A Review of the Potential Effects of Disturbance on Sea Lions: Assessing Response and Recovery

Laura Kucey and Andrew W. Trites
University of British Columbia, Marine Mammal Research Unit, Fisheries Centre, Vancouver, British Columbia, Canada

Abstract
Human intrusion within areas of sea lion habitat is increasing worldwide, leading to concerns about disruption of distribution and daily activities of sea lions. Sea lion responses to disturbance can be quantified by recording changes in behavioral patterns, documenting numbers of animals on shore before, during, and after the disturbance, or by measuring physiological stress of individual animals. However, assessing recovery is not so straightforward, as highlighted by an example from a study of the short-term effects of disturbance on Steller sea lions. Recovery is generally recognized as a return to an original state or normal condition, but is often operationally defined as a percent-return to pre-disturbance numbers or behaviors. Simple interpretation of disturbance effects can be easily confounded by concurrent natural seasonal changes in behaviors or haul-out patterns, or by daily variability in numbers of animals present that can be attributed to weather, tidal cycle stage, and other factors. Overall, a range of recovery criteria needs to be simultaneously applied when assessing the effects of human disturbance on sea lion populations. Insights gained from research on the effects of disturbance on Steller sea lions may help guide the development of studies undertaken on other species of sea lions.

Introduction
Human intrusion within sea lion habitat has increased worldwide as development, resource exploitation, tourism, and research activities have expanded. Incursions may cause sea lions to deviate from their normal or

reference behavioral state. They may also disrupt sea lion daily activities and cause them to move to new areas or redistribute themselves on their existing haul-outs. Severe disturbances may even interrupt community interactions or ecosystem functioning (Forbes et al. 2001).

Knowing how populations and individuals respond to disruptions to daily activities is necessary for assessing viability of populations faced with human pressures (Andersen et al. 1996). However, field experiments on a wide range of species have yielded conflicting conclusions about the effects of human disturbance on wild populations (e.g., Andersen 1996, Engelhard 2002, Kerley 2002). This inconsistency of results suggests that studies need to be species-specific.

Recent pinniped studies have focused on two types of disturbance: anthropogenic (Salter 1979, Lewis 1987, Suryan and Harvey 1999, Engelhard et al. 2001, Boren et al. 2002, Born et al. 2002, Blackwell et al. 2004, Cassini et al. 2004) and non-anthropogenic (Ono et al. 1987, Grellier et al. 1996, Porter 1997, Deecke et al. 2002). Human forms of potential sea lion disturbance include noise, vessel and aircraft traffic, human approach (both scientific and recreational), industrial activities, and development. Non-human disturbances can involve environmental changes, storms, birds, other sea lions, other species, predators, and landslides.

The following provides an overview of some of the scientific considerations that need to be addressed when evaluating the effects of disturbance on sea lions. Our insights stem from a detailed study of human disturbance on Steller sea lions (*Eumetopias jubatus*) (Kucey 2005) and have general applicability to pinnipeds. We examine how sea lions might respond to disturbances in time and space, and how their response can be measured. We also consider what is meant by recovery from a disturbance, and how it might be assessed. Finally, we provide an example from our study of Steller sea lions that highlights some of the difficulties in assessing recovery.

Response

Response of animals to disturbance may vary both temporally and spatially among groups within an area, and may result in greater avoidance or tolerance of certain areas depending on the source of the disturbance (Suryan and Harvey 1999, Gill et al. 2001a). Elements that might affect how animals respond to disturbance events can include the quality of the occupied site, the distance, availability, and quality of other sites, the risk of predation, density of competitors, or the investment that an individual or group has made in a site (Gill et al. 2001a). Responses may also be specific to an individual, or may occur at a group or population level. In general, behaviors of individual sea lions tend to be narrower and more specific than those of the population. However, preferences and response of individuals shape group behavior and can determine how the group will collectively act during any event or population change (Gentry 1998).

Animals may also have physiological responses to disturbance. One of the most promising means of assessing this is by measuring the concentration of stress hormones released by animals into their bloodstream, or passed through urine and feces (Whitten et al. 1998, Wingfield 2003). Research on a wide range of terrestrial birds and mammals suggests that differences in stress hormone concentrations pre- and post-disturbance are valid measures of response to disturbance (e.g., Wasser et al. 1997, Foley et al. 2001, Millspaugh et al. 2001).

In the short-term, the source of disturbance and whether it causes temporary displacements can usually be determined. However, knowing whether the disturbance impacts the population is another matter. Activities with no immediate, short-term effects may have the potential to cause cumulative effects that do not become apparent until the disturbance has continued for some time. Conversely, disturbances that cause immediate effects may not necessarily generate cumulative effects over time (Riffell et al. 1996). Disturbance thresholds and habituation are difficult to measure in wild populations and may affect response and recovery time. From a population viewpoint, species with high fitness costs and few habitat choices are the ones most likely to be adversely affected by disturbance. Displacement may reduce reproductive success for rare or declining species as well as reduce parental care and prey intake rates. It may also increase levels of vigilance and stress responses (Andersen et al. 1996, Riffell et al. 1996, Gill et al. 2001b, Engelhard et al. 2002).

Recovery

Determining what is meant by recovery is essential for assessing whether there is an effect of disturbance on sea lion haul-out behavior. This is critical for the design of experiments, and ultimately affects the methodologies that will be employed, as well as the length of time that observations need to be conducted.

In the strictest sense, recovery can be defined as a return to an original state or normal condition. However, operational definitions of recovery tend to be less rigorous. Some studies have considered recovery to be attained when 50% of the animals present at the time of flushing return to shore (Allen et al. 1984, Henry and Hammill 2001). Other criteria that might be employed include setting higher percent-return-targets (e.g., 75%, 90%, or 100%), or applying statistical approaches that consider average densities and daily variation in numbers on shore. For example, the grand mean number of animals on shore before a disturbance could be used as the benchmark for comparison with numbers of animals that return to the haul-out. Such a measure would likely be a more accurate means of assessing recovery due to the large daily variation in number of sea lions that tend to haul out each day.

Describing the average state of a group of sea lions before a disturbance is challenging given the wide daily variability in numbers and behaviors that can be attributed to weather, tidal cycle stage, and other factors. Similarly, identifying the period over which the average state is to be described is an equally important consideration, as is controlling for natural seasonal changes in behaviors or haul-out patterns that could confound the simple interpretation of disturbance effects. In the case of Steller sea lions, documenting average conditions for 1 to 2 weeks prior to disturbance resulted in seven of ten sites reaching recovery in the following week to 50-75% of the pre-disturbance levels (Kucey 2005). Whether this applies to other species of sea lions remains to be tested.

Overall, it is appropriate to use a range of recovery criteria rather than locking into any single measure of recovery. Knowledge of how various measures of recovery are attained provides a method for assessing the rate of return to a pre-disturbance state. As such, point counts, daily means, and grand mean post-disturbance counts are all valid measures of recovery.

Experimentally assessing disturbance: A Steller example

Steller sea lions tend to avoid people, and generally appear to be skittish while on shore. Disruptions often affect entire haul-outs and rookeries (Lewis 1987, Loughlin 2002). Sea lions that are approached directly (as with scat collection) tend to become agitated, and increase the frequency and level of their vocalizations and head movements. Animals that are startled may stampede into the water, or may gradually enter the water if the disturbance (or disturbance stimulus) is moderate and prolonged. Those that enter the water may leave the area, while some may remain in the vicinity and vocalize toward the haul-out from the water. Some animals may also swim in front of the haul-out in small groups with their heads oriented toward the researchers, occasionally vocalizing. Sudden movements by researchers may cause individual animals to dive under water, possibly initiating a group response.

The apparent susceptibility of Steller sea lions to disturbance raises behavioral and physiological concerns for populations that experience high levels of intrusion. Only one study to date has addressed the effects of research disturbance on Steller sea lions. It consisted of observations that documented sea lions responding to biologists walking through a rookery, and led to recommendations to improve census counts and reduce disturbance to pups (Lewis 1987).

We conducted a study of short-term effects of disturbance of Steller sea lions at haul-outs and rookeries in British Columbia and Southeast

Alaska (Kucey 2005). Our approach was to observe haul-out patterns at six sites between May and August of 2003, and to repeat our observations between February and April in 2004. Counts were performed at 20-minute intervals, 12 hours a day during the summer season, and during daylight hours in the winter and spring months. Observations were performed from a fixed location blind with the aid of binoculars and spotting scopes to avoid detection by the sea lions. At each site, the study occurred from 1-2 weeks before, to 1-2 weeks after a predetermined research disturbance to collect fecal samples (scats) for dietary analysis. Researchers approached the haul-outs and guided the sea lions into the water using slow arm movements. They were typically on shore for less than 2 hours.

Counts documenting the number of animals hauled out before, during, and after a directed research disturbance are shown in Fig. 1 and illustrate the large daily variation in number of animals hauled out. The data are from one of the 12 sets of observations, and are representative of the other sites studied. The particular site shown in Fig. 1 was a year-round Steller sea lion haul-out located in Southeast Alaska (SW Brothers Island) that was composed of mixed age and sex classes, and was greatly influenced by tidal fluctuations. Plotting the grand mean numbers of animals present pre- and post-disturbance shows that mean numbers were lower at this site following the disturbance (Fig. 1a). However, one of the 20-minute counts made on the day following the disturbance equaled the mean number of sea lions counted during all 8 days preceding the disturbance (Fig. 1b). Similarly, recovery could also have been deemed to have occurred quickly based on mean daily counts that reached 50% of the pre-disturbance mean less than 6 hours after the disturbance (Fig. 1c). Using more conservative recovery criteria, these data suggest that recovery occurred between 1 and 6 days later when the mean daily counts were respectively 75% or 100% of the pre-disturbance mean (Fig. 1c). Thus the assessment of recovery very much depends on the criteria used.

Conservation

The example from Steller sea lions highlights how difficult it is to assess the effects of disturbance as well as determine when recovery has occurred. Experiments such as ours are useful for assessing short-term effects of disturbance, but cannot evaluate potential long-term consequences, thus indicating the need for additional methodologies for long-term studies. Intuitively, preventing human disturbance of land-based sea lion activities such as breeding, nursing, resting, and maintenance of a cohesive social structure should enhance reproductive success and species perpetuation (Kruse et al. 2001). However, disturbing non-reproducing individuals at haul-outs may not have immediate life history consequences. Measuring the physiological stress of individual animals

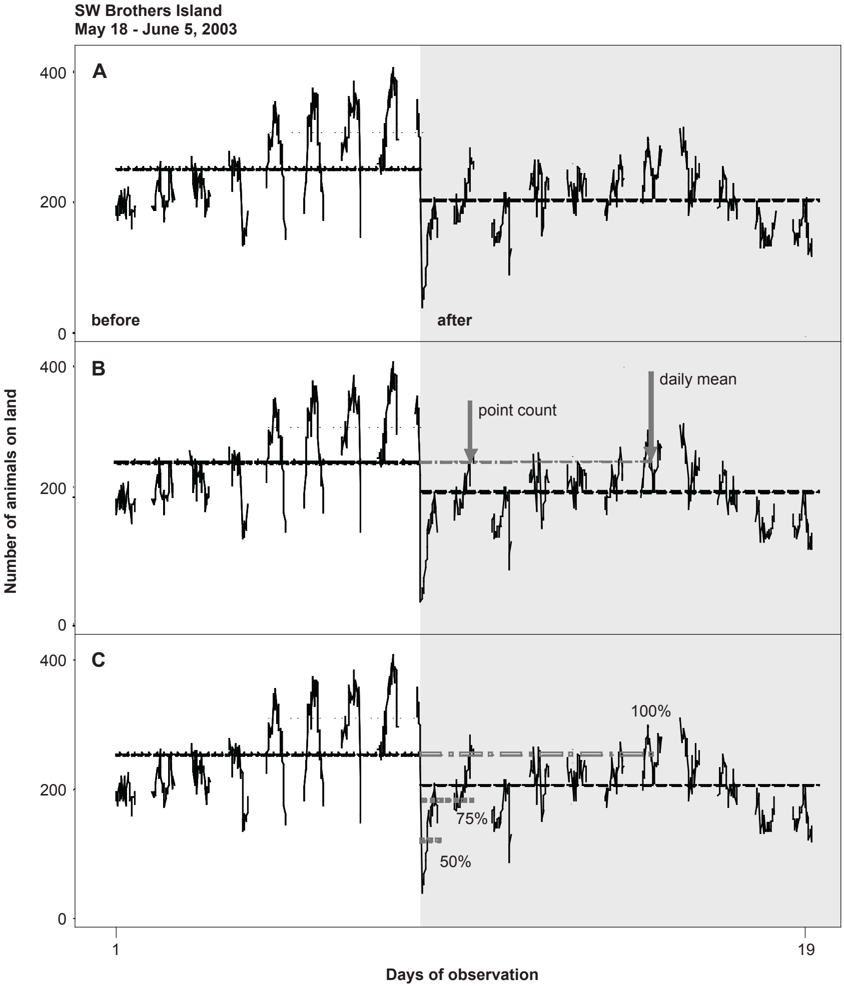

Figure 1. Counts made before and after scat collection at SW Brothers Island from May 19 to June 5, 2003. Total number of Steller sea lions on land were recorded every 20 minutes from 0800 to 2000. Gaps in counts reflect night-time when no observations were made. Shaded area represents counts made after scat collection. Dashed lines indicate the grand mean number of animals on land before and after the experimental disturbance (A, B, and C). Point count and daily mean recovery of the number of sea lions hauled out to the pre-disturbance grand mean (B). Daily mean recovery levels to 50, 75, and 100% of the pre-disturbance grand mean (C).

can be used as an alternative method for determining biological ramifications of disturbance (Andersen et al. 1996). Addressing changes in stress levels with hormone analysis, either through blood or scat analysis, can indicate changes in glucocorticoid levels (Andersen et al. 1996, Creel et al. 2002, Hunt et al. 2004). However, in wild populations, it is extremely difficult to obtain baseline physiological measurements without the confounding effects of research handling. Therefore, documenting changes in behavior and numbers is an alternative and accessible method to monitor the effects of disturbance on individual populations.

Understanding the effects of human disturbance on endangered wildlife populations is critical to conservation efforts (Kerley et al. 2002). Only by knowing whether animals are physiologically affected or significantly modify their behaviors in response to disturbance can effective protection measures be applied. The insights that can be gained by assessing the effects of disturbance on sea lions may help to guide research activities, air and boat operations, and human approaches within areas of sea lion habitat. Similarly, the lessons gained by thinking critically about what a disturbance response is and how recovery should be evaluated may also help to guide the development of other studies of disturbance that might be undertaken on other species of sea lions.

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