Northwest Science Notes

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Carolyn M. Kurle,[1] Division of Biological Sciences, Ecology, Behavior, and Evolution Section, University of California San Diego, 9500 Gilman Drive, #0116, La Jolla, California 92093-0116[1]

Carrie V. Kappel, National Center for Ecological Analysis and Synthesis, 735 State Street, Suite 300, Santa Barbara, California 93101

David D. Hope, Simon Fraser University, Burnaby, British Columbia V5A IS6, Canada

and

Athena Lam, Division of Biological Sciences, Ecology, Behavior, and Evolution Section, University of California San Diego, 9500 Gilman Drive, #0116, La Jolla, California 92093-0116

Invasion Status of Terrestrial Mammals on Uninhabited Islands within the San Juan Archipelago, Washington

Abstract

To assess potential impacts of native and invasive terrestrial mammals on near-shore marine ecosystems on islands within the San Juan archipelago, Washington, we surveyed for the presence or non-detection of predatory mammals on a subset of 14 uninhabited islands: 10 that are part of the San Juan Islands National Wildlife Refuge, 3 that are managed by the Bureau of Land Management (BLM), and 1 that is owned by The Nature Conservancy (TNC). We were unable to detect invasive terrestrial mammals on any of the 14 islands. We found native mice (*Peromyscus maniculatus*) and voles (*Microtus townsendi*) on one island each, and native raccoons (*Procyon lotor pacifica*) on three islands. We speculate that the nearly ubiquitous presence of native river otters (*Lontra canadensis*) along with native predatory birds may be preventing immigrant invasive mammals (primarily house mice [*Mus musculus*] and rats [*Rattus* spp.]) from gaining a foot-hold on the islands. Inadequate habitat and/or island size and distance from larger islands and their source populations along with insufficient trap nights may also have contributed to the non-detection of small mammals on the islands we surveyed. For the best chance at keeping these islands free of invaders, we recommend future surveys using continuous measurement methods (e.g., track plates and monitoring blocks) for early detection of future invasions.

Keywords: invasive mammals, rat, mouse, raccoon, river otter

Introduction

Understanding impacts of invasive terrestrial mammals introduced to oceanic islands is important as they currently occur on over 80% of the world's major island groups and their alteration of native species and habitats can be extreme (Jones et al. 2008, Simberloff 2009). For instance, invasive rodents such as rats (*Rattus* spp.) and house mice (*Mus musculus*) are probably responsible for the largest number of extinctions and ecosystem alterations on islands (Towns et al. 2006) making the introduction and spread of invasive species on islands a primary component of global change and a leading threat to biodiversity (Howald et al. 2007). However, investigating invasive species on islands can have significant benefits for conservation and restoration because islands are

[1]Author to whom correspondence should be addressed.
E-mail: ckurle@ucsd.edu

relatively closed systems, making successful eradication highly possible (Howald et al. 2007). To decide if eradication is warranted, scientists must determine if invasive animals are causing substantial ecosystem change and harm to native and endemic species.

We investigated the presence or non-detection of several invasive and native mammalian species on uninhabited islands within the San Juan archipelago in Washington State. Despite their accessibility, human habitation, and a long history of scientific research on the islands, surprisingly little is known about their invasion status. Invasive and native mammals are present on the larger, inhabited islands (Miller et al. 1935), but there are no quantitative studies of their distribution, abundance, or potential impacts on the San Juan Islands' ecosystems. Worldwide, invasive predatory mammals are known to prey on birds, eggs, invertebrates, vegetation, and other species, causing significant reductions in native species as well as indirect impacts on island communities (Jones et al. 2008). This may also be happening on the San Juan Islands. For instance, marine bird abundance on islands in the Salish Sea, which includes the San Juan Islands, declined dramatically between 1975 and 2007 (Bower 2009); a possible contributor to those declines may have been predation by invasive predators.

To assess the potential role of invasive and native mammals in shaping island ecosystem structure via predation effects while controlling for other human-related impacts, we targeted small, uninhabited islands within the archipelago. Our goal was to determine if invasive and native terrestrial mammals could be detected on a sub-set of uninhabited San Juan Islands to increase regional knowledge of the distribution of invasive species and assess the islands' potential for future studies of the foraging and other effects of invasive mammalian predators on native ecosystems.

Study Area

The San Juan archipelago contains ~200 islands, islets, and reefs and is located in the Salish Sea in the northwest corner of Washington State (Figure 1). The Salish Sea is comprised of the inland waters of Washington and British Columbia and extends north to the Strait of Georgia and Desolation Sound, south to Puget Sound, and west to the mouth of the Strait of Juan de Fuca. The islands were covered by ~1,800 m of ice until the retreat of the Cordilleran Ice Sheet 12,000 to 13,000 years ago (Easterbrook 1992). Fossil bison (*Bison antiquus*) bones found in the San Juan Islands indicate a brief and early postglacial land mammal dispersal corridor which, combined with over water immigration, served to populate the fauna of the San Juan Islands from the nearby mainland following retreat of the ice nearly 12,000 years ago (Wilson et al. 2009).

The larger islands are inhabited, but many small islands are owned and/or managed by the United States Fish and Wildlife Service's (USFWS) Washington Maritime National Wildlife Refuge, Bureau of Land Management (BLM), or The Nature Conservancy (TNC), and are largely undisturbed by humans.

Methods

We targeted 14 of these islands for our survey sites (Figure 1; Table 1), and they ranged in size from 0.40 to 22.7 hectares with a mean size of 3.3 ± SD 5.7 hectares. Distance from larger, inhabited islands ranged from 20 to 2365 m with a mean of 722.1 ± SD 723 m. Islands were chosen for their lack of human inhabitants, accessibility, proximity to larger islands, size, and our ability to spend the necessary time to set and collect traps, which was a function of distance and accessibility. We targeted two types of islands: those large enough to house small mammals and close enough to receive small mammals from larger, source population islands (that could serve as experimental islands in possible future studies), and islands that were likely too far from source populations or too small to support mammals (control islands).

Species of Interest

The large, inhabited islands within the San Juan archipelago are known to contain the following invasive terrestrial mammal species: Norway (*Rattus norvegicus*) and black (*Rattus rattus*) rats (Miller et al. 1935, Schoen 1972, USFWS 2010), house

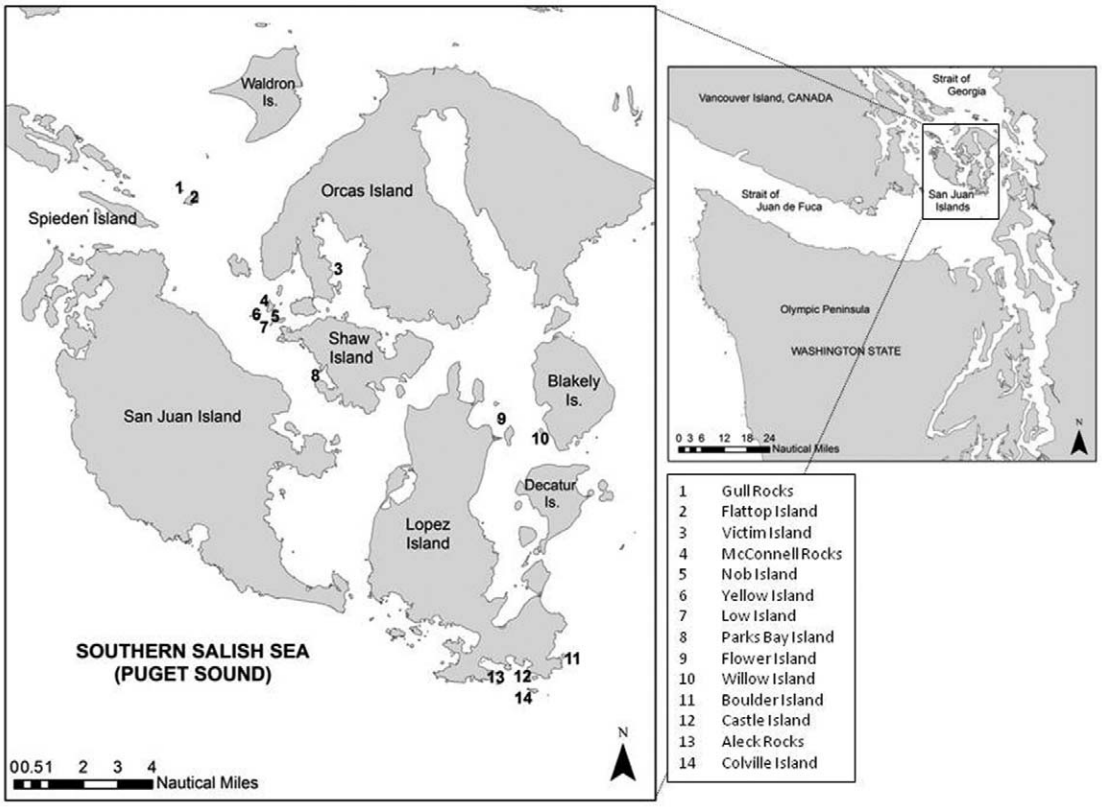

Figure 1. Map of the study islands within the San Juan archipelago in Washington State.

mice (*Mus musculus*) (Miller et al. 1935, Schoen 1972), lowland red foxes (*Vulpes vulpes fulva*) (Aubry 1984, Carlton and Hodder 2003), Douglas squirrels (*Tamiasciurus douglasii*), fox squirrels (*Sciurus niger*), Townsend chipmunks (*Neotamias townsendii*), European rabbits (*Oryctolagus cuniculus*) (Couch 1929, Hall 1977), and muskrats (*Ondrata zibethica*; native to Washington, but their range was artificially expanded to the San Juan Islands by human transport, so they are considered invasive in the San Juan Islands) (Miller et al. 1935, Pedersen 1998, Carlton and Hodder 2003), and European rabbits (*Oryctolagus cuniculus*) (Couch 1929, Hall 1977). Domesticated cats and dogs are also common invaders throughout the archipelago.

Native terrestrial mammals on the large islands include seven species of bats (Schoen 1972), Columbia black-tail deer (*Odocoileus hemionus columbianus*) (Schoen 1972, USFWS 2010; personal observation), deer mice (*Peromyscus maniculatus*) (Schoen 1972; personal observation), Townsend meadow voles (*Microtus townsendi*) (Aubry and West 1987), Pacific raccoons (*Procyon lotor pacifica*) (Schoen 1972, USFWS 2010, personal observation), and vagrant or wandering shrews (*Sorex vagrans*) (Miller et al. 1935). Pacific mink (*mustela vison energumenus*) are native (Schoen 1972, Carlton and Hodder 2003), but their numbers were significantly increased by the release of farmed mink. The native, wild mink have a brown color morph, whereas the farm-released mink are black. North American river otters (*Lontra canadensis*) are native, semi-aquatic mammals that also inhabit the San Juan Islands (Schoen 1972, Everett et al. 1979, Speich and Pitman 1984). We were interested in surveying for omnivorous and carnivorous terrestrial mammals, so herbivores (deer and rabbits) were not targeted.

Trapping

We used Longworth live traps for mice and two sizes of Tomahawk live box traps (16 x 5 x 5”

TABLE 1. Islands surveyed for small and medium mammals in the San Juan archipelago. Nearest inhabited islands all contained invasive species that could have served as potential sources for our surveyed islands. All trap nights were in 2010.

Island	Latitude	Longitude	Size (ha)	Distance to (m) and nearest inhabited island	Date of first trap night	# nights traps were set	Traps[1]	River otter scat and/or trails observed
Aleck Rocks[2]	48° 25' 21.6"	122° 50' 59.7"	1.21	100, Lopez	9/21	1	20, 6, 2	Yes
Boulder[2]	48° 25' 56.6"	122° 48' 06.9"	2.27	130, Lopez	9/19	2	20, 6, 3	Yes
Castle[2]	48° 25' 16.3"	122° 49' 19.7"	2.63	130, Lopez	9/21	1	21, 6, 2	No
Colville[2]	48° 24' 55.1"	122° 49' 23.1"	3.64	770, Lopez	9/19	1	20, 6, 3	Yes
Flattop[2]	48° 38' 48.3"	123° 04' 58.9"	22.66	1930, Spieden	9/08	2	22, 8, 6	Yes
Flower[2]	48° 32' 42.8"	122° 51' 13.9"	1.21	550, Lopez	9/16	1	20, 6, 2	Yes
Gull Rocks[2]	48° 39' 03.8"	123° 05' 23.2"	0.61	2365, Spieden	9/09	1	12, 5, 1	Yes
Low[2]	48° 35' 20.5"	123° 01' 32.5"	0.45	875, Shaw	9/01	1	12, 5, 1	Yes
McConnell Rocks[3]	48° 35' 41.6"	123° 01' 09.5"	0.57	1000, Orcas	9/02	2	12, 7, 6	Yes
Nob[2]	48° 35' 27.6"	123° 00' 51.3"	0.40	550, Shaw	9/02	1	12, 5, 3	Yes
Parks Bay[3]	48° 33' 57.9"	122° 59' 04.6"	0.89	20, Shaw	8/25	1	12, 6, 6	Yes
Victim[3]	48° 36' 50.0"	122° 58' 31.5"	1.32	100, Orcas	9/15	1	20, 6, 6	Yes
Willow[2]	48° 32' 24.6"	122° 49' 20.3"	4.05	290, Blakely	9/16	1	22, 6, 4	No
Yellow[4]	48° 35' 31.9"	123° 01' 54.9"	4.86	1300, Shaw	9/01	1	22, 7, 6	Yes

[1]Number of animal traps listed, in order, are: mouse, rat, and raccoon

[2]Managed by The U.S. Fish and Wildlife Service

[3]Managed by The Bureau of Land Management

[4]Managed by The Nature Conservancy

for rats and 32 x 10 x 12" for raccoons and other mid-size mammals; Tomahawk Live Trap Co., Tomahawk, WI) set during late-summer (August and September 2010) as indicators of small and medium mammal presence or absence. To estimate the amount of trapping effort required on each island, we conducted initial surveys across all or part of each island (as determined by island size and accessibility) to estimate the probability of mammal detection based on several factors (MacKenzie and Royle 2005). For rats, we looked for middens/burrows, footprints on sandy beaches along the terrestrial vegetation line, foraging signs, and scat. In addition, our previous work indicated that rats on islands occur in significantly higher numbers in coastal habitat, so we targeted coastal sites more heavily than inland sites (Kurle 2005, Kurle et al. 2008). For mice and voles, we surveyed for holes/burrows and scat, and for raccoons we looked for scat, fur, foraging signs, and potential dens at the base of trees. While river otters were not targeted for trapping in this study, we looked for signs of their presence. These included latrine sites (with scats containing prey remains) and slides (areas where grass and other vegetation were flattened by otters repeatedly sliding from the island into the water).

Based on these initial surveys, we installed traps at reasonable intervals to encompass small and medium mammal home ranges, and we only targeted potential mammal habitat so as not to waste survey effort (MacKenzie and Royle 2005). Therefore, only subsets of the islands were surveyed; we placed traps in areas near mammal sign and likely habitats (at the base of trees for raccoons and near potential burrow holes/midden sites for mice, voles, and rats), and/or mammal runs (e.g. along fallen logs or up against rock walls for small rodents). As almost all of our initial natural history surveys indicated that small mammals would be rare or nonexistent, we trapped on more sample units (islands) less intensively as per MacKenzie and Royle (2005). We stopped surveying an island if a mammal of interest was found (as per a removal design sampling scheme; MacKenzie and Royle 2005). The numbers of rat and mouse traps

were roughly scaled to the amount of accessible habitat and dictated by our initial surveys and experience from our previous work with rodent trapping (Kurle 2005, Kurle et al. 2008). Rodent trap densities (one mouse trap every ~5 m, one rat trap every ~20 m) within targeted habitats were higher than typical for successful trapping (Weihong et al. 1999, Marshall et al. 2008), as were raccoon trap densities (Gehrt and Fritzell 1996).

Rodent traps were baited with peanut butter and oat balls and set with strips of cotton that could be used as bedding. Large Tomahawk traps were set with cat food, sardines, marshmallows, and 3–4 drops of Hard-Core brand raccoon lure. Traps were placed in a mix of accessible coastal (cobble or rocky bench) and terrestrial habitats (grassy or forested) on each island. All traps were set during the day, left overnight for either one or two consecutive trap nights, and checked each morning. We traveled between islands via motorized boat, which restricted us to islands where we could land and anchor or tie up the boat. Captured rodents were measured for length and weight, and sexed, whereas captured raccoons were weighed, sexed, and ear-tagged with cattle tags.

Results

We found no evidence of invasive mammal species on any of the small islands on which we trapped (Table 2). We trapped native deer mice on Castle Island, raccoons on McConnell Rocks, and Nob and Willow Islands, and one vole on Parks Bay Island. We found no rat or mice sign (scat, burrows, bones) on any of the islands except for clear burrow holes on Parks Bay Island. We found fresh signs of river otters (scat and trails) on all but 2 of the 14 islands (Castle and Willow) and deer scat on six islands (Boulder, McConnell Rocks, Nob, Parks Bay, Victim, and Yellow). There were signs (scat, and/or nests and eggshells) of lesser Canada geese (*Branta canadensis leucopareia*) on six islands (Aleck, Boulder, Colville, Flower, Low, and Nob), and signs of abandoned nests from Glaucous-winged gulls (*Larus glaucescens*) and cormorants (either Brandt's (*Phalacrocorax pencillatus*) or Baird's (*Phalacrocorax pelagicus resplendens*) on Gull Rocks. There was also a pair of Black Oystercatchers (*Haematopus bachmani*) foraging in the rocky intertidal on Flattop.

Discussion

Our goal was to survey a group of the San Juan Islands to determine if they would be suitable for comparing invaded islands with 'control' islands in future studies of invader impacts on island ecosystems. Therefore, following the theory of island biogeography which states that smaller islands will support fewer species and more remote islands will not be colonized as often, we targeted two subsets of islands to survey for mammals: A set large enough and near enough to source populations to potentially contain invaders, and a set that was likely too small and/or too far from source populations to adequately house invaders.

Previous work in the Bay of Islands, Alaska, and other studies indicate that rats can swim up to 600 m between islands (Russell et al. 2005) and can inhabit islands smaller than 1 ha (Howald et al. 2007). Raccoons can also swim great distances (up to 1300 m; MacClintock 1981, Zeveloff 2002), as can voles (up to 1000 m; Aubry and West 1987). Mice are more reliant on drifting or rafting on kelp or other detritus, and they have been observed making interisland migrations of up to 760 m (Crowell 1973, Aubry and West 1987). They also inhabit islands as small as 1 ha (Crowell 1973, Howald et al. 2007). Mink and river otters can swim great distances as well (Jones 2000).

TABLE 2. Native mammals captured on small islands within the San Juan Archipelago. Island locations are given in Table 1.

Location	Animal	Number captured	Date captured	Age	Sex
Castle Island	Mice (*P. maniculatus*)	4	9/21/2010	Adult	Unknown
McConnell Rocks	Raccoon (*P. pacifica*)	2	9/2/2010	Adult	Unknown
Nob Island	Raccoon	1	9/2/2010	Adult	Male
Willow Island	Raccoon	1	9/16/2010	Adult	Female
Parks Bay Island	Vole (*M. townsendi*)	1	8/25/2010	Adult	Unknown

Therefore, we reasoned that islands over 1 ha and within swimming distance from larger islands with potential source populations would be adequate to accommodate immigrant mammals.

Despite targeting nine islands that were greater than 1 ha and eight islands that were well within swimming/rafting range (600 m or less) of larger islands with potential source populations, we found no evidence of invasive rats or mice on any of the 14 islands we surveyed. It is possible some islands were still too small to support long-term populations of invasive rats or mice (Sheppe 1965). This seems unlikely because the islands on which we did trap native voles and mice were 0.89 (Parks Bay) and 2.63 (Castle) hectares, respectively, and the three islands on which we trapped raccoons were 0.40 ha (Nob), 0.57 ha (McConnell Rocks), and 4.05 ha (Willow).

Several factors may have prevented invasive rats and mice from gaining footholds on the islands we surveyed, including failure to disperse, failed establishment (Williamson 1996), and/or predation by river otters (Jones 2000). Our trapping effort may have been inadequate to properly detect presence/absence of the species we targeted (Weihong et al. 1999, MacKenzie and Royle 2005); however, we do not think this was the case for two reasons. First, we are confident in the natural history surveys we conducted to detect mammal signs (see Methods), especially for rats as we found no evidence of their presence (tracks, scat, burrow holes, foraging signs). In contrast, we surveyed 17 islands in the Aleutian archipelago for a previous study, and all displayed clear signs of rat presence (Kurle et al. 2008). Second, our traps were very successful at catching small mammals on the inhabited islands for a separate study. Following the same protocols (one to two trap nights, 20 or fewer traps per night) as those described above, we trapped mice and rats on three of the main islands (Lopez [3 sites], San Juan [3 sites], and Shaw [3 sites]) with mean trapping successes of 51% ± SD 23% and 15% ± SD 7% for mice and rats, respectively. Densities of these mammals were likely higher on these three islands, but our trapping successes indicate that, when small mammals were present, our methods were adequate to catch them.

In conclusion, we did not detect evidence of invasive mammals on the 14 islands within the San Juan archipelago targeted in this study. While these islands are unsuitable for comparative experiments testing for ecological impacts of invasive mammals on islands, the results are promising for the conservation of native habitat and species within the San Juan Islands National Wildlife Refuge and on BLM and TNC managed islands.

We do not conclude that invasive mammals from the larger islands have never or could never colonize these smaller islands. We recommend invasive mammal monitoring throughout the archipelago to ensure early detection of invasive species and maximize the potential for control. Continuous measurement methods (e.g., track plates, monitoring blocks) may be the most cost effective and time efficient means by which to monitor these islands (Whisson et al. 2005). This is in line with the recommendations put forth in the recent Comprehensive Conservation Plan for the San Juan Islands by the U.S. Fish and Wildlife Service (USFWS 2010) for an integrated pest management approach to avoid the introduction and dispersal of invasive animals.

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