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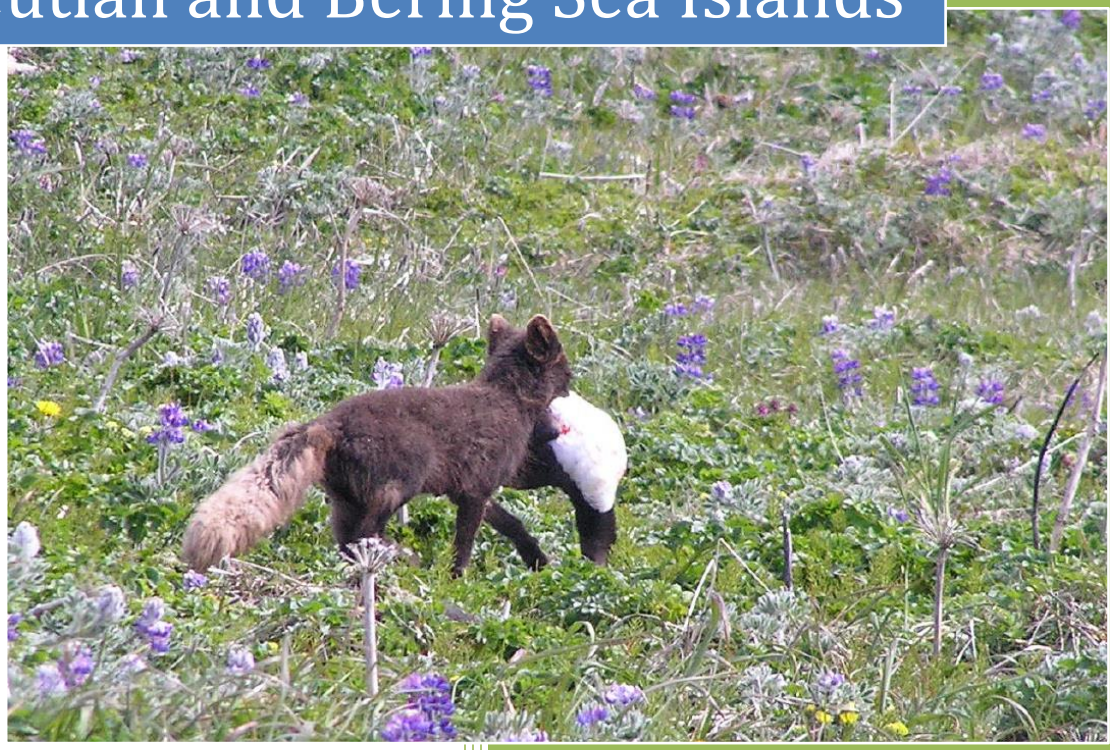
A Synthesis and Vulnerability Assessment of Terrestrial Invasive Species in the Aleutian and Bering Sea Islands



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Cover photo: Arctic fox with murre. Photo credit, Steve Ebbert, USFWS.

A Synthesis and Vulnerability Assessment of Terrestrial Invasive Species in the Aleutian and Bering Sea Islands

Executive Summary

The intentional or accidental introduction of invasive species into island ecosystems has been the greatest contributor to the loss of global biodiversity, being implicated in 51% of all historical extinctions with identifiable causes (Clavero and Garcia-Berthou 2005). Even if invasive species are not completely extirpated, island ecosystems are often adversely modified from natural conditions. In spite of isolation and a harsh environment, Alaskan islands have not escaped accidental and intentional introductions (Ebbert and Byrd 2002).

The Aleutian and Bering Sea Islands Landscape Conservation Cooperative (ABSI LCC) has identified impacts from invasive and introduced species as a priority under their 2013 Strategic Science Plan[1]. The introduction, establishment, and subsequent spread of invasive species potentially threaten native flora and fauna, disrupt ecosystems, and cause significant socioeconomic damage. The severe consequences of introduced rats, foxes, cattle, and reindeer are of particular concern for terrestrial ecosystems in the ABSI LCC region. Predation, competition, and habitat alteration by these non-indigenous species has already impacted the abundance, diversity, and distributions of native species in the region (Ebbert and Byrd 2002).

Our primary goal with this project was to provide managers, researchers, and communities with up-to-date information regarding invasive terrestrial animal species known to occur in the ABSI LCC region. This included preparing a comprehensive list of both known and potential introduced species in the region and mapping their current and historic distribution. We identified key factors contributing to species introduction and used the existing Alaska Invasiveness Ranking System for non-native animals to evaluate each species.

With the assistance of Alaska Maritime National Wildlife Refuge (AMNWR) staff, we conducted a thorough review of existing information on invasive terrestrial animal species to produce a comprehensive list of species known or suspected to occur within the ABSI LCC region. We used the Alaska Invasiveness Ranking System (Gotthardt and Walton 2011) to evaluate the overall level of invasiveness for each of the species on the final species list. This ranking system was developed as a tool to help set priorities for research and control efforts of invasive species across marine, aquatic, and terrestrial environments. The ranking system uses sixteen criteria grouped into four broad sections: distribution, biological characteristics and dispersal ability, ecological impacts, and feasibility of control. In addition, we developed range maps for each species within the ABSI LCC region and housed them in a project specific geodatabase.

[1] Available online: http://tinyurl.com/npc8jk7

Our synthesis of peer-reviewed publications, gray literature, and expert comment yielded a list of 17 invasive species for the ABSI LCC region occurring across 87 unique islands, for a total of 135 documented invasions. We combined results for red and Arctic fox (*Vulpes vulpes, V. lagopus*), as the documentation for foxes was often not species specific. Collectively, foxes were the most commonly described mammal known to occur, either currently or historically, on 65 islands. Norway rats were the second most common invasive species, known from 17 islands, followed by reindeer/caribou from 12 islands. Several species were only detected on a single island, such as Alaskan (Arctic) hare, bison, common muskrat, deer mouse, feral cat, and roof rat.

We classified "invasiveness status" into four categories: disappeared, eradicated, present, or unknown. Invasive species have been recorded but subsequently disappeared from 33 islands, successful eradications have occurred on 34 islands, 31 islands presently support one or more viable invasive species populations, and the status of one or more invasive species is unknown on 10 islands. Of these 34 islands where eradication efforts have been implemented, foxes were removed from 33 islands, Norway rats from one island, and European rabbits from one island. For the 31 islands with invasive species considered present, rats occur on 12 islands, reindeer/caribou on 11, ground squirrel on seven, and despite extensive eradication efforts across the Aleutian Islands, foxes are still present on six islands. Other invasive species still considered present on an island include horse (4), cattle (4), European rabbit (2), house mouse (2), sheep (2), bison (1), deer mouse (1), elk (1), European hare (1), feral cat (1), and roof rat (1).

Several islands have more than one invasive species associated with them. Islands with the highest number of invasions include Umnak and Unalaska, with eight species each; Adak and Akutan have four species associated with them; and Kagalaska, Kavalga, Kiska, Shemya, and St. George each have three species.

Our risk assessment considered the results of the invasiveness ranking and the spatial synthesis of information to make recommendations for management actions. Out of a total possible 100 points (100 being the most invasive), individual species scores ranged from 30 (Alaskan hare, very weakly invasive) to 91 (Norway rat, extremely invasive). The mean score was 64 (SD = 16.6), with the majority of scores between 40-49 (weakly invasive) and 60-79 (moderately to highly invasive).

To provide users of the ranking system with an alternative to numerical scores, we adopted categories from Gotthardt and Walton (2011), to divide species into six groups. Species ranked as "Extremely Invasive" or "Highly Invasive" are considered very threatening to ecosystem integrity in Alaska and require more immediate attention (High Risk). Species ranked as "Moderately Invasive" or "Modestly Invasive" also pose significant threats to ecosystems and should be watched (Moderate Risk). Species considered "Weakly Invasive" or "Very Weakly Invasive" likely alter ecological processes to a lesser degree and probably do not require as much attention as the other risk categories (Low Risk).

Of the 17 total species ranked, five (29%) scored between 70 and 100 (highly invasive to extremely invasive), suggesting these species have the highest invasiveness potential and the greatest capacity to cause harm to native species or ecosystem processes. Their reproductive biology and other attributes

are conducive to moderate to high rates of dispersal and establishment. These species are usually widely distributed, both among and within ecosystems. Not only do these species pose serious threats to ecosystem health, they are also generally hard to control. These included the Norway rat, fox (Arctic and red), roof rat, house mouse, and domestic (feral) cat.

Oftentimes the most problematic groups of non-native species are those with poorly understood and intermediate impacts and those newly arriving to the state (Carlson et al. 2008, Gotthardt and Walton 2011). Therefore, in addition to focusing management efforts on those species with the highest invasiveness scores, concern should also be directed at those species with intermediate scores. These species typically have substantial and apparent, but generally not severe, impacts on ecosystems, and plant and animal communities. They generally have the capacity for moderate to rapid expansion in natural settings, but may be currently present in a restricted range or in small numbers (D'Antonio and Meyerson 2002). This group of species is generally easier to control than species ranked as highly invasive. Seven (41%) of the 17 species scored between 50 and 69, and were categorized as modestly to moderately invasive. Many of these species had relatively high scores for ecological impacts and low scores for the feasibility of control criteria. Species categorized as modestly to moderately invasive included the European hare, European rabbit, and muskrat, as well as four ungulates: feral horse, reindeer/caribou, sheep, and cattle.

Species that scored below 49 were categorized as weakly or very weakly invasive and were considered low risk for invasiveness. These included bison, elk, ground squirrel, deer mouse, and Alaskan hare. The ecological impacts of these species to natural areas and native species are generally considered minor, and in most cases invasions are localized. However, localized invasions can sometimes be persistent and problematic. Because distribution is restricted, these species are also generally easier to control. The Alaskan hare was historically known from only one ABSI region island but has since disappeared; consequently, it should be removed from further consideration as invasive to the region. Overall, weakly invasive species do not require as much attention as the other categories. In the case of the bison and elk, modern introductions have been intentional, requiring extensive planning and expense. It may be misleading to consider these populations invasive, as they do not need to be controlled or removed, but rather monitored for potential deleterious effects in the future.

Human mediated introduction, both accidental and intentional, were the leading vectors for transmission of invasive species within the ABSI LCC region. Of the 135 documented islands with current or historical infestations, 102 were the result of human intentional introductions, 22 were human accidental, two otherwise introduced species were actually native to select islands, one introduction was natural (range expansion onto a neighboring island), and eight introductions are of unknown origin.

Species distributions in relation to areas managed both publicly and privately reflect the overall ratio of land ownership within the ABSI LCC area, with the highest percentages of species distributions occurring on US Fish and Wildlife Service (USFWS) land, followed by Native Patent land, and Department of Interior (DOI) land. With the exception of the Alaskan hare, common muskrat, deer mouse, and roof rat, ranges of all other species evaluated are shared by two or more landowners. The Alaskan hare, known only from Chirikof Island (AMNWR), and the common muskrat, known only from St. George (Native

Patent), are no longer considered present and require no current management actions. The deer mouse (low risk) and roof rat (high risk) are both present on Shemya Island, which is managed exclusively by the DOI.

About 70% or more of total range for high risk species such as Norway rat, fox, and feral cat occur on AMNWR lands, while ungulate distribution is more evenly divided between AMNWR and Native Patent lands. For ungulate species in particular, establishing and maintaining management goals for many of these populations will require continued collaboration and support among the different land owners. We hope that the Invasiveness Ranking and range mapping can be used in combination to help answer complex management questions, especially under mixed management situations.

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Introduction

The intentional or accidental introduction of invasive species into island ecosystems has been the greatest contributor to the loss of global biodiversity, being implicated in 51% of all historical extinctions with identifiable causes (Clavero and Garcia-Berthou 2005). Even if non-native species are not completely extirpated, island ecosystems are often adversely modified from natural conditions. In spite of isolation and a harsh environment, Alaskan islands have not escaped accidental and intentional introductions (Ebbert and Byrd 2002). Invasive species can alter ecosystems by displacing or preying on native species, contaminating gene pools by interbreeding with native taxa, and causing mortality of native populations (NatureServe 2006).

Cattle on Chirikof Island. Photo by Steve Ebbert, USFWS.

The Aleutian and Bering Sea Island Landscape Conservation Cooperative (ABSI LCC) region includes the islands of the Aleutian archipelago, the Pribilof Islands of St. Paul and St. George, St. Matthew and Hall Islands, and St. Lawrence Island. Wildlife on each of these islands is managed by the Alaska Maritime National Wildlife Refuge (hereafter AMNWR), whose primary focus is to provide for the conservation of 80% of Alaska's seabird nesting colonies (USFWS 2008). Many islands that are now part of AMNWR historically had no native terrestrial mammals, but intentional and accidental introductions have occurred, mostly prior to or during World War II (WWII; Ebbert and Byrd 2002). These islands have previously been used as range for livestock, subsistence, and recreational game species, as well as for fox farming (S. Ebbert, pers. comm.).

The ABSI LCC has identified management of invasive species as a priority under their 2013 Strategic Science Plan[2]. The introduction, establishment, and subsequent spread of invasive species potentially threaten native flora and fauna, disrupt ecosystems, and cause significant socioeconomic damage. The severe consequences of introduced rats, foxes, cattle, and reindeer are of particular concern for terrestrial ecosystems in the ABSI LCC region. Predation, competition, and habitat alteration by these non-indigenous species has already impacted the abundance, diversity, and distributions of native species within AMNWR (Ebbert and Byrd 2002).

A well-coordinated terrestrial invasive species management effort is warranted in the ABSI LCC region to identify existing invasive species issues and safeguard against further ecological and economic impacts. Efforts to prevent invasions in the ABSI LCC region are especially pressing given the inherent vulnerability of these islands to invasive species and the region's importance as one of the world's most productive breeding area for millions of seabirds. Islands within the ABSI LCC region are also home to many endemic subspecies (e.g., Evermann's rock ptarmigan, [*Lagopus muta evermanni*]; Kaler et al.

[2] Available online: http://tinyurl.com/npc8jk7

2010) and species of conservation concern (e.g., red-throated loon [*Gavia stellata*], Aleutian tern [*Onychoprion aleuticus*]; USFWS 2008) that are highly vulnerable to impacts of invasive species.

Removing introduced species, preventing future introductions, and restoring ecosystems are high priorities for both ABSI LCC and AMNWR. Before successful management, prevention, or early detection efforts can be implemented, it is necessary to determine which invasive species are currently present and which species pose the greatest risk. AMNWR has already identified islands where non-native mammals occur, documented impacts to native birds, conducted some eradications, and assessed benefits of eradication (Ebbert and Byrd 2002). However, these efforts have not been consistently applied across species or the geographic area. For example, AMNWR has focused its attention on eradicating introduced foxes in support of a recovery program for the endangered Aleutian Cackling goose, and has removed foxes from at least 40 islands. While this program has met with success, more widespread efforts to address other species and islands would have far reaching benefits (Byrd et al. 1994, Byrd 1998, Ebbert and Byrd 2002).

Norway rat. Photo by Steve Ebbert, USFWS.

Currently there is no comprehensive data repository for introduced terrestrial animal species within the ABSI region or at the state level. The most detailed information available is housed at the AMNWR Refuge Headquarters in Homer, Alaska. However, the data are disparate, exist primarily in unpublished reports and government documents, and have not been organized. There is tremendous potential for these data to be used as a management tool, to identify current threats, prioritize projects, initiate early detection and rapid response plans, and prevent future introductions. However, the data first needs to be summarized, standardized, and mapped.

Our primary goal with this project is to provide managers, researchers, and communities with up-to-date information regarding invasive terrestrial animal species known to occur in the ABSI LCC region. Specific project objectives included: 1) preparing a comprehensive list of known and potential invasive terrestrial animal species in the ABSI LCC region and mapping their current and historic distribution, 2) identifying key factors that contribute to the unintentional introduction of invasive species to the region, and 3) using the existing Alaska Invasiveness Ranking System for non-native animals (Appendix 1) to evaluate the impacts and potential invasiveness of introduced species known to occur or with potential to occur in the ABSI LCC region.

Methods

Study Area

The ABSI LCC region includes the islands of the Aleutian archipelago, the Pribilof Islands of St. Paul and St. George, St. Matthew and Hall Islands, and St. Lawrence (Figure 1). The majority of these islands are managed within the Alaska Maritime National Wildlife Refuge. The remainder is primarily owned by Alaska Native Corporations. Data collection for this study focused on terrestrial invasive species known to inhabit islands within or adjacent to the study area boundary.

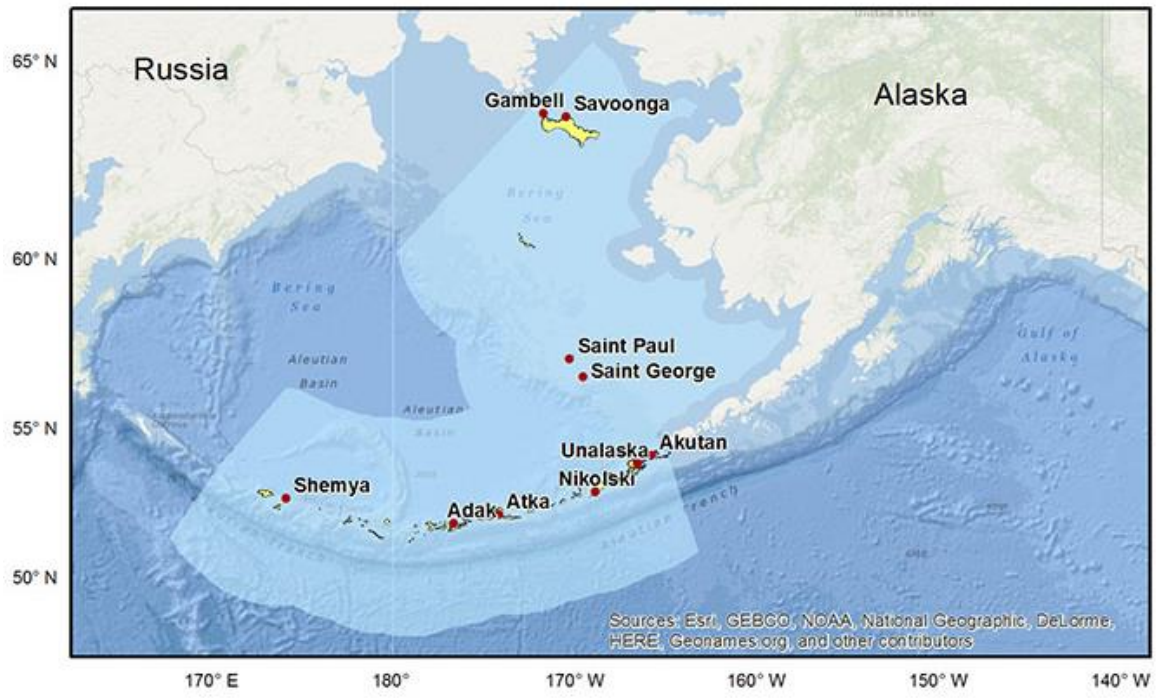

Figure 1. ABSI LCC region boundary (https://absilcc.org/about/sitepages/geography.aspx).

Species List Development

With the assistance of AMNWR staff, we conducted a thorough review of existing information on invasive terrestrial animal species to produce a comprehensive list of species known or suspected to occur within the ABSI LCC region. AMNWR biologists provided us access to field notes, refuge reports, government documents, and published data, which we summarized into a common format. Specific data that were captured included species name, location (island name and/or specific coordinates), date and method of introduction, source population, current status (present, eradicated, disappeared, or unknown), and date of eradication. We also conducted a thorough review of both published and gray literature beyond what was found at the refuge to further support our findings.

We also relied heavily on the expert knowledge of Steve Ebbert, the invasive species biologist with AMNWR. He generously provided us with technical reports, and personal observations, and assisted greatly in developing and reviewing our final species list and associated attributes.

Estimating the current and historical range of non-native species

Using the location information obtained during the literature review phase of the project, we developed range maps for each species within the ABSI LCC region. All spatial information was housed in a project-specific ArcGIS 10.3 geodatabase. We also included a land ownership data layer in the geodatabase to aid in the assessment of land stewardship and a seabird colony layer to help assess risks to areas important to nesting birds.

Invasiveness Ranking and Vulnerability Assessment

We used the Alaska Invasiveness Ranking System (Gotthardt and Walton 2011) to evaluate the overall level of invasiveness for each of the taxa on the final species list. This ranking system was developed as a tool to help set priorities for research and control efforts of invasive species across marine, aquatic, and terrestrial environments. The ranking system uses sixteen criteria grouped into four broad sections: distribution, biological characteristics and dispersal ability, ecological impacts, and feasibility of control (Appendix 1). Answers to individual questions are assigned a point value which is used to calculate subranks for each of the four sections. The four sections are weighted differently to reflect their relative contribution to the overall ranking, with distribution, biology, and ecology sections each accounting for 30% of the total score, and feasibility of control accounting for 10% of the total score (Table 1).

Table 1. Explanation of the four major sections of the Alaska Invasiveness Ranking System, justification for each of the sections, and their weighting proportionate to the overall invasiveness score.

Category	Justification	No. of Q's	Weight (%)
Distribution	Distribution of invasive species elsewhere and in their native range is one of the most recognized predictors of the success of species as invaders.	4	30
Biological characteristics and dispersal ability	Invasive species literature has been relatively successful at identifying a suite of biological traits that are found in many successful invaders. The questions in this section address the biological and dispersal traits that are commonly used to predict invasiveness across a variety of taxa.	6	30
Ecological impact	Invasive species can have devastating impacts on natural systems. Understanding these potential impacts at the population, community, and ecosystem levels are important for managers in order to determine how biotic and abiotic functions may change.	3	30
Feasibility of control	Species that are more difficult to control are considered more invasive and pose a greater threat to native species and ecosystems.	3	10

Using information obtained during the extensive literature review previously described, we evaluated each species to produce a numerical score. This synthesis of information also allowed us to develop a list of the most likely vectors for transmission and the greatest impacts to native ecosystems caused by invasive species within the ABSI LCC region.

Results

Species List

Our synthesis of peer-reviewed publications, gray literature, and expert comment yielded a list of 17 non-native species for the ABSI LCC region occurring across 87 islands, for a total of 135 documented invasions (Table 2). We combined results for the red and Arctic fox, as documentation for foxes was often not species-specific. Collectively, foxes were the most commonly described mammal known to occur, either currently or historically, on 65 islands. Rats were the second most common invasive species, known from 17 islands, followed by caribou from 12 islands. Several species were only detected on a single island, such as Alaskan hare, bison, common muskrat, deer mouse, feral cat, and roof rat (Table 2). A full species list with the islands they have been documented on is provided in Appendix 4.

Table 2. Invasive species list for the ABSI LCC region, including the number of islands a species has been documented on and the status of their occurrence (disappeared, eradicated, present, or unknown).

		Status			
Species name	**# of Islands**	**Disappeared**	**Eradicated**	**Present**	**Unknown**
Alaskan hare (*Lepus othus*)	1	1			
Bison (*Bison bison*)	1			1	
Cattle (*Bos taurus*)	6			4	2
Common muskrat (*Ondatra zibethicus*)	1	1			
Deer mouse (*Peromyscus maniculatus)*	1			1	
Elk (*Cervus Canadensis*)	1			1	
European hare (*Lepus capenus)*	2			1	1
European rabbit (*Orctolagus cuniculus*)	5	2	1	2	
Feral cat (*Felis catus*)	1			1	
Fox (*red or arctic*)	65	26	33	6	
Ground squirrel (*Spermophilus parryii)*	7			7	
Horse (*Equs caballus*)	9			4	5
House mouse (*Mus musculus)*	3	1		2	
Norway rat (*Rattus norvegicus)*	17	2	1	12	2
Reindeer/Caribou (*Rangifer tarandus)*	12	1		11	
Roof rat (*Rattus rattus)*	1			1	
Sheep (*Ovis aries*)	2			2	
Total	**135**	**34**	**35**	**56**	**10**

Invasion Status

Invasion status was classified into four categories: disappeared, eradicated, present, or unknown. When source data allowed, we recorded the known status of invasion for each species on individual islands (Appendix 2). Invasive species have been recorded but subsequently disappeared from 33 islands, successful eradications have occurred on 34 islands, 31 islands presently support one or more introduced populations, and the status of one or more species is unknown on 8 islands (Figure 2).

Of the 34 islands where eradication efforts have been implemented, foxes have been removed from 33, Norway rats from one, and European rabbits from one (Table 2).

Of the 31 islands with introduced species present, rats occur on 12, reindeer/caribou on 11, and ground squirrels on seven. Despite extensive eradication efforts across the Aleutian Islands, foxes are still present on six islands (Figure 3). Additional extant populations include horse (4 islands), cattle (4), European rabbit (2), house mouse (2), sheep (2), bison (1), deer mouse (1), elk (1), European hare (1), feral cat (1), and roof rat (1). See Appendix for detailed information regarding the status of invasion by species and a list of the individual islands with each species.

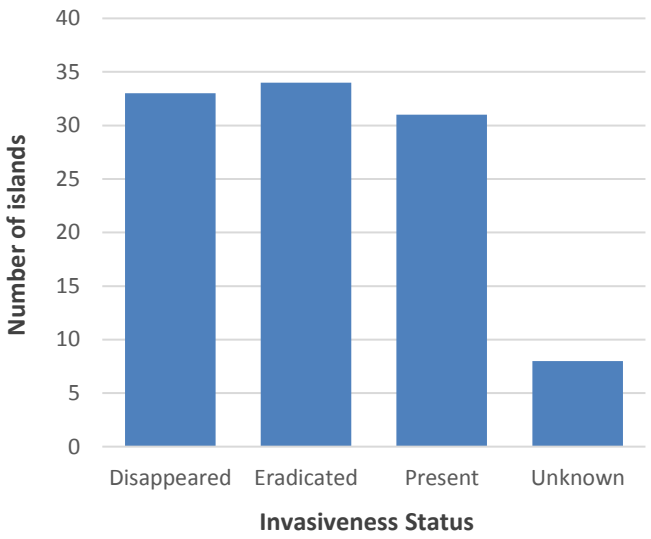

Figure 2. Number of islands in the ABSI LCC region with animal species (n=17) of various invasiveness status.

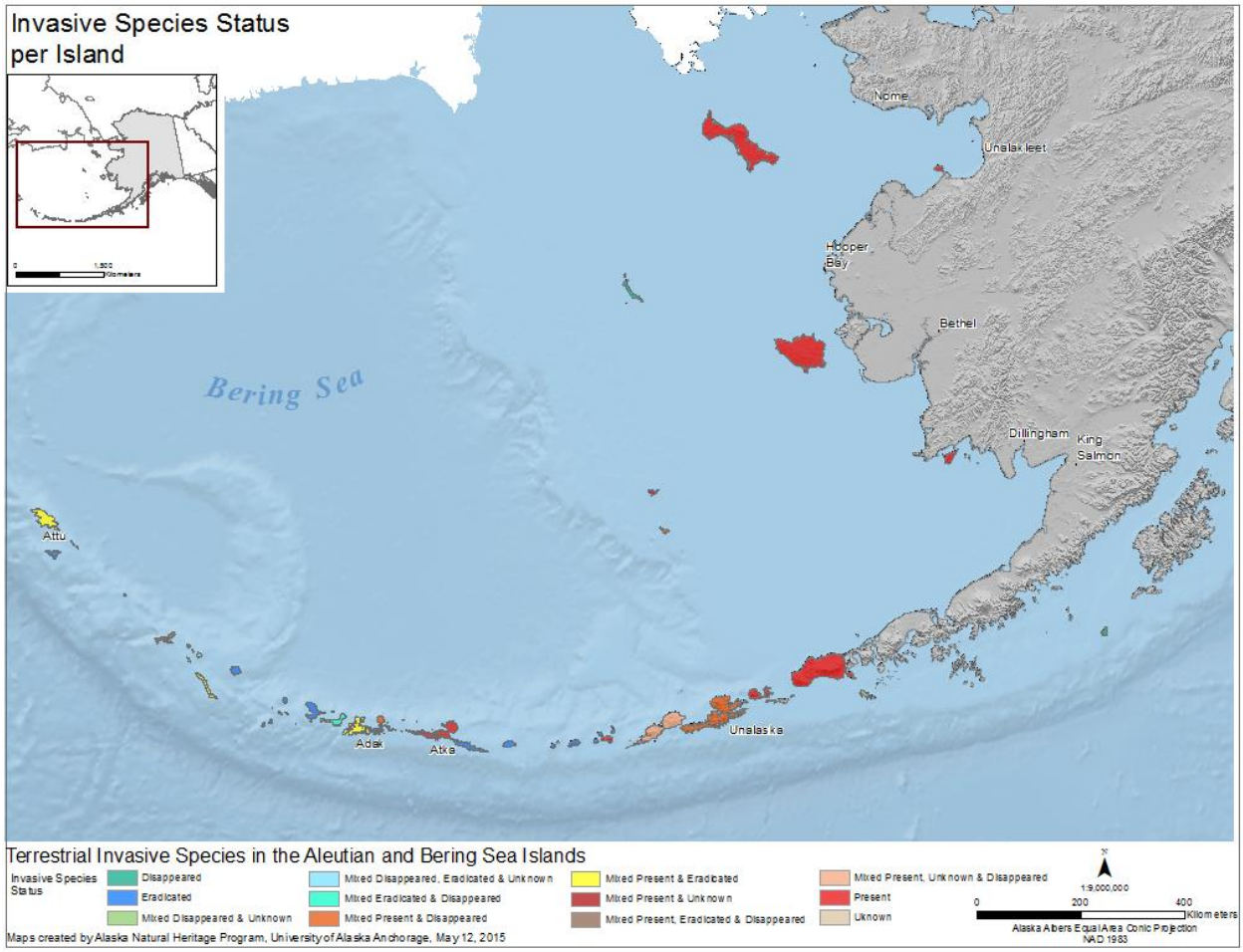

Figure 3. Map of islands in the ABSI region depicting invasive species status.

Invasive Species by Island

Several islands have more than one invasive species associated with them. Islands with the highest number of invasions include Umnak and Unalaska, with eight species each; Adak and Akutan have four species each; and Kagalaska, Kavalga, Kiska, Shemya, and St. George each have three species (Table 3). Appendix 3 provides a comprehensive list of invaded islands and the introduced species known from each.

Table 3. Islands in the ABSI LCC region and the number of unique invasive species known to occur (historically or currently) on each of them.

Island name	No. of species		Island name	No. of species		Island name	No. of species
Adak	4		Gareloi	1		Sanak	2
Adokt-Koschekt	1		Great Sitkin	2		Sedanka	1
Adugak	1		Hagemeister Island	1		Seguam	1
Agattu	1		Herbert	1		Segula	1
Aiktak	1		Hog	1		Semichi (Shemya)	1
Akun	2		Igitkin	1		Semisopochnoi	1
Akutan	4		Kagalaska	3		Shemya	3
Alaid	1		Kagamil	1		Skagul	1
Amaknak	2		Kanaga	2		St. George	3
Amatignak	1		Kasatochi	1		St. Matthew	1
Amchitka	2		Kavalga	3		St.Lawerence	1
Amlia	1		Khvostof	1		St.Paul	2
Amukta	1		Kiska	3		Stuart	1
Ananiuliak	2		Little Kiska	2		Tagadak	1
Atka	3		Little Sitkin	1		Tagalak	1
Attu	2		Little Tanaga	1		Tanadak	1
Avatanak	1		Long	1		Tanaga	1
Aziak (Hazuk)	1		Nizki	1		Tanaklak	1
Bobrof	1		Nunivak	1		Tangik	2
Bolshoi Islets	1		Ogangen	2		Ugamak	1
Buldir	1		Ogluiga	1		Ulak	1
Carlisle	1		Peter	1		Uliaga	1
Cherni	1		Poa	2		Umak	1
Chinkoff	1		Rabbit	1		Umnak	8
Chirikof	1		Rat	2		Unalaska	8
Chuginadak	1		Rat Islands	1		Unalga	1
Clifford	2		Rootok	1		Unimak	1
Davidof	1		Sagchudak	1		West Unalga	1
Finney	2		Samalga	1		Yunaska	1

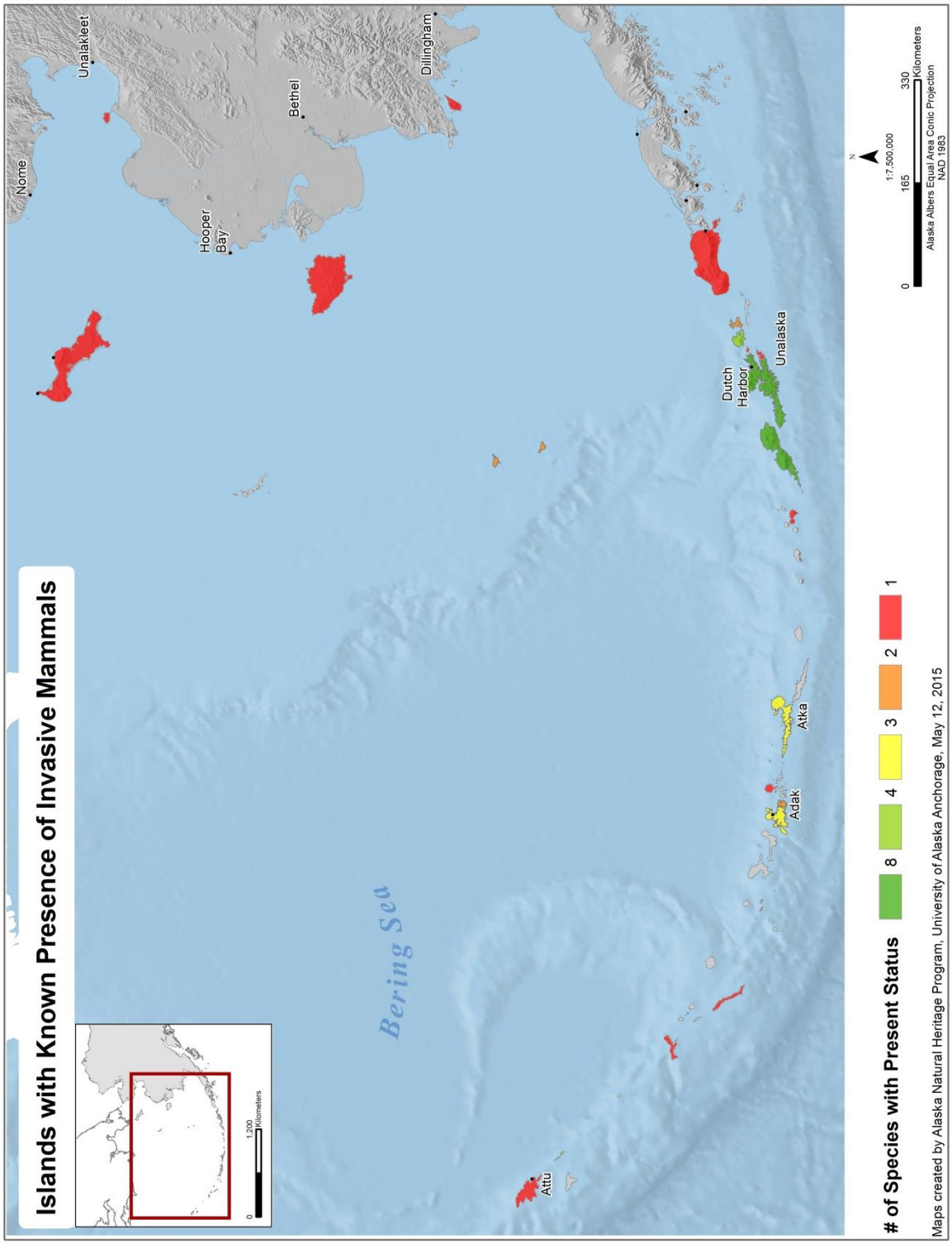

Figure 4. Number of non-native species per island in the ABSI LCC region.

Range Mapping

We produced polygon range maps for each of the 17 introduced species in the ABSI LCC region. Specific location information was frequently unavailable, so species ranges are given at a relatively coarse, island-wide scale (e.g. Figure 5). Range maps for each species are provided in the individual species ranking templates, presented in Appendix 4.

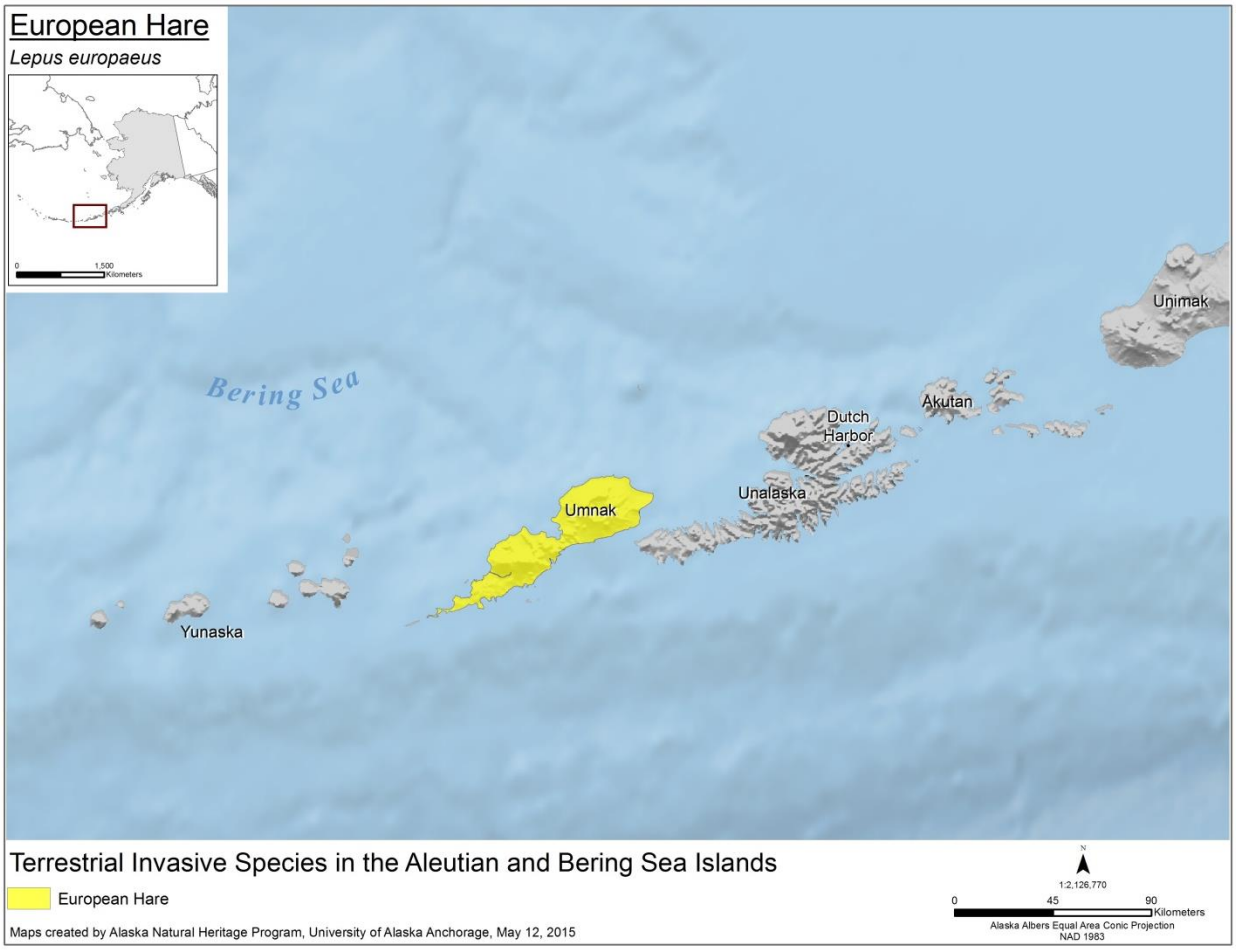

Figure 5. Example range map for the European hare (*Lepus europaeus*) within the ABSI LCC region.

Vulnerability Assessment

Clockwise from top left: red fox, cattle, Norway rat, reindeer

Vulnerability assessments are an important element of invasive species management, providing a basis and rationale for management decisions that address newly invading, as well as established invasive animal populations. Knowledge gained from this assessment can provide a deeper understanding of the problems and solutions associated with animal invasions so that land managers are better equipped to identify management strategies, establish measurable management objectives and action thresholds, and select safe and effective management methods.

This vulnerability assessment provides an overview of the results from evaluations of the 17 taxa on the ABSI LCC invasive species list, using the Alaska Invasiveness Ranking System (Gotthardt and Walton 2011). Results are presented in three sections: invasiveness ranking summary, vectors of introduction, and implications for management. The overall goal of this assessment is to identify the most highly invasive species, key threats from existing populations, and the most common introduction vectors and thus the islands with the highest risk of invasion. Overall, we hope to inform management decisions, to effectively target resources for early detection and prevention efforts.

Invasiveness Ranking Summary

The invasiveness ranks of 17 species are summarized in Table 4 and completed ranking forms for each species are presented in Appendix 4. Out of a total possible 100 points, individual species scores ranged from 30 (Alaskan hare, very weakly invasive) to 91 (Norway rat, extremely invasive). The mean score was 64 (SD = 16.6), with the majority of scores between 40-49 (weakly invasive) and 60-79 (moderately to highly invasive; Figure 6).

Table 4. Summary scores of invasiveness ranking for 17 non-native animal species in the ABSI LCC region, ordered by overall invasiveness score. Total possible points for distribution, biological, and ecological sections were 30 points each; the control section was worth 10 points. If questions were answered as unknown, the adjusted possible points for each section are shown in parentheses.

Common Name	Distribution	Biological	Ecological	Control	Invasiveness Score	Level[1]
Norway rat	30	25	27	9	91	Extreme
Fox	30	20	27	8	85	Extreme
Roof rat	21	24	24	9	78	High
House mouse	27	26	17	6	76	High
Domestic cat	24	19	17 (20)	7	76	High
European Rabbit	17	18	27	6	68	Moderate
Horse	21	19	21	6	67	Moderate
Muskrat	30	13	21	0	64	Moderate
European hare	17	17 (20)	7 (10)	1 (3)	62	Moderate
Cattle	20	14	21	6	61	Moderate
Sheep	14	16 (20)	21	6	60	Moderate
Reindeer/Caribou	17	13	21	8	59	Modestly
Ground squirrel	10	11	20	6	47	Weak
Deer mouse	2 (25)	13 (25)	7 (10)	1 (3)	42	Weak
Bison	8	16	13	1 (7)	39	Very Weak
Elk	17	9	9)	4	39	Very Weak
Alaskan hare	5 (25)	10 (20)	6 (20)	0 (3)	31	Very Weak

[1]Level of invasiveness: ≥ 80 = extremely invasive, 70-79 = highly invasive, 60-69 = moderately invasive, 50-59 = modestly invasive, 40-49 = weakly invasive, and <40 = very weakly invasive (adapted from Gotthardt and Walton 2011).

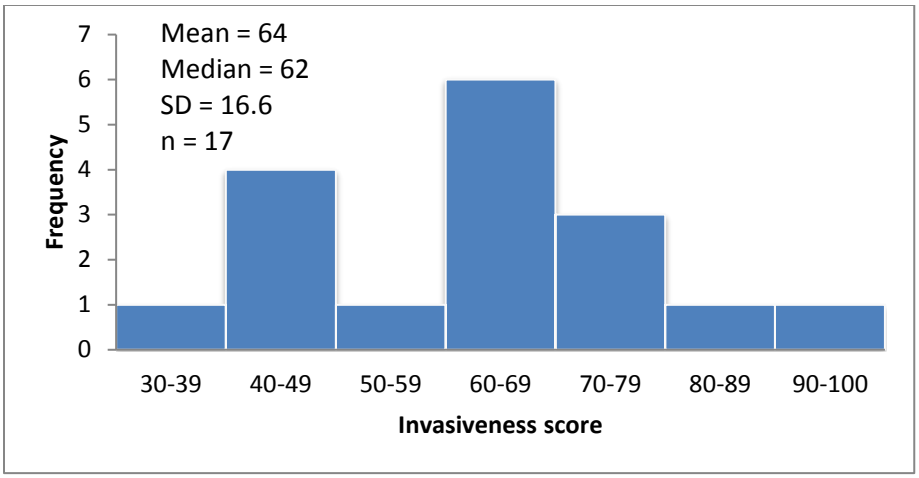

Figure 6. Frequency distribution of invasiveness scores for 17 species ranked.

The overall invasiveness scores are instructive in identifying those species that may cause the greatest harm to native species or ecosystems. However, ranking systems have inherent limitations and may work for some species better than others. To provide users of the ranking system with an alternative to numerical scores, we adopted categories from Gotthardt and Walton (2011), to divide species into six groups (Table 4). Species ranked as “Extremely Invasive” or "Highly Invasive" are considered very threatening to ecosystem integrity in Alaska and require more immediate attention (High Risk). Species ranked as "Moderately Invasive" or "Modestly Invasive" also pose significant threats to ecosystems and should be watched (Moderate Risk). Species considered "Weakly Invasive" or "Very Weakly Invasive" likely alter ecological processes to a lesser degree and probably do not require as much attention as the other risk categories (Low Risk). A summary of our findings for each of the three risk categories is provided below.

High Risk

Of the 17 total species ranked, five (29%) scored between 70 and 100 (highly to extremely invasive), suggesting these species have the greatest capacity to cause harm to native species and ecosystems. Their reproductive biology and other attributes are typically conducive to moderate to high rates of dispersal and establishment. These species are usually widely distributed, both among and within ecosystems. These species are generally difficult to control and include the Norway rat, fox (Arctic and red), roof rat, house mouse, and domestic (feral) cat.

Norway rat. Photo by Steve Ebbert, USFWS.

Norway rats are invasive worldwide including most of the US and Canada (NatureServe 2015). They were spread throughout Alaskan islands by cargo ships during WWII, and seaports continue to be a source of unintentional introductions (Murie 1959). Norway rats have been documented from at least 17 AMNWR islands including Adak, Akutan, Amaknak, Amchitka, Atka, Attu, Bolsoi Islets, Great Sitkin, Kagalaska, Kiska, Little Kiska, Ogangen, Rat, Sanak, Sedanka, Shemya, and Unalaska.

They have since disappeared from Ogangen and Sanak, have been eradicated from Rat Island, have an unknown status on Little Kiska and Shemya, and are presumably present on the remaining islands (Bailey 1993, Ebbert et al. 2007, MacDonald and Cook 2009). This species received the highest invasiveness rank of all taxa evaluated due to its wide distribution in northern latitudes, high fecundity, ability to thrive in both natural and anthropogenic environments, high mobility and crypticity within human pathways (e.g. cargo ships, airplanes), propensity to cause hyperpredation, and potential to transport diseases that affect other taxa (Ebbert and Byrd 2002, Vignieri 2006, Fritts 2007, Johnson 2008, NatureServe 2015). Most concerning is the Norway rat's opportunistic omnivory, which has been known to reduce or extirpate a variety of bird species and cause cascading effects within ecosystems, such as altering invertebrate communities and nutrient cycling (Kurle et al. 2008, Towns et al. 2009, NatureServe 2015). If rats are introduced to additional islands they may threaten endemic and critically important seasonal wildlife populations. For example, the Red-legged Kittiwake, a Beringian endemic species with a limited range, could be decimated if rats became established in the Pribilof Islands, particularly on St. George Island where 80% of the world's population of this bird nests. Furthermore, the potential for accidental rat introductions in the Pribilof Islands is relatively high because of the presence of commercial harbors (Fritts 2007). Successful rat eradications have been accomplished on many islands (Ebbert and Byrd 2002, Fritts 2007, Howald et al. 2007, Taylor et al. 2000). Rat eradication requires a long-term commitment of resources and accidental reintroductions are possible (Ebbert and Byrd 2002). The best management practices are preventative, and can include public education and outreach and establishing bait and trap stations at ports.

Fox with Murre. Photo by Steve Ebbert, USFWS.

Because documentation was not consistently available, we were unable to separate the data for foxes by species, and therefore we combined the results for both red and Arctic foxes for this assessment. Red and Arctic foxes, collectively, received an extremely high invasiveness score, although the former exhibits more invasive characteristics. Red foxes are Holarctic and have been introduced worldwide, including on hundreds of Alaskan islands (Bailey 1993, IUCN 2015). Alaska has a few native red fox populations on nearshore islands of the Alaskan Peninsula and the Fox Island group in the eastern Aleutians, but introduced Eurasian red foxes have largely replaced or hybridized with North American endemic red foxes (Ebbert and Byrd 2002). Within the ABSI LCC region, foxes have been eradicated from 33 islands, disappeared from 26, and are known to be present on six, including Atka, Chuginadak, Samalga, Shemya, Unalga, and St. George (the latter is considered a native population). Invasive red foxes are a highly adaptable habitat and climatic generalist, dispersing up to 300 km and ranging from desert to tundra, and sea ice to forest to urban landscapes. They establish in greater densities than native foxes, and therefore have a greater ecosystem impact (Sargeant 1972, Voigt 1987, Aubry 1984, Crabtree 1993, Kamler and Ballard 2002).

The Arctic fox is circumarctic, native to western and northern Alaska, some Bering Sea islands, and many Arctic islands (Ebbert and Byrd 2002, IUCN 2015, NatureServe 2015). It is better adapted to the Aleutians relative to introduced red foxes, but utilizes a narrower range of habitat types (Fay and Cade 1959, Chapman and Feldhammer 1982). In the Aleutians, it stays near the coastline and pack ice; it is able to travel thousands of kilometers over sea ice and swim over two kilometers (Audet et al. 2002, Tarroux et al. 2010, IUCN 2015, NatureServe 2015). Both species of fox regularly feed on ground nesting birds and eggs, causing declines, extirpations, and extinctions (Ebbert and Byrd 2002, NatureServe 2015). Fox-free islands in the Aleutians have seabird densities two orders of magnitude higher than islands with foxes (Croll et al. 2005). Reductions in bird populations have cascading ecological impacts, including altering nutrient cycling and plant communities. Foxes also potentially carry diseases that can affect other species (GISD 2010, Saunders et al. 1995). Foxes have been documented transforming productive grasslands to maritime tundra (Croll et al. 2005). There are several strategies for fox management, but they are all highly resource intensive (Gentle et al. 2007, DEWHA 2008, GISD 2010). Control methods include baiting, fencing, trapping, or shooting.

The roof rat is widespread globally, including much of the US and Canada, and in Alaska it is primarily spread as a hitchhiker on ships (Vignieri 2006, GISD 2011, NatureServe 2015). The roof rat is commensal with humans but also establishes in natural landscapes and utilizes a variety of habitats (Vignieri 2006, Amori et al. 2008, GISD 2011, NatureServe 2015). Currently, this species is only known to be present on a single island, Shemya, in the Aleutian Islands. The Shemya Air Force Base (renamed Eareckson Air Station) was estabslished on the island during World War II, and is likely the cause of roof rat introductions. As an invasive species, it causes hyperpredation, increases competition for food, transmits diseases that affect other mammals, and exhibits extremely high fecundity (Ebbert and Byrd 2002, GISD 2011, Lindsey et al. 2009, NatureServe 2015, Vignieri 2006). The roof rat is omnivorous, feeding on birds and eggs, and has been documented causing declines, extirpations, and extinctions of numerous species of insular birds, plants, invertebrates, and mammals (Innes 1990, Innes et al. 1999, GISD 2011). The roof rat is globally responsible for more insular bird species extinctions than any other introduced pest (King 1980). In the Aleutians, their presence is mutually exclusive with several species, and they threaten a number of vulnerable taxa, including Puffins, Storm Petrels, Murrelets, and Auklets, as well as McKay's Bunting and fur seals (ASG 1999, Ebbert and Byrd 2002, Kuletz and Hess Undated). As previously mentioned, elimination of bird populations affects plant communities and soil properties (Croll et al. 2005). The best management practice for this species is prevention, as control requires a large investment of resources and may cause inadvertent effects on non-target species by primary or secondary poisoning (Ebbert and Byrd 2002, GISD 2011, Kuletz and Hess Undated).

The house mouse is a cosmopolitan species worldwide. In Alaska, this species is found in major human centers and on several islands, although its full distribution in the state is not well documented (Musser et al. 2008, GISD 2015, MacDonald and Cook 2009, NatureServe 2015). This species ranked high due to its generalist diet and habitat requirements, high fecundity, and high likelihood for reintroduction given its ability to spread via human transport in cargo (Bronson 1979, Baker 1994, GISD 2010, NatureServe 2015). The house mouse can transmit disease to other mammals, as well as reduce native vegetation, bird, and invertebrate populations due to predation, which can have cascading effects on other

ecosystem processes such as nutrient cycling and erosion (Crafford 1990, Chown and Smith 1993, Smith et al. 2002, Croll et al. 2005, Fukami et al. 2006, Angel et al. 2009, Traveset et al. 2009). Eradication of house mice requires an intensive short-term investment of resources and has been successfully undertaken on several island systems (Moro 2001). In urban areas, house mouse control involves population reduction by using traps, toxicants, repellants, and fumigants (GISD 20015). In the ABSI LCC region, this species is known to be present on St. Paul and Unalaska, both islands with relatively large human populations, which could complicate control measures. Currently, there is no eradication program active in AMWNR for this species (Ebbert and Byrd 2002).

Cat eating a rabbit. Photo by Eddy Van.

The domestic cat has been translocated worldwide as a pet. Cats are sometimes abandoned by their owners to become feral; this is likely the reason for feral cats on Adak Island, as it supported a large naval base that is no longer in operation. Historically, cats were carried on ships for rat control and occasionally escaped onto land (GISD 2011). Cats are a habitat generalist and are able to persist in both anthropogenic environments and a wide variety of natural landscapes (GISD 2011, NatureServe 2015). Feral cats are detrimental to native species by causing predation, competition, and disease transmission (Medina et al. 2011). As a generalist carnivore they are culpable for declines of dozens of endemic and insular bird species and are known to have contributed to 14% of global extinctions of mammals, birds, and reptiles (based on the IUCN Red List; Rebstock 2006, GISD 2011, Medina et al. 2011, NatureServe 2015). Overall, domestic cats are known to impact at least 175 vertebrate species worldwide. Within the Aleutians, domestic cats are a threat tothe endemic Pribilof Island shrew (*Sorex hydrodromus*) and Red-legged Kittiwake (*Rissa brevirostris*; TIB 2015). Changes to vertebrate populations can have negative impacts on native predator species by reducing prey, and can cause a variety of cascading effects on ecosystem processes (Nogales et al. 1996, Bourgeois et al. 2004, Rebstock 2006). Management of feral cats is difficult due to social stigma caused by their relationship with humans as pets. Successful eradication has only taken place on fewer than 100 of the approximately 9000 islands on which they are introduced (Campbell et al. 2011, Nogales et al. 2004). Eradications are more feasible on smaller islands, less than 1000 hectares in size (Medina et al. 2011). In the ABSI LCC region, feral cats are known to be present on Adak Island.

Each of these high risk species severely threatens island ecosystems and the native species that inhabit them, both directly and indirectly. Not only do these species pose serious threats to island health, they are also generally difficult and expensive to control. Typically, prevention is the most cost-effective strategy for managing high risk invasive species. It is much easier to eradicate species at early stages of invasion, before a breeding population becomes established and population size skyrockets (Fritts 2007). Prevention focuses on eliminating vectors of introduction and opportunities for reproduction. It relies on improving public awareness, laws, and response capability. Increased public awareness can sometimes lead to increased acceptance of, and funding for, removal efforts.

Each of these species ranked as high risk because they are generally hard to control and/or eradication is expensive and risks harming non-target species. The logistics associated with invasive species control work on islands in the ABSI LCC region provides an added challenge due to the islands' large size and difficult terrain. However, the benefits of meeting those challenges may be substantial. A robust cost-effectiveness analysis is likely warranted for each of these high risk species to determine whether eradication, control, or long term investments are most prudent for each species and island. While a cost-benefits analysis is beyond the scope of this assessment, we hope that the data assembled here will provide a baseline of current and historic invasions that can be used as the foundation for this kind of analysis.

Moderate Risk

Often, the most problematic groups of non-native species are those with poorly understood and intermediate impacts and those newly arriving to the state (Carlson et al. 2008, Gotthardt and Walton 2011). Therefore, in addition to focusing management efforts on those species with the highest invasiveness scores, concern should also be directed at those species with intermediate scores. These species can have substantial, but generally not severe, impacts on ecosystems, and plant and animal communities. They generally have the capacity for moderate to rapid expansion in natural settings, but may be currently present in a restricted range or in small numbers (D'Antonio and Meyerson 2002). This group of species is generally easier to control than species ranked highly invasive. Seven (41%) of the 17 species scored between 50 and 69 and are categorized as modestly or moderately invasive. Many of these species had relatively high scores for ecological impacts and low scores for the control questions. The modestly to moderately invasive species are the European rabbit, feral horse, muskrat, reindeer/caribou, European hare, sheep, and cattle.

Introduced reindeer. Photo by Becky Howard.

Four of the seven moderately invasive mammals are ungulates (horse, reindeer/caribou, sheep, and cattle). We combined our discussion for ecological impacts from ungulates, because this clade of animals poses similar threats to insular Alaskan ecosystems. Introduced ungulates have great potential to cause damage on Aleutian and Bering Sea islands because there are no native species to provide intra-guild competition, no native predators to provide top-down control, and vegetation has evolved without large herbivores, therefore native plants have no natural defenses against them (Oksanen and Oksanen 2000, Ricca et al. 2012). As a K-selected species, fecundity is moderate, typically with one offspring per year, generally high survival rates, and relatively stable population sizes. An exception to this trend occurs when an introduced ungulate is not well adapted to Alaska's climate and die-off takes place during harsh winters or where food sources are depleted and dispersal is precluded by the isolation and small size of islands.

Introduced ungulates can have a number of direct, negative impacts on vegetation, soils, and other animal species. They utilize a variety of habitat types and feed on vascular and nonvascular plants (Csurhes et al. 2009). They can overgraze graminoids, forbs, and nonvascular species; overbrowse trees and shrubs, causing bark damage that reduces overall health and outpacing their ability to regenerate; crater into soil to forage on roots; and what they don't consume, they trample and crush (Aston 1912, Ebbert and Byrd 2002, Schott 2002, GISD 2010). Lichens are particularly affected, as they take 20-40 years to fully recover from overgrazing (Ricca et al. 2012). Introduced ungulates cause soil erosion, compaction, track formation, change dune morphology, and in some cases cause bare ground (Ebbert and Byrd 2002, De Stoppelaire et al. 2004, Csurhes et al. 2009). Trampling banks of streams and watering holes, along with contaminating water with feces, reduces the quality of waterways, and loss of littoral and aquatic flora leads to a loss of biological activity (Csurhes et al. 2009). Several AMNWR islands with introduced ungulates also support USFWS Region 7 priority species, and those taxa affected include Tufted puffin (*Fratercula cirrhata*), Fork-tailed storm petrel (*Oceanodroma furcata*), Harlequin duck (*Histrionicus histrionicus*), Emperor geese (*Chen canagica*), and Steller's eider (*Polysticta stelleri*; USFWS-AMNWR, pers. comm.). Ungulates can harm these sensitive populations by transmitting disease and trampling surface and burrow nesting birds (Ebbert and Byrd 2002, Csurhes et al. 2009). Overall, ungulates directly damage landscapes, reduce aboveground biomass, and decrease biodiversity.

Indirect effects on plants, soils, and ecosystem processes caused by introduced ungulates can cause disruptions to feedback loops that are responsible for maintaining intact native ecosystems and resiliency (Oksanen and Oksanen 2000, Scheffer et al. 2001, Suding et al. 2004). Grazing and browsing cause changes in floral community composition, litter reduction, decreased seedling recruitment, and decreased species diversity of plants (Van Vuren and Coblentz 1987), which in turn can cause permanent plant community loss, preclude succession from reaching climax stages, and in extreme cases causes desert conditions (Swanson and Barker 1992, Ebbert and Byrd 2002). Soil disturbance and removal of native vegetation can potentially promote the establishment of nonnative plants by increasing opportunities for exotic propagule introduction and creating disturbed, barren soils for opportunistic species to establish (Ebbert and Byrd 2002, Csurhes et al. 2009). In particular, lichen recovery can be inhibited by competition with quick growing vascular flora, of both native and introduced species (Swanson and Barker 1992). Additionally, foraging typically reduces graminoids and increases woody plant biomass, which can subsequently alter fire regimes (Csurhes et al. 2009). As plant communities change, so do hydrologic regimes and soil microbial communities, which further affects erosion, nutrient cycling, and overall island fertility, consequently creating positive feedback loops that perpetuate additional changes (Ebbert and Byrd 2002, Klinger et al. 2002, Renner et al. 2014).

Fauna are impacted by these indirect ecosystem changes, as alterations to vegetation structure and biomass can contribute to reduced diversity and numbers of bird species (Ebbert and Byrd 2002, Klinger et al. 2002, GISD 2010). For example, removing vegetation can increase the visibility of nests, consequently intensifying predation on bird eggs, particularly where non-native predator species have also been introduced (Zalba and Cozzani 2004). Trampling by ungulates changes soil properties, such as compaction, that impacts surface and burrow nesting birds (Ebbert and Byrd 2002, Klinger et al. 2002, GISD 2010). Additionally, introduced ungulates have been documented changing community

composition of many other animal species, including native mammals, ants, snails, fishes, and crabs (Turner 1987, Beever and Brussard 2000, Levin et al. 2002, Nimmo and Miller 2007, Csurhes et al. 2009). Management of introduced ungulates is often resource intensive and culling is often met with public opposition (Ebbert and Byrd 2002, Nimmo and Miller 2007, Csurhes et al. 2009, NatureServe 2015). The ungulates we reviewed have variation in invasiveness ranks based on somewhat differing life history traits, ability to affect ecosystem changes, mode of introduction and intent, range extent within the ABSI, and available scientific literature.

European rabbit. Photo by Steve Ebbert, USFWS.

The remaining three moderately invasive species are the European rabbit, muskrat, and European hare. Each of these species was intentionally introduced to Alaskan islands for reasons similar to ungulates (i.e. economic and subsistence resource). Like ungulates, they are generalist feeders, although the rabbit and hare are herbivorous, while the muskrat is omnivorous. Unlike most ungulates, these species have small home ranges and limited dispersal abilities and exhibit moderate to high fecundity. However, all species ranked modestly to moderately invasive affect similar changes to vegetation, soils, and ecosystem functions. The moderately ranked ungulate and non-ungulate species varied most in their habitat specificity and management challenges.

Given limited resources for invasive species management in Alaska, and the likely expenses associated with eradication and control efforts, we advocate for increased monitoring of species that fall within the modest to moderate risk categories. Monitoring can assess changes to range sizes and threats to native species and natural systems. Muskrats have disappeared from the one island they were known from in the ABSI LCC region and should be removed from further consideration as invasive to the region. Control measures for the majority of species classified as an intermediate risk are generally not recommended, but should be considered on a case by case basis. Most of these species have well-documented impacts elsewhere, but were lacking ABSI LCC-specific data, documented effects on insular maritime tundra landscapes, and general distribution data. A more detailed understanding of their distribution and ecological role on Alaskan islands is required before effective control measures can be considered. However, if monitoring or research provides evidence of significant ecological impacts, or a high likelihood of subsequent introductions (which would likely result in raising their overall invasiveness score), then immediate control actions should be considered.

Low Risk

Species that scored below 49 were categorized as weakly or very weakly invasive and were considered low risk for invasiveness. These included bison, elk, ground squirrel, deer mouse, and Alaskan hare. The ecological impacts of these species are generally considered minor, and in most cases invasions are localized. However, localized invasions can be persistent and problematic. Because distribution is restricted, these species are also generally easier to control. The Alaskan hare has disappeared from the one island it was known from in the ABSI region LCC and should be removed from further consideration as invasive to the region. Overall, weakly invasive species do not require as much attention as the other

categories. In the case of the bison and elk, modern introductions have been intentional, requiring extensive planning and expense. It may be misleading to consider these populations invasive, as they do not need to be controlled or removed, but rather monitored for potential deleterious effects in the future.

Vectors of Introduction

Human mediated introduction, both accidental and intentional, were the leading vectors for transmission of invasive species within the ABSI LCC region. Of the 135 documented islands with current or historical infestations 102 were the result of human intentional introductions, 22 were human accidental, two otherwise introduced species were actually native to select islands, one introduction was natural (range expansion onto a neighboring island), and eight introductions are of unknown origin (Table 5).

Table 5. Method of introduction for 17 invasive species from the ABSI LCC region.

Common Name	Human accidental	Human intentional	Native	Natural	Unknown
Alaskan hare		1			
Bison		1			
Cattle		4			2
Common muskrat		1			
Deer mouse					1
Elk		1			
European hare		2			
European rabbit		5			
Feral cat	1				
Fox (red or Arctic)		64	1		
Ground squirrel		6	1		
Horse		4			5
House mouse	3				
Norway rat	17				
Reindeer/Caribou		11		1	
Roof rat	1				
Sheep		2			
Total	**22**	**102**	**2**	**1**	**8**

Human Accidental

Norway rats have become established on 17 or more islands within the ABSI LCC region, and the roof rat is known from one island – Shemya – likely in association with the Eareckson Air Station. The majority of accidental or presumed accidental introductions (77%) of rats were due to hitchhiking aboard ships and either coming to shore when docked at harbors or as a result of shipwrecks (Murie 1959, Ebbert and Byrd 2002, MacDonald and Cook 2009, GISD 2011). Five of the sites with Norway rats were occupied by

the military during WWII, and the numerous cargo ships unloading supplies at ports were likely culpable for rat introductions (Ebbert and Byrd 2002).

Although the origins of house mouse introductions in the ABSI LCC region are unknown, this species is also a known hitchhiker in cargo. It has been suggested that tens of thousands of mice leave the US each year as stowaways in grain, straw, and hay shipments (Baker 1994).

Human Intentional

The most common method of introduction in this assessment was human intentional, responsible for 75% of all known introductions in the ABSI LCC region. Intentional introductions for the 17 species considered fell under three major categories: supplemental food, recreation/hunting, and economic/agricultural (Figure 7).

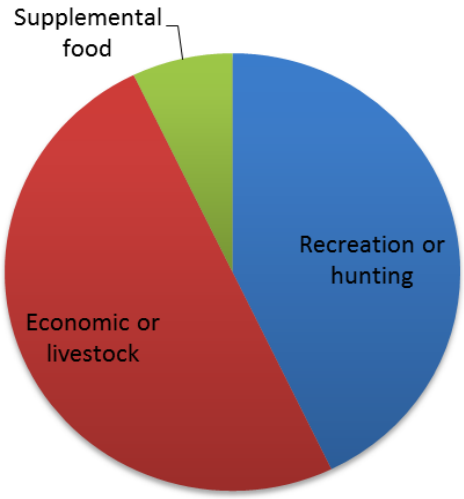

Figure 7. Human intentional methods of introduction for 17 invasive species in the ABSI LCC region.

The ground squirrel naturally occurs on the Alaskan mainland and on some islands, and it has been introduced and persists on at least seven islands within the ABSI LCC region. Early introductions were by native Alaskans and early Russians who were using squirrels for clothing and food. Some island introductions were also performed by ranchers who were using ground squirrels as a food source for foxes after seabird populations began to decline (Ebbert and Byrd 2002).

The European hare, Alaskan hare, common muskrat, caribou, elk, and bison were introduced on numerous islands to increase sport and/or subsistence hunting opportunities. The European hare has been introduced as a game species worldwide (Smith & Johnston 2008). In Alaska, Hog and Umnak Islands previously had intentional introductions of the European hare, but their current status is unknown (Bailey 1993). The Alaskan hare, native to western Alaska, was intentionally introduced on Chirikof Island in 1891, but has since disappeared (Bailey 1993). Both hare species have been released on 10 or more AMNWR islands, and may still be present on a few (Ebbert and Byrd 2002). Muskrats were introduce on St. George Island in 1913, but did not survive their first winter (MacDonald and Cook 2009); no subsequent introductions are known.

Caribou are native to mainland Alaska but occasionally swim to nearby large islands. The only introduction in the ABSI LCC region is on Adak Island where caribou were purposefully released in the late 1950s at the request of the U.S. Navy to provide sport-hunting opportunities for military personnel stationed on the island. While Adak was occupied by the military, hunting largely limited the caribou population size. Numbers increased over 300% within 12 years following the closure of the military base and the functional end of hunting (Ricca 2014). The herd was recently estimated at approximately 900

animals (Williams 1998 in Ebbert and Byrd 2002). More recent ungulate introductions related to promoting subsistence and/or sport hunting opportunities involve elk, which were introduced on Akun Island in the 2010s as part of a program to populate the Aleutian Islands with game (Klint 2013), and bison were introduced on Umnak Island in 2007 and 2008.

Arctic and red fox, reindeer, cattle, horse, sheep, bison, and ground squirrels were all introduced on Aleutian Islands to enhance economic opportunities or as livestock, or both. The rationale behind introductions varied among islands. Arctic and red foxes were introduced by Aleut and Russian fox ranchers on over 450 Alaskan islands, as early as 1741. Another 86 islands in the Aleutian chain were stocked with foxes between 1910 and 1940, at which point AMNWR stopped permitting their introduction. Seabird declines across Refuge islands precipitated changes in government policy regarding fox ranching on islands; eradication efforts started in 1949 and by 2002 they had been eliminated from 39 islands and over 500,000 hectares (Bailey 1993, Ebbert 2000, Ebbert and Byrd 2002).

Introductions of reindeer primarily occurred at the beginning of the 20th century as a means of providing a reindeer-herding based economy and reducing starvation among indigenous people (Swanson and Barker 1992, Ebbert and Byrd 2002). Cattle were introduced to several islands primarily after WWII (Ebbert and Byrd 2002). Herding and ranching efforts largely failed given the logistical difficulties associated with the remote region, and most herds were abandoned and became feral (Renner 2014).

Natural or Native

Irruptive population growth likely drove emigration and natural colonization of caribou from Adak to nearby Kagalaska Island, where these animals are now invasive on lands managed as wilderness by AMNWR (Ricca 2014). St. George supports a native population of Arctic fox, and a native population of Arctic ground squirrel occurs on Unimak Island.

Implications for Management

Invasive species occurring on islands with mixed land ownership pose more challenging management options compared with those solely occupying AMNWR lands. For example, a sustainable population of caribou on Adak provides recreation for sport hunters, subsistence opportunities for island residents, and an important source of economic revenue for state and private entities. However, the presence of introduced species is incompatible with the stated AMNWR mission of maintaining native biodiversity (Ricca 2014). This type of paradox often results in management goals that may not be entirely compatible among state, federal, and private stakeholders (Renner et al. 2014).

The relative amount of management responsibility on public and private lands for each of the 17 species was assessed by intersecting the invasive species range maps with a general land management status layer (Table 6). Although state and federal agencies and public landowners have different management mandates and responsibilities for specific fish and wildlife species, this assessment provides an estimate of the proportion of a species' distribution that occurs within the boundaries of areas managed by public agencies and private entities. We used the relative proportion of a species' distribution falling within landowner boundaries as a proxy for relative amount of management/stewardship responsibility.

Species distributions in relation to areas managed both publicly and privately reflect the overall ratio of land ownership within the ABSI LCC area, with the highest percentages of species distributions occurring on USFWS land, Native Patent land, or DOI land, respectively (Table 6). With the exception of the Alaskan hare, common muskrat, deer mouse, and roof rat, ranges of all other species evaluated are shared by two or more landowners. The Alaskan hare, known only from Chirikof Island (AMNWR), and the common muskrat, known only from St. George (Native Patent), are no longer considered present and require no current management actions. The deer mouse (low risk) and roof rat (high risk) are both present on Shemya Island, which is managed exclusively by DOI.

Table 6. Relative management responsibility for 17 non-native species on public and private lands in the ABSI LCC region. Cells highlighted in blue indicate >50% of a species range occurs under the jurisdiction of that landowner, cells highlighted in light orange indicate 25-49% of a species range occurs under the jurisdiction of that landowner.

	Landowner					
Species	**Bureau of Land Management**	**Fish and Wildlife Service**	**Military**	**Native Patent or Interim Conveyance**	**Native Selected**	**State Patent or Tentative Approval**
Alaskan hare	0.01	0.99	0.00	0.00	0.00	0.00
Bison	0.00	0.33	0.01	0.59	0.03	0.05
Cattle	0.00	0.47	0.07	0.42	0.03	0.02
Common muskrat	0.00	0.00	0.00	1.00	0.00	0.00
Deer mouse	0.00	0.00	1.00	0.00	0.00	0.00
Elk	0.00	0.31	0.00	0.69	0.00	0.00
European hare	0.00	0.33	0.01	0.59	0.03	0.05
European rabbit	0.00	0.42	0.01	0.51	0.02	0.04
Feral cat	0.00	0.84	0.05	0.10	0.00	0.00
Fox (red or arctic)	0.00	0.79	0.04	0.15	0.01	0.00
Ground squirrel	0.00	0.70	0.04	0.23	0.02	0.01
Horse	0.00	0.46	0.07	0.43	0.03	0.02
House mouse	0.00	0.60	0.12	0.26	0.03	0.00
Norway rat	0.00	0.69	0.06	0.23	0.01	0.00
Reindeer/Caribou	0.00	0.49	0.02	0.47	0.01	0.01
Roof rat	0.00	0.00	1.00	0.00	0.00	0.00
Sheep	0.00	0.49	0.08	0.39	0.03	0.02

About 70% or more of total range for high risk species such as Norway rat, fox, and feral cat occur on AMNWR lands (Table 6), while ungulate distribution is more evenly divided between AMNWR and Native Corporation lands. For ungulate species in particular, establishing and maintaining management goals for many of these populations will require continued collaboration and support among the different land owners. We hope that results of the invasiveness ranking and range mapping of individual

species can be used in combination to help answer complex management questions that might arise, especially under mixed management situations.

We have combined the results of the species ranges here to provide a generalized summary of management responsibility across a species range in the ABSI LCC region. For each of the 17 species, we have also generated spatial data layers that provide an estimate of management responsibility by individual island. These data are available in the project geodatabase.

Conclusion

We used the results of the invasiveness ranking to identify those invasive species considered the most threatening in the ABSI LCC region and provided some very general management suggestions. The consolidated local knowledge, expert biological observation, field notes, and internal agency reports that were included in this assessment provide a centralized repository of information that can now be used as a decision support tool. We hope that this will inform and justify management actions and identify candidates for monitoring and control. It should also be useful in weighing the ecological impacts of introduced species against opportunities for sport and subsistence hunting. Additionally, this assessment may provide the scientific basis for a cost-benefits analysis of management options.

As we have indicated above, management of the majority of lands on which invasive species are known to occur in the ABSI LCC region is shared, and not the sole responsibility of any one agency. The management guidelines we offer are aimed at the preservation of native species across the region, irrespective of differing management goals, mandates, and responsibilities for specific fish and wildlife species. It is our hope that the information provided within this risk assessment will be useful to managers, promote collaboration, and increase management efficacy across political boundaries and throughout the ABSI region.

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Appendix 1

The Alaska Invasiveness Ranking System criteria and scoring (from Gotthardt and Walton 2011).

1. Distribution	Score
1.1. Current global distribution (includes current invasive and native range).	
Studies comparing invasive species that successfully established to those that failed, found freshwater fish, mammals, and birds with a widespread range are more likely to establish additional populations than species with a restricted range (Long and Mawson 1991, Blackburn and Duncan 2001, Duncan et al. 2001, Bomford 2003, Bomford and Glover 2004, Forsyth et al. 2004).	
a. Occurs in one or two continents or regions (e.g., Mediterranean region).	0
b. Extends over three continents.	6
c. Widespread distribution; extends over four or more continents.	10
u. Unknown.	
1.2. Extent of the species US range and/or occurrence of formal state or provincial listings.	
Species that occur throughout the United States and Canada have an increased likelihood of invading because of their widespread range (Brown 1989, Long and Mawson 1991, Blackburn and Duncan 2001, Duncan et al. 2001, Bomford 2003, Bomford and Glover 2004, Forsyth et al. 2004) and close proximity to the newly invaded area (lower likelihood of dying in transport).	
a. 0-5 percent of the states/provinces.	0
b. 6-20 percent of the states/provinces.	3
c. 21-50 percent of the states/provinces.	7
d. Greater than 50 percent of the states/provinces.	10
u. Unknown.	
1.3. Role of anthropogenic and natural disturbance in establishment.	
Species that inhabit human disturbed areas are less of a threat to the functioning of natural ecosystems than those species that invade undisturbed natural areas (Lockwood et al. 2007).	
a. Requires anthropogenic disturbance to establish.	0
b. May occasionally establish in undisturbed areas but can readily establish in areas with natural or human disturbances.	2
c. Can establish independently of any known natural or anthropogenic disturbances (e.g., once introduced to a region, the species can spread and establish in natural areas).	5
u. Unknown.	
1.4. Climatic similarity between site of origin and release.	
Species are more likely to establish in new locations with a similar climate (temperature and rainfall) to their native range (Nix and Wapshere 1986, Brown 1989, Mack 1996, Pheloung 1996, Williamson 1996, Davis et al. 1998, Duncan et al. 2001). Examples include successful predictions of mammals, amphibians, reptiles, and freshwater fish invasions (Duncan et al. 2001, Forsyth et al. 2004, Bomford and Glover 2004, Bomford et al. 2005).	
a. Inhabits climatic zones that do not exist in regions of Alaska.	0
b. Inhabits similar climatic zones at the extreme of its range that exist in regions of Alaska.	2
c. Inhabits similar climatic zones to those that exist in Alaska.	5
u. Unknown.	

2. Biological characteristics and dispersal ability	Score
2.1. Invasive elsewhere?	
*For this question, invasive is referring to a species that **adversely** affects the habitats it invades ecologically, environmentally, and/ or economically. Species that are good invaders elsewhere have previously demonstrated invasive attributes and have an increased likelihood of being a successful invader in other locations (Bomford 1991, Williamson 1996, 1999, Duncan et al. 2001, Kolar and Lodge 2002, Bomford 2003).*	
a. No, not invasive in areas outside of Alaska.	0
b. Yes, invasive in areas outside of Alaska.	5
u. Unknown.	
2.2. Dietary specialization.	
Species with broad diets and the ability to incorporate new foods into their diet are more successful invaders. Generalist diets are associated with nearly all invasive vertebrates in Australia (Bomford et al. 2005).	
a. Specialist dependent on a restricted range of foods.	0
b. Generalist for the majority of lifecycle, but dietary specialist (on foods that are moderately available in Alaska) for one season or stage of lifecycle (e.g., as a juvenile, during breeding).	2
c. Generalist with a broad diet of many foods.	5
u. Unknown.	
2.3. Habitat specialization.	
Species able to establish in a wide range of habitats and are adaptable to using available habitat types are more likely to find refuges in the invaded area (Swincer 1986, Ehrlich 1989, Brooks 2001, Cassey 2002, Marachetti et al. 2004).	
a. Habitat specialist dependent on a narrow range of habitat types for majority of lifecycle.	0
b. Habitat generalist for the majority of lifecycle; however, a more specific habitat (that is moderately available in Alaska) is necessary for one stage of lifecycle (e.g., while a juvenile, during breeding).	2
c. Habitat generalist, can utilize a variety of habitat types.	5
u. Unknown.	
2.4. Average number of reproductive events (e.g. clutches, litters) per female per year.	
A high rate of population growth often increases the probability a population will reach the threshold of the number of individuals necessary for the invading population to establish and survive (Javis 1980, O'Connor 1986, Ebenhard 1988, Ehrich 1989, Griffith et al. 1989, di Castri 1991, Lidicker 1991, Lodge 1993, Williamson 1999, Dean 2000, Sol and Lefebvre 2000, Sakai et al. 2001, Cassey 2002). Using number of reproductive events (instead of fecundity) does not automatically inflate the score of fish and invertebrates and reduce the score of mammals.	
a. 0-1 reproductive events/female/year.	0
b. 2-3 reproductive events/female/year.	2
c. > 3 reproductive events/female/year.	5
u. Unknown.	

2.5. Potential to be spread by human activities (both directly and indirectly- possible mechanisms include: commercial sales, pet trade, aquaculture, transport on boats and in ballast water).

Human activity has resulted in the intentional and unintentional introduction of numerous terrestrial and aquatic invasive species (Shine et al. 2000, Kolar and Lodge 2001, Bomford 2003, Ruiz and Carlton 2003, Vermeij 2005, Pauchard and Shea 2006, Keller and Lodge 2007). Humans have aided in the dispersal of the majority of recent invasions by constantly providing opportunities for species to be transported and allowing multiple introductions of the same species, which increases the likelihood of establishment (Williamson 1996, Davis 2009).

a. Does not occur.	0
b. Low (human dispersal is infrequent or inefficient).	1
c. Moderate (human dispersal occurs).	3
d. High (there are numerous opportunities, such as different modes (ways) of dispersal to new areas.).	5
u. Unknown.	

2.6. Innate potential for long distance dispersal (attach to other animal, ability to walk, swim, or fly long distances, water current dispersal).

Animals with good long distance dispersal abilities, such as traveling long distances in search of food and nesting resources, have a greater probability of invading a new location (Mayre 1965, Sakai et al. 2001).

a. Does not occur (no long distance mechanisms).	0
b. Infrequent or inefficient long distance dispersal (occurs occasionally despite lack of adaptation).	1
c. Moderate (long distance dispersal occurs).	3
d. Numerous opportunities for long distance dispersal or dispersal occurs often (species travels long distances or attaches to another organism that is very motile).	5
u. Unknown.	

2.7. Terrestrial or aquatic species.

Aquatic environments are more vulnerable to invasion than terrestrial environments because of the ease of dispersal in water and the extensive inadvertent exchange of organisms via ballast water and canals (Beisel 2001, Kinlan and Hastings 2005, Gherardi 2007).

a. Terrestrial.

b. Aquatic.

u. Unknown.

3. Ecological impacts	**Score**

3.1. Impact on population dynamics of other species, including animal, fungi, plant, microbe, and other organisms.

*This question focuses on the **direct impacts on populations** of other species, and does NOT include alterations to assemblages of species that result from these population level impacts cascading to other trophic levels. Invasive species can impact native populations by causing **changes in life history characteristics, fitness (e.g., breeding success), morphology, survival, and abundance**. Changes may be caused by competition (for food, space, breeding sites), predation, herbivory, etc... (Lockwood et al. 2007, Davis 2009).*

a. Negligible perceived impact.	0
b. Has the potential to or does cause minor impacts on other populations (e.g., causes small change in life history characteristics, survival and/ or abundance, but does not threaten the existence of native populations).	3
c. Has the potential to or does cause moderate impacts on other populations (e.g., impacts cause a substantial decrease in native abundance, but not extirpation).	7

d. Likely to or does cause severe, possibly irreversible, alteration to other populations (e.g., causes extinction of one or more populations of native species).	10
u. Unknown.	

3.2. Impact on natural community composition.

*This question focuses on the **impacts on communities** (e.g., typically two or more species of plants and/or animals) that often result from **1) alterations of food webs where the impacts cascade to higher/other trophic levels, 2) displacement of a keystone species, which in turn alters the abundance and interactions of many other species in the community, 3) when entire assemblages of species go extinct, and 4) when the biodiversity of a community changes.** Additionally, changes to populations of species (from the above question) can have a domino effect directly and indirectly changing communities of organisms or their interactions.*

a. No perceived impact; causes no apparent change in native communities.	0
b. Has the potential to or does cause a minor alteration of community composition (e.g., produces a small reduction in the number of individuals in more than one native species in the community, but has little or no impact on the overall functioning of the community).	3
c. Has the potential to or does significantly alter community composition (e.g., produces a significant reduction in the population size of several native species in the community or dramatically alters interactions between species).	7
d. Likely to or does cause major, possibly irreversible, alteration in the community composition (e.g., results in the extirpation of several native species, reducing biodiversity or changing the community composition towards species exotic to the natural community).	10
u. Unknown.	

3.3 Impact on natural ecosystem processes (e.g., ecosystem productivity, water quality, nutrient availability and cycling, sedimentation rate).

*This question focuses on how an invasive species alters **ecosystem processes** (including **abiotic factors**) by changing the **flow of material through an ecosystem, altering ecosystem productivity, and/ or altering the natural disturbance regime** of the system (Lockwood et al. 2007).*

a. No perceivable impact on ecosystem processes.	0
b. Has the potential to or does influence ecosystem processes to a minor degree, but changes have little or no impact on species utilizing the ecosystem.	3
c. Has the potential to or does cause significant alteration of ecosystem processes, which have noticeable impacts on the abiotic and/ or biotic components of the system.	7
d. Likely to or does cause major, possibly irreversible, alteration or disruption of ecosystem processes.	10
u. Unknown.	

4. Feasibility of control	**Score**

4.1. Number and extent of populations in Alaska.

An increase in the number of individuals and locations of populations released increases the ability of a species to successfully establish (Duncan et al. 2001, Bomford 2003, Bomford and Glover 2004, Forsyth et al. 2004), making control more difficult.

a. No populations (has not spread into Alaska).	0
b. Few; scattered.	1
c. Intermediate number; patchy (only in certain regions of Alaska or exclusively in urban areas).	2
d. Several; widespread and dense.	3
u. Unknown.	

4.2. Significance (economic and conservation value) of the natural areas and native species threatened.	
Invasive species are known to have harmful effects on native species, timber, waterways, domesticated animals, ecological services, etc... (Davis 2009). Species that threaten highly valuable resources should receive a higher invasiveness ranking and priority for management.	
a. Insignificant (e.g., found in human disturbed habitats and is not known to impact any vulnerable or high quality native species or communities).	0
b. Low significance (e.g., usually inhabits common, unthreatened habitats and rarely impacts vulnerable or high quality species or communities).	1
c. Moderately significant (e.g., may occasionally threaten vulnerable or high quality species or communities).	2
d. Highly significant (e.g., known to inhabit one or more vulnerable or high quality communities and/or often threatens rare native species).	3
u. Unknown.	
4.3 General management difficulty.	
Managing invasive species is often difficult and the cost, time, effort, and expected results should all be considered to determine the feasibility of management options. For some species, the only plausible management option may be prevention of further spread, while control or even complete eradication may be feasible for other species. Possible management strategies include mechanical (firearms, traps, and harvests), chemical (pesticides, biological control), habitat management, and an integrated approach using a combination of the above methods (Davis 2009).	
a. Managing this species is not necessary (e.g., species does not persist without repeated anthropogenic disturbance).	0
b. Management is often relatively easy and inexpensive; requires a minor investment in human and financial resources.	2
c. Management often requires a major short term investment of human and financial resources, or a moderate long term investment.	3
d. Management often requires a major, long term investment of human and/ or financial resources or is not possible with available technology.	4
u. Unknown.	

Appendix 2

Invasive species documented in the ABSI LCC region and the islands (or island group) where they have been reported.

Species/Island	Disappeared	Eradicated	Present	Unknown	Grand Total
Alaskan hare ***Lepus othus***	**1**				**1**
Chirikof	1				1
Bison ***Bison bison***			**1**		**1**
Umnak			1		1
Cattle ***Bos taurus***			**4**	**2**	**6**
Akun			1		1
Akutan			1		1
Clifford				1	1
Finney				1	1
Umnak			1		1
Unalaska			1		1
Common muskrat ***Odontra zibethicus***	**1**				**1**
St. George	1				1
Deer mouse ***Peromyscus maniculatus***			**1**		**1**
Shemya			1		1
Elk ***Cervus elaphus***			**1**		**1**
Akutan			1		1
European hare ***Lepus europaeus***			**1**	**1**	**2**
Hog			1		1
Umnak				1	1
European rabbit ***Oryctolagus cuniculus***	**2**	**1**	**2**		**5**
Ananiuliak			1		1
Kanaga	1				1
Poa		1			1

Species/Island	Disappeared	Eradicated	Present	Unknown	Grand Total
Tangik			1		1
Umnak	1				1
Feral cat ***Felis catus***			**1**		**1**
Adak			1		1
Fox (red or Arctic) ***Vulpes vulpes, V. lagopus***	**26**	**33**	**6**		**65**
Adak		1			1
Adokt-Koschekt	1				1
Adugak		1			1
Agattu		1			1
Aiktak	1				1
Alaid		1			1
Amatignak		1			1
Amchitka		1			1
Amlia		1			1
Amukta		1			1
Ananiuliak	1				1
Atka			1		1
Attu		1			1
Avatanak		1			1
Aziak (Hazuk)	1				1
Bobrof	1				1
Buldir	1				1
Carlisle		1			1
Chinkoff	1				1
Chuginadak			1		1
Davidof	1				1
Gareloi		1			1
Great Sitkin	1				1
Herbert		1			1
Igitkin		1			1
Kagalaska		1			1
Kagamil		1			1
Kanaga		1			1
Kasatochi		1			1

Species/Island	Disappeared	Eradicated	Present	Unknown	Grand Total
Kavalga	1				1
Khvostof	1				1
Kiska		1			1
Little Kiska	1				1
Little Sitkin		1			1
Little Tanaga		1			1
Nizki		1			1
Ogangen	1				1
Ogluiga	1				1
Peter	1				1
Poa	1				1
Rat		1			1
Rat Islands	1				1
Rootok		1			1
Sagchudak	1				1
Samalga			1		1
Seguam		1			1
Segula		1			1
Shemya			1		1
Semisopochnoi		1			1
Skagul	1				1
St. George			1		1
Tagadak	1				1
Tagalak	1				1
Tanadak	1				1
Tanaga		1			1
Tanaklak	1				1
Tangik	1				1
Ugamak		1			1
Ulak		1			1
Uliaga		1			1
Umak		1			1
Unalaska	1				1
Unalga			1		1
West Unalga	1				1
Yunaska		1			1

Species/Island	Disappeared	Eradicated	Present	Unknown	Grand Total
Ground squirrel *Spermophilus parryii*			**7**		**7**
Amaknak			1		1
Cherni			1		1
Kavalga			2		2
Umnak			1		1
Unalaska			1		1
Unimak			1		1
Horse *Equus caballus*			**4**	**5**	**9**
Akun			1		1
Akutan			1		1
Clifford				1	1
Finney				1	1
Long				1	1
Rabbit				1	1
Sanak				1	1
Umnak			1		1
Unalaska			1		1
House mouse *Mus musculus*	**1**		**2**		**3**
Kiska	1				1
St.Paul			1		1
Unalaska			1		1
Norway rat *Rattus norvegicus*	**2**	**1**	**12**	**2**	**17**
Adak			1		1
Akutan			1		1
Amaknak			1		1
Amchitka			1		1
Atka			1		1
Attu			1		1
Bolshoi Islets			1		1
Great Sitkin			1		1
Kagalaska			1		1
Kiska			1		1

Species/Island	Disappeared	Eradicated	Present	Unknown	Grand Total
Little Kiska				1	1
Ogangen	1				1
Rat		1			1
Sanak	1				1
Sedanka			1		1
Shemya				1	1
Unalaska			1		1
Reindeer/Caribou *Rangifer tarandus*	**1**		**11**		**12**
Adak			1		1
Atka			1		1
Hagemeister Island			1		1
Kagalaska			1		1
Nunivak			1		1
St. George			1		1
St. Matthew	1				1
St.Lawerence			1		1
St.Paul			1		1
Stuart			1		1
Umnak			1		1
Unalaska			1		1
Roof rat *Rattus rattus*			**1**		**1**
Shemya			1		1
Sheep *Ovis aries*			**2**		**2**
Umnak			1		1
Unalaska			1		1
Grand Total	**34**	**35**	**56**	**10**	**135**

Appendix 3

Islands (or island groups) in the ABSI LCC region with documented invasive species. See end of table for key to common and scientific names.

Island/Species	Disappeared	Eradicated	Present	Unknown	Grand Total
Adak		**1**	**3**		**4**
Feral cat			1		1
Fox (red or arctic)		1			1
Norway rat			1		1
Reindeer/Caribou			1		1
Adokt-Koschekt	**1**				**1**
Fox (red or arctic)	1				1
Adugak		**1**			**1**
Fox (red or arctic)		1			1
Agattu		**1**			**1**
Fox (red or arctic)		1			1
Aiktak	**1**				**1**
Fox (red or arctic)	1				1
Akun			**2**		**2**
Cattle			1		1
Horse			1		1
Akutan			**4**		**4**
Cattle			1		1
Elk			1		1
Horse			1		1
Norway rat			1		1
Alaid		**1**			**1**
Fox (red or arctic)		1			1
Amaknak			**2**		**2**
Ground squirrel			1		1
Norway rat			1		1
Amatignak		**1**			**1**
Fox (red or arctic)		1			1
Amchitka		**1**	**1**		**2**
Fox (red or arctic)		1			1
Norway rat			1		1
Amlia		**1**			**1**
Fox (red or arctic)		1			1

Island/Species	Disappeared	Eradicated	Present	Unknown	Grand Total
Amukta		**1**			**1**
Fox (red or arctic)		1			1
Ananiuliak	**1**		**1**		**2**
European rabbit			1		1
Fox (red or arctic)	1				1
Atka			**3**		**3**
Fox (red or arctic)			1		1
Norway rat			1		1
Reindeer/Caribou			1		1
Attu		**1**	**1**		**2**
Fox (red or arctic)		1			1
Norway rat			1		1
Avatanak		**1**			**1**
Fox (red or arctic)		1			1
Aziak (Hazuk)	**1**				**1**
Fox (red or arctic)	1				1
Bobrof	**1**				**1**
Fox (red or arctic)	1				1
Bolshoi Islets			**1**		**1**
Norway rat			1		1
Buldir	**1**				**1**
Fox (red or arctic)	1				1
Carlisle		**1**			**1**
Fox (red or arctic)		1			1
Cherni			**1**		**1**
Ground squirrel			1		1
Chinkoff	**1**				**1**
Fox (red or arctic)	1				1
Chirikof	**1**				**1**
Alaskan hare	1				1
Chuginadak			**1**		**1**
Fox (red or arctic)			1		1
Clifford				**2**	**2**
Cattle				1	1
Horse				1	1
Davidof	**1**				**1**
Fox (red or arctic)	1				1

Island/Species	Disappeared	Eradicated	Present	Unknown	Grand Total
Finney				**2**	**2**
Cattle				1	1
Horse				1	1
Gareloi		**1**			**1**
Fox (red or arctic)		1			1
Great Sitkin	**1**		**1**		**2**
Fox (red or arctic)	1				1
Norway rat			1		1
Hagemeister Island			**1**		**1**
Reindeer/Caribou			1		1
Herbert		**1**			**1**
Fox (red or arctic)		1			1
Hog			**1**		**1**
European hare			1		1
Igitkin		**1**			**1**
Fox (red or arctic)		1			1
Kagalaska		**1**	**2**		**3**
Fox (red or arctic)		1			1
Norway rat			1		1
Reindeer/Caribou			1		1
Kagamil		**1**			**1**
Fox (red or arctic)		1			1
Kanaga	**1**	**1**			**2**
European rabbit	1				1
Fox (red or arctic)		1			1
Kasatochi		**1**			**1**
Fox (red or arctic)		1			1
Kavalga	**1**		**2**		**3**
Fox (red or arctic)	1				1
Ground squirrel			2		2
Khvostof	**1**				**1**
Fox (red or arctic)	1				1
Kiska	**1**	**1**	**1**		**3**
Fox (red or arctic)		1			1
House mouse	1				1
Norway rat			1		1
Little Kiska	**1**			**1**	**2**

Island/Species	Disappeared	Eradicated	Present	Unknown	Grand Total
Fox (red or arctic)	1				1
Norway rat				1	1
Little Sitkin		**1**			**1**
Fox (red or arctic)		1			1
Little Tanaga		**1**			**1**
Fox (red or arctic)		1			1
Long				**1**	**1**
Horse				1	1
Nizki		**1**			**1**
Fox (red or arctic)		1			1
Nunivak			**1**		**1**
Reindeer/Caribou			1		1
Ogangen	**2**				**2**
Fox (red or arctic)	1				1
Norway rat	1				1
Ogluiga	**1**				**1**
Fox (red or arctic)	1				1
Peter	**1**				**1**
Fox (red or arctic)	1				1
Poa	**1**	**1**			**2**
European rabbit		1			1
Fox (red or arctic)	1				1
Rabbit				**1**	**1**
Horse				1	1
Rat		**2**			**2**
Fox (red or arctic)		1			1
Norway rat		1			1
Rat Islands	**1**				**1**
Fox (red or arctic)	1				1
Rootok		**1**			**1**
Fox (red or arctic)		1			1
Sagchudak	**1**				**1**
Fox (red or arctic)	1				1
Samalga			**1**		**1**
Fox (red or arctic)			1		1
Sanak	**1**			**1**	**2**
Horse				1	1

Island/Species	Disappeared	Eradicated	Present	Unknown	Grand Total
Norway rat	1				1
Sedanka			**1**		**1**
Norway rat			1		1
Seguam		**1**			**1**
Fox (red or arctic)		1			1
Segula		**1**			**1**
Fox (red or arctic)		1			1
Shemya			**1**		**1**
Fox (red or arctic)			1		1
Semisopochnoi		**1**			**1**
Fox (red or arctic)		1			1
Shemya			**2**	**1**	**3**
Deer mouse			1		1
Norway rat				1	1
Roof rat			1		1
Skagul	**1**				**1**
Fox (red or arctic)	1				1
St. George	**1**		**2**		**3**
Common muskrat	1				1
Fox (red or arctic)			1		1
Reindeer/Caribou			1		1
St. Matthew	**1**				**1**
Reindeer/Caribou	1				1
St.Lawerence			**1**		**1**
Reindeer/Caribou			1		1
St.Paul			**2**		**2**
House mouse			1		1
Reindeer/Caribou			1		1
Stuart			**1**		**1**
Reindeer/Caribou			1		1
Tagadak	**1**				**1**
Fox (red or arctic)	1				1
Tagalak	**1**				**1**
Fox (red or arctic)	1				1
Tanadak	**1**				**1**
Fox (red or arctic)	1				1
Tanaga		**1**			**1**

Island/Species	Disappeared	Eradicated	Present	Unknown	Grand Total
Fox (red or arctic)		1			1
Tanaklak	**1**				**1**
Fox (red or arctic)	1				1
Tangik	**1**		**1**		**2**
European rabbit			1		1
Fox (red or arctic)	1				1
Ugamak		**1**			**1**
Fox (red or arctic)		1			1
Ulak		**1**			**1**
Fox (red or arctic)		1			1
Uliaga		**1**			**1**
Fox (red or arctic)		1			1
Umak		**1**			**1**
Fox (red or arctic)		1			1
Umnak	**1**		**6**	**1**	**8**
Bison			1		1
Cattle			1		1
European hare				1	1
European rabbit	1				1
Ground squirrel			1		1
Horse			1		1
Reindeer/Caribou			1		1
Sheep			1		1
Unalaska	**1**		**7**		**8**
Cattle			1		1
Fox (red or arctic)	1				1
Ground squirrel			1		1
Horse			1		1
House mouse			1		1
Norway rat			1		1
Reindeer/Caribou			1		1
Sheep			1		1
Unalga			**1**		**1**
Fox (red or arctic)			1		1
Unimak			**1**		**1**
Ground squirrel			1		1
West Unalga	**1**				**1**

Island/Species	Disappeared	Eradicated	Present	Unknown	Grand Total
Fox (red or arctic)	1				1
Yunaska		**1**			**1**
Fox (red or arctic)		1			1
Grand Total	**34**	**35**	**56**	**10**	**135**

Key to common and scientific names

Alaskan hare - *Lepus othus*

Bison - *Bison bison*

Cattle - *Bos taurus*

Common muskrat - *Odontra zibethicus*

Deer mouse - *Peromyscus maniculatus*

Elk - *Cervus elaphus*

European hare - *Lepus europaeus*

European rabbit - *Oryctolagus cuniculus*

Feral cat - *Felis catus*

Fox (red or Arctic) - *Vulpes vulpes, V. lagopus*

Ground squirrel - *Spermophilus parryii*

Horse - *Equus caballus*

House mouse - *Mus musculus*

Norway rat - *Rattus norvegicus*

Reindeer/Caribou - *Rangifer tarandus*

Roof rat - *Rattus rattus*

Sheep - *Ovis aries*