Conservation of Marine to Terrestrial Subsidies on the Gaviota Coast

Zoe Zilz & Hillary Young

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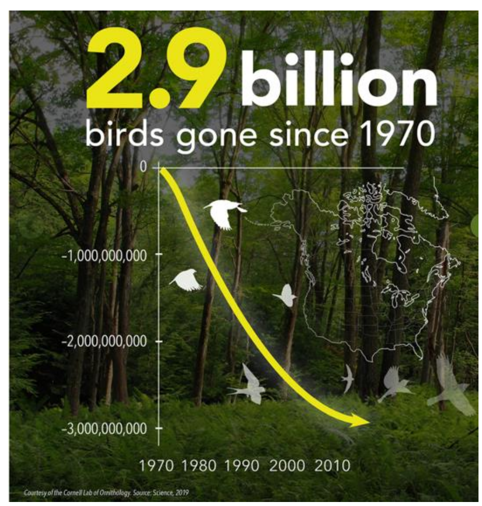
Objectives

Marine to terrestrial resource subsidies likely play an important role in the ecology of the Gaviota Coast (Young and Zilz 2021). The natural ecological connectivity appears to persist in this region due to relatively conserved condition of both land and sea ecosystems in Gaviota. In contrast, elsewhere in California such connectivity has been greatly impacted by coastal development. Preliminary evidence suggests that terrestrial animals—primarily small bodied organisms but including large, highly-mobile carnivorous and omnivorous mammals like mountain lions and bears—are foraging in the Gaviota Coast beaches and intertidal zones. This is unlikely to occur in more human-developed regions of the West Coast where such species are often unable to persist in their natural behavior. The marine foraging behavior of these animals could represent a significant movement of resources from marine habitats inland, with potentially large ecological consequences. Previous work has described the natural phenomena and Gaviota Coast species that are likely to provide, vector, or rely on marine subsidies. The objectives of this report are to 1) summarize how increases in anthropogenic disturbances, especially coastal development, has been shown to impact resource subsidies globally, and 2) apply this knowledge to evaluate threats to marine to terrestrial resource connectivity on the Gaviota Coast.

1.0. Disturbing Connectivity



Currently an estimated 50 to 70% of the earth's surface has been modified for human use. Wild animals are in catastrophic decline (Dirzo et al., 2014). Across all vertebrate animals, species are disappearing (Ceballos et al., 2015) and population sizes of vertebrates have declined an average of 68%, since 1970 (LPI 2020). To put that into more tangible numbers, there are approximately 3 *billion* fewer birds, just in North America, since 1970 (Rosenberg et al., 2019). The situation for invertebrates appears to be equally dire (Dirzo et al., 2014). Migratory species, and species that use multiple ecosystems (e.g. amphibians, shorebirds) that are particularly important for connectivity appear to be suffering from disproportionate losses. Mass mortality events, which result in dramatic nutrient pulses are also changing in frequency (Fey et al., 2015). Not only are populations declining, but the animals that do persist are moving less, particularly so when the Human Footprint (a combined metric that integrates multiple aspects of human influence) is high (Figure 2; Tucker et al., 2018). Human-modified landscapes impede wildlife movement both physically (e.g. highways, fencing) and behaviorally (e.g. fear-based avoidance of humans and human infrastructure). Given the critical importance of animal movemeny in driving

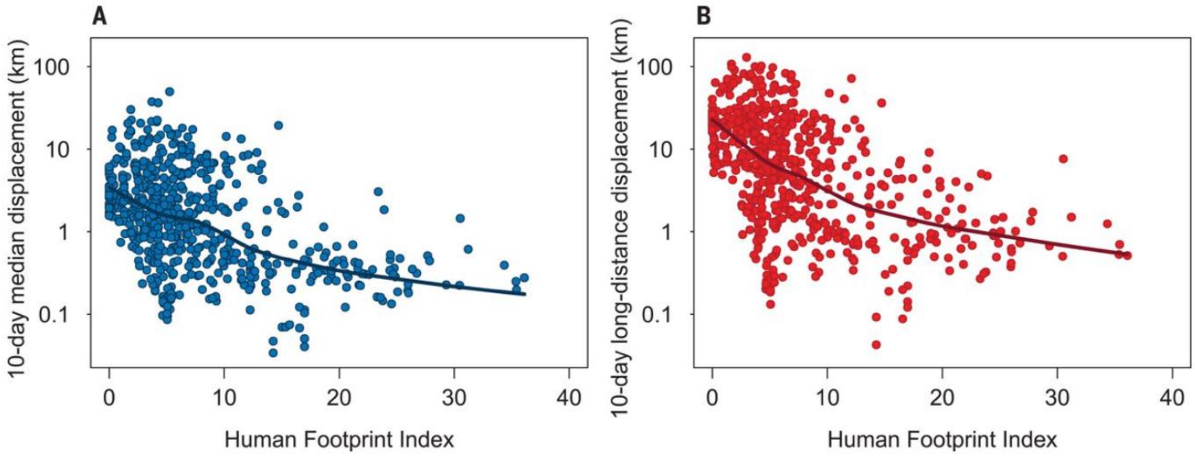


Figure 2. Measures of animal displacement (movement) show decreased movement of animals with increasing human footprints. This is especially true for long distance movements. Figure from Tucker et al. 2018.

subsidy delivery, these two changes alone suggest that animal driven landscape connectivity has been dramatically impacted by humans.

Many of the same stressors that are driving declines of animals are also changing subsidy delivery through abiotic processes. For instance, changing climates are affecting storm intensity and frequency, precipitation timing and nature, and global wind and water current patterns, all of which directly impact the amount or delivery of subsidies between ecosystems. Many abiotic vectors of subsidies—e.g. wind, rain, groundwater runoff—rely on natural gradients like slope and elevation. As such, development of physical infrastructure such as break walls and levees, or channeling, damming and draining of surface water impedes the abiotic movement of subsidies.

Consistent with these patterns, we now have hundreds of well documented studies of humans disturbing landscape connectivity dating from the Pleistocene to the present (Doughty et al., 2015). Sprawl in both ocean and terrestrial ecosystems greatly inhibits connectivity (Aguilera et al., 2020; Bishop et al., 2017). However, there is, to the best of our knowledge, no comprehensive global synthesis of the extent of this connectivity disruption. A conservative estimate would suggest that animal-borne connectivity loss, which is a result of multiple linkages being impacted (donor, recipient, and vector), will be at least proportionate to the loss of animal life on the planet (e.g. >68% declines since 1970). However, loss of connectivity might be much higher given that animals that rely on multiple systems are known to be disproportionately vulnerable (Bauer & Hoye, 2014; Runge et al., 2014; Wilcove & Wikelski, 2008). Estimates of abiotic connectivity loss are more complex, as there are no aggregated numbers on the proportion of abiotic vectors impacted by anthropogenic change, but it is likely at least proportionate to the Earth's surface modified for human use (50-70%).

2.0. Threats to Connectivity on the Gaviota Coast

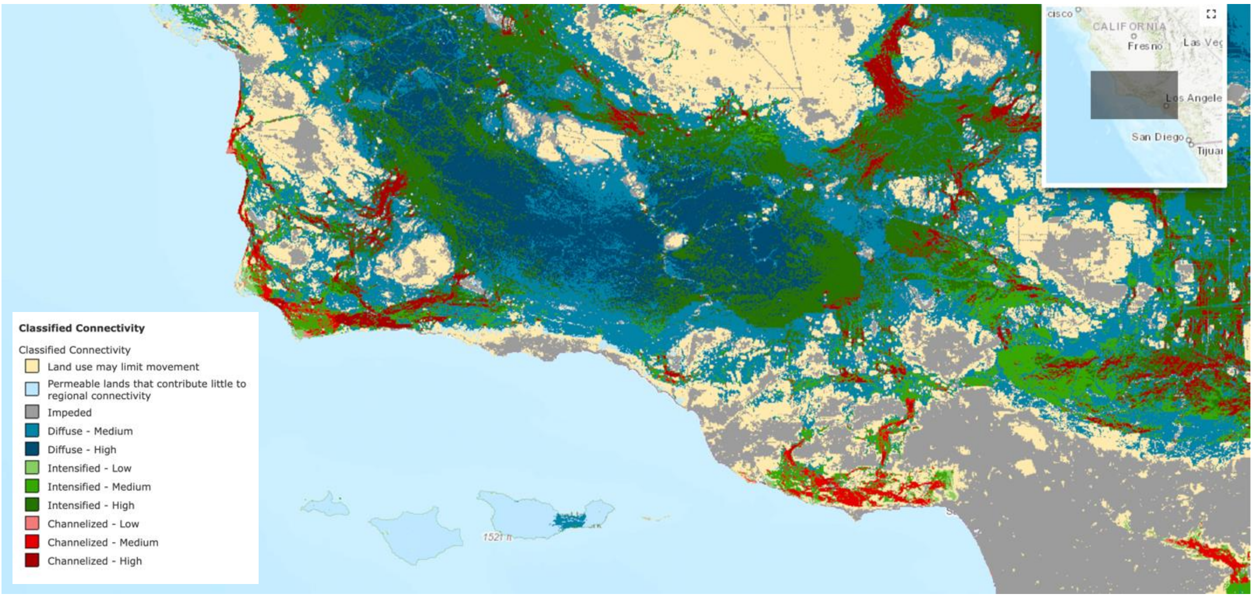


Figure 3. Map of the degree of potential habitat connectivity in the greater coastal and inland area of California around the Gaviota Coast. Areas of intense development and urbanization are shown in grey. Map created by and used with permission from The Nature Conservancy.

There is, to the best of our knowledge, no quantitative analysis of the relative importance of spatial subsidies across ecosystems, much less any analysis of where those subsidies are most frequently disrupted. However, 60% of the world's largest cities and greater than 40% of the world's population are concentrated in coastal environments, a pattern which is becoming more extreme (Nicholls et al., 2009; Tibbetts, 2002). Because the importance of reciprocal marine to terrestrial subsidies is among the best documented across ecosystems, it is thus highly likely that coastal systems have experienced some of the greatest disruptions to subsidy movement (Buckner et al., 2017).

Southern California is one of the most heavily anthropogenically modified regions in the United States and simultaneously one of the world's primary hotspots for endemic, endangered species (Dobson et al., 1997). The coastal regions of California are especially impacted, with 26.3 million of the 38.4 million California residents living in coastal areas, primarily in the southern half. At least 55% of the Southern California's coastline is developed, 20% is undeveloped but heavily used for recreation, and 6% is agricultural land. Of the remaining coastline, only 5% is protected or managed specifically for biodiversity (Heady et al., 2018). The Gaviota Coast thus represents one of the very few Southern California ecosystems that maintains relatively intact connectivity between marine and terrestrial habitats (Figure 3). However, this connectivity faces threats from many of the same anthropogenic influences that have disrupted the rest of the California coastal habitat, including coastal development, armoring, trampling, recreation, hunting and fishing, pollution, sea level rise, and climate change.

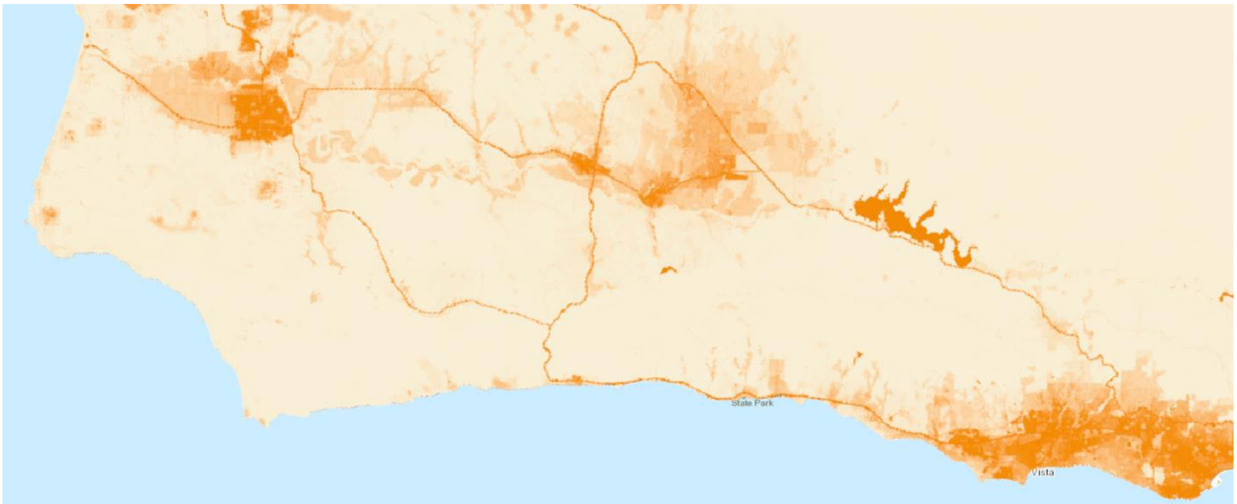


Figure 4. Map of animal movement potential on the Gaviota Coast. Areas of high resistance to animal movement are darker orange and are concentrated around major high-speed roadways and areas of human development. The cities of Goleta and Santa Barbara can be seen in the lower right corner. Map created by and used with permission from The Nature Conservancy.

3.0. Types of Anthropogenic Disturbance Disrupting Connectivity

Human disruption of spatial subsidies can have enormous consequences for the functioning of both donor and recipient ecosystems. There are 5 commonly discussed categories of human planetary impacts: overharvest and persecution, introduced species, pollution, habitat alteration or destruction, and climate change. Below we highlight just a few common or well-studied examples of connectivity loss caused by each major category of human disturbance.

3.1. Overharvest and Persecution

Direct human harvest has been responsible for the decline of many subsidies. Overharvest is one of the earliest anthropogenic drivers of extinction and, as such, many disruptions to connectivity are hard to detect. For instance, early humans likely dramatically disrupted connectivity by large migratory megafauna across the world, including in California, by the overharvest of these species (Doughty et al., 2015; Wolf et al., 2013). Harvest does not need to target the vector or donor to have important impacts. Wolves are known to cause important redistribution of nutrients via their impacts on ungulate behavior and mortality patterns, and historic catastrophic harvest of wolves no doubt dramatically changed the nutrient dynamics in their native habitat (Bump, Peterson, et al., 2009; Bump, Tischler, et al., 2009).

The connectivity of California has undoubtedly been heavily impacted by persecution of a number of taxa. Terrestrially, the most notable impact is the historic extirpation of the grizzly bear in the early 20th century. Grizzly bears, once likely abundant along the Gaviota Coast, are prominent consumers of aquatic resources, with established effects on connectivity in other systems, and their loss likely caused significant direct and indirect losses of connectivity across the west coast. Connectivity of the marine ecosystem of California has also certainly been impacted by historic harvest of marine mammals, including whales, otters and pinnipeds. Whales are well known to connect deep water to surface water environments, often increasing productivity in surface water (Lavery et al., 2014; Roman et al., 2014; Roman & McCarthy, 2010). Otter predation on sea urchins is critical in regulating the production of marine wrack, a major subsidy to terrestrial ecosystems (Watson & Estes, 2011). Seals and sea lions often directly connect marine to terrestrial environments, especially through their colonial haul out behavior (Bokhorst et al., 2019). All of the aforementioned marine mammals have been extensively hunted by humans for products ranging from fur to oil to meat, and even sometimes persecuted as nuisance species (e.g. sea lions competing with fishermen). Most of these species have still not recovered to pre-overharvest population sizes. While game hunting is likely no longer a major threat to connectivity in most of California, a strong legacy of overhunting and persecution in disrupting natural connectivity persists.

3.2. Introduced Species

The roles of introduced species in disrupting subsidies are unique to the species and system in question, but can be devastating to natural ecosystem function. Introduced predators can reduce the movement of nutrient subsidies from a donor to a recipient habitat, especially if they increase predation on a critical vector of such subsidies (Epanchin et al., 2010; Finlay & Vredenburg, 2007; Gergs et al., 2014). The best studied example of species invasion altering subsidies comes from the introduction of non-native predators on seabirds. Introduced predators (rats, foxes, pigs, cats, ants, etc.) have reduced and even extirpated seabird populations worldwide (Doherty et al., 2016; Towns et al., 2011). Because of the nutritional importance of seabird guano subsidies, cascading effects of seabird decline includes changes to productivity, consumer diversity and body size, and ecosystem functioning across a range of ecosystems (Benkwitt et al., 2022; Young et al., 2013). Introduced species can also outcompete vectors of subsidies (e.g. hatchery-raised versus wild salmon) (reviewed in Buckner et al 2018). The effects of invasive species can also drive changes in subsidies by changing the behavior of native competitors, prey, or predators that would otherwise be subsidy vectors. For example, experimental work on rainbow trout showed that they greatly reduced the subsidy created by insects emerging from streams into terrestrial environments. This reduction was not due to direct predation of emerging insects, but rather by causing a native fish to forage on algae instead of the insects, thus outcompeting the insects (Benjamin et al., 2011). Invasive predators can also affect quality of subsidies by changing nutritional value of subsidies (Subalusky & Post, 2019). Research on guppies has shown that guppies raised with predators produce 39% less nitrogen than guppies raised without predators (Dalton & Flecker, 2014). Introduced species themselves can change the movement of nutrients if they serve as novel vectors for an existing subsidy. For instance, introduced catfish from the aquarium trade generate biological hotspots by aggregating nutrients in novel locations (Capps & Flecker, 2013).

There are not many well documented examples of introduced species on subsidy movement in the California coastal ecosystem. However, California’s coast is heavily impacted by invasive species – including a range of introduced plant species and also the introduction of wild pigs

(Omasta et al., 2021). Introduced plants can change nutrient cycling in many ways – from changing rates of nutrient acquisition (e.g. nitrogen fixing) to removing food or habitat for important vectors (e.g. Young et al 2010). The extent to which introduced plants change connectivity on the California coast has not been explored. Invasive feral and wild pigs are voracious omnivores that have been known to dramatically affect abundance of native consumers; they also physically damage and modify the landscapes they occupy (Seward et al., 2004). They are anecdotally reported to forage on beaches, and due to their wide-ranging movements, likely transport marine-derived nutrients a substantial distance inland (Salbosa & Lepczyk, 2009). The feral pig population on Santa Cruz Island in the Santa Barbara Channel was recently completely extirpated due to the introduced pigs' devastating impact on all of the island's endemic animal species (Parkes et al., 2010). Through their multiple direct and indirect effects on invaded systems, pigs on the Gaviota Coast are thus highly likely to disrupt the natural movement of marine subsidies.

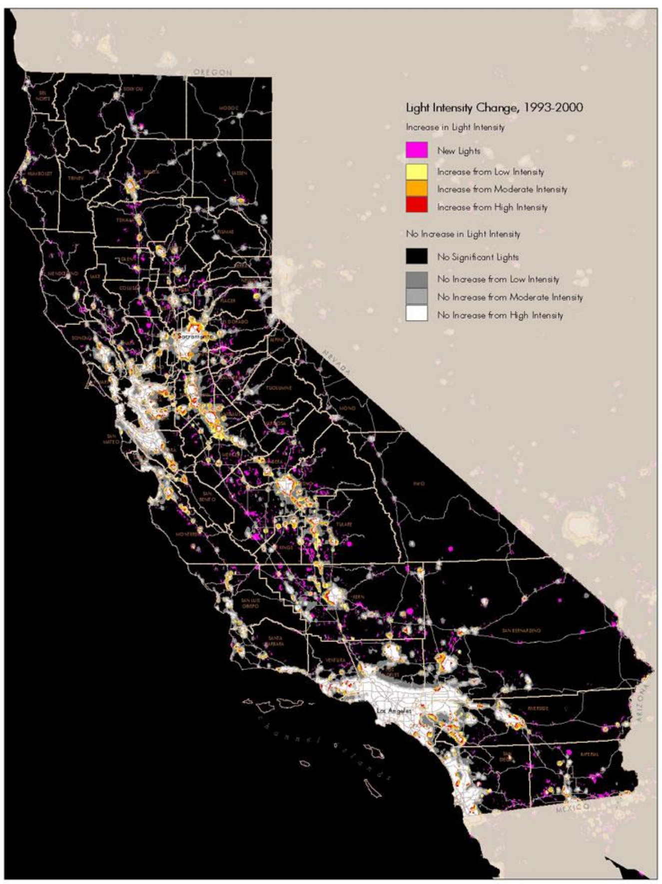


Figure 5. Map of lights visible in the California night sky (prepared for the National Geographic Society by GreenInfo) demonstrating the relative lack of light pollution on the Gaviota Coast.

3.3. Pollution

Pollution comes in many forms, encompassing physical garbage, chemical inputs from agricultural and mining activities, light pollution, and noise pollution. Given the strong impact pollution can have on abundance, physiology, and behavior of organisms it is unsurprising that pollution can impact subsidy movement. Agriculture and mining have been shown to drive strong variation in aquatic to terrestrial subsidies (Burdon, 2020). Fish in streams polluted with trace metals increase their reliance on terrestrial insect prey, given the lack of aquatic insect prey in polluted streams (Kraus et al., 2016). Multiple studies exploring the effects of light pollution have shown that artificial lights at night can dramatically affect subsidies, especially the emergence of insects from aquatic environments to terrestrial ones (Manfrin et al., 2017; Meyer, 2012; Parkinson et al., 2020). Light pollution contributes to the fragmentation of large mammal ranges by facilitating behavioral avoidance of artificially bright areas and disrupting habitat connectivity (Ditmer et al., 2021). Noise and sonar pollution impacts 60% of marine mammals, who, due to their vast movements, play a critical role in ecosystem connectivity (Roman et al., 2014; Schipper et al., 2008).

The lack of significant development on the Gaviota Coast may make this area a refuge for some species that cannot tolerate high levels of light or sound pollution. As seen in the Lights at Night map from National Geographic (Figure 5), this is one of the only areas in Southern California to provide a refuge from light pollution in the region. Any increase in noise or lighting pollution in the area might have significant impacts on habitat connectivity (Ditmer et al., 2021). However, a major outstanding pollution threat on the Gaviota Coast is that of oil and gas spills, especially due to the proximity to major shipping lanes in the California Channel, coastal oil pipelines, and Highway 101 (MacFadyen, 2017). Oil spills disproportionately affect nearshore marine taxa and beach habitats—including seabirds, shorebirds, and marine mammals (Brody et al., 1996; Hampton et al., 2003)—and contaminate beach wrack (which is often then removed by oil spill response teams), thereby disrupting movement and subsidy use across the ecotone (Beyer et al., 2016; de la Huz et al., 2005).

3.4. Habitat Destruction & Alteration

Habitat destruction and alteration can affect connectivity in myriad ways. Perhaps most obviously, habitat destruction can directly alter the movement of either abiotic or biotic vectors. Recent work showed that barriers such as dams that block the migration of fish can have large secondary effects on the surrounding ecosystem (Childress et al., 2014; Childress & McIntyre, 2015). Dams can also reduce prevalence of algal mats which are critical for aquatic emergence of stream insects, therefore reducing aquatic to terrestrial subsidies (Power et al., 2004). Seawalls and other beach armoring may also physically block the ability of waves to wash marine resources to shore as wrack (Heerhartz et al., 2014). Road development impacts the movements of many species of terrestrial animals, both due to an increase in mortality and behavioral avoidance (Forman & Alexander, 1998).

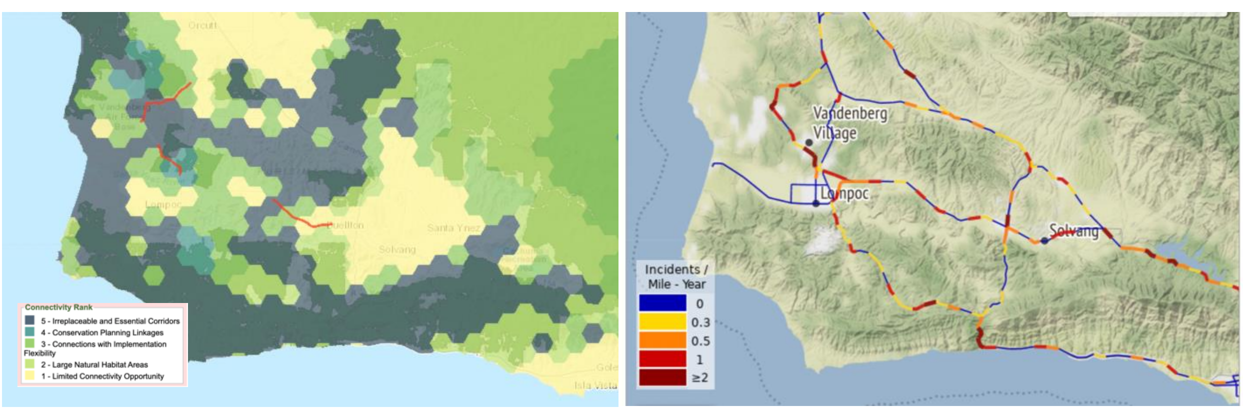


Figure 6. Two maps representing A) three segments of road on the Gaviota Coast that have been identified by CDFW to be priority barriers to wildlife movement (in red) overlaid on a base map of habitat connectivity (adapted from CDFW 2020) and B) wildlife vehicle collision incidents on Gaviota Coast roadways (adapted from Shilling 2021).

Physical barriers to connectivity, such as roadways, hiking trails, privately owned property, and converted ranchland, are prevalent along the Gaviota Coast. The scale of disruption depends on the size of the barrier and the species in question, but roadways, especially major highways, are a ubiquitous barrier to all wildlife species. Highway 101 runs directly parallel to the ocean throughout much of the otherwise moderately developed Santa Barbara County Coastline. This highway creates a significant boundary preventing animal movement and dispersal, and thus disrupts local connectivity between land and sea (Figure 4, Figure 6). Along the southernmost twenty miles of the Gaviota Coast specifically, Highway 101 represents an immediate barrier to beach access by wildlife. The California Department of Fish and Wildlife has identified three stretches of roadway in this area that are significant obstacles to animal movement due to their location, road dynamics, roadkill statistics, and the surrounding animal community (Figure 6). Furthermore, a study done by UC Davis has identified the Gaviota Coast as a “wildlife-vehicle conflict hotspot” (Shilling, 2021). In addition to these roadways, a coastal railroad runs along the bluffs, even through otherwise lightly disturbed landscapes (e.g. the Jack and Laura Dangermond Preserve and Vandenburg Space Force Base). Little research has been done on the impact of the railway in Southern California, but a review of current knowledge on the barrier effects of railways suggests that they are both physical and behavioral impediments to wildlife movement, as well as a source of mortality for animals of multiple sizes (Borda-de-Água et al., 2017). In the future, the construction of a California high-speed railway could exacerbate these issues if careful ecological planning is not considered (Cameron et al., 2005). Other barriers to subsidy movement on the Gaviota Coast include coastal armoring structures such as creosote pilings, sea walls, and riprap. These large structures are designed to impede the natural erosion and movement of sediments, and they often halt abiotic vectorization of subsidies (Heerhartz et al., 2014). Armoring actually narrows beaches, since it does not allow for the natural retreat of the terrestrial boundary over time, and this decreases both beach habitat and access to intertidal resources for land-based consumers (Buckner et al., 2017; Dethier et al., 2016; Heerhartz et al., 2014).

3.5. Climate Change:

In both donor and recipient systems, climate change is shifting fundamental rates and timing of ecosystem productivity. To name just a few of the most relevant impacts for connectivity, climate affects range distributions, abundance and community composition of organisms, timing and nature of abiotic vectors, as well as behavior, fecundity, body size, and mortality patterns of organisms. With so many potential routes of impact, climate change will clearly have severe consequences for habitat connectivity. Climate change-related phenomena drive up the frequency and intensity of storm events (Bender et al., 2010). Storm events often create significant changes in seaweed and other wrack deposition (Spiller et al., 2010). This in turn can entirely restructure food-web interactions in coastal, wrack-subsidized ecosystems (Piovia-Scott et al., 2011). Climate change is also changing the primary productivity of the entire planet, in turn affecting the total amount of resources that flow from donor to recipient ecosystems (Jones & Lennon, 2015). Climate is also shifting the total abundance and body size of many organisms who are themselves subsidies; anadromous fish like salmon are a very well-studied example of this phenomenon (Adams et al., 2010; Bilby et al., 2003; Finney et al., 2000; Oke et al., 2020).

Climate change represents a significant modern anthropogenic threat to local flora and fauna on the Gaviota Coast. Sea level rise is especially pressing, simply because it threatens to reduce, and in some cases eliminate, intertidal habitats. Sea level rise is predicted to reduce suitable beach habitat in Southern California by 90% by 2100 (Revell et al., 2011). Many Gaviota Coast beaches are backed by natural bluffs, manmade seawalls, or development, all of which impede shoreline retreat (Dugan & Hubbard, 2010a). Additionally, precipitation along the coastline is predicted to rise, but during progressively concentrated time intervals, especially as the rate of extreme weather events increases (Heady et al., 2018; Swain et al., 2018). An assessment of threats to the Jack and Laura Dangermond Preserve by The Nature Conservancy and Butterfield *et al.* (2019) found that the most significant effect of precipitation will be an increase in sediment deposition to beaches and that increased rainfall will affect dynamics of Gaviota Coast watersheds. Creeks like Jalama Creek typically close seasonally with summer sand inundation, which is very important for some sensitive riparian, estuary, and beach species (e.g. tidewater goby and steelhead trout) (Butterfield et al., 2019). Extreme weather events are likely to disrupt these seasonal closures by washing out sediment barriers asynchronously with the natural rhythms of resident species that rely on those barriers (Heady et al., 2015). This disruption will undoubtedly have downstream effects on estuaries, vegetation, and consumers supported by Gaviota Coast waterways (Butterfield et al., 2019).

4.0. Anthropogenic Disruption of Subsidized Systems

The anthropogenic disruption of subsidies has been documented to occur across by changes either to the donor system and to the recipient system, as well as to the vectors themselves. Such subsidy disruption can cause downstream cascading effects on recipient ecosystems and alter ecosystem functioning.

4.1. Donor Systems:

Anthropogenic disturbance of the donor system can alter the amount, timing or quality of the subsidy vectored to recipient ecosystem. Human-driven reductions in the abundance of a subsidy—often via changes to the population size of plant or animal providing the nutrients—are an especially important mechanism (Subalusky & Post, 2019). For instance, direct harvest of whales likely caused dramatic declines in whale fall subsidies to deep sea environments (Amon et al., 2013), declines in salmon populations have likely driven enormous reductions in upriver and inland nutrient transfer (Harding & Reynolds, 2014; Rüegg et al., 2020) and changes in riparian tree density around rivers dramatically changes leaf inputs into river ecosystems (Mineau et al., 2012; Rowekamp et al., 2020). Reductions in the quantity of subsidy produced can happen both by top-down processes—in which the subsidy is removed by harvest or predation—or by bottom-up processes that change the rate of production of the subsidy. Examples of top-down processes include the direct harvest of species whose natural death and decomposition provide resources to nutrient-poor systems (e.g. whales falling to the ocean floor, salmon migrating upstream, kelp washing ashore). Bottom-up processes that interfere with the production of the subsidy have similar impacts but have different underlying mechanisms. For example, climate-driven changes in upwelling dynamics, rainwater runoff, and resultant nutrient delivery on the California coast will likely affect rates of kelp growth (Brzezinski et al., 2013). Changes in timing of when subsidies are produced are also important. Climate change-related temperature regimes will undoubtedly affect the seasonal dynamics of many temperature-sensitive processes like breeding, pollination, molting, and emergence, potentially decoupling long-standing relationships between resources and their consumers. Climate change is also predicted to alter the quality of subsidies. For instance, vegetation grown in experimentally warmed soils has different lower leaf carbon and phosphorus from that grown in cooler soils; shifting nutrient profiles in vegetation will impact recipient ecosystems, for example reducing bacterial densities, increasing light availability and stimulating zooplankton growth (Fey et al 2015).

4.2. Recipient Ecosystems:

Changes to recipient ecosystems can also change the extent to which subsidies are taken up and the cascading effects those subsidies have. Changes in abundance of organisms that consume the subsidy mean it may not be redistributed throughout the recipient habitat, and human driven alteration of wildlife movement will change how and where subsidies are delivered. For instance, a loss of bears in riparian areas would greatly alter the extent to which salmon-derived nutrients from marine ecosystems move into terrestrial ecosystems. Roads and highways can especially disrupt connectivity between coastal donor and inland recipient habitats (Forman & Alexander, 1998) and can reduce access to trophic resources for many species (Carlton & Hodder, 2003). This may have cascading effects on nutrient poor inland communities that are dependent on aquatic resources (Rose & Polis, 1998).

Human activity in recipient ecosystems may also directly remove or alter subsidies. In California, removal of marine wrack and beach stranded carcasses via regular grooming is a standard practice. Furthermore, as with donor systems, human activities may alter an ecosystem so dramatically that it is unable to host the vector of the subsidy. For instance, draining of wetlands reduces their value as a stopover site for migrating birds, undoubtedly changing the delivery of avian-derived subsidies (Stewart Jr., 1996). Additionally, changes in the recipient ecosystem can change the impact of subsidies delivered; terrestrial subsidies to streams can boost primary productivity in time of high water flow, but in times of drought, or as a result of human extraction of water, terrestrial subsidies can instead lead to eutrophication and toxic algal blooms (Hilton et al., 2006).

5.0. Anthropogenic Impacts on the Gaviota Coast by Subsidy Type

The various sources of resource subsidies from nearshore marine communities to inland terrestrial landscapes on the Gaviota Coast are reviewed in (Young & Zilz, 2021). While we have touched on some of the major types threats already, below we present a summary of the anthropogenic impacts threatening each subsidy source using data either identified from the Gaviota Coast or inferred using research in ecoregions similar to the Gaviota Coast.

5.1. Marine Algal Wrack

Significant resources have been dedicated to understanding the transport and use of marine algal wrack subsidies and the impacts of human on disrupting these subsidies. Much of this research has been concentrated on the West Coast, where kelp forests are one of the largest sources of primary productivity, and wrack input has been shown to increase the diversity (Dugan et al., 2003) and downstream productivity (Dugan & Hubbard, 2010b, 2016; Lowman et al., 2019) of coastal landscapes. Algal wrack deposition is primarily threatened by the widespread practice of beach grooming, which mechanically removes all debris from sandy beaches to make them more appealing to recreating human visitors (Fairweather & Henry, 2003). Wrack is typically removed from the beach ecosystem completely and usually deposited in a landfill, disrupting thousands of kilograms of potential resources and diverting an unknown amount of nutrients from beaches and connected landscapes. The removal of this kelp subsidy has bottom-up consequences for the entire beach community, and groomed beaches in Southern California have remarkably low biodiversity compared to ungroomed beaches (Schooler et al., 2019). Removal of wrack also inhibits the formation of dunes and dunegrasses, which are critical components of a healthy beach ecosystem (Nordstrom et al., 2012). The donor ecosystem for algal wrack subsidies, the kelp forest, is also impacted by anthropogenic disturbance. Algal wrack is mostly made up of giant kelp, *Macrocystis pyrifera*, which is currently a species of conservation interest on the California coast. The historic and current removal of kelp-forest top predators (otters, lobster, and fish) has increased the abundance of purple and red sea urchins, which consume giant kelp and create urchin barrens, thus threatening the deposition of critical kelp subsidies onto California's beaches (Dayton et al., 1998; Filbee-Dexter & Scheibling, 2014). This creates a positive feedback loop of kelp reduction, decreasing habitat suitability for urchin predators, as well as increasing the impact of wave action, both of which reduce the colonization of giant kelp and perpetuate the urchin barren state (Filbee-Dexter & Scheibling, 2014).

5.2. Rocky Intertidal Fish and Invertebrates

Intertidal fauna provide significant resources to beach-dwelling, volant, and terrestrial predators (Figure 7). However, these organisms, adapted to an extremely harsh and dynamic environment, are already living at the edge of their abiotic tolerance threshold, and are therefore extremely likely to be impacted by climate change (Tomanek & Helmuth, 2002). Mass mortality events are common in rocky intertidal habitats, and while these events provide an acute pulse of subsidy to the beach and coastal habitats in the form of thousands-to-millions of corpses, they have obvious negative effects on the long-term population dynamics of the organisms affected. Mass mortality events in the rocky intertidal are predicted to increase in frequency with climate change, which is likely to reduce the availability of rocky intertidal prey for that subsidizes terrestrial and beach consumers (C. Harley, 2008).

Rocky intertidal areas are extremely popular sites for human recreation, including tidepooling, collecting, and fishing. Humans physically impact this sensitive environment via trampling and removal of animals, plants, and algae for human consumption (C. D. G. Harley & Rogers-Bennett, 2004; Murray et al., 1999). Even the curious turning-over of rocks can significantly affect intertidal community structure on a large scale. In Southern California, even the implementation of marine protected areas (MPAs) does little to deter the negative effects of human visitation (Jhaveri & Smith, 2019; J. R. Smith et al., 2008). Furthermore, the presence of humans in the rocky intertidal deters more sensitive consumers from accessing a potential food source (Lindberg et al., 1998). Humans tend to aggregate in rocky intertidal areas to recreate during low tide, which is also a critical time for terrestrial and volant consumers to take advantage of exposed food resources.

Figure 7. A lactating female coyote carries a gumboot chiton, a large mollusk commonly found in California's tide pools, from the rocky intertidal zone up into the coastal scrub at Vandenberg Space Force Base.

5.3. Marine-Derived Carrion

Pulsed delivery of carrion, if left to decompose, can subsidize terrestrial consumers both in the short and the long term, but on beaches with significant human traffic, these carcasses are rarely left in place (J. P. Tucker et al., 2018). Regular grooming removes carrion of all sizes along with algal wrack. Fish and other carcasses provide important, high quality, pulsed subsidies to decomposers like beetle larvae (Figure 8) and scavengers like turkey vultures. Whale falls and other large marine mammal carcasses, which would naturally provide long-standing and slow pulses of nutrients to terrestrial systems are instead usually dragged out to sea, buried, or moved to landfills (NOAA Marine Mammal Stranding Network Database, 2021; Tucker et al., 2018). Only on the most remote beaches are they left to decompose and be consumed naturally. The removal of these carcasses is problematic because carrion is an extremely nutrient rich resource, more so than other types of detritus, and can create nutrient hot spots in an otherwise xeric sandy beach environment.

While human activity disrupts the reception of marine carrion by consumers, anthropogenic influence also impacts the delivery of this important subsidy. Any reduction in marine mammal, coastal fish, and invertebrate populations will reduce the amount of dead sea life washing ashore (Buckner et al., 2017). Ship strikes threaten whale populations in the Santa Barbara Channel, which has downstream effects on the rate of carcass deposition (Buckner et al., 2017). Bioaccumulation of toxins (pollutants, heavy metals, and biotoxins) contributes to the death and sometimes mass mortality events of seals, sea lions, and otters on the Gaviota Coast (Schipper et al., 2008). This phenomenon creates pulses of carrion deposition in the short term, especially during pupping season, but will eventually reduce the rate of subsidy delivery if marine mammal populations are reduced. Furthermore, toxins in washed-up carcasses might contribute to the death, illness, or resource avoidance of scavenging taxa that rely on those subsidies (e.g. California condor), and could potentially decouple marine-terrestrial connectivity as a result (Kurle et al., 2016).

Figure 8. The carcass of a perch, washed up on the beach at the Jack and Laura Dangermond Preserve, being actively consumed by a larval beach-dwelling beetle.

5.4. Coastal Bird Guano, Carrion, and Gametes

Nesting shorebird and seabird eggs, decomposing bodies, and guano represent a major subsidy to terrestrial primary producers and consumers. Both eggs and guano are vectored inland by birds, so anything that disrupts the movement of birds will inevitably reduce the rate of this subsidy. Just as seabirds and shorebirds are in decline globally due to habitat degradation, bioaccumulation of toxins, and introduced predators, so too are the subsidies they provide. On the Gaviota Coast, threats to coastal birds include light pollution (Gouveia, 2022), both natural and human-associated predators (McChesney & Tershy, 1998; Millus et al., 2007; Page & Whitacre, 1975), human recreation (Lafferty, 2001a), and loss of critical habitat (Heady et al., 2018; Wiens & Gardali, 2013). While most seabirds in the Santa Barbara area nest on the Channel Islands, two iconic species, the snowy plover and the least tern, build their nests on mainland beaches. Unfortunately, these two species are threatened and at risk of extinction due to this nesting behavior, which puts nests at risk of being crushed by humans, pets, horses, and mechanical beach grooming (Hardy & Colwell, 2012). Depredation of their nests by terrestrial predators, which could represent a key movement of nutrients inland, also further threatens their population (see Appendix 1-J for more information). Management of plovers and terns attempts to protect their nests from predation, including by natural predators, simply to maintain the remaining nesting shorebird population, and such management might impact egg-subsidy consumption by terrestrial predators.

Based on our understanding of seabird subsidies in similar low-productivity habitats worldwide, seabird and shorebird guano likely enrich the Gaviota Coast. On xeric beaches on the Gulf of California, shorebird guano contributes to rocky intertidal algal growth, a primary food source for beach arthropods, who are in turn prey for terrestrial side-blotched lizards. Stable isotopes reveal that marine-derived nutrients can be detected in multiple trophic levels in this coastal area, and algae-subsidized invertebrates make up nearly half of the terrestrial lizards' diet (Barrett et al., 2005). Outside of rocky intertidal areas, guano directly enhances the nutrient content of the soil, supporting coastal primary productivity (Polis et al., 2004).

Dead seabirds and shorebirds, like marine mammals, invertebrates, and fish, regularly wash up or die on the beach. Here they are either processed by invertebrates on the sand or dragged inland by scavengers (Figure 8). Their decomposing bodies undoubtedly provide critical nutrients to the coastal habitat. Sea and shorebirds play a fundamental role in coastal nutrient cycles especially when they die by supporting a significant biomass of scavenging taxa, especially small arthropods (Polis et al., 2004). Like other carrion however, this abundant subsidy is often raked away by mechanical beach grooming or otherwise disposed of before it can contribute nutrients to the beach ecosystem. Furthermore, toxin bioaccumulation in coastal birds, a common contributor to their mortality, could render their carcasses toxic to scavengers at higher trophic levels. Seabirds are particularly at risk for harmful algal bloom (HAB) poisoning, which increases in incidence in the spring and summer in conjunction with blooms of *Pseudo-nitzschia,* a marine diatom that produces toxic domoic acid (Bejarano et al., 2008; J. Smith et al., 2018). As it moves up the food chain, HAB toxins increase in concentration, finally reaching lethal levels in fish-eating seabirds, and is one of the factors threatening global seabird populations (Gibble & Hoover, 2018).

Figure 8. A cormorant carcass, likely dragged up-beach by a coyote, decomposing amongst foredune vegetation at the Jack and Laura Dangermond Preserve.

5.5. Beach Invertebrates

Beach invertebrates are likely the most important and least appreciated coastal species mentioned in this report. They are essential for the processing, sequestration, and vectoring of many marine derived subsidies on the Gaviota Coast (Lastra et al., 2008). Their populations provide significant bottom-up support for more charismatic megafauna like the snowy plover

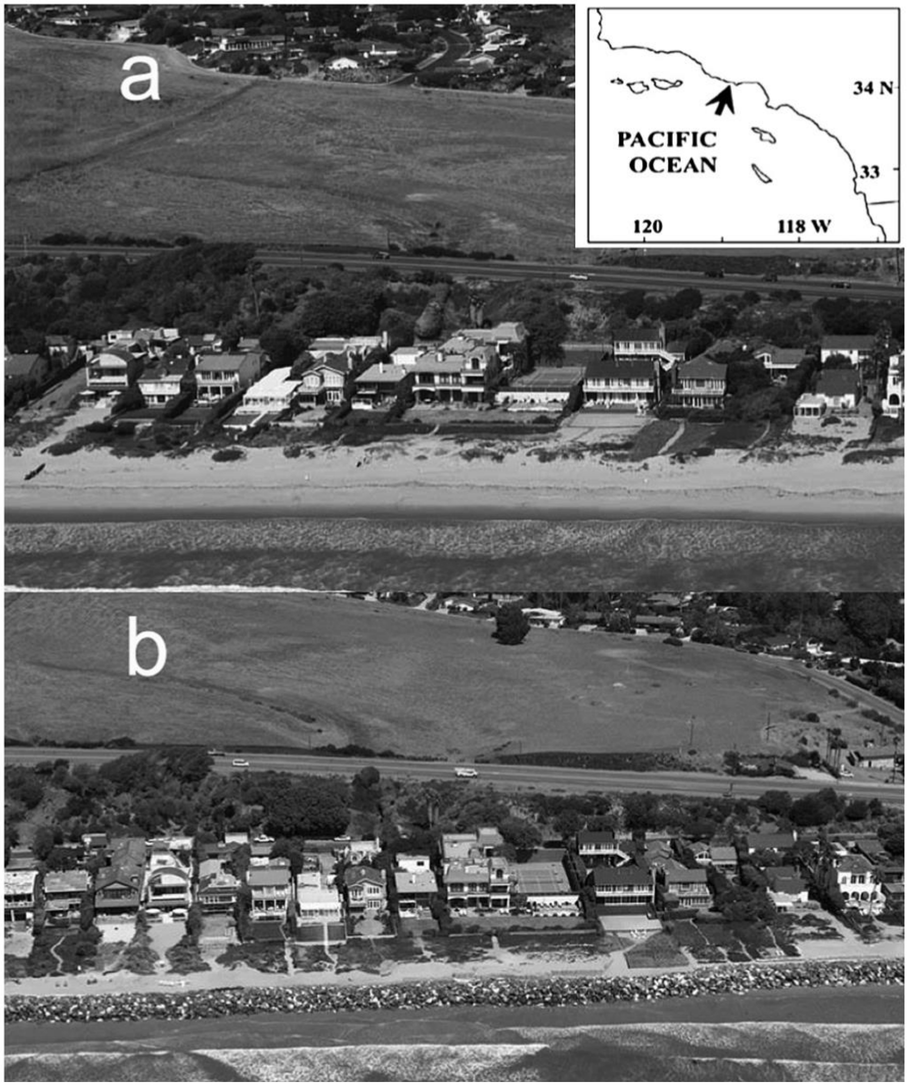


Figure 9. Beach habitat at Broad Beach in Los Angeles County in (A) 2002 and (B) 2010, demonstrating the extreme loss of sandy shoreline in a short period of time. One endemic species of beach isopod was found in high abundance here in 2002, but was absent in 2010. This figure was adapted from Hubbard et al. (2014) and the images are courtesy of the California Coastal Records Project.

(Dugan et al., 2003). However, due to their miniscule size, cryptic fossorial lifestyle, and lack of charisma, beach invertebrates—including talitrid amphipods, isopods, annelids, and insects—are often disregarded when it comes to determining conservation priorities. Unfortunately, just like many of their predators, beach invertebrates are in decline across California (Hubbard et al., 2014). Beach invertebrates are typically highly endemic, with very narrow habitat ranges and limited ability to disperse (Grantham et al., 2003). Beach invertebrates are especially impacted by sea level rise and climate change due to their reliance on a narrow margin of the beach littoral zone (Dugan & Hubbard, 2010a). As sea level rises and the rate of storm intensity increases, sandy beaches tend to decrease in width, a process that is intensified by coastal armoring and human development that abuts beaches (Figure 9). In combination with their constricted environmental requirements, sand-dwelling invertebrates are at risk of extinction because their beach habitats are degraded by anthropogenic development, human recreation, beach grooming, sea level rise, and climate change (Defeo et al., 2009; Dugan & Hubbard, 2010b). Beach invertebrates seem to be especially sensitive to trampling (Fanini et al., 2005; Schlacher et al., 2016). Furthermore, several of these invertebrates reproduce later in life and have few offspring, characteristics that make them more vulnerable to disruption (Hubbard et al., 2014). On beaches spanning the coastal area between Point Conception, CA, and Mexico, there has been widespread extirpation of at least two beach-dwelling endemic isopod species. One of these species (*Alloniscus perconvexus*) currently only remains on isolated, un-modified, ungroomed beaches (Hubbard et al., 2014). In fact, 74% of the population of *A. perconvexus* and a similar isopod, *Tylos punctatus*, is concentrated in only two of their seven historical stretches of coastline, indicating a severe reduction in habitat for these species (Hubbard et al., 2014).

6.0. Anthropogenic Impacts on Gaviota Coast Consumers

In this report, we are specifically interested in what the effects of increased anthropogenic influence on the Gaviota Coast, especially increased recreational visitation, will be on endemic species that interact with marine subsidies in some way. Increased human use of remote parts of the coastline will likely require the improvement of existing roads or the building of new road or trail infrastructure. Conservation and management policy necessitates that this type of infrastructure includes the construction of culverts, bridges, or other corridors enabling the movement of wildlife, which will hopefully ameliorate the effects of disruption to connectivity. In the table below we summarize the current anthropogenic threats to species and faunal groups of special concern on the Gaviota Coast. The organisms covered by this section of the report are either highly likely to rely on marine subsidies, are vectors of marine subsidies, or have already been documented foraging in intertidal habitats on the Gaviota Coast. The organisms in the following table are listed from the most sensitive to human impacts to the least sensitive.

Table 1. Large-bodied terrestrial consumers that are likely to both rely on marine to terrestrial resource subsidies—as identified by Young & Zilz (2021)—and be impacted by anthropogenic disturbance. This table does not represent an exhaustive list of potential anthropogenic impacts on these species, but is limited to what has been documented in the scientific literature.

CONSUMER	SUBSIDY SOURCE	ANTHROPOGENIC IMPACT	FURTHER READING
SNOWY PLOVER	Beach invertebrates	Introduced species, habitat destruction and degradation likely to negatively impact populations	Appendix 1-A
CALIFORNIA CONDOR	Marine-derived carrion	Habitat destruction and degradation, pollution likely to negatively impact populations	Appendix 1-B
COYOTE	Beach invertebrates, marine-derived carrion, bird gametes and carrion, live rocky intertidal fish and invertebrates	Habitat destruction and degradation likely to negatively impact populations	Appendix 1-C
MOUNTAIN LION	Marine-derived carrion, potentially live pinnipeds	Habitat destruction and degradation likely to negatively impact populations	Appendix 1-D
BLACK BEAR	Marine-derived carrion, live rocky intertidal fish and invertebrates, potentially live pinnipeds	Habitat destruction and degradation likely to negatively impact populations	Appendix 1-E
GREY FOX	Live rocky intertidal fish and invertebrates	Habitat destruction and degradation likely to negatively impact populations	Appendix 1-F
BOBCAT	Prey that are primary consumers of marine subsidies	Habitat destruction and degradation likely to negatively impact populations	Appendix 1-G
AMERICAN BADGER	Prey that are primary consumers of marine subsidies	Habitat destruction and degradation likely to negatively impact populations	Appendix 1-H

RACCOON	Marine-derived carrion, bird gametes and carrion, live rocky intertidal invertebrates, beach invertebrates	Abundance will likely increase with increase in human disturbance	Appendix 1-I
STRIPED SKUNK	Marine-derived carrion, bird gametes and carrion, live rocky intertidal invertebrates, beach invertebrates	Abundance will likely increase with increase in human disturbance	Appendix 1-J

7.0. Conservation of Connectivity

There has been surprisingly little synthesis or review of the best practices for conserving connectivity (although see Buckner et al., 2018) . However it is clear that conservation and even restoration of connectivity is very possible and can be quite effective. For instance, eradication of rats is now well documented to restore nutrient subsidies from seabirds across both terrestrial and inshore environments (Benkwitt et al., 2021). While a great deal more research is needed to make comprehensive statements about how best to protect connectivity globally, we highlight here three conservation practices that seem likely to have relatively high impact on connectivity. 1) Protect and facilitate natural animal foraging and movement patterns, especially for highly mobile species that are often critical for providing connectivity. 2) Target protection to highly mobile species, species that are known to use multiple ecotypes, and other taxa that are known to be critical in connectivity. 3) Minimize impediments to the natural movement and integration of subsidies through the construction of barriers or the direct removal or relocation of subsidies.

APPENDIX

1. Further Information on selected large mobile consumers from the Gaviota Coast, their relationship to marine-to-terrestrial subsidies, and their current conservation status.

A. Western Snowy Plover

The iconic Western snowy plover (*Charadrius nivosus*) heavily relies on an intact coastal ecotone due to its use of relatively narrow nesting and overwintering habitat along beach strand and amongst dunes. The loss of this habitat across much of the plover's range has resulted in a significant and devastating decline in snow plover populations. The snowy plover primarily consumes beach wrack-associated invertebrates, which are also in decline (US Fish and Wildlife Service, 2007). In Santa Barbara County, plover abundance is correlated with wrack and wrack associated abundance (Dugan et al., 2003)**.** As a result, the Western snowy plover is a federally protected threatened species. On the Gaviota Coast, plover recovery has become a priority for coastal managers, but numbers are still consistently decreasing (*Five Year Review - Western Snowy Plover*, 2019). Plover nesting habits put them in direct risk from beach grooming, human recreation, trampling, and direct predation. Plovers on high traffic beaches in California, such as Devereaux and Sands Beach in the Coal Oil Point Reserve, face significant disturbance, especially during the March – September breeding season, which corresponds with periods of high recreational beach use. Before protective infrastructure was put in place, plovers at this location were disturbed by humans, dogs, horses, and low flying aircraft at a rate of 115 disturbances per plover per week, which was sixteen times higher than at more remote nesting locations (e.g. on the Channel Islands) (Lafferty, 2001b). While disturbance (i.e. taking flight) did not directly result in the mortality of plovers, the abundance of humans negatively correlated with plover feeding activity (Lafferty, 2001b). When parental plovers take flight, nests are at an increased risk of trampling because they are simultaneously exposed and cryptic. Experimental quail egg nests in plover nesting areas outside of protective fencing had an 8% chance of being trampled, compared with 0% inside of the protected fenced area (Lafferty et al., 2006). Furthermore, human population density is positively correlated with the abundance of corvids, a major predator of snowy plovers and their eggs (US Fish and Wildlife Service, 2007). Because corvids are attracted to human refuse and anthropogenic food sources, they are also common in areas that are technically uninhabited by humans but popular for recreation. Other mesopredators that are likely to opportunistically prey on plover nests, such as raccoons, skunks, and possums, are similarly attracted to areas with high levels of human activity because of supplemental anthropogenic food sources.

Sensitive snowy plover populations have been successfully managed even on high traffic beaches. At Coal Oil Point Reserve in Santa Barbara, CA, managers implemented a barrier that reduced plover nest disturbance by half, and restored successful reproduction at a site where it was previously nonexistent. (Lafferty et al., 2006)**.** Fencing has been very successful at other plover nesting sites; compliance with restricted areas was high at Coal Oil Point Reserve, with only 5% of disturbances to plovers occurring within the roped-off area (Lafferty et al., 2006). Lafferty (2001) used beach observations of wintering plovers to construct a management model that suggests that a buffer of no more than 400 meters offered 90% protection to adult plovers and 96% protection to plover nests. Furthermore, reduction of beach trash and food waste might reduce the abundance of corvids in the area, thus reducing plover nest predation risk.

B. California Condor

Efforts to manage the critically endangered California condor (*Gymnogyps californianus*) include improving their access to marine resources, especially carrion. Currently, a few reintroduced California condors regularly feed on the carcasses of marine mammals washed up on beaches. (Dugan & Hubbard, 2016). However, as scavengers, condor are particularly sensitive to the bioaccumulation of toxins, including heavy metals from lead bullets and biotoxins from algal blooms; feeding on carcasses of predatory marine mammals—who themselves often die from the effects of toxin bioaccumulation—puts coastal condors at high risk (Kurle et al., 2016). Therefore, one of the acute threats to recovering condor populations is the bottom-up effects of algal blooms and heavy metal pollution in nearshore habitats, and their consumption of dead marine mammals should be carefully monitored.

C. Coyote

Coyote populations in California are not of high concern from a conservation perspective, and urban-adjacent populations are often considered a nuisance (Breck et al., 2019). However, these wide-ranging opportunistic omnivores are extremely important for the movement of marine-derived subsidies to less productive inland habitats (Polis & Hurd, 1996; Rose & Polis, 1998). In California, marine resources are likely a recent subsidy available to coyote populations. Until the extirpation of the grizzly bear, it appears that coyote populations were competitively excluded from accessing marine food sources, especially pinnipeds and marine carrion (Reid et al., 2018). Where there are seal rookeries, modern coyote populations seem to heavily rely on these food hotspots. Coyote have also been observed to consume live and dead seabirds captured on the seashore, and often drag the carcasses into beach-adjacent terrestrial habitats to feed (author, pers. obvs). These carcasses decompose amongst vegetation and terrestrial invertebrates that are likely immediately subsidized by acute increases in essential nutrients (Figure 8).

Like other mesocarnivores, coyote populations are facing increasing constraint due to human expansion into wild habitats. The abundance of non-urban coyotes in natural habitat patches tends to decline with suitable (undeveloped) patch size (Crooks, 2002). However, coyotes persist in urbanized, fragmented habitats, often by increasing their range size and nocturnal activity (Tigas et al., 2002). Urban and suburban coyotes are subsidized by anthropogenic food sources (garbage, pets, intentional feeding by humans, etc.) which could disrupt the natural movement of resource subsidies that non-urban coyotes likely provide in more intact habitat patches (Bucklin, 2020; Timm et al., 2004). This subsidization increases coyote *density* (coyotes per unit area) in more impacted areas compared to non-impacted areas (Fedriani et al., 2001). Furthermore, coyotes in human-impacted ecosystems tend to be more aggressive and bolder, which, coupled with denser coyote distribution in these areas, increases the chances of human-wildlife conflict and persecution (Breck et al., 2019).

D. Mountain Lion

Mountain lions (*Puma concolor*) in Southern and Central California are currently being considered for inclusion on the endangered species list under the California Endangered Species Act (CESU). California mountain lions have been anecdotally reported foraging on large beach-deposited carrion and even hunting live pinnipeds on more isolated parts of the Gaviota Coast (Jack and Laura Dangermond Preserve Staff, pers. comm.), and it is likely that highly connected coastal habitat is important for the persistence of Gaviota Coast lions (Fletcher et al., 2022). These big cats rely on large swaths of intact habitat, which is rapidly disappearing, thus increasing human-mountain lion conflict at the boundary between human-occupied and wild landscapes. Depredation due to human-wildlife conflicts resulted in six permitted depredation events in the Santa Ana Mountains between 2001 and 2013, and likely higher mortality due to illegal poaching (Vickers et al., 2015). Education of public seems unlikely to reduce human wildlife conflicts, as humans are likely to use wildland areas even if there is a risk of encounter with a mountain lion (Beier & Barrett, 1993)**.**

Unsurprisingly, decreasing habitat availability and increasing human encroachment is one of the major threats to existing mountain lion populations. This threat has been intensely studied in the mosaic of suitable mountain lion habitat in the mountain ranges behind Los Angeles, Orange, and San Diego Counties. Probability of mountain lion occurrence in a particular habitat patch is directly proportional to patch size, and also decreases with increasing patch isolation (Crooks, 2002). In Southern California, specifically in the Santa Ana Mountain Range, mountain lion home ranges span between 65-93 km^2 for females and 363-608 km^2 for males, and these ranges usually shrink in the dry season when mountain lions stay nearer to water sources (Grigione et al., 2002). Mountain lion home range sizes also track the dispersion of mule deer, who expand and contract their ranges seasonally in some mountainous habitats in California (e.g. the Sierra Nevada Mountain Range). However, seasonal differences in home range size for mountain lions do not seem as extreme in more coastal regions (e.g. the Santa Ana Mountains) where seasons are moderate and less pronounced (Grigione et al. 2002). Regardless of season, mountain lions tend to prefer riparian habitats (Dickson & Beier, 2002). In California and elsewhere, agricultural development subsumes mountain lion habitat. In the Santa Ana Mountains, mountain lions strongly avoid farm and grasslands because they provide little cover for stalking, hunting, and caching kills (Dickson & Beier, 2002). Crooks (2002) suggests that in California, the probability of habitat use by mountain lions will be low in ten 10 km^2 fragments of habitat but would be higher in a contiguous reserve area larger than 100 km^2.

Mountain lions typically avoid including paved roads when establishing their home ranges (Dickson & Beier, 2002). Roadways in otherwise "conserved" puma habitat can restrict animal movement to the extent that it forms genetic bottlenecks, effectively creating unsustainable subpopulations; in the Santa Ana Mountains the I-15 highway has resulted in two genetically distinct puma populations with only one recorded event of gene flow (one individual male crossed the highway and produced offspring between 2001 and 2013) (Vickers et al., 2015). Construction of roads pushes puma into more urban landscapes that they would otherwise avoid (Dickson & Beier, 2002). Vehicle collision is a leading cause of mountain lion deaths in Southern California (Beier & Barrett, 1993). Mountain lions will avoid paved, high-speed roads in their movements, but they habitually travel along dirt or gravel roads within their home ranges. Tracking of cougars in Redwood National Parks suggests that construction of new, heavy-use roads, especially in areas where there were previously low- or moderate-use roads (e.g. expanding road infrastructure) will reduce habitat quality for mountain lions and simultaneously increase the risk of collision with vehicles (Meinke, 2004). Unfortunately, mountain lions do not seem to benefit from the construction of wildlife road crossings. Cougars studied in the Santa Ana Mountains from 2001 to 2013 never used a dedicated wildlife undercrossing under State Route 91, but two adults were killed attempting to cross this roadway nearby (Vickers et al., 2015). The Gaviota Coast Highway 101 near the Gaviota Pass is considered a hotspot for wildlife-vehicle conflicts as determined by the UC Davis Road Ecology Center, and three mountain lions have been the victims of collisions with cars there since 2018 (California Roadkill Observation System).

E. Black Bear

Black bears are ubiquitous in wild, rural, and exurban habitats in California, where there has been a long history of human-bear conflict. However, the black bear populations in Central and Southern California are a more recent introduction, with black bear populations experiencing a range expansion following the extirpation of the California grizzly that culminated in the 1920s (Storer & Tevis, 1996). Generally, a reduction in bear habitat, reduction in wild food resources for bears, continuing infringement of human development into bear habitat, increase in recreation, all bring bears into closer and more regular contact with humans.

Bear populations in California have been increasing rather than decreasing, especially where they interface with urban areas. In the Sierra Nevada Mountains, bear populations near human development were three times higher than historical values, female bears had a longer reproductive lifespan and more cubs, and urban bears were on average 30% larger than wild conspecifics (Beckmann & Berger, 2003). Wild-ranging black bear home range sizes are likely directly proportional to habitat quality and tend to increase in more fragmented landscapes (Koehler & Pierce, 2003), but urban bear home ranges were 70-90% smaller than their wild counterparts (Beckmann & Berger, 2003). Even though urban bears in the Lake Tahoe Basin had more cubs per female, fewer urban cubs than wild cubs survived, suggesting that urban areas are a “sink” for bear populations and that increasing urban bear numbers won’t necessarily supplement dwindling wild bear populations (Beckmann & Lackey, 2008). Furthermore, increases in urban bear populations will result in more individual bears interfacing with humans, putting urban bears at higher risk for antagonistic interactions and eventually depredation. Therefore, the current conservation priority for black bears is to keep them away from humans (California Department of Fish and Wildlife, 2022).

Cause of mortality among black bears has not been well studied in California where bears are usually a nuisance, but in Florida, where black bears (*Ursus americanus floridanus*) are a conservation target, research suggests that collision with vehicles is a significant source of bear mortality (Hostetler et al., 2009). In areas facing increasing human development, especially road construction, managers should implement highway underpasses to reduce road mortality of black bears. On the Gaviota Coast specifically, bear-vehicle collisions are of particular concern, and black bears are regular victims of the wildlife-vehicle conflict “hot spot” on the Gaviota Pass section of Highway 101. Hunting does slightly impact bear populations – over 30,000 tags were issued in 2020, resulting in over 1000 bears killed in California, 5 of which were in Santa Barbara County (California Department of Fish and Wildlife, 2021).

Currently, management of black bear populations is focused less on conservation and more on removing sources of human-wildlife conflict (California Department of Fish and Game, 1998; California Department of Fish and Wildlife, 2022). The California Department of Fish and Wildlife Black Bear Policy categorizes bears as one of the following: public safety bear, depredation bear, conflict bear, no harm/no foul bear, and habituated bear. These designations allow the CDFW to target management strategies to specific bears, and to implement a series of steps specific to each incident of human-wildlife conflict (California Department of Fish and Wildlife, 2022). Very little management exists to conserve natural bear populations other than education directed at humans visiting bear habitat that is specifically designed to reduce conflict with and attractants of bears. Along the Gaviota Coast, similar management practices should be put in place if human visitation (and therefore human refuse) increases in remote areas that are likely to be important to bears. Increasing human activity, especially recreation, on remote parts of the Gaviota Coast is likely to have one of two impacts: (1) it will either disrupt the willingness of bears to access parts of their habitat that are visited by humans, such as the beach and intertidal areas or (2) increased garbage and human food resources will attract bears to those food sources in lieu of the sparce and scattered natural resources that they are accustomed to. In either case, increasing human activity may disrupt any potential movement of nutrients from marine habitats inland by black bears. It is also important to note that in other remote areas on the West Coast where bears are active, disrupting bears’ use of marine resources is predicted to lead to an increase in human-wildlife conflict (Artelle et al., 2016).

F. Gray Fox

Gray foxes are charismatic mesopredators and are not endangered. However, foxes are predated upon by coyotes in Southern California, and have lower survival rates when they leave their home ranges (Farias et al., 2005). Therefore, there is often an inverse relationship between coyote and fox populations, and foxes often avoid areas with high coyote density, which can include urbanized landscapes. While coyote predation results in high fox pup mortality, the population in Southern California appears stable, although there is little recent data on fox birth and death rates (Farias et al., 2005).

Foxes rely on connectivity between inland habitats, beaches, and coastal marshes on the Gaviota Coast, although they can and do also persist in urbanized environments (Larson et al., 2015). Foxes consume many small rodents, birds, and invertebrates that depend on coastal strand habitat (Fritzell and Haroldson, 1982). Gray foxes can forage in a fragmented landscape, and have been found in habitat patches surrounded by urbanization in Southern California (Crooks, 2002; Larson et al., 2015), but gray fox foraging is impacted by human activity, and they are less likely to use habitat that experiences human visitation (Farías et al., 2012).

G. Bobcat

Bobcats are shy and elusive carnivores. They are particularly sensitive to a lack of connectivity between suitable habitat patches, and can only persist in modified landscapes if there are adequate corridors between patches in place (Crooks, 2002). That being said, bobcats are more likely to reside in a large contiguous reserve-type landscape (10 km^2 or larger) than in an equal area of small habitat patches (Crooks, 2002). Riparian areas are likely used as corridors by bobcats and the presence of intact rivers and streams can ameliorate the effects of urbanization and vegetative monoculture on bobcat populations and movement patterns (Kozakiewicz et al., 2019; Serieys et al., 2021). Unlike coyotes and foxes, bobcats are less likely to capitalize on anthropogenic food sources, especially since they are often absent from smaller habitat patches surrounded by human development (Larson et al., 2015).

Bobcats attempt to select home ranges that have fewer roads on average than the surrounding landscape, often using multi-lane highways as home range boundaries. However, there is very little intact, roadless landscape from which to choose (Poessel et al., 2014). As a result, bobcat home ranges tend to exhibit a phenomenon referred to as "pileup", where ranges along barriers tend to be smaller and more concentrated (Kozakiewicz et al., 2019). Due to their spatial relationships with roadways, vehicular collision is a significant source of mortality for bobcats. Bobcats on the coastal side of Highway 101 are likely isolated from their more inland counterparts, and are therefore at a high risk of extinction due to random genetic processes (i.e. genetic drift). There is very little successful dispersal across roadways even for wide ranging carnivores, and home ranges for bobcats thus tend to cluster adjacent to major roadways instead of crossing them. Mesocarnivores with small relative population sizes, like bobcats, tend to disperse as a method to avoid inbreeding, but bobcats rarely successfully disperse across Highway 101 (Riley et al., 2006; Ruell et al., 2012). Furthermore, bobcats do not seem to benefit from wildlife crossing bridges or culverts, and anecdotal reports suggest that Gaviota Coast bobcats in particular do not utilize the existing culverts to cross roadways (Doug Campbell, pers. comm.). Isolated bobcat populations face the downstream effects of inbreeding depression, which can increase rate of detrimental genetic defects, diseases like Feline Immunodeficiency Virus (FIV), and risk of extinction (Lee et al., 2012).

H. American Badger

The American badger is a shy but iconic mesopredator on the California coast. Despite their small size, badgers maintain large home ranges and require large swaths of uninterrupted habitat in order to successfully forage and raise young. In California, badger home ranges are between 1 and 12 km^2, with females at the lower end and males ranging wider , although males reduce space use in winter (Duquette et al., 2014; Quinn, 2008). Badgers in California are highly sensitive to habitat fragmentation, and are rarely detected outside or even near the edge of large, contiguous habitat patches (Crooks, 2002). However, badgers will increase their ranges to include fragmented landscapes when feeding, mating, and den-building opportunities are scarce (Duquette et al., 2014). Badger home range sizes in Central California require that successful management strategies should maintain a core of at least 30 km^2 of suitable habitat, buffered from human activity and infrastructure (Quinn, 2008).

The relationship between badgers and roadways is complex. Paved roads are barriers to badger movement and may result in habitat fragmentation for badgers. Badgers sometimes select home ranges that include highways, but they also sometimes avoid them (Duquette et al., 2014). Regardless, high-speed roads represent a direct mortality risk (Duquette et al., 2014; Kinley & Newhouse, 2009; Sunga et al., 2017). In one study that tracked badgers with home ranges bisected by high speed roads, half of the sixteen tracked badgers died due to collision with vehicles (Klafki, 2014). Culverts put in place to aid road-crossing by badgers are definitely used and could reduce the rate of vehicle collisions. In Canada, roads that were associated with badger mortality had fewer road-crossing implements (culverts and bridges) per kilometer (Kinley & Newhouse, 2009). In British Columbia, badgers of all ages used culverts and cattle crossings, most commonly using 500mm culverts (Klafki, 2014). However, anecdotal reports from Gaviota Coast residents suggest that badgers are victims of roadkill along Highway 101 despite the presence of culverts (Doug Campbell, pers. comm.)

I. Raccoon

Raccoons are typically highly successful in human-modified landscapes, and their populations are often positively influenced by anthropogenic impacts (Bozek et al., 2007; Gehrt, 2004; Ordeñana et al., 2010; Prange et al., 2004). Due to their opportunistic and omnivorous foraging style and their propensity for foraging in the intertidal, raccoons are an important component of connectivity between marine and nearby terrestrial ecosystems (Cox et al., 2020). The addition of anthropogenic food sources to an otherwise undisturbed habitat is likely to change the foraging habits of these opportunistic consumers, and there is evidence to suggest that raccoons will shift their focus and reduce their home ranges to exploit anthropogenic food sources instead of natural ones (Bozek et al., 2007). Thus, the addition of anthropogenic food sources to the wild Gaviota Coast via an increase in recreational visitors could indirectly disrupt a raccoon-vectored marine subsidy to coastal terrestrial ecosystems. While outside of the scope of this report, it is well established that anthropogenically subsidized predators can be a threat to many taxa across a range of ecosystems and species (Gompper & Vanak, 2008; Newsome et al., 2015; Rand & Louda, 2006). An increase in human visitors might also lead to an increase in localized raccoon density, which could have downstream effects on sensitive species, for example the red-legged frog and Western pond turtle, that might serve as raccoon prey (Kukielka et al., 2021). While raccoons are not typically considered a species of conservation concern due to their success in anthropogenically modified systems, they, like other mesopredators, are often victims of road mortality. In California, raccoons are the most commonly reported roadkill, especially along roadways that straddle the boundary between urban and wild landscapes, indicating that roads disrupt connectivity for this otherwise resilient mesopredator (Kreling et al., 2019).

J. Striped Skunk

Skunks are primarily nocturnal omnivorous foragers that persist both in the wild and in areas of increased human influence. In Central and Southern California, skunk populations and activity are actually positively correlated with human development, and skunks are often considered nuisance animals (Elliot, 2008; Wang et al., 2015). Like raccoons, coyotes, and foxes, skunks may change their foraging patterns if there is an influx in anthropogenic food sources, disrupting natural subsidies they may provide to inland habitats (Gehrt, 2004; Theimer et al., 2015). They are also common victims of human-wildlife conflict, especially due to road mortality (Caro et al., 2000; Puig et al., 2007). Other than some research on skunk-vehicle collisions, very little work has been done with respect to skunk conservation in California, and most management strategy is focused on decreasing skunk-human conflicts and mitigating zoonotic disease risk (Gehrt, 2004).

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