The Ocean-going Adventures of Invasive Rodents

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With some help from people, rodents have been hitching rides on ships to islands all over the world, becoming superabundant invasive species. The Hawaiian Islands has four species of Old World rats and mice which originated in Asia; black rats (*Rattus rattus*), Norway rats (*R. norvegicus*), Polynesian rats (*R. exulans*), as well as the much smaller house mouse (*Mus musculus*). Invasive rodents have caused endangerment and extinction of native biota on these islands but have also threatened people with dangerous diseases and are persistent agricultural pests. The ancestors of Polynesian explorers brought rats with them in sailing canoes to almost every island they visited in the Pacific Ocean. However, these rats have recognized value for some groups of people that view them as *'aumakua*, or deified ancestors, as a species to harvest and eat, or for sport hunting with miniature bows and arrows, but most often as thieves of crops. Black rats were latecomers to Hawai'i in comparison to Polynesian rats, unable to reach land until ships were tied directly to shoreline wharfs in the 1870s and 1880s. Other rats arrived as WWII progressed across far flung reaches of the Pacific Ocean, causing yet more species extinctions. In recent decades there have been advances allowing the complete removal of rats from islands of increasingly larger size, resulting in the reestablishment of many native plant and bird species, most notably seabirds, as well as the elimination of diseases affecting people. Rodents have now been completely removed from over 800 islands throughout the world, protecting species such as puffins in Alaska, penguins in the South Atlantic, and ground and burrow nesting seabirds throughout the tropical Pacific. Predator-exclusion fences have also been constructed in 18 locations throughout the Hawaiian Islands where whole-island rodent eradications are not yet feasible. These fences are dug into the ground to prevent rodents from tunneling under, have mesh fine enough to keep mice out, and have overhanging tops to prevent predators from climbing over. Plants, animals, and people all benefit from the control of invasive rodents. Integrated pest management around places where people live, work, farm, and go to school can effectively control rodents to reduce the risk of diseases associated with rats.

Ever since ships were invented, there have been rodents hitching rides, and shipwrecks. The unintentional introductions of several species of rodents throughout the world as a consequence of shipwrecks are what we call "ratspills". Some of the most commonly introduced rodent species that have become invasive are black rats (*Rattus rattus*), Norway rats (*R. norvegicus*), Polynesian rats (*R. exulans*), as well as the much smaller house mouse (*Mus musculus*). These rodents are all considered Old World rats and mice, having originated in Asia. While Polynesian rats inhabit most of the tropical islands of the Pacific Ocean, and larger Norway rats favor islands and continents at higher latitudes, black rats can be found just about anywhere, and the house mouse is the most widespread rodent in the world. The Hawaiian Islands has all four of these invasive rodent species. However, in recent decades there have

been advances allowing the complete removal of rats from islands of increasingly larger size, resulting in the reestablishment of many native plant and bird species, most notably seabirds, as well as the elimination of diseases affecting people. For example, after black rats were eradicated from Midway Atoll National Wildlife Refuge by USDA Wildlife Services in 1996, Bonin petrels (*Pterodroma hypoleuca*) have become dramatically more abundant, filling the evening sky with the innumerable birds and their calls.

Polynesian rats were among the first ocean-going rodents in the world. The ancestors of Polynesian explorers brought these rats in sailing canoes to almost every island they visited in the Pacific Ocean, but it is still not known if introductions to each island group was intentional or not. Originating in Island Southeast Asia westward to Bangladesh, the easternmost point Polynesian rats reached was Rapa Nui (Easter Island) near the coast of South America, the southernmost is the Stewart Island group in New Zealand (Aotearoa), and the northernmost was Kure Atoll in the Hawaiian Islands, where they were eradicated in 1993. When Polynesian rats arrived in Hawai‘i 900–1,000 years ago, they may have been responsible for the disappearance of native lowland forest of the ‘Ewa Plain of O‘ahu within a 50-year period. Palynology, paleontology, and archeology indicate the native forest collapsed before Polynesian people ever occupied this part of the island. Palynological evidence showed the rapid disappearance of lo‘ulu palms (*Pritchardia* species), although core samples contained little charcoal indicating slash-and-burn agriculture, but sinkholes contained abundant bones of Polynesian rats and rat-chewed palm seeds from the same time period. Similarly, Polynesian rats may have also been responsible for the disappearance of native palm (*Jubaea* species) forests on Rapa Nui.

Because Polynesian rats do not hybridize with any other rat species or varieties, their genetics have served as a model to trace the prehistoric movement of people they accompanied throughout the vast Pacific Ocean. Scientists used the molecular clock of mitochondrial DNA to determine the order in which rat populations on each island diverged from the other islands. Polynesian rats also have recognized value for some groups of people that may view them as deified ancestors or as a species to harvest for human consumption. They are known in *‘Ōlelo Hawai‘i* as *‘iole*, and were considered thieves of crops, but were also considered as an *‘aumakua* or deified ancestor. Shooting rats with miniature bows and arrows, or *pana‘iole*, is mentioned in the *Kumulipo* as a favorite sport of chiefs. In Aotearoa, the Māori people know them as *kiore*, and some regard them as a treasure, with oral traditions describing trapping methods, cooking techniques, and chants that followed the successful capture of *kiore* for feasts. Nonetheless, they are destructive to agriculture and natural ecosystems, as evidenced by the recovery of native species, particularly seabirds, after the rats have been removed, and therefore widely regarded as pests. The eradication of Polynesian rats from Lehua Islet near Ni‘ihau in 2021 has allowed Bulwer’s petrels (*Bulweria bulwerii*) and wedge-tailed shearwaters (*Ardenna pacifica*) to successfully reproduce without predation on eggs and chicks. Full recovery of the island’s avifauna may take decades or even centuries.

Black rats were latecomers to Hawai‘i in comparison to Polynesian rats. Although black rats were aboard ships anchored offshore, the rats were apparently not able reach land until mooring lines tied the ships directly to shoreline wharfs, which happened between 1870 and 1880. The earliest confirmed specimens of black rats from the Hawaiian Islands were collected in 1899. Black rats compounded the detrimental effects of the other three rodent species already established in Hawai‘i because they actively forage in treetops and depredate the nests of native forest birds. Controlling this arboreal rat species has always been more challenging in the large, forested areas of Hawai‘i with interconnected treetops, which essentially provides rats with a highway in the sky. Black rats were also accidentally introduced to many other islands during the course of World War II. Within 18 months of the rats being first noticed on Midway Atoll in 1943, both the Laysan finch (*Telespiza cantans*) and Laysan rail (*Zapornia palmeri*), which had been successfully translocated from Laysan Island, were exterminated. For the flightless Laysan rail, this meant extinction. The flightless Wake Island rail (*Hypotaenidia wakensis*) also went extinct after the Asian house rat (*R. tanezumi*) was introduced to Wake Atoll during World War II, although the rail had coexisted with Polynesian rats for centuries.

Rat research at Hakalau Forest National Wildlife Refuge goes back to 1994. At that time, black rats comprised over 60% of all rats trapped, Polynesian rats 38%, and Norway rats were only 1%. Black rats are more dominant and arboreal than Polynesian rats, which were confined to the ground. Experimental rat control was conducted on a grid at the Nauhi Tract from 1996 to 1999 using snap-traps and bait stations with rodenticide, which reduced rodent abundance 58–90% compared to an adjacent grid where no rat control was conducted. It can be difficult to determine if the rat control efforts yielded positive benefits for forest birds because they nest high in trees, making them hard to monitor. Nonetheless, USGS biologists found that the ratio of young (hatch-year) birds to adults (after hatch-year) captured in mist nets was higher for ‘elepaio (*Chasiempis sandwichensis*), ‘apapane (*Himatione sanguinea*), and i‘iwi (*Vestiaria coccinea*) in 1997, indicating an increase in nest productivity compared to the other grid. But the El Niño-Southern Oscillation drought cycle in 1998 and 1999 caused lower nest productivity. Ideally these studies would be conducted over large, well-separated areas, and long periods of time, which requires a great deal of resources.

One solution that is gaining traction for the larger islands where whole-island rat removal is not yet feasible is to create areas that are entirely free of predators with specially designed fences. There are now 18 of these predator-exclusion fences throughout the Hawaiian Islands, which are dug into the ground to prevent rodents from tunneling under, have mesh fine enough to keep mice out, have overhanging tops to prevent predators from climbing over. In forested areas, swaths of forest canopy are cleared on each side of the fence. The fenced areas are manageable in size to allow the removal of all rodents and predators inside for the protection of nesting birds such as the ‘ua‘u (Hawaiian petrel; *Pterodroma sandwichensis*), and even kāhuli, the tree snails endemic to Hawai‘i. Even in areas without predator-proof fences where rodenticide bait stations and snap traps have been used to suppress rats, the nesting success of

O‘ahu ‘elepaio (*Chasiempis ibidis*) in the Wai‘anae Mountains has increased measurably, and the population has grown.

When we look further north towards Alaska, on the volcanic islands of the Aleutian and Bering Seas, there are numerous species of breeding seabirds in vast numbers. One of the most striking families of birds is the alcidae, also known as auks, which include two species of puffins, and five species of smaller auklets. Islands without rats like Buldir in the Aleutians and St. George in the Pribilofs have hundreds of thousands of nesting seabirds each year, whereas islands with rats have far fewer birds overall. In 2008, Norway rats were eradicated from Hawadax Island in the Aleutians, and now tufted puffins (*Fratercula cirrhata*), song sparrows (*Melospiza melodia*), and snow buntings (*Plectrophenax nivalis*) have returned to breed, and other species like black oystercatchers (*Haematopus bachmani*) have increased measurably. The intertidal marine environment has even begun to recover because of the change in a trophic cascade on the island and now resembles marine environments of other rat-free islands. Where islands are free of rats, and fish-eating seabirds are abundant, guano is a major source of marine nutrients that birds deliver to the land which has a strong fertilizing effect on plants both on land and in nearshore waters.

Bird colonies throughout the region are always at risk of new ratspills. The probability of ratspills in the Aleutian and Bering Seas has been modeled, based on historic shipwrecks and the intensity of nearby fishing traffic from ship transponder data. Attu, Kiska, and Unalaska had a comparatively low expected frequency of shipwrecks in relation to their size, but St. George and Buldir have higher risks of catastrophic consequences given their large seabird colonies. Islands in the Alaska Maritime National Wildlife Refuge were prioritized for rat removal based on their probability of remaining rat-free into the future. In August of 2022, a team from USDA’s National Wildlife Research Center and Island Conservation made an expedition to the remote Great Sitkin Island to determine the feasibility of safely eradicating rats from an island much larger than Hawadax, also having permanent snowfields, an active lava dome, and hurricane-force storms even in summer. Project planning will likely include the use of ships, helicopters, and drones to ensure every part of the island can be accessed and treated for rats. In a similar environment in the far southern Atlantic Ocean, South Georgia Island, which is 24 times larger than Great Sitkin, was declared free from Norway rats and house mice in 2018 and now provides predator-free habitat for the recovery of penguins and many other birds. South Georgia is the largest island, and one of over 800 islands throughout the world where rodents have been removed. Alleviating another island in the Aleutians from the destructive effects of rats will provide a refuge for seabirds and other wildlife.

Rats are not merely destructive; they can also be deadly to humans. Hawai‘i had a 50-year history of bubonic plague carried by the fleas (*Xenopsylla cheopis*) on rats that killed more than 60 people at the turn of the twentieth century. Although the threat of bubonic plague in Hawai‘i has long passed, rat lungworm disease caused by the nematode *Angiostrongylus cantonensis* has recently been on the rise. The first known human deaths from rat lungworm disease in

Hawai‘i occurred in 1961. This nematode requires both rats and snails or slugs complete its life cycle, and occurs on every island except Lāna‘i. Although humans are not normally part of the rat lungworm life cycle, we may contract the disease by accidentally eating slugs with infective rat lungworm larvae, which can cause a form of meningitis. The University of Hawai‘i at Hilo Daniel K. Inouye College of Pharmacy and USDA's National Wildlife Research Center have conducted research into the prevention and treatment of rat lungworm disease. Recommendations for Hawai‘i residents can be found at the Governor's Joint Task Force on Rat Lungworm Disease. Other debilitating bacterial diseases like leptospirosis (*Leptospira* species) are less lethal, but more common, being transmitted in the waste of rats as well as many other species of mammals. Hawai‘i has also had outbreaks of murine typhus (*Rickettsia* species), carried by mites, ticks, and lice as recent as 2002 on five different islands. Integrated pest management to control rodents around places where people live, work, farm, and go to school can effectively reduce the risk of all these diseases associated with rats. Indeed, plants, animals, and people all benefit from the control of invasive rodents.

For further reading:

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