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Urban life of Galapagos sea lions (*Zalophus wollebaeki*) on San Cristobal Island, Ecuador: colony trends and threats

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ABSTRACT

Worldwide, pristine environments are influenced by human societies. In the Galapagos Islands, the endangered, endemic Galapagos sea lion (*Zalophus wollebaeki*) has formed one of the biggest colonies within the town center of Puerto Baquerizo Moreno. About 8,000 people live there and human wildlife interactions occur daily.

With colony counts and direct observations from 2008 to 2012, we analyze cause of death, injuries and disease of urban sea lion colonies at Wreck Bay. Population increase since 2008 can be attributed to an immigration of adult sea lions in 2010, resulting in an increase in the pup and juvenile production in 2011 and 2012. Pup mortality increased drastically to 2009 and again in 2011 and 2012. Besides pup mortality, most of the deaths are caused by increased disease incidences and human activity. Our observations suggest that overall 65% of the injuries observed are produced by human interaction.

The increase in threats leading to death, injuries or disease can have long-term effects on the population. Although threats that cause physical injuries can be managed locally, sea lions range movements contributes to the spread of infectious pathogens, which may affect neighbor colonies and potentially have an impact on the survival of the species. Our study reveals the need of stronger efforts towards a more complete understanding of threats and especially disease spread among Galapagos Sea lions in urban environments and the establishment of more effective management measures.

Key words: Galapagos sea lion, *Zalophus wollebaeki*, mortality, population trends, human impact, conservation
INTRODUCTION

Habitat loss, degradation and overharvesting are impacting coastal ecosystems worldwide. Today, few places in the world remain unaffected by humans. Wherever wildlife and human societies share the same habitat, wildlife is forced to adapt to challenging conditions. About 13% of all Galapagos sea lions (Zalophus wollebaeki) live on San Cristobal Island (Salazar 2002), with one of the biggest colonies at Wreck Bay in Puerto Baquerizo Moreno where they share their resting beaches with tourism and other activities of the local population. In the Galapagos Islands the human resident population has increased exponentially approaching 30,000 inhabitants and 185,000 yearly visitors as of 2011 (Walsh and Mena 2013).

Galapagos sea lions are endemic to the Galapagos Islands where the population deals with strong climatic variations of El Niño (ENSO) and la Niña years, which disrupt seasonal patterns (Chavez et al. 1999). ENSO can cause extreme food shortages (Glynn 1988), whereas productivity is very high during la Niña years (Wang and Fiedler 2006). The results are drastic population declines in Galapagos sea lions and fur seals (Arctocephalus galapagoensis), of up to 50% during strong ENSO events (Trillmich and Dellinger 1991, Salazar and Denkinger 2010). This led to the species being listed as Endangered in the Red List of the International Union for the Conservation of Nature (IUCN) (Aurioles and Trillmich 2008). However the population recovered during the more productive la Niña years (Salazar and Denkinger 2010) though full recovery may take up to seven years (Dan 2013).

Galapagos sea lions breed up to four months per season but varying between 2 and 11 months between islands (Wolf and Trillmich, 2007). Pups on San Cristobal Island are born between July and February, peaking during October to November. Females stay with their pups for the first week after giving birth (Trillmich 1990) and show strong site fidelity throughout the year (Wolf
and Trillmich. 2007). Within Wreck Bay, sea lions concentrate on Playa de los Marinos in the town center during the non-breeding season and disperse among adjacent beaches for breeding between July and December (Montero-Serra et al. 2014). Because of their extended nursing periods (Trillmich 1986, 1990; Trillmich and Wolf 2008), beaches and coastlines are crucial for the development of sea lion offspring. At these sites, impacts of increased human presence are manifold, changing sea lion behavior and decreasing resting intervals (Fietz 2012, Kucey 2005), which can be associated with a decrease in fecundity and population decline (French et al. 2011).

To assess the human influence on Galapagos sea lions living in Wreck Bay, we monitored sea lions at Puerto Baquerizo Moreno from 2008 to 2012 and present observations on mortality, injuries and disease to evaluate the effect of human presence on sea lion welfare and colony development.

MATERIALS AND METHODS

Study area

Wreck Bay is located in Puerto Baquerizo Moreno, the Capital of the Galapagos Province in the Southwest of San Cristobal Island (0°54´3´´S, 89°36´37´´W). The archipelago is situated in a mixing zone (Edgar et al. 2004), where the cold, productive waters of the Humboldt Current are prevalent from June to November and the warm, nutrient poor Panama Current from December to May.

Wreck Bay is the main port for fishery and the second most important port for tourism in Galapagos. The rookeries at Carola beach, Playa Mann, Playa de los Marinos, and Loberia are at
the same time major sites for recreation or boat repairs (Fig. 1). According to the special law of Galapagos (LOREG, Article 62), it is illegal to transport domestic animals from the continent to the islands and the Inter-Institutional Committee for the Management of Introduced Species (CIMEI) controls cats and dogs. However, since 2009, control for stray dogs on San Cristobal Island became more and more inefficient and gangs of dogs can be seen within the sea lion colonies on a daily base.

**Data collection**

From 2008 to 2012 we conducted weekly sea lion censuses at the study sites. Rookeries were defined as the beaches, where adult males establish harems, consisting of subadult males, females, juveniles and pups during the reproductive season from June to December. All other sea lion aggregations (haul-out sites) consisted mostly of adult males without harems and were only included in the threat analysis. Individual sea lions were separated into five different categories, according to their sex and age: Adult males (including subadults), adult females, unknown adults, juveniles, and pups (see Wolf and Trillmich 2007).

**Data analysis**

To estimate colony increase with data collected from 2008 to 2012 during the peak of the breeding season in November, we used generalized linear models (GLMs) to determine temporal trends of sea lion abundance (see McCullagh and Nelder 1989). As the data was over-dispersed (deviance/ df > 2), we adjusted the models with a negative binomial distribution, including an
extra parameter describing dispersion. As this parameter approaches 0, over-dispersion decreases and the negative binomial distribution approaches a Poisson distribution.

Furthermore, the amount of variance that the models explained (D^2) was calculated using the equation:

\[ D^2 = \frac{(ND - RD)}{ND} \times 100 \]

where ND is the null deviance of the data and RD is the residual deviance. All analyses were conducted using the software language R (R Development Core Team 2008).

**Threat assessment**

We recorded and photographed events of dead and injured or diseased sea lions at the study sites and analyzed reports of the Galapagos National Park. We classified all observations based on the physical condition of each animal as dead (without any vital signs or decomposed), injured (including entanglements, cuts, and fractures), or diseased (external symptoms, such as skin disease, eye infections, nasal secretions or parasites). Within these categories, death or injury were considered as results of direct human impact whenever there was clear evidence, such as clear and straight cuts caused by sharp objects, or bruises caused by blows to the head, as well as burned skin and fur. Indirect human impact, was recorded when entanglement in debris and fishing gear was observed. Other causes included dog bites, whenever the wound clearly showed bite marks from dogs, or shark attacks in the case of round bite wounds, with several distinct rows of teeth marks. All cases where the causes could not be determined with certainty were categorized as “not identified”.
To analyze the frequency of all events causing injury or death we used percentage of occurrence in relation to all death or injury events. We used a T-Test set at 95% confidence interval to figure out, which age class was most affected by the human caused injuries (entanglement and cuts and blows). In order to observe trends in the occurrence of death or injuries over the study period we calculated the frequency of events observed each year in relation to the amount of animals during colony counts. Pup mortality was calculated as the amount of dead pups in relation to all pups born during each year.

RESULTS

Colony size

The overall trend of sea lion abundance at the rookeries of Puerto Baquerizo Moreno was positive in all age classes ($D^2_{\text{adults}} = 64.5\%$; $D^2_{\text{juveniles}} = 63.1\%$; $D^2_{\text{pups}} = 64\%$) (Table 1a and b). The overall mean abundance of November censuses rose from 278 sea lions in 2008 to 402 sea lions in 2011, slightly declined again to 391 sea lions in 2012 (Fig. 2).

Among years, the proportion of adults, juveniles and pups was highly variable. There was a strong increase in adults in 2010, which led to the high pup production in 2011 with 92 pups representing 23% of the population. This reflects the high proportion of juveniles (124 animals, 31%) in 2012 whereas the proportion of pups decreased to (18%) (Fig. 2).

The number of juveniles fluctuated from year to year but declined from 2010 to 2011, following increased pup mortality during the 2009/2010 breeding season. In 2012 their number increased again despite high pup mortality in 2011 (Fig. 2).
Mortality in Galapagos sea lions

Among the total of 308 dead Galapagos sea lions at Wreck Bay recorded within 2008 to 2012, pup mortality is the most common death with 71% of all the dead animals reported. Disease and human caused death both represents 5% of all the dead animals (Fig. 3a). Over the years, the number of dead individuals in relation to colony size increased especially in terms of stillborn, new born or pups less than a months old, here specified as pup mortality, whereas other causes of death, excluding disease, remained stable over the years. Overall, death caused by any disease, such as infection, parasites etc. increased slightly from 2008 to 2012 with a total of 9 animals (but pups) that died from disease. At the same time, pup mortality peaked in 2011 with 97 dead pups and still remained high with 58 pups in 2012. Human caused death slightly increased to 2012. (Fig. 3b).

Injuries in Galapagos sea lions

Most of the injuries reported in Wreck Bay are related to human impact (65%), while natural predators (sharks) caused 13% and dogs caused 8% of all injuries. Of all direct human impacts clear-cut lacerations or blows made up 41% of all cases. Overall, 38% of the sea lions directly impacted by humans were entangled in plastic bags, rubber rings, or other debris; boat propellers injured 14% of the impacted sea lions. Impact of fishing gear was observed in 8% of all affected sea lions. Human caused injuries were significantly different within different age classes (T-test, p<0.001): whereas entanglements mostly affected juveniles, adult sea lions suffered from direct human harassment with higher presence of cuts and blows. (Fig. 4).
From 2008 to 2012, there was a strong increase in the frequency of recorded injuries, where juveniles were most affected with a very significant positive trend ($y=0.0857x-0.1325$, $R^2=0.88$). (Fig.5).
**DISCUSSION**

Human-interaction is leading to negative consequences for the Galapagos sea lion population of Wreck Bay. Although a positive trend was estimated based on count data from 2008 to 2012, the observed growing number of human related mortality and injuries highlights a potential risk for the long-term viability of this colony.

High mobility of sea lions was observed in 2010, when adults immigrated from elsewhere. This immigration increased pup and juvenile abundance in subsequent years. Overall, average number of pups was stable with considerable fluctuations over the mean. The strong increase in 2011 is most likely due to the immigrated adults in 2010.

For subsequent years, the proportion of adults decreased, but the strong pup production in 2011 produced the high proportion of juveniles in 2012. However, total number of sea lions may have slightly declined from 2011 to 2012.

Colonies at Wreck Bay are clearly affected by a continuously growing human population (see INEC 2011) resulting in increasing death, injury and disease, on beaches used for recreation and tourism. Human presence in sea lion colonies produces changes in their behavior (Fietz 2012). The resulting indirect and direct effects are reflected in instances of death, injury and disease, which sea lions suffer on beaches used for recreation, boat repair and transit. The mere presence of humans in sea lion colonies, already produces changes in their behavior (Fietz 2012), alters haul out behavior and nursing patterns (Allen et al., 1984; Suryan and Harvey 1999) and decreases mother pup recognition abilities (Semrl 2010). Even though, the population is still on an increasing trend, there is already a decline from 2011 to 2012, but the fact, that here we use rather short term data sets does not necessarily reflect real trends. Long-term exposure of
pinnipeds to human interaction can cause a decrease in breeding success due to continuous stress (Johnson and Lavigne 1999).

Marine mammals are most threatened by fisheries by-catch and vessel strike (Schipper 2008) and this is also evident in protected areas like the Galapagos Marine Reserve. Worldwide, sea lions benefit from feeding in close association with fishermen (Hueckstedt and Antezana, 2003), where they cause conflict as they steal fish from the fishing lines, nets or even aquacultures. As a result, in the Galapagos as elsewhere in the world, sea lions are illegally killed in order to protect catch (see Lavigne 2006). Adult individuals are involved in such interactions more frequently than the more shallow water-associated juveniles and pups and are therefore more affected by direct aggressions than juveniles or pups. Overall, 5% of all observed mortality could be related to direct anthropogenic impacts. However, adult and pup mortality resulting from introduced diseases and contamination may relate to indirect anthropogenic impacts, including malnutrition of pups or juveniles, if their mothers are killed in fishery interactions. The strong increase in pup mortality throughout the survey period could be related to a likewise increase in disease-associated mortality in adults and juveniles. It should therefore be monitored and investigated carefully in order to detect and prevent upcoming epidemics (see Harvell et al. 1999). Considering, that only two thirds of all pups survive to the age of a year and half of the juveniles to the age of two years (Kraus et al. 2012), an increase in mortality due to human related causes or disease may impede population recovery in the long term.

Boat strike poses risk for all age classes; during the study period 21 animals were observed with wounds resulting from propeller strikes. Speedboats from Wreck Bay commute to Santa Cruz and for local tourist trips on a daily base and so far no regulations in near shore areas are in force. Boat strikes have been shown to affect sea turtles in the same area, with 20% of sea turtles
in near-shore foraging areas bearing wounds from boat strikes (Denkinger et al. 2013). Even though boat strikes don’t belong to the most frequent injuries, they can often result in severe injuries or death and many affected animals will not be accounted for when they die at sea where they are easy prey for the abundant predators in the Marine Reserve.

Disease reports of marine mammals have increased in recent years (Harvell 1999). The increased pup mortality in 2009, 2011 and 2012 could be a first indicator for an ecosystem, impacted by anthropogenic factors or zoonotic pathogen transfer from dogs or cats to sea lions. Human fecal contamination is evident in the Bay by elevated *Enterococcus spp.* concentrations, which can cause gastroenteritis and respiratory illness (Stumpf et al. 2013). Bacterial infections were the most common cause of pup mortality of South American Fur seal pups at Guafo Island, South Chile (Seguel et al. 2011). Exposure to pathogens is suspected as one of the reasons for the lack of recovery in Steller sea lions at Kodiak Island as fecundity and body conditions are reduced under stress (Burek et al. 2005).

**CONCLUSIONS**

While direct human impact can be managed through local management within the area, indirect impacts such as pathogen-related diseases are more difficult to control. High pup mortalities in 2009, 2011 and 2012 indicate the presence of pathogens in the colonies (Denkinger et al in prep).

Both direct and indirect anthropogenic impacts may have severe long-term effects on the Galapagos sea lion population, calling for a special management attention for colonies located in urban environments.
ACKNOWLEDGEMENTS

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REFERENCES


### TABLES and FIGURES

Table 1a: November colony counts and means of animals according to age class.

<table>
<thead>
<tr>
<th></th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
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<td>3</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
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<tr>
<td>mean adults</td>
<td>149.67</td>
<td>139.50</td>
<td>205.19</td>
<td>210.13</td>
<td>198.59</td>
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<tr>
<td>mean juveniles</td>
<td>74.00</td>
<td>62.00</td>
<td>100.16</td>
<td>99.64</td>
<td>121.48</td>
</tr>
<tr>
<td>mean pups</td>
<td>46.33</td>
<td>30.00</td>
<td>32.94</td>
<td>92.32</td>
<td>120.30</td>
</tr>
</tbody>
</table>
Table 1b: Trend analysis of Galapagos sea lions at Wreck bay using a GLM and Poisson distribution.

<table>
<thead>
<tr>
<th>Age class</th>
<th>Parameter</th>
<th>Estimate</th>
<th>SE</th>
<th>Z Value</th>
<th>P value</th>
<th>D² (%)</th>
</tr>
</thead>
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<td>Adults</td>
<td>Intercept</td>
<td>-185.9</td>
<td>64.78</td>
<td>-2.87</td>
<td>0.004</td>
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</tr>
<tr>
<td></td>
<td>Year</td>
<td>0.095</td>
<td>0.032</td>
<td>2.95</td>
<td>0.003</td>
<td>64.5</td>
</tr>
<tr>
<td>Juveniles</td>
<td>Intercept</td>
<td>-288.4</td>
<td>67.4</td>
<td>-4.28</td>
<td>&gt;0.001</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Year</td>
<td>0.146</td>
<td>0.034</td>
<td>4.35</td>
<td>&gt;0.001</td>
<td>63.1</td>
</tr>
<tr>
<td>Pups</td>
<td>Intercept</td>
<td>-594.6</td>
<td>208.5</td>
<td>-2.85</td>
<td>0.004</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Year</td>
<td>0.298</td>
<td>0.104</td>
<td>2.87</td>
<td>0.004</td>
<td>64.6</td>
</tr>
<tr>
<td>Total</td>
<td>Intercept</td>
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<td>78.03</td>
<td>-2.99</td>
<td>0.003</td>
<td></td>
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<tr>
<td></td>
<td>Year</td>
<td>0.119</td>
<td>0.039</td>
<td>3.06</td>
<td>0.002</td>
<td>64.4</td>
</tr>
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**Figure 1**: Situation of San Cristobal Island in the Galapagos Archipelago and the study sites at Puerto Baquerizo Moreno (dark shaded area represents the town limits).
Figure 2: Numbers and trends of Galapagos sea lion age classes, a) adults, b) juveniles, c) pups, at Puerto Baquerizo Moreno rookeries (Loberia, Carola, Playa Mann and Playa de los Marinos) using the mean of November colony counts from 2008 to 2012. Error bars indicate SD of all counts.
Figure 3: a) Frequency in cause of death reported for Galapagos sea lions at Wreck Bay colonies from 2008 to 2012 (N=308) and b) Frequency in cause of the most common causes of death in relation to colony size per year.

Legend: pup mortality, human impact (human), disease and unidentified causes (no id)
Figure 4: Injuries observed in Galapagos sea lions (left) and human related injuries in detail as total animals affected, with percentage of each age classes most affected by entanglement and direct harassment, such as cuts and blows (right).
**Figure 5**: Number of observations of injured animals per year in relation to colony size of November colony counts at Carola, Playa Mann, Playa de los Marinos and Loberia. (N= 242).
Highlights

Increasing colony size in urban sea lion colonies due to immigration
Disease and pup mortality are the most frequent cause of death
65% of injuries in sea lions are due to human impact.
Entanglement mainly affects juveniles and cuts and blows adult animals
The cumulative amount of injured animals increased significantly from 2008