Latitudinal variation in diet and patterns of human interaction in the marine otter

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ABSTRACT

The marine otter (*Lontra felina*) inhabits patches of rocky coastline from central Peru to southern Chile and is classified as Endangered by the IUCN. Given the
limited information available about the species, we set out to assess marine otter diet with a view to detecting latitudinal differences, and to assess marine otter activity budgets and interspecific interactions (including anthropogenic) at Peruvian fishing villages and to compare results with similar Chilean studies. Nine study sites from central Chile to southern Peru were sampled for otter spraints to assess relative frequency of prey types and two fishing ports in southern Peru were monitored through focal and scan observations to assess activity patterns, interspecific interactions, habitat use patterns, and dive durations. Results indicate that toward the northern part of its range, crustaceans become less important and fish more important in the diet. Interactions were observed between marine otters and other species, including stray dogs and cats. The strong dependence of marine otters on the availability of safe rocky shelters, and the species’ apparent tolerance to living alongside humans raise conservation concerns about vulnerability to anthropogenic threats. These factors, if not correctly managed, could turn some of these rocky seashore patches into population sinks.

Key words: *Lontra felina*, marine otter, human interaction, latitudinal variation, Peru, Chile.

The marine otter (*Lontra felina*) has a limited and patchy distribution that ranges from central Peru (6°S) to the southern tip of Chile (56°S) (Alvarez and Medina-Vogel 2008, Medina-Vogel *et al*. 2008), with isolated populations in Argentina (Larivièere 1998). The species was historically hunted for pelts in Peru and Chile, resulting in considerably reduced abundance and geographic distribution (Brownell 1978, Cabello 1978, Iriarte and Jaksić 1986, Iriarte *et al*. 1997). The species population is thought to be declining and is classified as Endangered by the International Union for the Conservation of Nature (IUCN 2008).

Published studies on marine otter distribution, activity budgets, prey composition, and anthropogenic effects are limited to populations in Chile (Ostfeld *et al*. 1989; Medina 1995a,b; Medina-Vogel *et al*. 2004, 2006, 2007, 2008). Similar studies of marine otters in Peru are confined to unpublished works. Previous research in Chile suggests that foraging is the dominant category of activity while marine otters are in sight, and that otters feed opportunistically, with a diet primarily comprised of crabs, followed by fish (Ostfeld *et al*. 1989; Medina-Vogel *et al*. 2004, 2006). Since studies of prey composition suggest that there is between-site and possibly latitudinal variation in marine otter diet (Cabello 1978, 1983; Castilla and Bahamondes 1979; Castilla 1982; Ostfeld *et al*. 1989), it is likely that differences in the diet, and possibly activity budgets, of otters may exist between Peru and Chile.

This otter species is forced to coexist with humans given its habitation of the marine littoral zone and exploitation of the same resources from the intertidal, subtidal, and terrestrial seashore that humans exploit for food, commerce, and housing (Moreno *et al*. 1984; Ostfeld *et al*. 1989; Moreno 2001; Medina-Vogel *et al*. 2004, 2007). Thus anthropogenic impacts on marine otters are of particular concern given the continuing human population expansion and development of the Peruvian and Chilean coast which may lead to habitat loss, degradation, or fragmentation (Larivièere 1998, Medina-Vogel *et al*. 2008).

Fishing villages are one interface between human activity and marine otter habitat (Medina-Vogel *et al*. 2007). By creating artificial den sites (e.g., wharfs and shipwrecks) and providing food in the form of fish refuse, fishing villages may attract marine otters (Medina-Vogel *et al*. 2007). For example, groups of marine otters have been observed feeding together at fish refuse piles (Medina-Vogel *et al*. 2007) which
has the potential of increasing exposure to direct and indirect anthropogenic threats (Castilla 1999; Medina-Vogel et al. 2004, 2008; Gaydos et al. 2007; Miller et al. 2008).

Given the paucity of information on the behavior, ecology, and conservation of marine otters throughout a large part of its continental distribution, our objectives were to (1) assess marine otter diet with a view to detect any latitudinal differences, and (2) assess marine otter activity budgets and interspecific interactions (including anthropogenic) at Peruvian fishing villages and to compare results with similar studies from Chile.

METHODS

Study Area

Four distinct study sites, 54.7–111 km long and more than 100 km apart, along the Chilean Pacific seashore between 28.05°S and 39.67°S, and five distinct study sites in Peru, 0.2–21.0 km long and separated by 7–40 km of coastline between 17.64° and 18.05°S were sampled for otter spraints (Fig. 1).

Figure 1. Locations of field sites for this study distributed along approximately 2,400 km of coastline in Peru and Chile. The upper inset map shows the five Peru study sites while the lower inset map shows the project area extent (black square) and the entire range of marine otters (in gray).
To obtain information on activity budgets and interactions with humans in Peru and for subsequent comparison with populations in Chile, otter observations were conducted from Morro Sama (17.98°S, 70.86°W) and Vila Vila (18.12°S, 70.71°W), two fishing villages in southern Peru separated by 23 km of rocky coastline (Fig. 1). Morro Sama and Vila Vila are active fishing ports with permanent human populations of approximately 200 and 350, respectively. Rats (*Rattus rattus*) as well as stray dogs and cats are common (Mangel, personal observation.). Both villages have developed around the placement of artificial breakwaters and fish processing facilities that have daily activity related to the arrival and departure of artisanal dive, net, and longline fishing vessels that use the ports as mooring and landing sites. Human activity is regular at both sites as are shore-based and nearshore fishing for fishes and invertebrates. These sites both possess resident groups of marine otters that use the breakwaters as den sites and forage in the vicinity of the ports.

**Latitudinal Variation in Diet**

Chilean sample sites were surveyed once between June 2005 and March 2006. For southern Peru, samples were collected at regular intervals from June 2003 to March 2009. Spraints were washed and dried at 75°C for 24–48 h and stored in paper bags (Bagenal 1978, Medina-Vogel *et al.* 2004). Spraints were analyzed for prey composition based on presence of fish or crustacean remains. Direct observations of otters feeding at the two Peruvian study sites were also made during focal follow observations (see *Human–Marine Otter Interactions* below). Prey were classified to genus or species when possible and grouped into broad categories (Table 1). Prey items that could not be identified because they were too small or were out of view, were classed as unidentified. Prey identification was guided by Chirinchigno and Cornejo (2001).

In order to compare with previous studies, data were expressed as frequency of occurrence (number of spraints in which a species occurred divided by the total number of spraints collected), and percentage of relative frequency (number of spraints in which a species occurred divided by the total occurrence of all species tested) (Medina 1997, 1998; Medina-Vogel *et al.* 2004).

Foraging dive durations were also recorded for the Peru study sites and compared with equivalent data from Curitanco, Chile (39°30′S, 73°W) collected from December 1990 to December 1992 (Medina 1995a). Dive times were grouped and separated by site (Peru, Chile).

**Table 1.** Marine otter prey composition at Morro Sama (MS) and Vila Vila (VV), Peru based upon focal follow observations (MS *n* = 513; VV *n* = 211).

<table>
<thead>
<tr>
<th>Composition of otter prey (%)</th>
<th>MS</th>
<th>VV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fish</td>
<td>40.6</td>
<td>48.2</td>
</tr>
<tr>
<td>Crab</td>
<td>29.3</td>
<td>20.3</td>
</tr>
<tr>
<td>Unidentified prey</td>
<td>13.6</td>
<td>29.2</td>
</tr>
<tr>
<td>Shrimp</td>
<td>15.2</td>
<td>1.4</td>
</tr>
<tr>
<td>Squid (bait)</td>
<td>1.0</td>
<td>0</td>
</tr>
<tr>
<td>Unidentified crustacean</td>
<td>0.2</td>
<td>0</td>
</tr>
<tr>
<td>Echinoderm</td>
<td>0</td>
<td>0.5</td>
</tr>
<tr>
<td>Mollusk</td>
<td>0.2</td>
<td>0</td>
</tr>
</tbody>
</table>
Human–Marine Otter Interactions

Focal samples were collected as a method of constructing activity budgets, estimating activity bout duration and assessing human–otter interactions. Observations were conducted from the breakwaters, docks, and coastline of Morro Sama and Vila Vila. Given the distance between sites and the known home range of marine otters (Medina-Vogel et al. 2007), they were considered independent. Monitoring was conducted by a total of 11 observers, with one to five observers per shift. Observers were professional biologists or trained undergraduate student volunteers. Observers used direct observation and 8 × 25 binoculars to aid in monitoring. Morro Sama was divided into 14 and Vila Vila into nine continuous, nonoverlapping zones approximately 50 m in length and delineated by natural or manmade markers. As the observation points selected were at locations with regular human activity related to port operation, the presence of observers did not result in otter fear or avoidance behavior. Monitoring was conducted during daylight hours (0600–1800) from October 2003 through November 2007 (excluding June and August 2004, January and February 2007, July through September 2007), for a total of 701 h at Morro Sama and 586 h at Vila Vila.

Otter behavior was categorized as foraging, traveling, socializing (intraspecific), interacting (interspecific), resting, or grooming (based upon Shimek and Monk 1977). Human–otter interactions in Morro Sama and Vila Vila study sites were assessed by (1) otter use intensity of the study sites zones, and (2) the level of human activity per zone. Human activity per zone was classified based upon the frequency of human use (constant daily activity, sporadic daily, infrequent) and the presence of permanent structures (docks, buildings, etc.). Human activity was classified as low (no structures and infrequent activity), medium (permanent structures and sporadic daily activity), or high (permanent structures and constant daily activity).

Scan samples were collected in order to assess habitat use within the study areas and used the same activity categories and monitoring zones as focal follows. Two-minute scans were conducted every 10 min during daylight hours (0600–1800), in March and October through December in 2003, and January through April in 2004. A total of 553 scans were conducted over 9 d at Morro Sama and 8 d at Vila Vila. Only scans that had full coverage by observers of all study site zones were used in this analysis.

To standardize zone sizes, aerial photographs of each site were obtained from Google Earth and zone boundaries were demarcated. Relative area utilization frequency (controlled for different zone sizes) was then determined by multiplying the total number of observations per zone by the log transformed proportional zone size. Finally, the percent of time used by otters in each zone was determined by dividing the relative area utilization frequency of each zone by the total frequency.

Statistical tests were performed using SYSTAT v.12 (Systat Software, Inc., Chicago, Illinois).

RESULTS

Latitudinal Variation in Diet

There was a significant latitudinal variation in the relative importance of crustaceans (GLM for unbalanced design, $F_{1,3} = 23.4, P = 0.02$) and fish (GLM for
Figure 2. Diet composition given in relative frequency (RF%) by crustaceans and fish prey, found in fecal samples of marine otters collected in southern Peru (A) and four study sites in Chile (B–E). Sample size is shown for each sampled site.

unbalanced design, $F_{1,3} = 30.4, P = 0.01$) across the latitudinal range of the study such that the proportion of fish in the diet increased from south to north while the proportion of crustaceans declined from south to north (Fig. 2). Focal observations of the marine otter diet at the Peru study sites also indicated that prey consisted mainly of fishes followed by crabs (Table 1). Of 14 identified prey species, 10 were observed more than once. The most commonly identified prey item was deep red crab (*Petrolisthes desmarestii*), followed by rock crab (*Cancer setosus*), and rock shrimp (*Rynchocinetes typus*), but also included queen rock crab (*Cancer coronatus*), sally lightfoot crab (*Grapsus grapsus*), and several fish species, including Peruvian jack mackerel, (*Trachurus murphyi*), Peruvian silverside (*Odontestes regia*), Peruvian morwong (*Cheilodectylus variegatus*), lorna drum (*Sciaena deliciosa, Doydixodon laevifrons*), damselfish (*Chromis* spp.), flounder (*Paralichthys* spp. and *Genypterus* spp.), rays from the family Rajidae, as well as discarded Humboldt squid (*Dosidicus gigas*) previously used as bait.

**Human–Marine Otter Interactions**

Focal follow data had equal variances (Bartlett test for equal variances $P = 0.52$), so a general linear model (GLM) for unbalanced designs and repeated measurements was used to assess for differences in behaviors, dive time, seasons, and study sites in Peru. As there were no differences between both Peruvian study sites ($F_{7,71} = 0.83, P = 0.43$), data were grouped and separated by season.

Assessment of activity budgets based upon focal follows in Morro Sama and Vila Vila indicated that foraging was the most frequently observed activity at both study sites followed by traveling and that these were significantly more frequent than all other behavior categories (GLM for unbalanced design, $F_{5,138} = 198.1, P < 0.01$). Otters at Morro Sama spent significantly less time traveling than otters at Vila Vila
Table 2. Frequency (%) of marine otter interactions with humans, fisheries, and other species (n = 190) as observed during 1,392 h of focal follows.

<table>
<thead>
<tr>
<th>Interaction type</th>
<th>Avoid/watch</th>
<th>Search/steal</th>
<th>Feeding</th>
<th>Fight/follow</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fishing gear</td>
<td>1.6</td>
<td>21.6</td>
<td>–</td>
<td>0.5</td>
<td>23.7</td>
</tr>
<tr>
<td>Person</td>
<td>22.1</td>
<td>7.4</td>
<td>6.3</td>
<td>–</td>
<td>35.8</td>
</tr>
<tr>
<td>Subtotal</td>
<td>23.7</td>
<td>28.9</td>
<td>6.3</td>
<td>0.5</td>
<td>59.5</td>
</tr>
<tr>
<td>Mammals</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stray cats</td>
<td>1.6</td>
<td>0.5</td>
<td>–</td>
<td>1.1</td>
<td>3.2</td>
</tr>
<tr>
<td>Otaria byronia</td>
<td>0.5</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>0.5</td>
</tr>
<tr>
<td>Subtotal</td>
<td>2.1</td>
<td>0.5</td>
<td>–</td>
<td>1.1</td>
<td>3.7</td>
</tr>
<tr>
<td>Seabirds</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pelecanus thagus</td>
<td>1.6</td>
<td>–</td>
<td>–</td>
<td>32.1</td>
<td>33.7</td>
</tr>
<tr>
<td>Larus sp.</td>
<td>–</td>
<td>0.5</td>
<td>–</td>
<td>1.1</td>
<td>1.6</td>
</tr>
<tr>
<td>Phalacrocorax</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>boulgainvilli</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>1.1</td>
<td>1.1</td>
</tr>
<tr>
<td>Arenia sp.</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>1.1</td>
<td>1.1</td>
</tr>
<tr>
<td>Subtotal</td>
<td>1.6</td>
<td>0.5</td>
<td>–</td>
<td>34.7</td>
<td>36.8</td>
</tr>
</tbody>
</table>

(Mann–Whitney $U_1 = 110$, $P = 0.03$), but more time foraging (Mann–Whitney $U_1 = 22$, $P = 0.04$).

Dive durations were compared between Peruvian and Chilean study sites. Results indicate that dive times were similar between study sites (GLM for unbalanced design, $F_{3,8} = 3.6, P > 0.16$), with average dive times of 27.9 ± 14.4 s ($n = 395$) in Peru and 33.3 ± 12.2 s ($n = 190$) in Chile.

Marine otter habitat usage by observation zones was assessed for each study site in Peru and compared with human activity classifications. In Morro Sama, otter presence was significantly higher in areas categorized by medium human presence (Kruskal–Wallis $H_2 = 6.2, P < 0.05$) but in Vila Vila, otter sightings did not vary in relation to intensity of human activity ($H_2 = 1.781, P = 0.41$; Fig. 3).

Focal follow observations of anthropogenic interactions included 113 recorded events, of which 45 (40%) were interactions with boats, and 68 (60%) were interactions with people (Table 2). This includes one instance when a marine otter was trapped in a fishing net. Of the interactions between marine otters and boats, 41 (91%) involved marine otters “searching” for food, which includes marine otters approaching boats and jumping into boats to forage for fish.

Interactions with pelicans (*Pelecanus thagus*) were frequent, with 64 events observed, including 60 instances of marine otters engaging in aggressive behavior toward pelicans. Events involving sea gulls (*Larus* spp.), guanay cormorants (*Phalacrocorax boulgainvilli*), and black-crowned night herons (*Nycticorax nycticorax*) were rare, with only one-to-two interactions observed per genus. Similarly, there was only one observed interaction between a marine otter and a South American sea lion (*Otaria byronia*), which did not result in any harm to the otter.

There were six observed interactions with stray cats, including two observed fights and one observed instance of an otter stealing food from a cat. One otter kill as a result of a stray dog attack was recorded in Morro Sama in September 2008. There were no observed interactions with rats, but given their nocturnal behavior this was not unexpected. Nevertheless, rats have been seen exiting the manmade breakwater at Vila Vila during storm events.
DISCUSSION

Latitudinal Variation in Diet

This study has shown that fish become more prevalent and crustaceans less prevalent in the diet of the marine otter as one moves north along its distribution (Medina-Vogel et al. 2008). Crustaceans are lower quality (in terms of energy) food for otters than fish (Kruuk 1995, Medina-Vogel et al. 2004, Medina-Vogel and González-Lagos 2008). Furthermore, at the Peruvian study sites we recorded less time spent foraging than in previous studies (Ostfeld et al. 1989, Medina 1995a) and a higher percentage of fish in the diet. The higher energy content of fish compared to crustaceans (Medina-Vogel et al. 2004) may contribute to this difference in activity patterns between this and previous studies, i.e., otters at our study sites may more easily fulfill their energetic needs and therefore can spend less time foraging. Thus, we postulate that capture and handling time and effort of fish prey was not sufficiently costly at our study sites to render them less “valuable” than crustaceans, as previous studies suggested (Estes 1989, Medina-Vogel et al. 2004). Hence, toward the northern part of its range, marine otter habitat seems to be of better quality in terms of prey quality, which might be concentrating otters and leading to higher population densities (Medina-Vogel et al. 2007). Similar prey gradients have also been identified in other mammal species such as Eurasian otter (Lutra lutra; Clavero et al. 2003, Remonti et al. 2009), puma (Felis concolor, Iriarte et al. 1990), and genet (Genetta genetta, Virgós et al. 1999).

Study results also indicated that otters at Vila Vila spent more time traveling and less time foraging than otters at Morro Sama. The greater reliance of otters at
Morro Sama on lower quality shrimp prey could help account for the difference. The disparity may also be due in part to the fact that the main den locations in Vila Vila were situated further from foraging sites than in Morro Sama. Distance from dens to foraging sites has been suggested as an important habitat limitation for marine otters (Medina-Vogel et al. 2007, 2008) consequently, influencing the distribution of the species as individuals balance risks and net energy gain (Buskirk 1984, Weber 1989).

**Human–Marine Otter Activity**

This study found a large number of interactions between marine otters and other species, including humans. Interactions between seabirds and otters were the most frequent, perhaps due in part to competition for prey items. Otters, including marine otters, have also been shown to feed upon seabirds (Sheldon and Toll 1964, VanWagenen et al. 1981, Mattern et al. 2002, de la Hey 2008). Observed interactions between otters and anthropogenic activities support concerns over potential human impact on marine otters (Medina-Vogel et al. 2007, 2008). Based upon our observations, otters appear to have adjusted to living near fishing villages in Peru, as in other fishing villages in Chile (Medina-Vogel et al. 2007). However, with otters stealing fish from nets and boats (including one occasion of an otter entangled in a fishing net) and interaction with populations of stray cats and dogs—whether through agonistic encounters, indirect competition, or disease transmission (Davis et al. 1972, Kimber and Kollias 2000, Funk et al. 2001, Butler et al. 2004)—there could be detrimental effects that threaten marine otters population survival (Medina-Vogel et al. 2007, Medina-Vogel 2010). Infectious diseases, possibly associated with nearby terrestrial human development have been posited as impeding the population recovery of the southern sea otters, *Enhydra lutris nereis* (Conrad et al. 2005, Miller et al. 2008, Johnson et al. 2009). Moreover, recent declines in European populations of the Eurasian otter have been attributed, in varying degrees, to anthropogenic impacts such as pollution, habitat loss, persecution, and accidental mortality (Macdonald 1983, Macdonald and Mason 1994, Cortés et al. 1998, Barbosa et al. 2001, Prenda et al. 2001).

Because marine otters demonstrate apparent tolerance to living alongside fishing communities (and may actually be attracted to habitat altered by fishing communities), these anthropogenic threats could turn some of these small rocky seashore patches into population sinks. However, the overlap between marine otters and fishing villages also demonstrates the flexibility of marine otter behavior toward people. Thus, if the artificial otter habitats made by wharfs, breakwaters, and shipwrecks are correctly managed in terms of otters habitat needs, they could be used as stepping stones between rocky seashore patches already separated by human dominated environments (Meegan and Maehr 2002, Wikramanayake et al. 2004, Medina-Vogel et al. 2008). The construction of a set of small artificial otter habitats along more isolated regions of rocky seashore could also be a strategy for marine otter conservation. Additional studies of marine otter ranging behavior (Medina-Vogel et al. 2007) and population densities (Medina-Vogel et al. 2006) in the northern portion of the species’ range would help further characterize environmental limits for this species. The existence of a latitudinal gradient in marine otter diet also highlights the need for additional research into marine otter prey selection and the potential for overlap with commercially exploited species (Medina-Vogel et al. 2004).
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