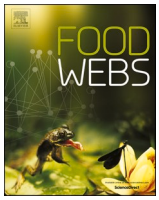
Food Webs 36 (2023) e00290

Contents lists available at ScienceDirect

Food Webs

journal homepage: www.elsevier.com/locate/fooweb



Puma predation on Magellanic penguins: An unexpected terrestrial-marine linkage in Patagonia

Mitchell W. Serota [a,*], Pablo A.E. Alarcón [b,c], Emiliano Donadio [d], Arthur D. Middleton [a]

[a] Department of Environmental Science, Policy, and Management, University of California - Berkeley, 130 Mulford Hall, Berkeley, CA 94720, USA
[b] INIBIOMA (University of Comahue – CONICET), 1250 Quintral, Bariloche 8400, Argentina
[c] Department of Ecology, University of Comahue, 1250 Quintral, Bariloche 8400, Argentina
[d] Fundación Rewilding Argentina, Raúl Scalabrini Ortíz 3355, Buenos Aires 1425, Argentina

ARTICLE INFO

Keywords:
Marine subsidy
Predator recovery
Predator-prey
Puma concolor
Spheniscus magellanicus
Patagonia

ABSTRACT

The global loss of top predators has led to widespread changes in food webs. In Patagonia, it is hypothesized that local extirpations of terrestrial predators, including the puma (*Puma concolor*), has led to the expansion of Magellanic penguin (*Spheniscus magellanicus*) colonies across the Atlantic coast of Argentina. Interestingly, more recent wildlife conservation efforts in the region have led to an unexpected trophic link between pumas and penguins. Here, we used a camera trap array to assess this novel predator-prey relationship between pumas and penguins in Monte León National Park (MLNP) over a three-month period. Pumas were detected 12.5 times more than any other mammalian predator and were detected on 95% of the days during our study period. We also observed 28 individual events of pumas preying upon penguins. Our work demonstrates a strong linkage between the marine and terrestrial ecosystem at MLNP. Puma predation of penguins may have widespread ecological implications including effects on puma and penguin abundance, changes in puma social behavior, and interspecific competition among other prey items and carnivores in the park. We propose hypotheses and questions to investigate these potential outcomes.

Human activities around the world are fundamentally restructuring ecosystems by changing trophic interactions through the introduction of invasive species, the extirpation of predators, habitat loss, and climate change. One of the most pervasive impacts is the extirpation of apex predators, which has extensively altered food webs through changes to species distribution and abundance of herbivores and autotrophs (Estes et al., 2011; Terborgh et al., 2010). Therefore, restoring functional populations of apex predators may entail re-establishing populations into food webs that have undergone substantial ecological changes (Stier et al., 2016; Terborgh et al., 2010).

The Patagonian steppe was inhabited by abundant populations of two medium-sized herbivores including guanaco (*Lama guanicoe)* and lesser rhea (*Rhea pennanta*), and their predator, the puma (*Puma concolor*). Following European colonization, herbivore numbers declined, and were replaced by sheep across much of the steppe (Walker and Novaro, 2010). In addition, predators, including pumas and foxes (*Lycalopex culpaeus* and *L. griseus)*, were extensively removed to protect livestock. Local eradications of mainland predators is hypothesized to have triggered the expansion of Magellanic penguin (*Spheniscus magellanicus*) colonies across the Atlantic coast of Argentina (Borboroglu and Boersma, 2013; Cruz et al., 2014). Indeed, recent archaeological and paleontological studies suggest that until the eighteenth century, penguin colonies were primarily restricted to offshore islands (Cruz et al., 2014). The Monte León ranch, a sheep ranch along the southern Argentinian coast, was home to a large breeding colony of Magellanic penguins. This ranch was donated to Argentinean Park Service in 2004. Shortly after Monte León National Park (MLNP) was created, penguin remains were found in puma scats (Zanón Martínez et al., 2012). Still, the extent and magnitude of this novel predator-prey relationship remains unknown.

Here, we document puma, and other predators, use of the penguin colony at MLNP. We deployed 20 Browning Strike Force HD cameras and RECONYX HyperFire 2 cameras separated by 200 m within the penguin colony (Fig. 1). For each species, we defined independent detections as photographs separated by at least 30 min. We report on the detections of all mammalian predators (n = 410) from January 15th, 2021, through April 15th, 2021, which represents nearly half of the penguin breeding season.

* Corresponding author.
E-mail address: mitchell_serota@berkeley.edu (M.W. Serota).

https://doi.org/10.1016/j.fooweb.2023.e00290
Received 15 March 2023; Received in revised form 3 April 2023; Accepted 26 May 2023
Available online 29 May 2023

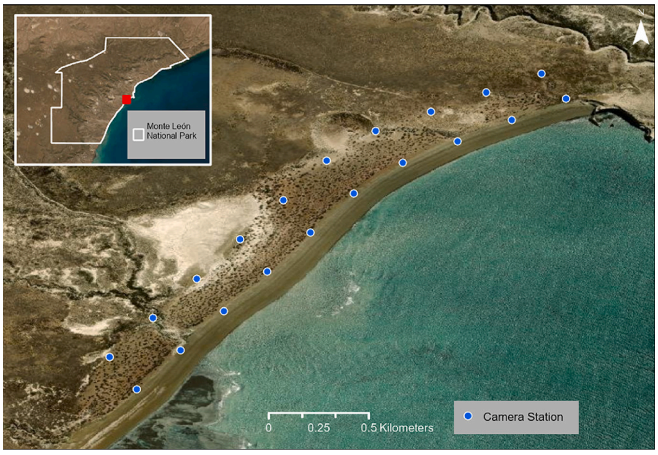


Fig. 1. Site map showing camera station locations within the penguin colony of Monte León National Park (50°06′S; 68°54′W). Camera locations border the extent of the penguin colony. The inset map shows the extent of the park with the red rectangle indicating the location of the penguin colony. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

We surveyed the penguin colony at MLNP for a total of 1800 camera trap nights. Pumas used the penguin colony extensively and were detected 12.5 times ($n = 373$; detection rate = 0.21) more than any other predator (Fig. 2). Foxes were the next most detected mammalian predator at 30 detections (detection rate = 0.02) followed by skunks, (*Conepatus humboldtii)*, ($n = 5$; detection rate < 0.01) and armadillos, (*Chaetophractus villosus)*, ($n = 2$; detection rate < 0.01). Pumas were detected on 95% of the nights ($n = 86$) during our study period. Further, we observed 28 events of pumas preying upon penguins (Fig. 3). Most puma detections ($n = 312$) were of unmarked individuals, while 62 detections were from 5 radio-collared individuals. Here, we lay out questions and hypotheses regarding this predator-prey relationship.

Predation by pumas is expected to have population-level consequences for Magellanic penguins. However, despite predation by pumas, recent surveys by the park have suggested that the penguin population is increasing, with over 40,000 breeding pairs (Millones et al., 2022). Additionally, penguin population dynamics may be influenced by changes in oceanographic conditions, immigration from other populations, and commercial fishing to name a few (Borboroglu and Boersma, 2013). Still, predation of penguins by pumas at the park is a new phenomenon and population effects may occur on a longer timescale.

Puma predation of penguins links the terrestrial and marine ecosystem at MLNP, and species interactions that couple ecosystems can have cross-boundary biodiversity effects (Polis et al., 1997). Cross-boundary interactions can subsidize populations and elicit strong numerical and behavioral responses for the consumer (Luskin et al., 2017). Marine subsidies (i.e., the movement of nutrients from sea to land) have led to high densities of second level consumers like bears (*Ursus arctos*), coyotes (*Canis latrans*), and jaguars (*Panthera onca*) (Egbert and Stokes, 2014; Eriksson et al., 2022; Rose and Polis, 1998). A recent review of puma densities across their range concluded that the 95th percentile of puma density was 3.64 independent pumas/100 km^2 (Murphy et al., 2022). In just a 2 km stretch of coastline, we recorded at least 6 individual pumas. The penguin colony appears to support a high density of pumas, but the extent remains unknown.

A numerical response in pumas, however, may ultimately be dependent on their behavioral plasticity. Historically, pumas are thought to be territorial carnivores with minimal overlap with other conspecifics. Recent research, however, shows a more adaptive sociality that allows conspecifics to overlap in areas with high prey density (Elbroch and Quigley, 2017; Elborch et al., 2017). Although the penguin colony at MLNP has abundant prey, it is spatially constrained and much smaller than a typical puma home range (Borrajo et al., 2016). Therefore, flexibility in sociality may determine the number of pumas that are able to utilize this resource.

The predation of penguins may have an indirect effect on other prey species like guanacos, rheas, and exotic European hares (*Lepus europaeus*) through apparent competition or apparent mutualism. Apparent competition may occur if puma predation on penguins leads to an increase in puma abundance and increased predation on other prey. Alternatively, the penguin colony may temporarily satiate the puma population, leading to apparent mutualism where the predation of penguins has no negative impact on other prey.

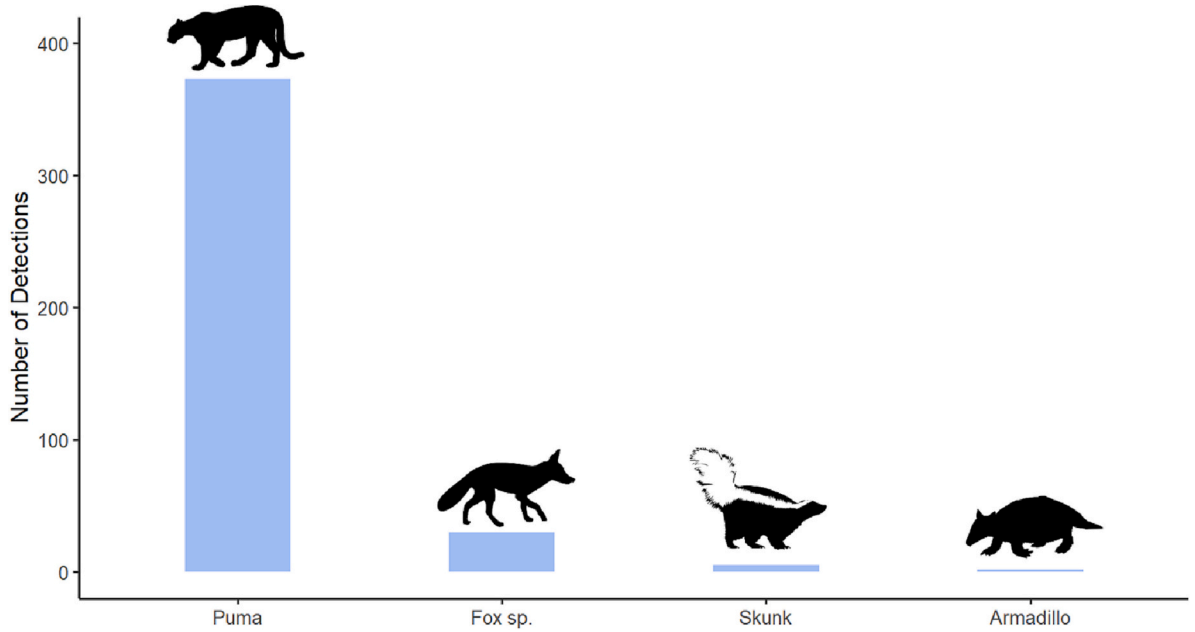


Fig. 2. Detections of medium and large mammalian predators in the penguin colony at Monte León National Park, Argentina, from January 15th, 2021, to April 15th, 2021.

Fig. 3. Pumas captured on our camera traps consuming Magellanic penguins in Monte León National Park, Argentina.

An increase in either the puma population or space use near the penguin colony may impact mesopredators at different spatial scales. An increase in puma numbers could affect mesopredators at the landscape level, whereas intense space use near the penguin colony may result in a local suppression of mesopredator activity (Díaz-Ruiz et al., 2020; Prugh et al., 2009). Our camera data suggests very little usage of the penguin colony by other mammalian predators (Fig. 2). Still, the influence of penguins as a resource on interspecific competitive interactions remains unanswered.

The predation of penguins in the park increases the amount of penguin carrion that is theoretically available to scavengers, like both fox species. However, our preliminary observations suggest that avian scavengers like kelp gulls (*Larus dominicanus*), southern giant petrels (*Macronectes giganteus*), and Chilean skuas (*Stercorarius chilensis*) dominate this carrion. Further, an increase in predation of penguins may reduce the availability of guanaco carrion, which can be a significant proportion of fox diet in the region (Johnson and Franklin, 1994). However, to what extent puma predation of penguins impacts carrion provisioning dynamics to all these facultative scavengers remains unknown.

Finally, the hypothesized effects of a novel linkage between pumas and penguins may be mediated by the seasonality of this interaction. Magellanic penguins are migratory and only present in MLNP from September through April. Therefore, the behavioral and numerical response of pumas and their impact on alternative prey and competitors may fluctuate seasonally.

Our results suggest that human activities on the coastal regions of Argentina have created a novel linkage between terrestrial and marine ecosystems through puma predation on penguins. The potential outcomes of this interaction are numerous; however, its effects are yet to be determined.

Declaration of Competing Interest

Mitchell Serota reports financial support was provided by Explorers Club. Arthur Middleton reports financial support was provided by Prince Albert II of Monaco Foundation.

Acknowledgements

We thank Administración de Parques Nacionales (APN) and APN staff at MLNP for their continued support and assistance. We also thank Conservación Patagónica Asociación Civil and The Explorers Club for logistical and financial support. Finally, we would like to thank Matias Chambon, Emilia Perucca, Rocio Asueta, and Carolina Chiara for field assistance. The research was conducted under permit # DRPA 162 issued by APN, Argentina.

References

Borboroglu, P.G., Boersma, P.D., 2013. Penguins: Natural History and Conservation. University of Washington Press.

Borrajo, N.G., López-Bao, J.V., Palomares, F., 2016. Spatial ecology of jaguars pumas and ocelots a review of the state of knowledge. Mamm. Rev. 47, 62–75.

Cruz, I., Lemaire, C.R., Nauto, G.D., Astete, Z.F., 2014. Historia natural de pingüinos y lobos marinos en la Patagonia. Desde la Patagon. Difundiendo Saberes 11, 2–9.

Díaz-Ruiz, F., Rodríguez, A., Procopio, D., Zapata, S., Zanón-Martínez, J.I., Travaini, A., 2020. Inferring species interactions from long-term monitoring programs: carnivores in a protected area from southern Patagonia. Diversity 12. https://doi.org/10.3390/D12090319.

Egbert, A.L., Stokes, A.W., 2014. The social behaviour of Brown bears on an Alaskan Salmon stream. Biol. Manag. 3, 41–56.

Elborch, M., Levy, M., Lubell, M., Quigley, H., Caragiulo, A., 2017. Adaptive social strategies in a solitary carnivore. Sci. Adv. 3, e1701218 https://doi.org/10.1126/sciadv.1701218.

Elbroch, M., Quigley, H., 2017. Social interactions in a solitary carnivore. Curr. Zool. 63, 357–362. https://doi.org/10.1093/cz/zow080.

Eriksson, C.E., Kantek, D.L.Z., Miyazaki, S.S., Morato, R.G., dos Santos-Filho, M., Ruprecht, J.S., Peres, C.A., Levi, T., 2022. Extensive aquatic subsidies lead to territorial breakdown and high density of an apex predator. Ecology 103, 1–9. https://doi.org/10.1002/ecy.3543.

Estes, J.A., Terborgh, J., Brashares, J.S., Power, M.E., Berger, J., Bond, W.J., Carpenter, S.R., Essington, T.E., Holt, R.D., Jackson, J.B.C., Marquis, R.J., Oksanen, L., Oksanen, T., Paine, R.T., Pikitch, E.K., Ripple, W.J., Sandin, S.A., Scheffer, M., Schoener, T.W., Shurin, J.B., Sinclair, A.R.E., Soulé, M.E., Virtanen, R., Wardle, D.A., 2011. Trophic downgrading of planet earth. Science (80-.) 333, 301–306. https://doi.org/10.1126/science.1205106.

Johnson, W., Franklin, W., 1994. Role of body size in the diets of sympatric gray and Culpeo foxes. J. Mammal. 75, 163–174.

Luskin, M.S., Brashares, J.S., Ickes, K., Sun, I.F., Fletcher, C., Wright, S.J., Potts, M.D., 2017. Cross-boundary subsidy cascades from oil palm degrade distant tropical forests. Nat. Commun. 8 https://doi.org/10.1038/s41467-017-01920-7.

Millones, A., Morgenthaler, A., Gandini, P., Frere, E., 2022. Population numbers of the Magellanic penguin along its central-southern distribution in Argentina: an update after 25 years. Waterbirds 44, 499–508. https://doi.org/10.1675/063.044.0411.

Murphy, S.M., Beausoleil, R.A., Stewart, H., Cox, J.J., 2022. Review of puma density estimates reveals sources of bias and variation, and the need for standardization. Glob. Ecol. Conserv. 35, e02109 https://doi.org/10.1016/j.gecco.2022.e02109.

Polis, G.A., Anderson, W.B., Holt, R.D., 1997. Toward an integration of landscape and food web ecology: the dynamics of spatially subsidized food webs. Annu. Rev. Ecol. Syst. 28, 289–316. https://doi.org/10.1146/annurev.ecolsys.28.1.289.

Prugh, L.R., Stoner, C.J., Epps, C.W., Bean, W.T., Ripple, W.J., Laliberte, A.S., Brashares, J.S., 2009. The rise of the mesopredator. Bioscience 59, 779–791. https://doi.org/10.1525/bio.2009.59.9.9.

Rose, M.D., Polis, G.A., 1998. The distribution and abundance of coyotes: the effects of Allochthonous food subsidies from the sea. Ecology 79, 998. https://doi.org/10.2307/176595.

Stier, A.C., Samhouri, J.F., Novak, M., Marshall, K.N., Ward, E.J., Holt, R.D., Levin, P.S., 2016. Ecosystem context and historical contingency in apex predator recoveries. Sci. Adv. 2, 1–15. https://doi.org/10.1126/sciadv.1501769.

Terborgh, J., Holt, R.D., Estes, J., 2010. Trophic cascades: what they are, how they work, and why they matter. Trophic cascades predators. Prey Chang. Dyn. Nat. 1–18.

Walker, S., Novaro, A., 2010. The World's Southernmost Pumas in Patagonia and the Southern Andes. Ecology and Conservation, Cougar. https://doi.org/10.1017/CBO9781107415324.004.

Zanón Martínez, J.I., Travaini, A., Zapata, S., Procopio, D., Santillán, M.Á., 2012. The ecological role of native and introduced species in the diet of the puma Puma concolor in southern Patagonia. Oryx 46, 106–111. https://doi.org/10.1017/S0030605310001821.