



Review of Seven Mammalian Species for Potential Reintroduction to Point Reyes National Seashore

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Introduction

This project's area of focus is Point Reyes National Seashore (PRNS) in Marin County, California, and specifically the idea that rewilding the area further and restoring it to its historical ecosystem, can be achieved in part with the reintroduction of certain mammalian species.

Although species reintroductions do not inherently guarantee population persistence or ecological success, several extirpated or functionally absent species have the potential to deliver substantial ecosystem services to PRNS. These range from keystone species such as sea otter (*Enhydra lutris*), which have been shown to restore trophic cascades, to ecosystem engineers such as North American beaver (*Castor canadensis*) that alter the environment in ways that support many other species. For example, the successful circa 1980 reintroduction of tule elk (*Cervus canadensis nannodes*) to PRNS has resulted in recovery of native grasslands from overgrowth of coastal shrubs and trees, as well as reductions of a non-native grass.¹

This project is intended as a jumping off point for PRNS reintroduction efforts, to initiate multi-stakeholder dialogue, and to help people not familiar with the area or species reintroductions in general. For each species analyzed and suggested additional in-depth analysis will have to be done with a range of various experts and stakeholders with specialized knowledge. We also acknowledge that habitat restoration done in tandem with some of the species reintroductions, would have mutually positive and reinforcing effects.

The initial species list selected for this analysis are: sea otter, beaver, pronghorn (*Antilocapra americana*), California ground squirrel (*Otospermophilus beecheyi*), Humboldt marten (*Martes*

caurina humboldtensis), fisher (*Pekania pennanti*) and North American porcupine (*Erethizon dorsatum*). (Note: fishers and porcupines should be introduced together as fishers balance porcupine numbers). Research and analysis was carried out for each species, which includes a survey that was sent out to 17 experts and stakeholders of various fields, 9 of which completed the survey.

Point Reyes National Seashore

Land Acknowledgement: Point Reyes National Seashore in Marin County is located on the native land of the Coast Miwok People.

General Info

Point Reyes National Seashore (PRNS) is a 71,028-acre park preserve located on the Point Reyes Peninsula in Marin County, California. It was authorized as a National Seashore in 1962, but officially established as a national seashore on October 20, 1972 and is the only National Seashore on the West Coast. PRNS is home to the Phillip Burton Wilderness*, a 30,000 acre designated wilderness area. Designated Wilderness is the highest level of conservation protection for federal lands.

The Wilderness Act was signed into law by President Lyndon B. Johnson in 1964. The Act gave a legal definition of the term wilderness :“A wilderness, in contrast with those areas where man and his own works dominate the landscape, is hereby recognized as an area where the earth and community of life are untrammelled by man, where man himself is a visitor who does not remain.”*

History / Cattle Ranching

PRNS has also been home to non-native cattle (*Bos taurus*), beef ranches and dairy farms. In 2025 11 lessees who operated 12 organic dairies or cattle ranches voluntarily agreed to end their operations and transition off the Seashore, leaving the areas to be managed by the National Park Service in collaboration with the Nature Conservancy. ²

Since the land will be vacated by its most recent settlers, it invites the question, what do we do with the land now? One appealing idea is to rewild PRNS and restore its historically balanced ecosystem beginning with the newly vacated lands.

While there are additional extirpated or nearly extirpated plant and animal species required to complete rewilding of PRNS, e.g. coast redwoods (*Sequoia sempervirens*), this report will focus on the reintroduction of some key mammalian species.

We note that significant habitat restoration and improvements such as fence removal, trash and toxics clean-up, removal of abandoned infrastructures, etc. will be required to optimize translocation success. Some species mentioned, such as sea otter and beaver, would not necessarily be introduced to these vacated ranchlands but their reintroduction to nearby areas of PRNS could have ripple effects that benefit PRNS as a whole. While some parts of PRNS are considered wilderness, many historically important species are absent and thus reintroducing them would make the area more authentically “wild”.

Ecology / Ecosystems of Point Reyes

The climate in Point Reyes is generally mild year-round, which allows for many different types of ecosystems within the National Seashore to thrive. Point Reyes consists of a few broad ecosystems: **Forests; Ocean; Prairies and Grasslands; Sand Dunes; and Wetlands**. The various ecosystem types allow for a plethora of wildlife to exist.

- There are two main *Forest* types: the northern Bishop pine forest (*Pinus muricata*) and the coast Douglas fir (*Pseudotsuga menziesii* var. *menziesii*) forest. Bishop pine trees are fire dependent, meaning they require fire or high temperatures to successfully reproduce whereas Douglas firs are fire resistant, although they usually can survive only moderate intensity fires. The proliferating Douglas fir forest along on the inland side of Inverness Ridge is likely replacing (based on habitat modeling) what historically was coast redwood forest, significant as Douglas fir poses significant wildfire risk relative to coast redwoods which survive even high intensity fires once they reach 40–50 years of age.³
- The *Ocean* ecosystem also includes the intertidal zone, which is the area where the ocean and land meet during high and low tides. The intertidal zone can have especially abundant, varied, and durable species which can often endure being completely submerged or in the open air. They encounter various temperatures and temperature changes and endure the crashing of waves. In the water itself there are kelp forests, sea grasses and algae, and various marine mammals can be found throughout the Seashore too, like northern elephant seals (*Mirounga angustirostris*) and gray whales (*Eschrichtius robustus*). Of note, elephant seals were extirpated from PRNS in the middle nineteenth century, but have naturally recolonized it with the first pup in 1976 and an enduring colony beginning in 1981⁴.
- *Prairies and Grasslands* also make up a part of the PRNS. The coastal grasslands are made up of both coastal prairie and agricultural ranchland. The most abundant type of prairie is northern coastal prairie.
- *Sand Dunes* are also an important ecosystem as they are home to 11 federally endangered species such as western snowy plovers (*Charadrius alexandrinus nivosus*). Dune ecosystems depend on constant movement of sand for their success. Invasive species, such as iceplant (*Carpobrotus edulis*), can be a threat to the species that depend on the dunes, as they displace local plants that are essential to the ecosystem.
- PRNS also contains several *Wetlands* ecosystems, such as estuaries, salt marshes and swamps as well as the creeks and streams that feed into some of them. Some of these wetland ecosystems and watersheds, such as Tomales Bay (marine-coastal estuary) and Olema Creek along the eastern side of PRNS are also important for coho salmon

(*Oncorhynchus kisutch*) rearing and spawning runs, which are listed . Notably, PRNS is home to the California Central Coast (CCC) Coho salmon Evolutionarily Significant Unit (ESU) where coho are listed as federally endangered.

Species at Point Reyes

Point Reyes is home to over 45% of North American avian species and nearly 18% of California's plant species. It also contains thirty federally listed threatened and endangered species of animals, and six federally listed threatened or endangered species of plants.⁵ It contains 46 different species of native land mammals, including mountain beavers (*Aplodontia rufa phaea*) - not to be confused with the larger North American beaver (*Castor canadensis*)- bats (*Chiroptera* spp.), Pacific harbor seal (*Phoca vitulina richardii*), long-tailed weasels (*Neogale frenata*) and American ermine (aka short-tailed weasel) (*Mustela richardsonii*), tule elk etc.

While Point Reyes has exceptionally high biodiversity there are a number of mammalian species that were historically present that are no longer extant at PRNS. Such species include beaver, pronghorn, California ground squirrel, sea otter, North American porcupine, Humboldt marten, fisher, gray wolf (*Canis lupus*), California grizzly bear (*Ursus arctos californicus*), American black bear (*Ursus americanus*), northern fur seal (*Callorhinus ursinus*), Steller sea lion (*Eumetopias jubatus*) and probably others.

Species Reintroductions

Species reintroduction is the primary tool to achieve rewilding, and is the deliberate translocation of a select number of individuals of a species to a historical part of their range that they no longer occupy - or exist in severely diminished numbers, due to habitat destruction, human interference, hunting etc. The goal of translocation is the re-establishment of species that previously lived in an area to rebalance the ecosystem. This is not a recent concept, indeed the first named species translocation was from Sweden to Scotland with the western capercaillie bird (*Tetrao urogallus*) in 1832. This appeared to be a successful reintroduction for 140 years, until the 1970's where they succumbed to habitat loss and climate change.⁶ Since the 1800s the science and practice of species translocations has been modified and improved.

In 1998 the International Union for Conservation of Nature (IUCN) released the first IUCN/SSC Guidelines for Re-Introductions⁷. This was a set of policy guidelines created by the Re-introduction Specialist Group of the IUCN's Species Survival Commission, in response to the increasing number of reintroduction projects worldwide. These guidelines help to ensure that the reintroductions achieve their intended conservation benefit whilst avoiding adverse side effects. These guidelines include pre-project activities such as conducting feasibility studies and background research, reviewing previous reintroductions success and failure in the area, choosing and evaluating an appropriate release site and determining the availability of suitable release stock, whether wild caught or captive bred.

Reintroducing species can be a lengthy and bureaucratically intensive process. There are several successful examples of previous species reintroductions done within National Parks in California (Fig. 1).



1. Reyes National Seashore - Tule Elk
2. Yosemite National Park - Peregrine Falcons
3. Yosemite National Park - Yosemite Toad
4. Death Valley National Park - Desert Bighorn Sheep
5. Pinnacles National Park - California Condors

Fig. 1. Map of previous species reintroductions done in California National Parks

Reintroduction Examples

Tule Elk at Point Reyes

Tule elk are a special status species as they are endemic to California, including the Central Valley, but due to human activity such as hunting and the conversion of much of the Central Valley wetlands to agriculture in the late 1800s, they were all but eradicated from their native range, which includes the PRNS.⁸ Point Reyes National Seashore historically supported more than 1,000 tule elk, as indicated by biological specimens and historical accounts.^{9,10} Tule elk were reintroduced to Tomales Bay in the PRNS in 1978, with a herd of 10 individuals, 2 male and 8 female. In the second year after reintroduction several bulls developed malformed antlers, which was thought to be caused by copper deficiencies. Several other sub-adults also died, likely to infection with Johnne's disease or paratuberculosis, which is thought to have been contracted from cattle which carried these diseases to North American wildlife from Europe. Due to the development of this disease, the tule elk of Point Reyes are not suitable to be used as a source for reintroductions to other locations in California - as required by state law - and are required to be screened (tested and culled) prior to being used to establish any new free ranging herds in Point Reyes.¹⁰ In 1998 a second herd of tule elk was created in the Philip Burton Wilderness near Limantour Estero, by relocating 45 healthy elk from Tomales Bay into a quarantined pen for six months, testing to confirm absence of infection, and then subsequently 23 were released from their pen into the wilderness area.

The tule elk reintroduction has been a success. In the 2023-2024 annual census there was a minimum estimate of 702 tule elk in the park - 315 individuals at Tomales Point, 188 in the Drakes Beach herd and 199 in the Limantour herd - all originating from the first 10 individuals that were reintroduced in 1978. Over the 45 years since their return the doubling time for the tule elk population is 7.3 years. Point Reyes National Seashore remains the only National Park unit where tule elk are found.

Wolves in Yellowstone

One of the most iconic and successful species reintroductions in recent history are the gray wolves in Yellowstone. After wolves recolonized Glacier National Park and a wolf pack was documented in 1982, Congress decided in 1991 to allocate funding to conduct an impact study on wolf recovery in accordance with the Endangered Species Act. In 1994 the wolf recovery plan for the lower 48 states was completed and recommended reintroducing wolves into central Idaho and Yellowstone National Park to establish two additional wolf populations. More than 160,000 public comments were received on the wolf reintroduction plan, which was the largest number of public comments on any federal proposal at the time. In 1995, 14 wolves were trapped in Canada and after an acclimation period they were released into Yellowstone National Park. In 1996, 17 more wolves were added. The five-year plan for this reintroduction included the potential for more transplanted wolves, however the program was successful in its early years, and did not require any additional wolves to be brought in. Currently within the park there

are around 90-110 wolves, and within the greater Yellowstone Ecosystem there are around 500 wolves.¹¹⁻¹³

The wolves in Yellowstone are considered a major success story, not only because they have managed to establish themselves and continue to have a thriving population, but also because of their role in changing the Yellowstone ecosystem. Wolves triggered a trophic cascade, which is an indirect effort of apex predators that extends down into food webs. Trophic cascades can influence biodiversity, primary productivity and nutrient cycling, making them key in understanding the structure and function of ecosystems.¹⁴ Because of the lack of large predators in Yellowstone before the wolves, elk numbers increased leading to increased herbivory, causing suppression of palatable woody plants in riparian areas.¹⁵ In one study that evaluated riparian willow (*Salix* spp.) crown cover after the wolf reintroduction, they found a ~1500 % increase in average willow crown volume over a 20-year period (2001-2020), which in turn, triggered return of beaver to the Park - highlighting the wolf-driven trophic cascade..

Failed reintroductions

Of course not every reintroduction attempt was a success. Some early sea otter translocations conducted in the 1950s and 60s attempted to return sea otters to various sites from Alaska to Oregon. Some of these sites were unsuccessful including the Pribilof Islands, Attu Island and the Oregon coast. Many of the initial deaths from these efforts were due to poor pre-release husbandry, leading to weight loss and to the soiling of their pelages, resulting in poor thermoregulation upon release. It is also thought that there were insufficient numbers of individuals released at these sites. There is an [Allee effect](#) or tipping point, below which populations do not recover. While we learn from the success stories we can also learn from these failures, especially in the case of the sea otter where natural range expansion has failed northwards of Pigeon Point, California.

“Value” of species

Beyond the conservation and ecosystem value of some of the proposed species, there is a monetary value related to wildlife viewing of large charismatic species at Point Reyes. In a study done by Wyoming Untrapped, an organization that promotes trapping reform through education and advocacy in Wyoming, and Panthera, a cat research and conservation organization, they found that a single live bobcat (*Lynx rufus*) had an economic value of \$308,105 related to guided wildlife viewing in the winter of 2016-2017 in Yellowstone National Park, vs. a fur trapping value of \$315.17 for a bobcat.¹⁶ Their study highlighted the wildlife viewing value of charismatic species, such as bobcats.

Another study “*The Economic Benefits of Elk Viewing at the Jewell Meadows Wildlife Area in Oregon*”, calculated that the total value of elk viewing in the area for winter of 2007 was \$6.5 million dollars, vs the annual budget for purchasing alfalfa to draw the elk to Jewell Meadows (and away from neighboring farms) which was approximately \$200,000.¹⁷

Point Reyes already attracts 350,000–400,000 visitors annually to view the tule elk, and they are considered one of the four main reasons people visit the Park (along with hiking, whale watching, and viewing elephant seals).¹⁸ Having a wider variety of charismatic species - especially highly charismatic and easy to observe large mammals - has the potential to bring more ecotourism to the area, increase awareness of these species, and help attract funding for further conservation efforts in the area. In addition, PRNS is located near large urban centers such as Oakland and San Francisco, making it an ideal location for communities that might not be able to afford longer and more expensive trips to Yosemite or Yellowstone, to have a comparable wildlife experience.

PRNS is unique among National Park Service lands in having breeding of both functional marine and land megafauna, i.e. elephant seals and tule elk. Whilst PRNS already offers exceptional wildlife viewing for these large mammal populations, an assumption can be made that similar economic value from wildlife viewing would be brought to the area by introducing other charismatic species such as sea otters, pronghorn, etc.

Species Selections and Approach

Species Selection

The target species selected for review are the following:

- North American beaver (*Castor canadensis*)
- Sea otter (*Enhydra lutris*)
- Pronghorn (*Antilocapra americana*)
- California ground squirrel (*Otospermophilus beecheyi*)
- Humboldt marten (*Martes caurina humboldtensis*)
- Fisher (*Pekania pennanti*)
- North American porcupine (*Erethizon dorsatum*)

The specific target species were selected based on various criteria such as historical range of species that included PRNS, ecosystem services provided by the mammal species (especially keystone species and apex predators that trigger trophic cascades), and suggestions from experts on current habitat suitability.

Approach

A survey was conducted, reaching out to experts in various fields of ecology and local stakeholders in an effort to get a varied and expert-based understanding of the present habitat suitability and potential ecosystem benefits for each of the target species. The survey was an effort to help evaluate each species based on various factors, such as ecosystem value, economic value, historical appropriateness, etc.. Each question was optional; not all questions on the survey were answered by all participants and each participant had various fields of

expertise. Thus the survey was used as a tool to get a general consensus on each species and as an initial starting point, and was not used as an accurate or comprehensive measure of the appropriateness of each species. Most participants chose to remain anonymous.

Survey Questions

Participants were asked to rank each species on a scale of 1-5 with the following criteria in mind:

Criterion Importance (how important each criterion should be in decision-making overall).

Species Performance (how well each species scores on each criterion at Point Reyes).

The questions for each species were:

- Ecosystem value: Expected positive ecological effects (trophic interactions, keystone functions, biodiversity).
- Economic value: Anticipated net economic benefits (tourism, ecosystem services) minus costs.
- Ease of management: Practicality of monitoring, conflict mitigation, logistics, and cost.
- Historical appropriateness: Alignment with historical presence/lineage at Point Reyes and cultural significance.
- Habitat suitability (current): Adequacy of current habitat and resources (prey/forage, shelter, hydrology).
- Legal & policy feasibility: Consistency with laws, regulations, and management plans; permitting likelihood.
- Public support & social license: Anticipated level of community acceptance and stakeholder support.
- Human–wildlife conflict risk: Likelihood and severity of negative interactions (property, safety, livelihoods).
- Source population availability: Practical access to viable source populations with minimal donor impacts.
- Disease & biosecurity risk: Probability of translocation-related disease/parasite introduction or spread.
- Climate resilience: Projected persistence under near- to mid-term climate scenarios.
- Infrastructure & land-use impacts: Interactions with ranching, roads, trails, facilities; mitigation needs.

Participants were then asked to list : What would you consider to be top deal-breaker(s) to reintroduction, and then to select the top three criteria driving your priorities based on the options given in the survey.

Data from Survey

Analysis and a weighted average were conducted for all respondents ratings of the top three criteria listed by the respondents which were: Ecosystem Value, Historical Appropriateness and

Current Habitat Suitability, along with Economic Value. The graphs below represented the weighted average score of each species which were rated on a 1-5 scale, where higher values indicate a greater perceived value.

The survey was sent out to 17 people, with 9 respondents. They were chosen based on their expertise either in a specific species, for their knowledge or PRNS or a combination of both.

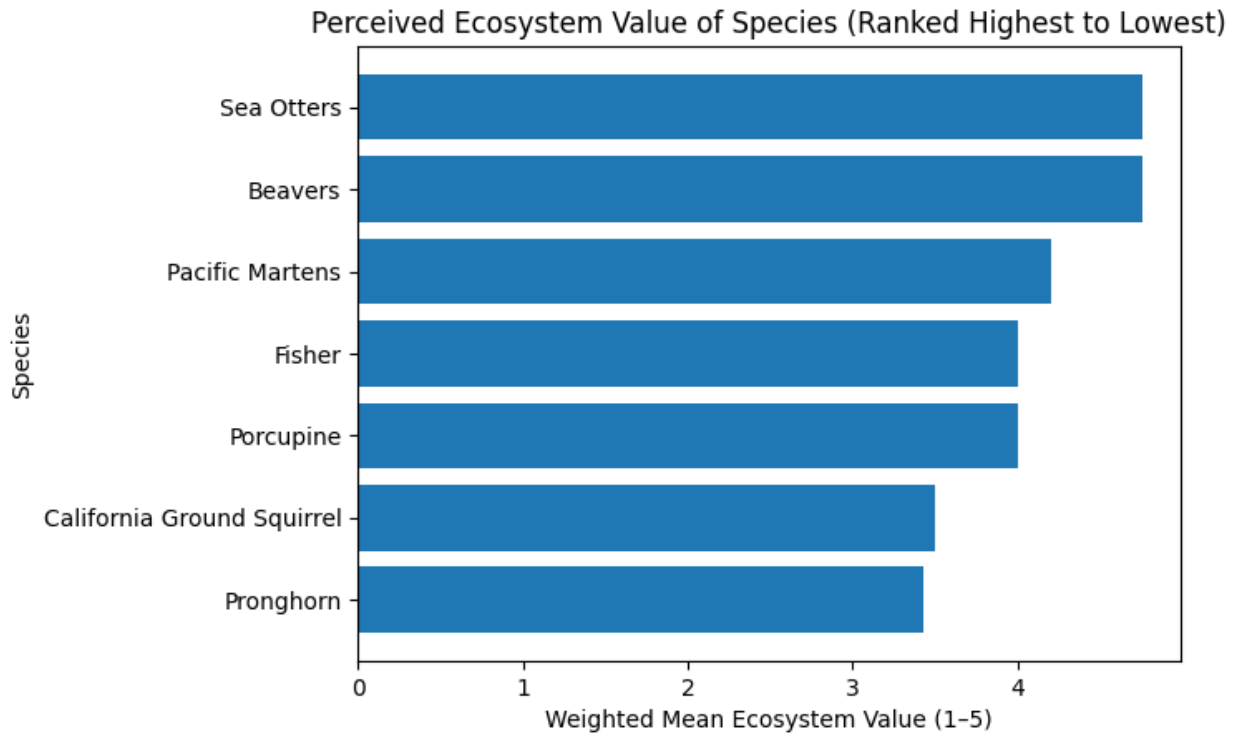


Fig. 2. Bar chart showing weighted average score for each species on perceived ecosystem value of species based on survey conducted

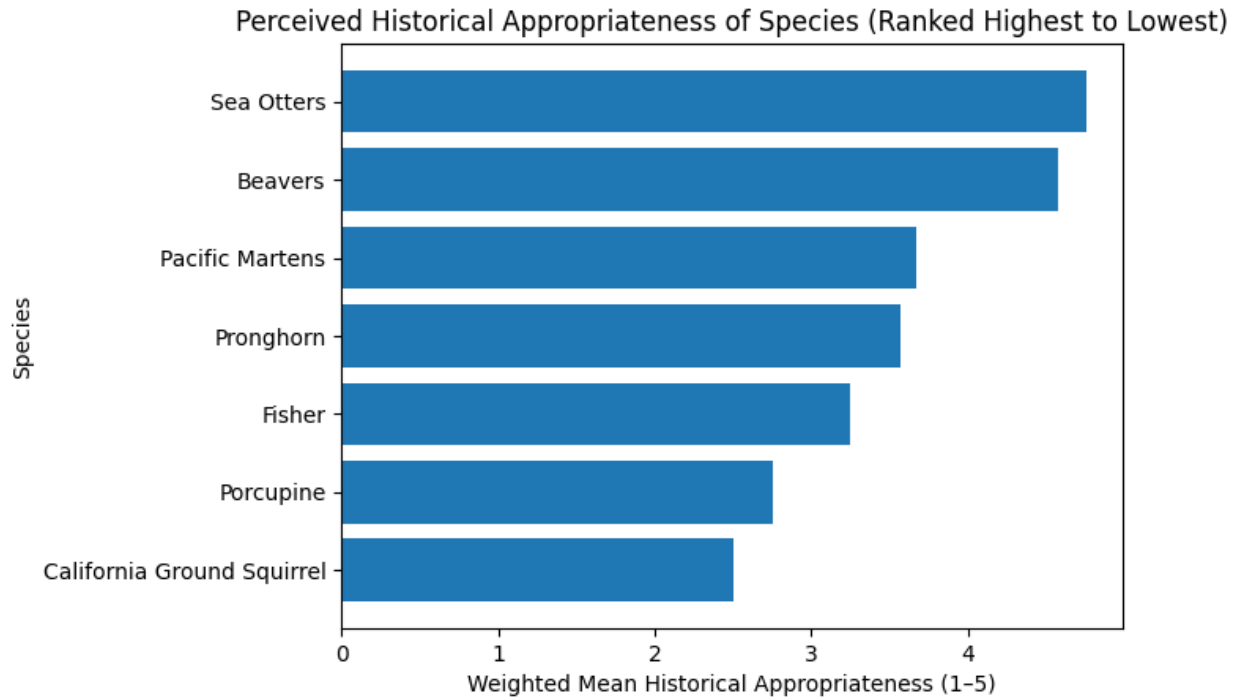


Fig. 3. Bar chart showing weighted average score for each species on historical appropriateness based on survey conducted

Perceived Habitat Suitability (Ranked Highest to Lowest)

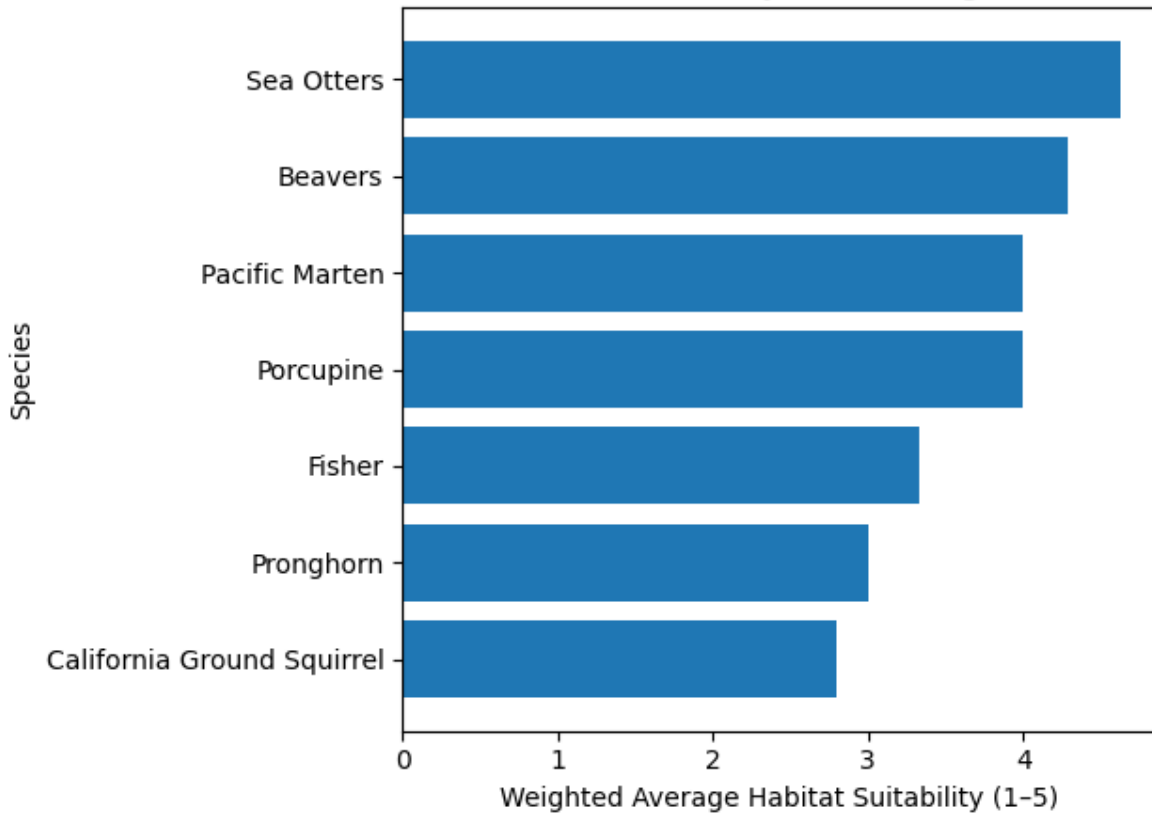


Fig. 4. Bar chart showing weighted average score for each species on habitat suitability based on survey conducted

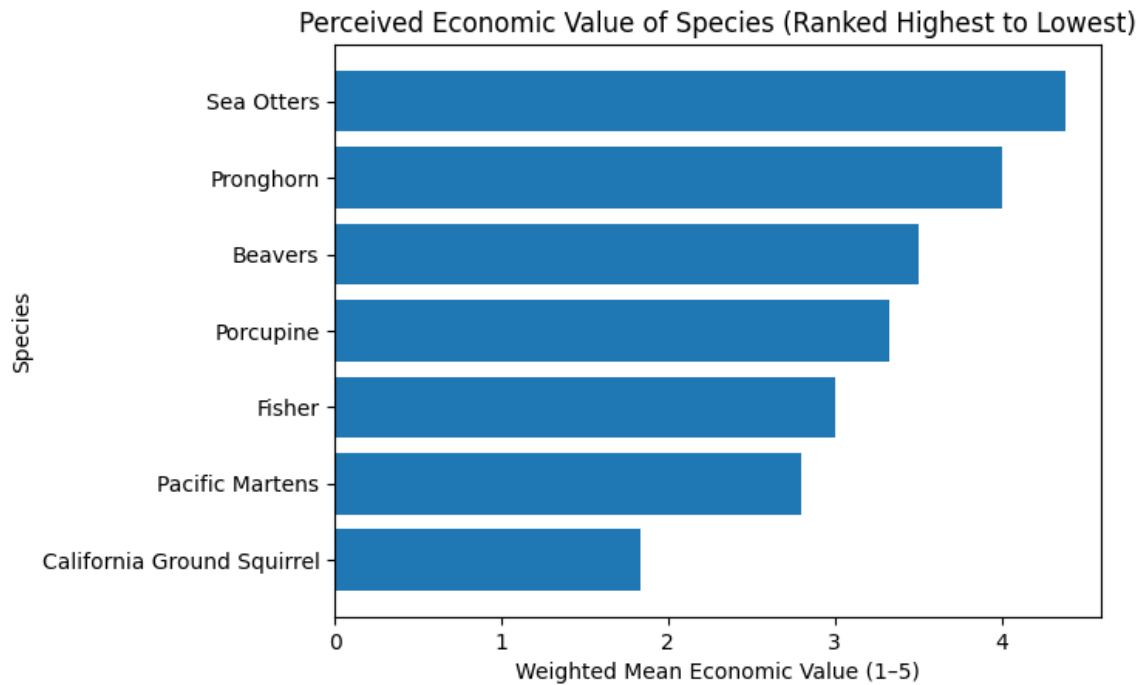


Fig. 5. Bar chart showing weighted average score for each species on perceived economic value based on survey conducted

Species Excluded from Study

Whilst other types of animals such as amphibians, birds, reptiles etc could also be appropriate candidates for reintroduction, this paper focuses on mammalian species as a starting point. There are also plant and vegetation reintroductions/restorations to consider, but the focus of this project is species reintroductions based on the current habitat of PRNS. Native plant restorations could alter habitats and make species more or less appropriate for reintroduction. Several of the species suggested would also cause significant alterations to the landscape and habitats, and could support native plant restorations.

Within the historical context of Point Reyes National Seashore, and California in general, grizzly bears have existed in the area and there is a high chance that wolves also historically existed in

the area. These large predatory species would have likely played an important ecological role, helping to keep larger prey animal populations in control, which in turn would have made the landscape we see today very different. In areas where wolves have been reintroduced, such as Yellowstone National Park, they have been shown to have a major impact not just on the population of elk, but also caused entire trophic cascades that altered the landscape, boosting biodiversity by allowing beavers, aspen and other vegetation to return to the area.

Whilst the move to restore wolves to Yellowstone has proved to be successful, it did and still does, face large opposition. Ranchers in the area are one of the groups opposed to the wolf reintroduction, due to fear that their cattle and ranches would be negatively affected.

Many ranches within PRNS are set to leave the area, some active ranches will still be left behind along with many ranches near but outside the park , which would probably have similar concerns to ranchers near Yellowstone. Resistance would also likely be met from local residents and officials.

Wolf pack territory size seems to be variable and depends on many factors, but their range can be anywhere from 25 –1000 square miles. PRNS comprises 111 square miles (287 km²), which could theoretically accommodate more than one pack but would still be on the smaller side for even a single pack and wouldn't have much space for growing packs. Dispersing packs would also have nowhere else to go but east into more ranches and ultimately suburban areas with highways.

Grizzly bears also have large ranges of 50–500 square miles (130–1,300 km²) so all of PRNS could only accommodate a couple resident bears with larger populations rapidly expanding to other areas outside the park and potentially towards more urban areas. Black bears appear to have recently recolonized West Marin County so are not added to our list of targeted species.¹⁹

Due to the anticipated controversy that reintroducing wolves and grizzly bears would bring, they are not included in this report on potential species for PRNS at this time, but merit future discussion after more rewilding success has taken place in PRNS.

Target Species

Fig. 6. Table of Seven Target Mammalian Species for Rewilding PRNS

Mammal Species	Prevalence at PRNS	California Special Status¹	Federal ESA Status
North American beaver (<i>Castor canadensis</i>)	Extirpated/Absent ²	Not listed	None
Sea otter (<i>Enhydra lutris</i>)	Extirpated/Absent ³	S3 (Vulnerable)	Threatened

Pronghorn (<i>Antilocapra americana</i>)	Extirpated/Absent ⁴	S3 (Vulnerable)	None
California ground squirrel (<i>Otospermophilus beecheyi</i>)	Common but patchy ⁴	Not listed	None
Pacific marten (<i>Martes caurina</i>)	Extirpated/Absent ⁵	S3 (Vulnerable)	None
Fisher (<i>Pekania pennanti</i>)	Extirpated/Absent ⁶	S2 (Imperiled) to S3 (Vulnerable)	None
North American porcupine (<i>Erethizon dorsatum</i>)	Rare ⁷	S3 (Vulnerable)	None

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North American beavers (*Castor canadensis*)

Natural History

Beavers are one of the largest rodents in the world, averaging about 40 lbs and measuring more than 3 feet in length, including the tail. They are herbivores, and are known for eating the leaves, twigs and inner bark of most types of woody plants that live near the water, but they also consume other vegetation such as grasses, sedges and other aquatic plants such as water lilies.²⁰

Historical Range

Beavers have historically existed throughout most of California, including Point Reyes in Marin County.²¹ They were however intensely trapped for their pelts throughout the 1800s and eradicated from many developed areas, as they were often considered a nuisance. Their populations became isolated and were drastically reduced, with only around 10% of their remaining historical populations centered in California's Central Valley where hunting and trapping in the Delta's deeper waters was more difficult.²²

Interactions with other species

Beaver are keystone species and ecosystem engineers. They build dams to create deep water ponds (refugia) for shelter, and their beaver ponds support increased species abundance and diversity for amphibians, salmonids and other fishes, aquatic and predatory birds, and semi-aquatic mammals like mink and river otter.²³

Coho Salmon (*Oncorhynchus kisutch*)

PRNS is an important habitat for the federally endangered Central California Coast coho salmon evolutionarily significant unit (ESU). Many studies have been done showing the positive impact of beavers on coho salmon populations. Coho salmon use various types of slow water habitat as juveniles²⁴⁻²⁶, and faster water during migration and spawning.²⁶ Beavers can help create the type of slow-water refugia that is used by juvenile coho.^{28,29} One study done in Fish Creek Basin in Oregon, found that beaver ponds only constituted 2.5% of the habitat at Fish Creek but produced 50.4% of the coho salmon smolts in 1986.³⁰ Other studies have also shown that beaver habitats supported more juvenile coho than non-beaver habitats, making beavers an important tool in supporting coho salmon populations at PRNS.

A 2004 study conducted in Stillaguamish River basin in Washington, found that due to the decline of beaver populations and the loss of their dams, a 61% reduction in summer coho habitat and 86% reduction in overwintering capacity was found.²⁶

Beavers are also herbivores, meaning they do not pose any threat to the salmon in terms of predation. Multiple studies show that coho salmon and steelhead trout cross beaver dams without difficulty.³¹ Olema and Pine Gulch Creeks found on the eastern border of PRNS, are low-gradient streams which would likely be ideal beaver habitat.³²

North American River otter (*Lontra canadensis*)

Another species of importance in PRNS that could come into contact with beavers are river otters. While both occupy similar freshwater habitat they have very different lifestyles and roles in the ecosystem. Beavers and river otters have been found coexisting in many areas. River otters likely gain more out of this coexistence than beavers, cleaner water, larger ponds, the use of abandoned den sites created by beavers etc. River otters are generalist carnivores, eating

fish, crustaceans, frogs, other small mammals, etc, and there has been some concern that river otters predate on young beavers. In one study that tried to analyze beaver - otter interactions, it was found that beavers did not make up any significant portion of river otter diet, indeed while beaver traces were found in a very small percentage of river over scat, it is unclear whether they were actively predated or eaten as carrion.³³ Whilst beavers don't seem to gain anything from the existence of river otters in the same area, no evidence could be found that they suffer any significant losses or harm from having river otters in the area.

Sea Otter (*Enhydra lutris*)

Sea otters are the smallest marine mammal in North America with a typical body length of 47- 56 in (119–143 cm) for adult males and 45–52 in (115–133 cm) for adult females. They live in nearshore coastal systems, bays, and estuaries. Sea otters are carnivorous and they forage by diving for various benthic animals such as sea urchins, crabs, clams, mussels, abalone, sea cucumbers, tubeworms, and sea snails.

Historical Range

The full geographic range of sea otters has fluctuated over the last 300 years. At its largest, it spanned the entire Pacific Rim from Southern California to some parts of Japan³⁴ (Fig. 2).

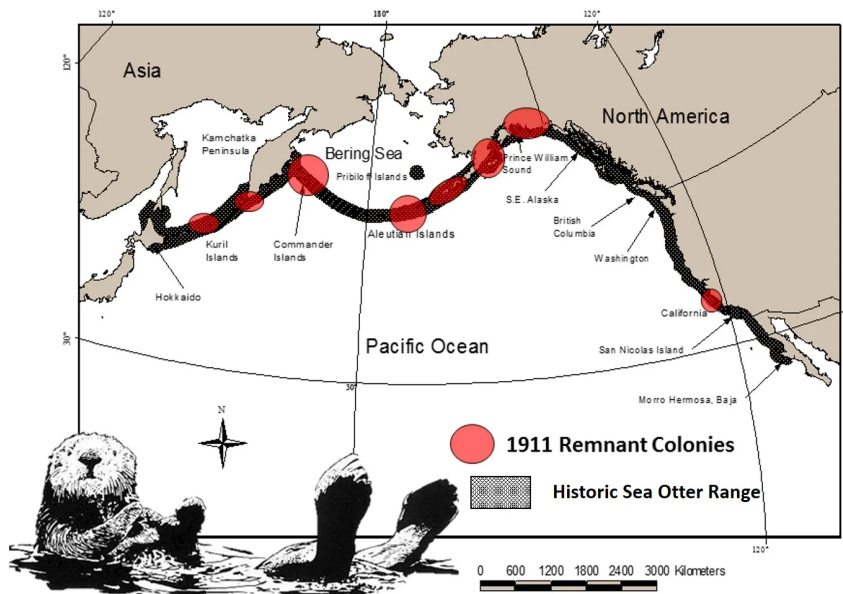


Fig. 7. Historical Sea Otter range. Map from: <https://www.seaottersavvy.org/sea-otter-natural-history>³⁵

However due to excessive fur hunting their range has diminished drastically (Fig. 3). The Southern sea otter population, which is the population that spanned California, gradually expanded but still largely been limited to pockets of sea otters population along California's from Pigeon Point to Point Conception. Recent range contraction seems to be related to great white sharks (*Carcharodon carcharias*) which have increased in numbers related to re-establishing northern elephant seal beach colonies. Sea otters are apex predators which have recently been shown to thrive in estuarine environments where they drive a trophic cascade – sea otter depredate crabs, snail populations rise and clean algae from eelgrass leading to expanding eelgrass beds which, in turn, serve as nurseries for young fish. Estuaries provide sea otter relative shelter from sharks and those recommended for sea otter re-introduction based on historical past presence and recent habitat suitability modeling include San Francisco Bay, Drakes Estero and Tomales Bay.³⁶ In addition to the estuarine trophic cascade, there is a marine trophic cascade driven by sea otters where their depredation of purple sea urchins (*Strongylocentrotus purpuratus*) leads to restoration of kelp (*Macrocystis pyrifera*, *Nereocystis luetkeana*) forests.³⁷ Kelp forests, in turn, act as fish nurseries. These two trophic cascades, one estuarine and one marine, highlight the sea otter's role as a keystone species. Our experts indicated sea otter restoration at PRNS as highest priority related to the catastrophic loss of coastal kelp forests due to unchecked urchin predation.³⁸



Fig. 8. Current Southern Sea Otter Range from: <https://www.fws.gov/media/current-and-historical-range-southern-sea-otter> ³⁹

Pronghorn (*Antilocapra americana*)

Pronghorn are ungulates - hoofed animals - and while they are commonly referred to as antelope, they are not true antelopes, but are the last surviving member of the taxonomic family Antilocapridae, a group of herbivores endemic to North America.

Adults stand about 3-3 1/2 feet tall at the shoulder, and weigh approximately 115 pounds. They can run an impressive 55 miles per hour, making them the second fastest land mammal in the world, second only to cheetahs. Pronghorn, as the name suggests, have horns, not antlers like deer or elk. They are the only animals that shed their horns annually. Other horned animals like bison or sheep keep their horns for their entire lives. Both males and females have horns. Female pronghorn have small spiky horns, whereas males have the more iconic pronged horns, which can reach 18 inches long.⁴⁰

Historical Range

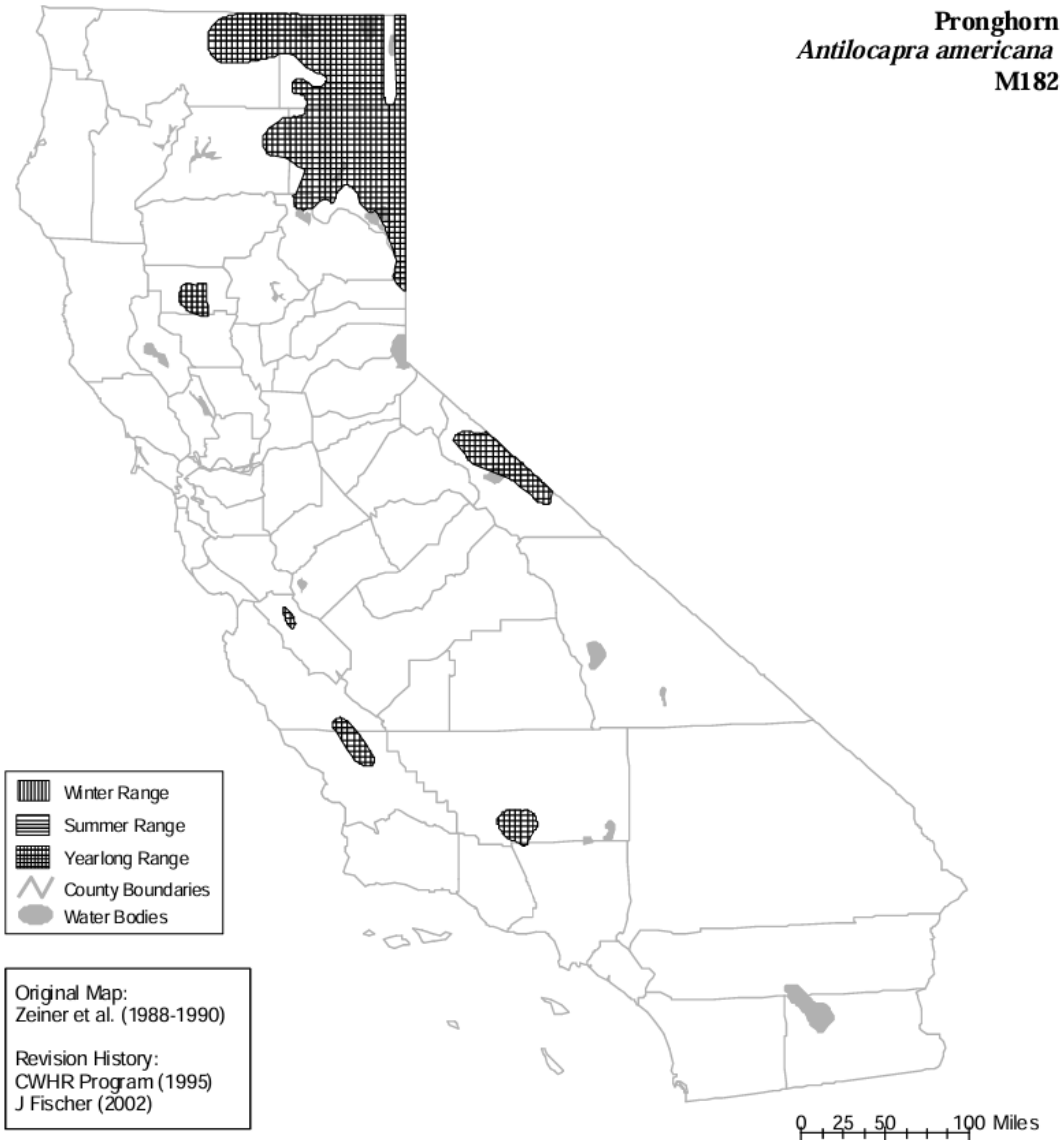
Pronghorn habitats include: grasslands, intermountain valleys and lower mountain slopes, warm deserts and grasslands.⁴¹ Pronghorn are uniquely adapted to relatively flat rolling landscapes, due to their excellent long distance vision and speed.⁴² Pronghorn play an important ecological role in western rangelands, contributing to the diversity of grazing regimes through their highly selective foraging patterns for forbs (flowering plants) and sagebrush (*Artemisia* spp.) and consumption of species unpalatable to domestic livestock.⁴³ Their conservation and restoration are vital for the health and resiliency of these rangelands. In addition, pronghorn have high economic value with hunting revenues of \$4.5 million in even a small state like South Dakota and wildlife viewing revenues likely several times that amount.⁴⁴

Historical range maps (Fig. 4) vary for pronghorn in coastal California typically with northern limits at San Francisco with many not including Marin County or PRNS. However, there are historical observer records supporting the existence of pronghorn in Marin County, pre-Gold Rush era. Bones of antelope have been recovered from shellmounds at West Berkeley and Coyote Hills on the eastern edge of San Francisco Bay, showing that their range extended to the coast.⁴⁵ "Antelope" were sighted in 1846 near Olema near the coast in Marin County from Jules Evens book "The Natural History of the Point Reyes Peninsula, 1988".⁴⁶ They are also listed in the National Parks "Mammals of Point Reyes National Seashore List" under "Historically Present Mammals" which was last updated in 2021.⁴⁷ In addition, there are late Holocene zooarchaeological remains of pronghorn at Point Reyes.⁴⁸ Evidence of pronghorn is consistent with the dominant grasslands ecosystem of Point Reyes and the peninsula could represent the highest quality forage available relative to the other arid habitats currently occupied by pronghorn in California.

California Wildlife Habitat Relationships System

California Department of Fish and Wildlife

California Interagency Wildlife Task Group



Range maps are based on available occurrence data and professional knowledge. They represent current, but not historic or potential, range. Unless otherwise noted above, maps were originally published in Zeiner, D.C., W.F. Laudenslayer, Jr., K.E. Mayer, and M. White, eds. 1988-1990. California's Wildlife. Vol. I-III. California Depart. of Fish and Game, Sacramento, California. Updates are noted in maps that have been added or edited since original publication.

Fig. 9. Pronghorn Range in California via <https://wildlife.ca.gov/Conservation/Mammals/Pronghorn> ⁴⁹

Interaction with Livestock Grazing Management

Around 99% of pronghorn populations are estimated to share their distribution with domestic or feral livestock, including domestic cattle, sheep, and domestic and feral horses.^{48,49} Interactions between pronghorn and livestock may be direct, such as diet overlap or competition for forage and water, or indirect, such as management practices for livestock that can affect habitat selection by pronghorn.⁴² Pronghorn have traits similar to other concentrate feeders⁵⁰ and intermediate feeders⁵¹ which suggests they are adapted to eating diets high in cell solubles, such as forbs and high quality shrubs. Due to their tendencies and the variety of plant species they consume, pronghorn result in little competition for forage with cattle and horses, although they can have extensive competition with domestic sheep.⁵² A study found that the annual diet overlap between cattle and pronghorn was less than 25%.⁵³ This percentage of overlap is based on rangeland conditions being in good health, when conditions deteriorate the foraging competition increases.⁵³ Indirect competition may also occur in areas where habitat quality is decreased through soil compaction and increased erosion.⁵⁴

California Ground Squirrel (*Otospermophilus beecheyi*)

Natural History and Distribution

California ground squirrels are typically about 18 inches long, with a white underbelly and long bushy tail. They live in burrows which they usually make themselves, and while some squirrels may share burrows with others, each one will have their own entrance. They usually don't travel further than 160 feet from their burrows, and mostly stay within 80 feet of their entrance. They are mostly herbivorous, eating plants, nuts and seeds, but have been observed eating insects and other small animals such as voles.⁵⁵

California Ground Squirrels are found in south central Oregon, western Washington and most parts of California. Their primary ecosystem service is that California listed as imperiled burrowing owls (*Athene cunicularia*) are almost entirely dependent on abandoned California ground squirrel burrows for nesting. Other species using their burrows include snakes, lizards, toads, and native bumblebees, establishing the ground squirrel as an ecosystem engineer and keystone species.⁵⁶ Ground squirrels occupy a basal position on the food web and are the main food source for golden eagles (*Aquila chrysaetos*), ferruginous hawks (*Buteo regalis*), and prairie falcons (*Falco mexicanus*) while serving as a protein-rich food source also for coyotes (*Canis latrans*), American badgers (*Taxidea taxus*), bobcats, and gray foxes (*Urocyon cinereoargenteus*). Ground squirrels distribute many seed plants as they often cache and forget the seeds they collect. Translocations to re-establish this keystone species in California grasslands has been successful.⁵⁷

Humboldt Marten (*Martes caurina humboldtensis*)

Natural History and Distribution

Pacific martens are a small, mostly carnivorous member of the weasel family. They average around 19 to 25 inches in length not including the tail, and can weigh up to 4 pounds. Males are usually considerably larger than females. Their tails account for up to a third of their total length. They like to den in cavities found in large trees, stumps, snags etc, as well as crevices in rocky areas.

Pacific martens are found in North America, from the Rocky Mountains to the West Coast of the Pacific Ocean, and from southern British Columbia to the southern terminus of the Rocky Mountains in north-central New Mexico.⁵⁵ The Humboldt marten subspecies (*Martes caurina humboldtensis*), which is the coastal distinct population segment (DPS) of the Pacific marten, is listed as federally threatened with less than 500 individuals remaining in just two locations. The marten is an important regulator of small rodent populations and as an omnivore that consumes large quantities of native berries (e.g. California huckleberry (*Vaccinium ovatum*) and salal (*Gaultheria shallon*), is an important seed spreader.⁵⁸ The Humboldt marten requires late seral forest (mature, closed-canopy forest) and the re-established Douglas fir forest on the inland side of Inverness Ridge would have to be evaluated for habitat suitability. While the southernmost historical record of the Humboldt marten is near the Sonoma County – Marin County border at Fort Ross, some historical range maps include Marin County based on historical presence of suitable habitat (historically extensive coastal Douglas fir and coast redwood forests).⁵⁹

Fisher (*Pekania pennanti*)

Natural History and Distribution

The fisher is a medium sized, mesocarnivore member of the weasel family (larger than the marten) and the only living member of the genus *Pekania*. Males and females are very similar physically, but males are larger than females. Males average 35-47 inches total length and weigh about 8-13lbs, while female length is about 30-37 in and weigh in at around 4-6 lbs.

Fisher are generalist predators but their primary prey includes porcupines. This is important as most predators avoid porcupines due to their quills. As such, fishers are specialized to regulate porcupine populations and mitigate the latter's impact on forest tree health. The fisher will also consume small rodents and will supplement their diet with insects, fruit, berries etc.⁶⁰

The fisher has a fairly widespread distribution. They are found in the boreal and mixed deciduous-coniferous forest belt that runs across Canada, and as far south as the mountains of Oregon. Within California there was a documented sighting of a fisher in Lake County in 2013, which is significantly further south than its previously documented range.⁶¹ Some other

anecdotal historical records point to Marin County being the southernmost limit of fisher.⁶² There are also some isolated populations in the Sierra Nevada in California, throughout New England, and the Appalachian Mountains. Like many smaller furbearing mammals they were overtrapped, which combined with habitat loss, caused a large decline in their numbers and eliminated them from many of their former territories. Fishers have been successfully reintroduced across North America, with a translocation of 40 fishers from 2009–2011 to northwestern California resulting in a tripling of their numbers and transition from the “establishment phase” or reintroduction to the “persistence phase”, where reproduction became independent of the founder population, in just seven years.⁶³

North American Porcupine (*Erethizon dorsatum*)

Natural History and Distribution

The North American porcupine is a large, quill covered rodent - in fact it's the second largest rodent in North America after beavers - and belongs to New World Porcupine Species.⁶⁴

They measure around 2-3 feet long, and can weigh on average 20-25 lbs. The most easily recognizable feature of porcupines is their quills. Quills are made of keratin, are hollow and lightly attached to their body so they can easily detach them when they encounter a predator. It's a myth that porcupines can “shoot” their quills out of their body. Their quills are also sharp and have barbs that embed in the skin and make them hard to remove once stuck. They have over 30,000 quills and grow new ones to replace any they lose.

They have a fairly widespread distribution, and are found throughout Alaska, Canada, the Great Lakes region and most of the western and northeast regions of the United States. They are well adapted to live in various climates and elevations, leading to their widespread distribution

Porcupines are rare at PRNS. As of the time of writing this paper the most recent sighting of porcupine near the area on iNaturalist is from 2023 in Occidental, so although there may be the occasional porcupine in the area their numbers would fall below the critical population threshold for a self-sustaining population. There is suitable porcupine habitat in the bishop pine (*Pinus muricata*) forests around Inverness Ridge and the Douglas fir stands near Bear Valley.

Discussion / Conclusions

There are many factors that come into play when attempting to assess the suitability and potential success of each species. In the survey conducted for this paper, many criteria were considered for each species: ecosystem value, economic value, ease of management, source population availability etc, but the top three criteria that were voted as driving experts priorities were ecosystem value and historical appropriateness - these were the top 2 given and were awarded equal points. These were followed by Habitat suitability. These are the main criteria

that will be discussed along with the Economic Value of Species. Many other criteria and factors, along with more in depth scientific surveys, require consideration for real world applications and for any concrete efforts to reintroduce any of the species suggested.

Economic Value of Species

Whilst it may be hard to calculate the direct economic value a specific species would bring to PRNS, certain "charismatic" species would certainly attract more tourists and photographers to the area. In the survey the economic value of each species was assessed on a scale of 1-5 with 5 being the highest economic value. On this scale sea otters scored the highest with an average rating of 4.35. All species scored above a 3.5. Sea otters are an extremely charismatic species, with very high public support, giving them a very high economic value.

Many factors can come into play when trying to assess the economic value of each species. Scarcity is one factor, with sea otters and pronghorn topping that list. Sea otter populations can be found south of PRNS starting in Santa Cruz County down to southwestern Santa Barbara County, and far north of PRNS in the state of Washington. Pronghorn are mainly found (90-95%) in northeastern California with a few small pockets of isolated herds throughout the rest of the state. A shorter commute to view these rare wildlife species would benefit the huge San Francisco Bay Region population, as well as drive tourism to the region.

Another factor to consider is how conspicuous or watchable a species will be. Similar to tule elk, pronghorn are large mammals that move in herds on open terrain, making them easy to locate and observe. They are also very striking and majestic animals, making them ideal for photographing. Sea otters are smaller mammals but tend to hang close to the shore for a large portion of the day as they need to spend many hours a day grooming their fur, making them another good candidate for photographers. Beavers are more elusive as they are mostly nocturnal or crepuscular, but would likely build visible dams on the relatively shallow Olema and Pine Gulch Creeks. California ground squirrels are very common throughout the state, so although they might be out and about more frequently their economic value for wildlife viewing or tourism is not high. Humboldt martens, fishers and porcupines are less watchable forest animals, so although they might be of higher value for tourism because of their rarity, the limited viewing of them doesn't support ranking them as having a high economic value.

Sea Otters and the fishing/ aquaculture industry

Whilst there could potentially be significant economic value that sea otters could bring to the park and surrounding areas via tourism, there are some industries that might argue that sea otters could be detrimental to them. Similar to the opposition wolves face from ranchers, the aquaculture industry and certain fisheries might oppose sea otter reintroduction, as they could compete with their fisheries. The possible economic effects could vary vastly from fishery to fishery. However, in a study conducted in Monterey Bay on the Dungeness crab industry, there was found to be no decrease in historical crab yields over the years, instead in ports where otters were present, fishing success was positively correlated with otter population size over

time.⁶⁵ Further research into the various aquaculture industries around PRNS could be conducted to evaluate the economic benefits vs potential losses sea otters could bring.

Ecosystem Value

In the survey, 'Ecosystem Value' was ranked as one of the top criteria driving responders priorities. Ecosystem value was defined as "Expected positive ecological effects (trophic interactions, keystone functions, biodiversity)." Fisher and Humboldt martens, both small / medium carnivores, would probably function in the ecosystem similarly to other weasel species in PRNS and check small rodent populations - a positive considering that rodents are a vector in Lyme Disease spirochete life cycles. However, introducing mesocarnivore predators to the region could possibly interfere with the Point Reyes mountain beaver population, but since numbers after reintroduction would probably remain fairly low for at least a decade or so it would likely not pose an issue for a number of years. There are currently mapping efforts underway in Point Reyes to locate Point Reyes mountain beaver burrows which could help determine sites to avoid reintroducing new mesocarnivores as to not interfere with the endemic mountain beavers.⁶⁶ It is also recommended that if porcupine were reintroduced to the area, fisher should also be reintroduced at the same time as they are the main predator of porcupine and would help keep populations in check.

Pronghorn scored lowest on perceived ecosystem value. Whilst it doesn't appear they would be in direct grazing competition with the tule elk populations or the remaining cattle ranches, it is unclear if they would offer any ecosystem services beyond what tule elk currently offer.

California ground squirrels create burrows which some other native species rely on once abandoned, like burrowing owls. There are however other burrowing species in the area such as Botta's pocket gophers (*Thomomys bottae*), which might fill a similar niche, along with various other squirrel species in the area.

Beavers and sea otters would provide the most ecosystem value as they are both considered to be keystone species that generate significant trophic cascades. Beavers and tule elk are also the only two native California species that help mitigate wildfires. Beaver ponds may act as partial barriers to fires, provide refugia to wildlife from fire, and provide water sources for firefighters.⁶⁷ Elk are California's largest native grazer and have been shown to reduce flame heights and wildfire spread rates, as do bison and non-native cattle.^{68,69}

Beavers as a Keystone Species

Beavers are ecosystem engineers and a keystone species. They alter riparian areas to suit their need for deep water refugia from predators.^{70,71} They alter their environment mainly by the creation of dams, which can impound and reduce stream velocity during storm events, retaining flow to reduce storm-water run-off and increasing water retention.^{72,73} They also create habitat complexity and diversity in stream systems and can prolong critical summer stream flow or help provide perennial flow to degraded streams that under other circumstances would run dry.^{71,74} As discussed previously in the beaver section, beavers would also have net positive effects on

coho salmon population in PRNS, making them an important tool in preserving and increasing the population.

Beavers and Wildfires

Wildfires are a significant concern across California, which are often exacerbated by long periods of drought. Beavers in their roles as ecosystem engineers have been shown to help protect areas from wildfire and provide refugia from wildfires for various species. In a study by Fairfax and Whittle it was found that riparian vegetation near beavers dams maintained Normalized Difference Vegetation Index (NDVI) values similar to their pre-fire values, whereas in areas not near a beaver dam, NDVI values were significantly reduced from their pre-fire values.⁷⁵ Their data also suggest that beaver-dammed riparian areas have enough stored water to keep plants hydrated enough that they are less likely to burn, similar to how it is harder to start a fire with wet leaves vs dry leaves and kindling. Another study that focused on megafires, found that riverscapes with beaver dams were 89% reliable as refugia, vs non-beaver dammed riverscapes which were 60% reliable.⁷⁶ These areas of fire resistant riparian corridors can provide temporary habitat for various species such as fish, amphibians, reptiles, small mammals and even wild and domestic ungulates.

Beaver habitat could also prevent or help reduce the severity of destructive and channel-incising debris-flow events that occur commonly after wildfires.⁷⁷ Beavers ecosystem engineering is complementary to current fire mitigation strategies, by also providing natural firebreaks.⁷⁸

Sea otters as a Keystone Species

Sea otters are also a keystone species. In the rocky nearshore where kelp forests are, they help control densities of herbivores, such as sea urchins, which if left unchecked can devastate these marine communities.^{79,80} In other habitats such as soft sediment estuaries or bays, they can trigger complex trophic cascades that result in enhanced productivity and biomass of seagrasses⁸¹ and even increase the genetic diversity within eelgrass communities.⁸² Both of these habitats - kelp forests and seagrass beds - provide lots of direct and indirect benefits, including habitat for hundreds of fish and invertebrate species, carbon storage, reducing coastal erosion, and offering shoreline protection.⁸³⁻⁸⁵ Both habitats have also been found to recover fairly quickly after sea otter reintroduction even if they have been absent for a long period of time.⁸⁶⁻⁸⁸

Historical appropriateness

In the survey conducted, 'Historical appropriateness' was defined as: Alignment with historical presence/lineage at Point Reyes and cultural significance, and was ranked as the top priority along with ecosystem value. Sea otters scored this highest with beavers a close second. Both of the species have historically existed in PRNS and each have had significant decreases in their natural range. Ground squirrels scored the lowest however they have historically existed in PRNS and were extirpated from the area. Since they were intentionally removed from the area it

could account for their low score, as they are abundant throughout the state and don't seem to hold any particular cultural significance to the area.

Habitat Suitability

Habitat suitability defined as : 'Adequacy of current habitat and resources (prey/forage, shelter, hydrology).' was ranked as the third most important factor in determining suitability for reintroduction.

Sea otters were ranked as highest for habitat suitability with beavers a close second. In both cases the species are keystone species which can cause trophic cascades and alter their environment and make it more suitable for them. Tomales Bay and Drakes Estero have been suggested as a good starting point for reintroducing sea otters,³⁵ and Olema Creek and Lagunitas Creeks have been recommended for beavers, such as Lagunitas creek. California ground squirrels were recently extirpated from many of the areas vacated by PRNS ranchers and dairy farmers, but are found abundantly throughout the state suggesting the current habitat is suitable for them.

Current livestock and fencing found throughout PRNS could pose issues to pronghorn, which typically need large open plains. Significant habitat modifications and restoration efforts would need to take place to make the habitat more suitable for pronghorn.

Final Thoughts

Whilst all species have intrinsic value and could boost the biodiversity of areas they are reintroduced to, the reality of environmental science is that funding and time limitations require priorities setting as to which species to focus on reintroducing.

Through research, talking with various experts and the survey conducted, **sea otters and beavers** are the **top choices** for reintroduction to Point Reyes National Seashore. Both are keystone species which would cause positive trophic cascades in their respective habitats. They are also both medium to large charismatic species that could attract tourists to the area.

Beavers would be beneficial to the coho salmon populations in the area, and are also one of the only two California mammalian species that mitigate wildfires (the other being elk, by fire fuel load reduction). Sea otters are pivotal in maintaining kelp forest health and eelgrass/seagrass communities, thus boosting marine biodiversity.

These two species occupy different habitats, so there would be no conflicts between them and they could even be reintroduced at similar times with little to no effect on the other. Sea otters are highly endangered and strictly regulated so it would most likely be a lengthy process to bring them to PRNS. Whilst beavers are not endangered, recent CDFW translocations have been fairly limited, and they are often seen as a controversial species due to their damming.

Pronghorn represents a third choice. They are large charismatic animals that would draw tourists, would not pose conflicts with the remaining ranchers or the local tule elk. Although some biologists felt that evidence of historical presence was not strong, not-yet-published physical evidence is forthcoming (personal communication, Dr. Richard Lanman).

Fisher, porcupine, Humboldt martens and California ground squirrels are all smaller species that would in theory pose significant benefits and minimum harm to the environment. Of course even small species in the wrong area can have significant consequences, however these species were all most likely historically found in the area. The benefit of these species is since they are smaller, not endangered and not perceived to pose conflicts to people or ecosystem health, it might be easier, less divisive, and require fewer resources to reintroduce them. Fisher and porcupine would be recommended to be reintroduced at the same time.

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