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Effects of Tour Boats on Dolphin Activity Examined with Sensitivity Analysis of Markov Chains

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Abstract: *In Patagonia, Argentina, watching dolphins, especially dusky dolphins* (Lagenorhynchus obscurus)*, is a new tourist activity. Feeding time decreases and time to return to feeding after feeding is abandoned and time it takes a group of dolphins to feed increase in the presence of boats. Such effects on feeding behavior may exert energetic costs on dolphins and thus reduce an individual's survival and reproductive capacity or maybe associated with shifts in distribution. We sought to predict which behavioral changes modify the activity pattern of dolphins the most. We modeled behavioral sequences of dusky dolphins with Markov chains. We calculated transition probabilities from one activity to another and arranged them in a stochastic matrix model. The proportion of time dolphins dedicated to a given activity (activity budget) and the time it took a dolphin to resume that activity after it had been abandoned (recurrence time) were calculated. We used a sensitivity analysis of Markov chains to calculate the sensitivity of the time budget and the activity-resumption time to changes in behavioral transition probabilities. Feeding-time budget was most sensitive to changes in the probability of dolphins switching from traveling to feeding behavior and of maintaining feeding behavior. Thus, an increase in these probabilities would be associated with the largest reduction in the time dedicated to feeding. A reduction in the probability of changing from traveling to feeding would also be associated with the largest increases in the time it takes dolphins to resume feeding. To approach dolphins when they are traveling would not affect behavior less because presence of the boat may keep dolphins from returning to feeding. Our results may help operators of dolphin-watching vessels minimize negative effects on dolphins.*

Keywords: activity budget, dusky dolphins, sensitivity analysis, stochastic matrix models, tourism

Efectos de Barcos Turísticos sobre la Actividad de Delfines Examinada con Análisis de Sensibilidad de Cadenas de Markov

Resumen: *La observación de delfines, especialmente* Lagenorhynchus obscurus*, es una actividad turística nueva en Patagonia, Argentina. En presencia de barcos, el tiempo de alimentación disminuye y el tiempo para volver a alimentarse después de abandonar la alimentación y el tiempo que toma un grupo de delfines para alimentarse aumentan. Tales efectos sobre la conducta de alimentación puede implicar costos energéticos en los delfines y por lo tanto reducir la supervivencia y la capacidad reproductiva de un individuo o quizá asociarse con cambios en la distribución. Tratamos de predecir los cambios conductuales que más modifican el patrón de actividad de los delfines. Modelamos secuencias conductuales de delfines mediante cadenas de Markov. Calculamos las probabilidades de transición de una actividad a otra y las acomodamos en un modelo matricial estocástico. Calculamos la proporción de tiempo que los delfines dedicaron a una actividad determinada (presupuesto de actividad) y el tiempo que le llevó a un delfín reanudar esa actividad después de abandonarla (tiempo de recurrencia). Utilizamos un análisis de sensibilidad de cadenas de Markov para calcular la sensibilidad del presupuesto de tiempo y el tiempo de reanudación de la actividad a los cambios de las probabilidades de transición conductual. El presupuesto de tiempo para alimentación fue más sensible a los*

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cambios en la probabilidad de que los delfines cambien de conducta de traslado a conducta de alimentación y de que mantengan la conducta de alimentación. Por lo tanto, un incremento en esas probabilidades pudiera ser asociada con la mayor reducción en el tiempo dedicado a la alimentación. Una reducción en la probabilidad de cambiar de traslado a alimentación también estaría asociada con los mayores incrementos en el tiempo que toman los delfines para reanudar la alimentación. Acercarse a los delfines cuando se están trasladando no afectaría menos su conducta porque la presencia del barco puede evitar que los delfines regresen a alimentarse. Nuestros resultados pueden ayudar a que los operadores de embarcaciones para observación de delfines minimicen los efectos negativos sobre los delfines.

Palabras Clave: análisis de sensibilidad, delfines, modelos matriciales estocásticos, presupuesto de actividad, turismo

Introduction

Watching animals in the wild (i.e., wildlife watching) is one of the fastest growing sectors of tourism worldwide. In some cases, it involves interactions with animals, such as touching or feeding them. Some conservation professionals think wildlife watching is beneficial locally because it generates income and stimulates development (Higginbottom 2004; Tapper 2006). However, wildlife watching is not sustainable if it decreases the probability of persistence of the watched species and their habitats.

Cetacean-based tourism is one of the fastest growing sectors and provides incomes for people in many countries. Whale watching (including dolphin and porpoise watching) grew 12% per year between 1991 and 1998 (Hoyt 2001). By 1998, whale watching was an approximately US$1-billion industry that attracted more than 9 million participants in 87 countries and territories (Hoyt 2001). People watch whales, dolphins, and porpoises from boats and swim with and feed them. Such activities are sometimes encouraged by conservation professionals because it is thought that the more people know about the behavior of a species or about an ecosystem the more likely they are to support measures to conserve them (Curtin 2003). Wildlife watching is also viewed as a replacement for some consumptive uses such as hunting (IFAW 2011). Since 1993, the International Whaling Commission has encouraged whale, dolphin, and porpoise watching (Williams et al. 2006).

However, tourism activities affect the behavior of cetaceans (Bejder & Samuels 2003). The short-term changes in behavior brought about by these activities may have long-term effects on populations (e.g., displacement of animals from their habitat and reduced survival and reproductive output). The link between short- and long-term effects is unclear. However, analyses of changes in activity budgets can reveal whether behavioral changes have energetic costs for animals. For example, several dolphin species, such as bottlenose dolphins (*Tursiops truncatus*) in Fiordland, New Zealand (Lusseau 2003), killer whales (*Orcinus orca*) in British Columbia, Canada (Williams et al. 2006), and common dolphins (*Delphinus delphis*) in Hauraki Gulf, New Zealand (Stockin et al. 2008), shift their activity budgets when exposed to boats. Tourism also is associated with short-term displacement of dolphins from their habitat. In a region of low vessel traffic in Shark Bay, Western Australia, Indo-pacific bottlenose dolphins (*Tursiops* sp.) have stronger and longer lasting responses to boats than dolphins in an area of high vessel traffic (Bejder et al. 2006*a*). Results of another study in Shark Bay show that dolphin watching has contributed to the long-term decline in dolphin abundance in this area (Bejder et al. 2006*b*). Bejder et al. (2006*b*) suggest that dolphins become habituated to vessels and that individuals disturbed by vessels leave the area.

In Patagonia, Argentina, Península Valdés, a World Heritage site, is a major year-round destination for national and international tourists. Interest focuses mainly on the presence of southern right whales (*Eubalaena australis*). In 2008, over 100,000 people came to watch whales from June to December, and the entire area received 350,000 over the course of the entire year (Losano & Tagliorete 2009). The number of tourists has been increasing, and some boat operators have begun to search for new activities to offer tourists, particularly when whales are absent and most tour boats do not operate. One new activity is dolphin watching (primarily dusky dolphins [*Lagenorhynchus obscurus*]) (Coscarella et al. 2003). From 2001 to 2005, 3 different commercial vessels operated dolphin-watching tours (an 11-m fiberglass boat and 2 inflatable boats of 8 and 10 m, all with outboard motors) and carried a few thousand passengers from January to March (Markowitz et al. 2010). The constant growth of the tourism industry in Península Valdés suggests the demand for alternative activities will increase.

Coscarella et al. (2003) and Dans et al. (2008) evaluated the effect of tour vessels on the behavioral budget of dusky dolphins. Results of these studies showed that feeding behavior and thus energy budget are affected by presence of tour boats. Boat operators in these studies found groups of dolphins mainly when they were feeding. Possibly, it was easier for skippers to find dolphins when they were feeding than when they were engaged in another activity (milling, resting, or socializing) because often feeding dolphins were associated with a flock of birds. Response of dolphins to vessel approach depends on the activity dolphins are engaged in and the distance between dolphins and the vessel. Half of the time feeding or milling groups change their activity when a vessel approaches, whereas traveling, socializing, and resting groups do not change their activity. When a vessel approaches a group of traveling dolphins, most of the time dolphins continue traveling. More dolphin groups change behavior when the vessel is <100 m away than when the vessel is farther away. During the time a group of dolphins is disrupted by a vessel, which is close to 10% of daylight hours, feeding-time budget decreases. The time it takes to return to feeding once it is interrupted and the time between any activity and feeding increases in the presence of tour vessels (Dans et al. 2008).

Dolphin watching in Península Valdés started in 1997 and is still unregulated (Coscarella et al. 2003), possibly because the number of tourists and companies conducting this activity is not as high as for whale watching. A national decree protects marine mammals and other animals. At the provincial level, laws protect marine mammals (harassing, pursuing, swimming, diving, and sailing with marine mammals are forbidden) and regulate right-whale watching. The number of companies, vessel characteristics, operator skills, and other aspects of whale watching are regulated. Dolphin-watching vessels are licensed by provincial authorities under a general nautical-trip category (Subsecretaria de Turismo de la Provincia del CHUBUT). A nautical trip may include watching animals, snorkeling, or approaching a sea-lion rookery. In 2010, authorities began issuing special permits for nautical trips in Golfo Nuevo. The Marine Mammal Laboratory helped authorities establish guidelines for these permits.

We sought to determine how to avoid or minimize effects of dolphin watching. We examined which behavioral changes would cause the greatest modifications in the activity pattern of dolphins, especially in regards to feeding. We considered the behavior of dusky dolphins as sequences of activities or behavioral states, modeled, and analyzed these sequences with a stochastic matrix model, and performed sensitivity analyses of activity budget and time to return to an activity. Our results were used to improve legislation on nautical trips and to develop a code of conduct for dolphin watching in Península Valdés.

Methods

Study Area

Golfo Nuevo, Argentina (42°20′–42°50′ S; 64°20′–65°00′ W), (Fig. 1) is southwest of Península Valdés, a protected World Heritage site. It is a semienclosed basin approximately 70 km long and 60 km wide (2500 km^2), has a maximum depth of 184 m, and opens to the Atlantic Ocean through a shallow sill 16 km wide (Mouzo et al. 1978) (Fig.1). The size of the population and emigration and immigration rates of dusky dolphins in the gulf are unknown. Coscarella et al. (2003) sighted groups of approximately 200 animals during the dolphin-watching season

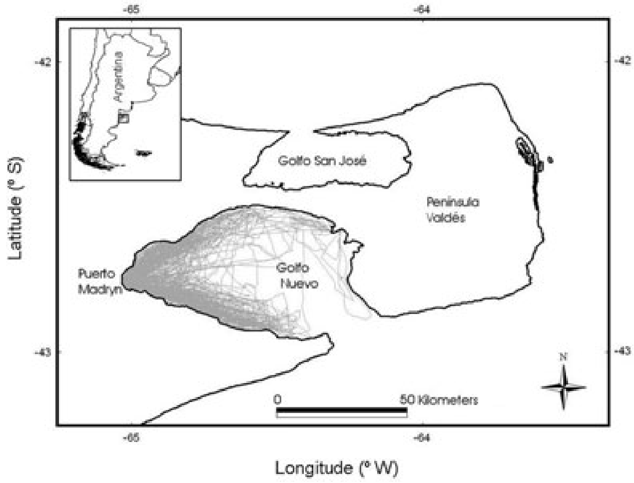

Figure 1. Study area where boat-based surveys of dusky dolphins were carried out from 2001 to 2005. Trips started from Puerto Madryn, Argentina (gray lines, show paths followed by the research boat).

of 2001, though half of time they occur in groups of 10–20 animals (Degrati et al. 2008). Population structure and connectivity between dolphin groups in open waters and closed bays such as Golfo Nuevo are poorly known. According to preliminary microsatellite analyses, Golfo Nuevo individuals are related to dolphins from Golfo San Jorge, which is located 400 km south of Golfo Nuevo (R. Loizaga de Castro, unpublished data).

Sampling Design

We studied dusky dolphins from summer to fall (January–April) in 2001–2005. Our boats departed from Puerto Madryn (Fig. 1), the same harbor from which tour vessels operate. We observed dolphins from boats instead of from land because dolphins occur most often 3–5 km from the coastline (Garaffo et al. 2010). We used a 6-m fiberglass boat with a 50 horsepower outboard motor from 2001 to 2003 and a 7.20-m fiberglass boat with a 105 horsepower outboard engine from 2004 to 2005.

We navigated random transects throughout the study area until we detected a group of dolphins (i.e., focal group [Mann et al. 2000]). We conducted observations of groups rather than individuals because dusky dolphins in Golfo Nuevo occur in groups of 10–100 individuals and because groups remain separated by several hundreds of meters. We determined the behavioral state of the focal group with an instantaneous sampling protocol (Altmann 1974; Lehner 1998) in which we recorded the behavioral state when the group was first sighted and every 2 minutes thereafter. Behavioral state was the activity in which most members of the group were engaged: traveling (dolphins moving continuously in a single direction with few or no interruptions), feeding (dolphins moving fast, diving, and emerging in all directions, dolphins pursuing and chasing fish, fish jumping out of water, and marine birds feeding simultaneously), socializing (dolphins in almost constant physical contact with each other, belly-to-belly swimming, aerial displays, frequently noisy), milling (dolphins moving slowly, changing direction continuously, and shifting location), and resting (dolphins tightly grouped, swimming slowly with numerous direction changes, and not shifting location).

To minimize the potential effect of the boat on the behavior of the study animals, we kept the distance between boats and the focal group at 100 m and we approached groups from the side in the same direction and speed of their movement (Dans et al. 2008). A focal group was followed until a change of sea state made assessment of behavior difficult (i.e., whitecaps became very frequent, Beafourt 4 or greater) or until a commercial boat approached the group.

Modeling Behavior with Markov Chains

Because behavioral states recorded at consecutive 2-minute intervals are not independent, we modeled behavioral sequences with Markov chains (Bakeman & Gottman 1997). The probability of occurrence of a specific behavioral state given that another behavioral state had occurred is the transition probability, and a set of transition probabilities forms a stochastic matrix model. We considered only the dependence between 2 consecutive intervals (i.e., a first-order Markov chain). This matrix (**P**) contained 5 rows (preceding activity *i*) and 5 columns (succeeding activity *j*). Each cell represented the probability of a transition from one state to another, and all probabilities in a row summed to 1.

$$\mathbf{P} = \begin{bmatrix} p_{11} & p_{12} & .. & .. & p_{15} \\ p_{21} & .. & .. & .. & .. \\ .. & .. & .. & .. & .. \\ .. & .. & .. & .. & .. \\ p_{51} & .. & .. & .. & p_{55} \end{bmatrix}. \quad (1)$$

We calculated transition probabilities from observations of focal groups. We classified each 2-minute interval according to the activity in the previous interval (preceding activity *i*) and the activity at the interval (succeeding activity *j*). We used the following to calculate transition probabilities:

$$p_{ij} = \frac{a_{ij}}{\sum_{j=1}^{5} a_{ij}} \quad (2)$$

and

$$\sum_{j=1}^{5} p_{ij} = 1, \quad (3)$$

where p_{ij} is the transition probability from activity *i* to activity *j* and a_{ij} is the number of 2-minute intervals in which activity *i* was followed by activity *j*. We pooled transitions calculated from different focal groups because we expected differences among group observations would arise only if we had considered much higher order chains.

To apply this model to dolphin behavior, we assumed transition probabilities over time are stable. To test this assumption, we classified intervals by year (2001, 2003, and 2004) and arranged frequencies of behavioral states in a $5 \times 5 \times 3$ contingency table (preceding vs. succeeding activity vs. year). We used log-linear models to analyze the effect of time on transitions. We compared the fully saturated model (preceding activity $\times$ succeeding activity $\times$ year) with the model with all 2-way interactions with ΔG^2 tests.

We derived activity budget from the ergodic properties of the Markov chains. We obtained the probability of observing a specific activity at a specific time from the fixed row vector **w** of the matrix **P.** This is the row vector that satisfies $\mathbf{wP} = \mathbf{w}$, and this vector is the left eigenvector of the matrix **P** corresponding to eigenvalue 1. The **w** is the stationary distribution of a Markov chain, and its components sum to 1. The fixed column vector **x** that satisfies $\mathbf{Px} = \mathbf{x}$ is the right eigenvector of **P** and corresponds to eigenvalue 1 (Grinstead & Snell 1997). In our analyses, **w** represents the activity budget of dolphins and each w_i represents the proportion of time spent in the activity *i* (Dans et al. 2008).

Mean time to return to an activity was calculated from mean recurrence time

$$r_i = \frac{1}{w_i}, \quad (4)$$

where w_i is the *i*th component of the fixed probability vector **w** for the transition matrix.

Sensitivity Analyses

Perturbations of **P** change the left eigenvector **w**. Thus, eigenvector sensitivity analyses allow one to identify changes in behavior that produce the greatest changes in dolphin activity budget and the time to return to an activity. Sensitivity is a derivative function and the sensitivity of **w** to p_{ij} is the slope of each w_i as a function of p_{ij} (Caswell 2001). Sensitivity measures the effect of absolute changes in matrix entries on the parameter of interest. In addition, in our case, all matrix entries p_{ij} varied between 0 and 1; therefore, sensitivities of **w** to different p_{ij} were easy to compare.

If the eigenvector is scaled so that $\|\mathbf{w}\| = \sum_i |w_i|$ the sensitivities of **w** are calculated with

$$\frac{\partial}{\partial p_{ij}} \frac{\mathbf{w}}{\|\mathbf{w}\|} = \frac{\partial \mathbf{w}}{\partial p_{ij}} - \mathbf{w} \sum_k \frac{\partial w_k}{\partial p_{ij}}, \quad (5)$$

where

$$\frac{\partial \mathbf{w}}{\partial p_{ij}} = w_i \sum_{m \neq 1}^{s} \frac{\overline{x_j}}{\lambda - \lambda_m} w_m$$

and w_j is the ith element of $\mathbf{w}$, $x_j^{(m)}$ is the jth element of the right eigenvector $\mathbf{x}_m$, and λ_m is the mth eigenvalue (Caswell 2001).

In other matrix models (e.g., population models), sensitivities of $\mathbf{w}$ to changes in any element of $\mathbf{P}$ can be obtained as partial derivatives of $\mathbf{w}$; they illustrate the effect of changing one p_{ij} on $\mathbf{w}$ and hold all other variables constant (Caswell 2001). In our case, $\mathbf{P}$ is a row stochastic matrix and thus sensitivity analysis is not directly applied because any change in p_{ij} must be accompanied by changes in the other entries of the row to preserve $\sum_{j=1}^{5} p_{ij} = 1$. Thus, we calculated a total derivative as

$$\frac{d\mathbf{w}}{dp_{ij}} = \frac{\partial \mathbf{w}}{\partial p_{ij}} + \sum_{m \neq i}^{s} \frac{\partial \mathbf{w}}{\partial p_{mj}} \frac{\partial p_{mj}}{\partial p_{ij}}. \qquad (6)$$

This equation yields a vector with 5 elements that correspond to the sensitivity of each activity budget w_i. The derivative $\partial p_{mj}/\partial p_{ij}$ is determined by the way it compensates for changes in p_{ij}. Although several compensation patterns are possible, we used proportional compensation (Caswell 2001):

$$\frac{\partial p_{mj}}{\partial p_{ij}} = \frac{-p_{mj}}{1 - p_{ij}} \qquad (7)$$

for $m \neq i$, where compensation for the change in p_{ij} is distributed over the other row entries in proportion to their values (adapted from Caswell 2001).

We used Poptools (2002) to obtain eigenvalues, eigenvectors, and the partial derivative $\partial \mathbf{w}/\partial p_{ij}$. We used uniform compensation to keep $\sum_{j=1}^{5} p_{ij} = 1$, and it yielded results similar to proportional compensation (change in p_{ij} was distributed uniformly over the other entries in a row [adapted from Caswell 2001]).

We evaluated the effects of perturbations of $\mathbf{P}$ on mean recurrence time r_i similar to the way we evaluated effects of $\mathbf{P}$ on activity budget $\mathbf{w}$. Because $r_i = 1/w_i$, sensitivities of r_i to changes in p_{ij} are

$$\frac{dr_i}{dp_{ij}} = -\frac{1}{w_i^2} \frac{dw_i}{dp_{ij}}, \qquad (8)$$

where w_i is the ith element of the eigenvector $\mathbf{w}$ and $\frac{dw_i}{dp_{ij}}$ is the ith element of the vector $\frac{d\mathbf{w}}{dp_{ij}}$.

Results

We observed 29 groups of dolphins. We based transition probabilities on 749 2-minute intervals and 706 behavioral sequences (Fig. 2). Transition probability matrix $\mathbf{P}$ was stationary throughout the study ($\Delta G^2 = G^2_{\text{all two way}} - G^2_{\text{saturated}} = 16.426$; df = 32; $p = 0.99$). The model showed dolphins spent 41% of their time traveling and 22% feeding (Fig. 3a). Once dolphins stopped feeding, it took 10 minutes for them to return to the previous activity (Fig. 3b).

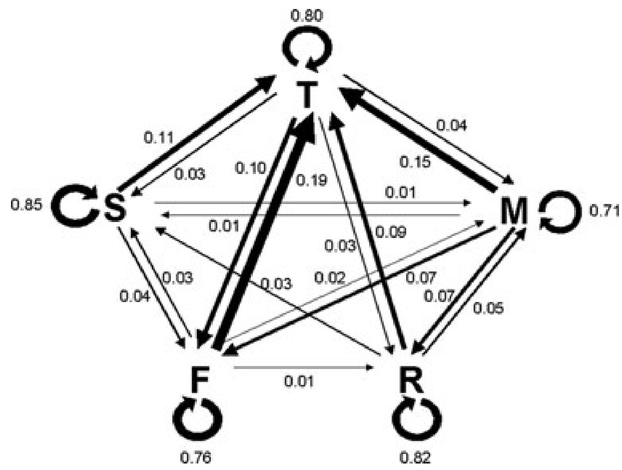

Figure 2. Markov chains representing transition probabilities (p_{ij}) from dolphin activity i *to activity* j *(F, feeding; T, traveling; S, socializing; M, milling; R, resting). Values are transition probabilities, and arrow thickness represents relative size of these values.*

Time invested in each activity was directly related to changes in transition probability from any other activity to that activity (Fig. 4). However, not all transitions to a particular activity altered the time budget in the same way. Feeding time budget was directly related to the probability of transition from traveling to feeding and the probability of continuing to feed, which suggests that a reduction in these 2 probabilities may result in the largest reduction in the time dolphins feed and vice versa (Fig. 4). Feeding time budget was also inversely related to some transition probabilities. An increase in the probability of transition from feeding to resting and from traveling to resting was associated with the largest reduction in feeding budget (Fig. 4).

In some instances, the socializing time budget was directly related to the probability of transition from traveling to socializing and from feeding to socializing (thus, a reduction in the probabilities of these transitions was associated with the largest reduction in the time dolphins socialized) and inversely related to the probability of transitioning from socializing to traveling (Fig. 4). Resting time budget would be most affected by probabilities of transitions from traveling to resting and from feeding to resting; thus, a reduction in the probabilities of these transitions would result in less time dedicated to rest. Milling time budget increased as the probability of transition from traveling to milling increased. Traveling and milling were inversely related to probabilities of

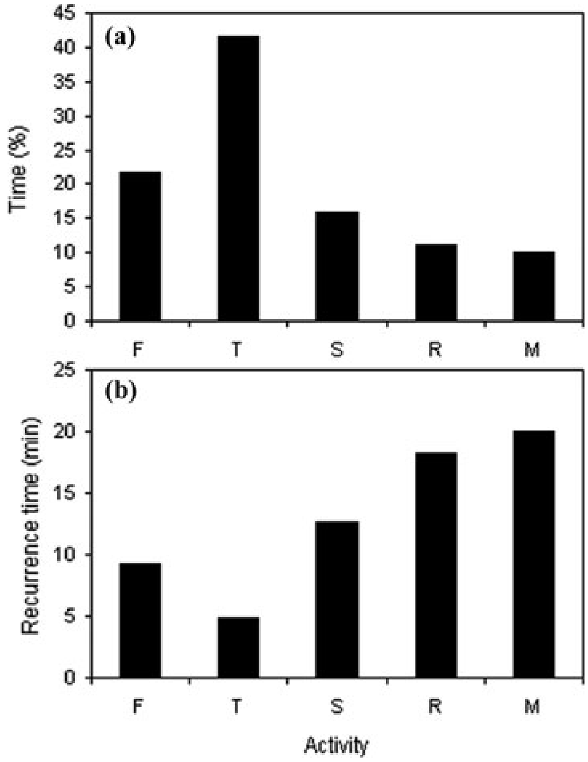

Figure 3. Time dusky dolphins in Golfo Nuevo, Argentina, (a) spent on 5 activities and (b) took to resume an activity after it had been stopped (F, feeding; T, traveling; S, socializing; R, resting; M, milling). An activity can be stopped as part of the normal sequence of behavior.

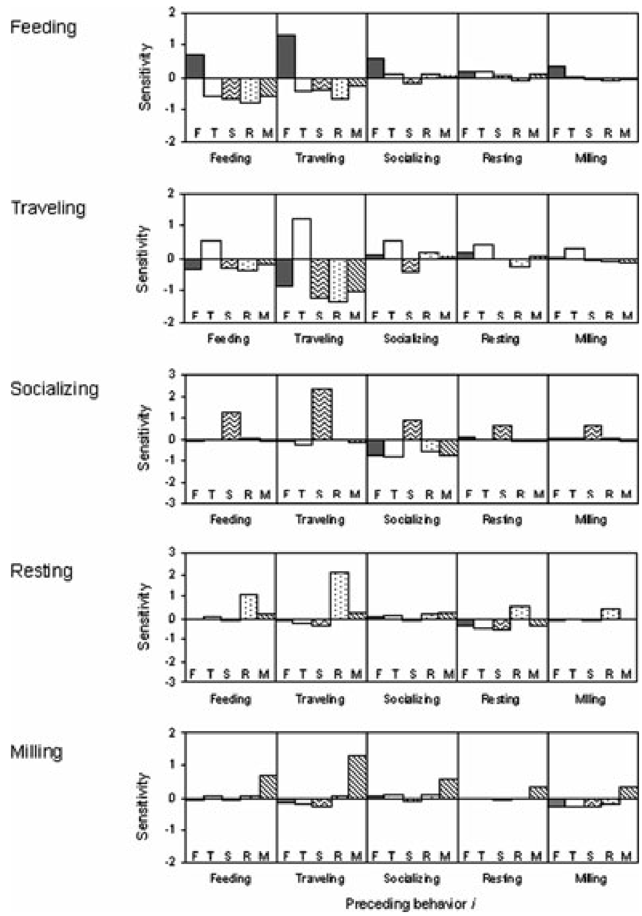

Figure 4. Sensitivity of dusky dolphin feeding, traveling, socializing, resting, and milling time budgets to changes in the probability of transitioning from one behavior (preceding behavior, i*) to another (succeeding behavior,* j*) (*i*, x-axis;* j*, bars; behaviors: F, feeding; T, traveling; S, socializing; M, milling; R, resting). For example, the sensitivity of time spent feeding to probability of transitioning from traveling to feeding is 1.29. This value is the greatest value; thus, the feeding time budget is most sensitive to this transition.*

some transitions, although their sensitivities were lower (Fig. 4).

Feeding recurrence time was more sensitive to the probability of transitioning from traveling to feeding than any other transition (Fig. 5). When dolphins are traveling, a reduction in the probability of switching to feeding may produce the largest increase in the time dolphins took to resume feeding once they had stopped feeding. Socializing recurrence time was most sensitive to changes in the probability of transitioning from traveling to socializing (Fig. 5), such that a reduction of this transition may produce the greatest increase in time taken to resume socializing.

Discussion

Stochastic matrix models are commonly applied to population dynamics and more recently to community succession (Caswell 2001; Hill et al. 2004). Markov chains are also being used to evaluate the effects of human activity on dolphin behavior (Lusseau 2003). However, the sensitivity analyses of Markov chains we used are a novel extension of the procedure that can be used to evaluate the effect of a disturbance on the behavioral budget of any group of animals.

Perturbation analyses help one detect changes in behavior that may have the largest effects on the ecological process of interest. These kinds of analyses are often used in demographic models (de Kroon et al. 1986; Horvitz et al. 1996) for which the main goal is to measure the sensitivity of the population growth rate to changes in vital rates. The application of sensitivity analyses to stochastic probability matrices and Markov chains is less common and has been applied only in succession models in rocky intertidal communities (Hill et al. 2004). It can, however, be used to

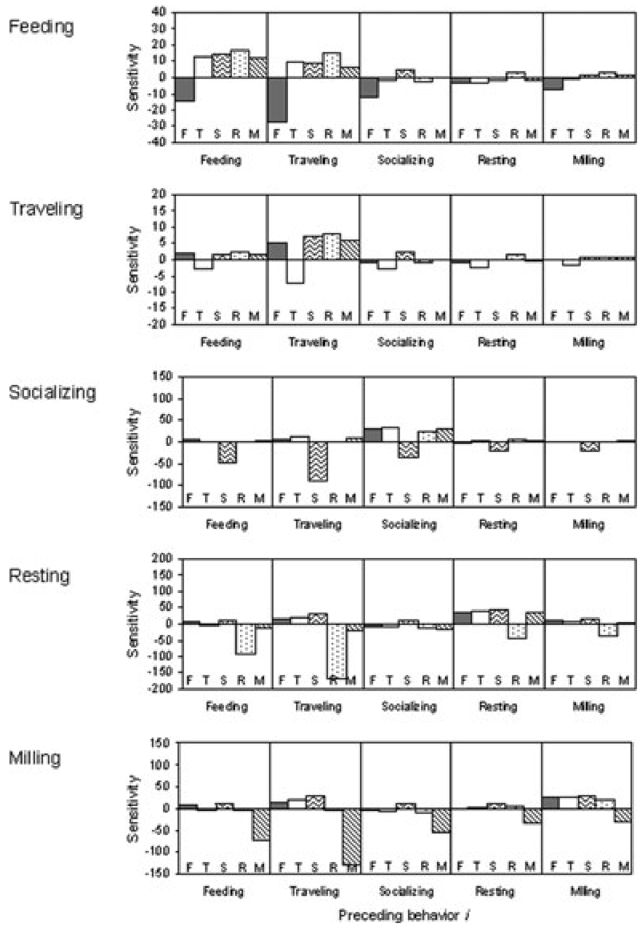

Figure 5. Sensitivity of dusky dolphin feeding, traveling, socializing, resting, and milling mean recurrence time (r_i*) to changes in the probability of transitioning from one behavior (preceding behavior,* i*) to another (succeeding behavior,* j*) (*i*, x-axis;* j*, bars; behaviors: F, feeding; T, traveling; S, socializing; M, milling; R, resting). For example, the sensitivity of time to resume feeding to probability of transitioning from traveling to feeding is −27.26. This value is the greatest value; thus, time to resume feeding is most sensitive to this transition.*

predict the results of changes in behavioral transition probabilities. Sensitivity analyses allow prospective perturbation analyses, the results of which may be used to inform management because they allow one to detect behavioral processes that may warrant protection to maintain the energy budget of animals. Minimizing potential changes in the balance between energetic costs and energy acquisition increases the chance of population persistence.

We detected which changes in dolphin behavior would produce the largest changes in feeding time budget and in the amount of time dolphins took to return to a feeding state. Dans et al. (2008) demonstrated that the behavior of dolphins changes in the presence of boats: the proportion of time dedicated to feeding and socializing decreases significantly in the presence of boats. Even though the probability of transitioning from traveling to feeding was not significantly different between undisturbed and disturbed groups, feeding time budget was more sensitive to changes in the probability of dolphins switching from traveling to feeding. Therefore, a change in the probability of this transition (though not significant) could produce the detected change in the feeding time budget.

Time dedicated to feeding and time taken to return to feeding are directly related to energy acquisition. However, the entire behavioral sequence (traveling to feeding and feeding to traveling) may be an important functional component of dusky dolphins' activity pattern. Possibly, during some traveling bouts dolphins are actually searching for food. Disruption to this behavioral sequence, such as may occur if dolphins fail to find food after a traveling bout and continue to travel in a search for food, may result in additional effort dedicated to foraging. In this example, foraging costs associated with searching and handling prey will increase in the presence of tourist boats, whereas the time dedicated to feeding will decrease.

Our most important finding was that feeding time budget was modified when boats interfered with the transition from feeding to traveling and from traveling to feeding. Boat operators tend to approach dolphins more closely when they are traveling so they will leap. When dolphins stopped feeding and began traveling, it took on average 10 minutes for them to return to feeding. If boats interfere with the probability of dolphins changing their behavior from traveling to feeding, it may take longer for them to return feeding.

On the basis of our results and the results of Coscarella et al. (2003) and Dans et al. (2008), guidelines for operators of dolphin-watching tours were developed by provincial authorities and implemented in 2011. These regulations require that a group of dolphins visited by one boat cannot be approached by another boat immediately after the first has left the area so that dolphins are allowed time to return to feeding. The guidelines do not say how long a close approach (<100 m) may last. The effects of the presence of boats on feeding time budget may be reduced by establishing a maximum time for close approaches (i.e., within 50 m), and results from additional studies may inform decisions about boat proximity to dolphin groups. The guidelines recommend that boats stay at ≥100 m from a dolphin group. This distance was determined on the basis of results of studies of dolphin reactions to boats in which a distance of 100 m was the control and a distance of <100 m was the treatment (Coscarella et al. 2003; Dans et al. 2008). We believe additional experiments are needed to determine whether the probability of change in behavior increases as the distance between boats and dolphins decreases.

Two companies operate dolphin-watching tours from Puerto Madryn Harbor (Fig. 1). These tours last several hours and boat operators usually spend a lot of time (sometimes 2 hours) searching for dolphins (Markowitz et al. 2010). Dolphins occur most often in the southern portion of the gulf (Garaffo et al. 2010), so operators from Puerto Madryn Harbor find dolphins frequently. Operators from Puerto Pirámides (Fig. 1), however, find dolphins only sporadically and opportunistically because their goal is to show tourists scenery, the sea-lion rookery, and seabirds. At present, no laws regulate the number of nautical trips. Therefore, the activity is regulated by cost and demand, which may change in the future.

We expect that adverse effects of dolphin watching in the Golfo Nuevo will be lessened by implementation of the tour-operator code of conduct. Adherence to the code is voluntary, and even though operators of dolphin-watching tours have to be licensed, control and monitoring of the activity are lacking. The provincial authority has no capacity for controlling tourism activities at sea. Rangers are dedicated primarily to controlling and monitoring human activities in protected areas on land. As tourism expands, we believe controls and limits must be properly planned and regulations updated.

In addition to being affected by tourism, dusky dolphins in the Golfo Nuevo may also be affected indirectly by shrimp (*Pleoticus muelleri*) and anchovy (*Engraulis anchoita*) fisheries (Markowitz et al. 2010), which are associated with the incidental mortality of dusky dolphins. The population may not be sustainable, not the threats (Dans et al. 2003). Therefore, several sources of perturbation may be stressing this population and could lead to their extirpation. The link between the effect of tour boats on the behavioral pattern of dolphins and persistence of the dolphin population remains unclear. However, if species persistence is threatened by tour boats, then in this case ecotourism fails as a conservation tool.

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