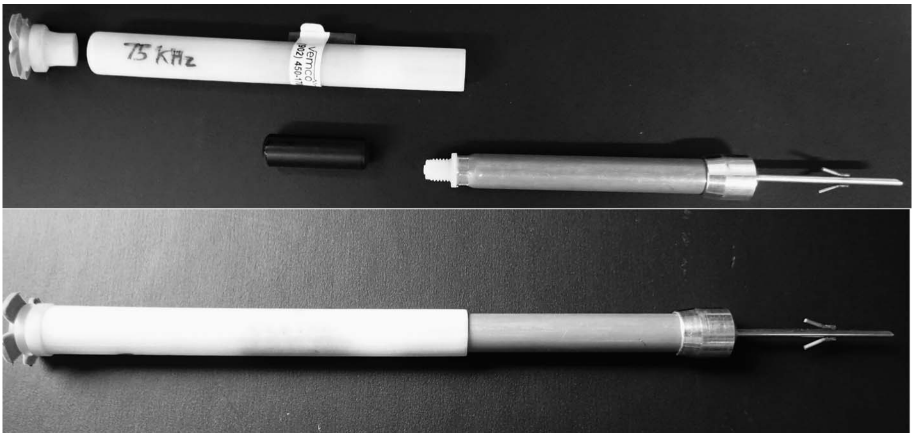

FIGURE 1. (top) Disassembled dart showing individual pieces and transmitter. The magnet placed on the outer housing is effective at shutting off the transmitter when not in use. (bottom) Fully assembled dart with the magnet removed is ready to fire.

the authors' experience, these doses have proven inadequate in wild CSL. In some instances, the estimated weight was reduced to calculate a lower drug dosage because of suboptimal body condition or concern for potential underlying health issues. Drugs were delivered via a barbed, 3-mL nonreusable drug containment vessel with either a 25- or 38-mm needle and fired from an X-Caliber Gauged CO_2 Dart Projector (Pneu-Dart Inc., Williamsport, Pennsylvania, USA).

A 9×29-mm, 4.7-g acoustic transmitter (V9H2, Vemco, Bedford, Nova Scotia, Canada) was used to track darted animals. The transmitters were coupled to the drug containment vessel by a protective plastic housing (Fig. 1). After the dart was imbedded in the target animal, the sea lions were tracked from a boat by using a VH110 unidirectional hydrophone attached to an acoustic tracking receiver (Vemco). Displayed numeric decibel readouts and variation in sound level from this unit provided an approximate distance and direction to the darted animal.

Changes in animal behavior were recorded at the time of darting and when animals began to respond to the drugs. The behaviors observed in response to darting and injection included animals remaining on land, immediately diving into the water, or entering the water several seconds to minutes after darting. The number of conspecifics disturbed during each event was also recorded. Disturbances included being agitated or flushed to the water by the darting or capture event.

The animals were followed until they were determined to be sedate enough to allow capture. The level of sedation was recorded as mild, moderate, or marked. Mild sedation was defined as animals that were still responsive to stimuli (i.e., conspecifics or birds nearby) and were exhibiting deliberate, directional swimming. Moderate sedation was defined as animals that were breathing regularly while resting on the surface in lateral or ventral recumbency. Moderately sedate animals would often exhale under water then lift their nose out to inhale. These animals occasionally would slowly dive when stimulated but would surface in the same area where disturbed. Marked sedation was defined as animals that rested laterally or dorsally with closed eyes, had a decreased respiratory rate, and were nonresponsive to physical stimuli. Markedly sedate animals were considered at higher risk for drowning. Once sedated, animals were approached by boat and netted from the water (n=11) or captured on land (n=4) by using hoop nets. Animals that were lightly sedated tended to be roused by netting attempts, conspecifics, or noise disturbance associated with the boat motor.

For each darting event, data were collected to analyze the safety and efficacy of remote sedation and telemetry. Age class (yearling, juvenile, subadult, and adult), sex, estimated weight, actual weight, time to drug effect (TTE) in minutes, time to capture (TTC) in minutes, level of sedation, and capture-related mortality were recorded. We used the ratio of estimated weight divided by actual weight (E/A) to represent the per weight dosing of drugs.

Four female and 11 male CSL, weighing between 33 and 103.5 kg and spanning in age from yearlings to adults, were darted between May 2014 to August 2015 in Monterey Harbor (36°36′N, 121°53′W; *n*=13), San Francisco Pier 39 (37°49′N, 122°25′W; *n*=1), and Santa Cruz Wharf (36°57′N, 122°1′W; *n*=1). Drug dosages used ranged from 0.017 mg/kg to 0.056 mg/kg Med and 0.11 mg/kg to 0.37 mg/kg each of But and Mid. Weight estimates for animals ranged between 57% and 186% of their actual body weight. In 11 of 13 cases, estimates were within 20% of actual body weight when weight was later determined. Thirteen of the 15 animals entered the water at some point between darting and capture. Of these 13 animals, seven traveled >100 m straight distance from an animal's dart injection location to final capture location (mean=307 m, SD=138 m), while six traveled <100 m (mean=41.6 m, SD=30 m). Actual distance traveled was often longer, as the animals' tracks did not follow a straight line.

A linear regression did not predict a significant association between E/A and TTE (r^2=0.269, P=0.124) or TTC (r^2=0.070, P=0.407). A significant association was found between TTE and TTC (P<0.001, r^2=0.878), indicating that animals that became sedate more quickly were captured more quickly. Results of a Somers' delta test showed younger CSL (yearlings and juveniles) become more heavily sedated following darting (t=–5.353, P=0.006).

Disturbances of conspecifics during darting and capture events were also reduced compared with conventional methods, such as hoop or seine nets. Zero to 10 conspecifics (mean=2) were disturbed by darting, with 0–40 disturbed during capture attempts (mean=10). Disturbance to conspecifics during capture with conventional methods in these same locations ranged from 0 to 250, mean=50 (G.D. unpubl. data).

Remote sedation is rife with variables and stochastic factors from dart loading through animal capture. Selection of dart type and needle size can affect where drugs are deposited (e.g., subcutaneously and intramuscularly), and darts may fail to inject on impact (Bergvall et al. 2015). Additionally, animal factors including weight, body condition, age class, and health condition can all potentiate drug effects. A recent review of darting in pinnipeds discusses the risks associated with this practice (Baylis et al. 2015).

Three animals died following remote sedation. The first animal was recovered from under a dock. We attempted resuscitation, but the animal ultimately died. Necropsy results from this animal were inconclusive. The second animal drowned due to overdose secondary to marked weight overestimation. This animal was recovered from the seafloor at a depth of 18 m by a diver, aided by the acoustic tracking system. The third animal was euthanized due to trauma caused by the dart penetrating into the abdomen. On necropsy, it was found that the dart perforated the stomach, causing acute peritonitis. The use of the tracking system allowed us to find and recover these three individuals at the time of the darting. The outcome for these sea lions may have been unknown prior to tracking system implementation. Findings from the mortalities has resulted in revisions of our protocols, including reducing needle length and decreasing drug dose and time before attempting capture.

Previous remote sedation studies of wild otariids were on adult animals. The results of this study found young sea lions had increased sedation levels with similar drug doses, even though generally they had a stronger initial reaction to dart impact, and all but one yearling entered the water following darting. The increased sedation seen in young animals may lead to increased susceptibility to drowning. Ultimately, all of the animals in this study were captured, even those that received lower dosages or were less sedate following injection. This suggests that lower dosages may be safer for the animals, without inhibiting capture success.

The use of the tracking system aided our ability to monitor and successfully recover target animals. This system was effective in tracking animals once they entered the water over distances up to 500 m. Additionally, one animal's dart failed to inject drug, and we were able to reacquire his signal and recover him the next day with a second darting. The acoustic signal allowed us to follow animals more precisely and determine their position while submerged. We have been able to determine the outcome of all animals since implementation of the acoustic dart. Prior to use of the transmitter dart, six of 15 animals (40%) darted in the same regions escaped following darting. Of those, one was found dead later, and the outcome of the others could not be determined.

Capture of CSL's has become an integral part of conservation, management, and rehabilitation efforts, and there are advantages and disadvantages to any capture technique. The use of this dart system can increase the costs and equipment necessary for darting. Additionally, the system requires use of a heavier, barbed dart, which may increase muscle trauma (Cattet et al. 2006). These factors should be considered when choosing whether to deploy this system. In areas where animals are likely to escape to the water and where tracking an animal may otherwise be impeded by animal behavior or environment, this system may add an additional degree of safety and increase the probability of capture. This system is a valuable tool for rescuers and researchers that may be deployed in a variety of other species and settings.

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