United States
Department of
Agriculture

Forest Service
Alaska Region

Alaska Natural
Heritage Program

August 2011

# Prioritizing the Risk of Invasive Animal and Aquatic Invertebrate Species in Alaska's National Forests

**On the cover**

Top left: European black slug- photo by Tracey Gotthardt. Top right: Skunk cabbage browsed on by European rabbits, Bottom center: European rabbits- photos by Kelly Walton.

# Prioritizing the Risk of Invasive Animal and Aquatic Invertebrate Species in Alaska's National Forests

Tracey A. Gotthardt and Kelly M. Walton

Alaska Natural Heritage Program
University of Alaska Anchorage
707 A Street
Anchorage, Alaska 99501

Prepared for:

USDA Forest Service
Alaska Region
709 W 9th Street
PO Box 21628
Juneau, AK 99802-1628

August 2011

**Recommended Citation**

T.A. Gotthardt and K.M. Walton. 2011. Prioritizing the Risk of Invasive Animal and Aquatic Invertebrate Species in Alaska's National Forests. Prepared for the USDA Forest Service, Alaska Region. Alaska Natural Heritage Program, University of Alaska Anchorage, Alaska. 109 pp.

## Table of Contents

## List of Tables



## List of Figures

## Abstract

Although Alaska is relatively isolated, it is not immune to invasive species and their negative impacts, particularly with recent increases in tourism, development, and commercial traffic. In order to insure the health of ecosystems and resources in Alaska, land managers need to know which invasive species are of greatest threat in order to efficiently allocate resources. We developed an invasiveness ranking system for non-native animal and invertebrate species in Alaska's National Forests to serve as a tool to help set priorities for research and control efforts. Numerous ranking systems exist for invasive plants, but to our knowledge, no ranking system has been designed to comprehensively evaluate the invasiveness of animals and produce a numerical rank. We designed a ranking system that is inclusive of marine, aquatic, and terrestrial species and uses sixteen criteria grouped into four broad sections: distribution, biological characteristics and dispersal ability, ecological impacts, and feasibility of control. Answers to individual questions are assigned a point value and the points are 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: distribution, biology and ecology sections are weighted as 30 percent of the total score while control is weighted as 10 percent of the total score.

We ranked 23 invasive species known to occur in Alaska's National Forests or identified as potential invaders and housed this information in a project-related database. Overall invasiveness scores ranged from a low of 29 for the Pacific chorus frog to a high of 91 (of a possible 0 to 100) for the Norway rat. The mean score was 63 and median score was 64 (sd = 14.3). In addition to just straight invasiveness scores, we also provided an alternative mechanism to group results according to level of invasiveness: extremely, highly, moderately, modestly, weakly and very weakly invasive. Twenty-six percent (n = 6) of the species were categorized as extremely to highly invasive; these included the Norway rat, northern pike, house mouse, whirling disease, New Zealand mudsnail, and zebra mussel. Fifty-seven percent (n = 13) of species ranked were categorized as moderately to modestly invasive; and seventeen percent (n = 4) were classified as weakly to very weakly invasive. The ranking system provides managers with a list of species to consider for action along with sufficient information to help guide those decisions. It also provides background information to defend a decision should management action be recommended. In the future, this system can be used to rank additional species and existing ranks can easily be modified as new information becomes available.

## Keywords

Alaska, National Forest, invasive species, invasive animals, invasive species management, invasiveness ranking, prioritization

## Introduction and Background

Invasive species are species that are both non-native (alien) to a particular ecosystem and whose introduction is likely to or can cause economic or environmental harm or harm to human health (Executive Order 13112 1999). Alaska's small human population and relative geographic isolation have kept invasive species introductions at comparatively low levels. However, recent increases in commercial and recreational traffic, development, agriculture, and changes to the landscape in association with climate change (Schrader and Hennon 2005, UCS 2005) all have the potential to increase invasive species introductions in the state.

Invasive species negatively affect biodiversity in a number of ways. Invasive species can alter ecosystems by displacing or preying on native species, contaminating gene pools by interbreeding with native species, and through widespread killing of native species, as seen with invasive insects in national forests (Schrader and Hennon 2005). Rare species with limited ranges and restricted habitat requirements are often particularly susceptible to the influence of invasive species (NatureServe 2006). The invasion of non-native species into intact ecosystems is recognized by scientists and land managers as one of the primary causes of biodiversity loss second only to habitat loss (Pimm and Gilpin 1989, U.S. Congress 1993, Myers 1997, Stein et al. 2000).

Ensuring the health of Alaska's National Forests requires the understanding and management of complex and interrelated natural resources. Threats from invasive and introduced species pose new and significant challenges to natural resource management. Besides the warranted concern for the integrity of natural areas, we also need to be concerned for resources that are managed for fisheries, tourism, agricultural production systems, and forestry. Invading species that become pests can be devastating.

### Non-Native Animals in Alaska

Animal invasions occur in both aquatic (including marine, coastal, estuarine, lake, and river) and terrestrial environments. A recent review of the literature found that at least 116 non-native animal species have been documented (either historically or currently) in Alaska, of which 21 species were classified as "high-risk" for invasiveness (Schrader and Hennon 2005, McClory and Gotthardt 2008). This list included 3 amphibians, 16 birds, 14 invertebrates, 42 mammals, 35 parasites, 4 reptiles, and one pathogen. An additional 41 animal species were identified as potential invaders based on their proximity in adjacent states and provinces and on their ability to disperse over large distances (McClory and Gotthardt 2008).

In the terrestrial environment, relatively few animal species are considered highly invasive or threatening to ecosystem health and integrity (Schrader and Hennon 2005). Those that are considered threatening, however, have done tremendous harm to native species, community composition, and ecosystem processes. For example, Norway rats (*Rattus norvegicus*) have been enormously detrimental in coastal ecosystems where they are responsible for severely reducing or extirpating native ground nesting seabirds, burrow nesting seabirds, and shorebirds (Ebbert and Byrd 2002, Major and Jones 2005, Kurle et al. 2008). Additionally, Norway rats provide supplemental prey to introduced foxes (*Vulpes lagopus*), which also prey on native bird species (Ebbert and Byrd 2002). Introduced foxes, in turn, have transformed plant communities on the Aleutian Islands by reducing abundant seabird populations, thereby disrupting nutrient subsidies vectored by seabirds from sea to land (Maron et al. 2006). Eradication of both Norway rats and introduced foxes on the Aleutian Islands, which are home to more than 40 million nesting seabirds, has been logistically challenging and costly.

Natural areas and resources in Alaska have also been damaged by intentional introductions of animals. Range extensions of native species have been encouraged by transplants of individual animals from one area into unoccupied suitable habitats. Although these transplants are generally viewed as beneficial to improving hunting and trapping opportunities, translocated animals may also pose risks to native ecosystems and native species. For example, elk (*Cervus elaphus*) were introduced in Southeast Alaska to Etolin and Zarembo Islands and sightings have been reported from five other Southeast islands including Wrangell, Mitkof, Kupreanof, Prince of Wales, and Farm Islands (Schrader and Hennon 2005). There are concerns that increasing elk densities will result in increased competition with native Sitka black-tailed deer (*Odocoileus hemionus*), an important subsistence and sport hunting species in the area.

Aquatic ecosystems in Alaska are some of the most pristine environments in the world. These habitats support valuable subsistence and commercial fisheries, world class sport fishing and other recreational activities. Maintaining these high-quality habitats in Alaska is a priority for all land management agencies (Schrader and Hennon 2005). However, aquatic habitats are especially vulnerable to invasion by non-native species because of the inherent transport capabilities of flowing water. Several non-native fishes and amphibian species have been introduced into and thrived in Alaska's aquatic environments. For example, red-legged frogs (*Rana aurora*), which are native to the Pacific Northwest, were released by a schoolteacher on Chicagof Island at the Freshwater Bay logging camp in 1982. Since that time, this species has successfully reproduced and dispersed widely into adjacent wetlands (Lerum, pers. comm.), utilizing habitats for breeding and foraging similar to the native western toad (*Bufo boreas*). There is now growing concern that this introduced species could potentially displace native amphibian species (MacDonald 2003).

Several non-indigenous fish species have been illegally or accidentally introduced in some areas of Alaska, including northern pike (*Esox lucius*), Atlantic salmon (*Salmo salar*), and yellow perch (*Perca flavescens*; Fay 2002). Northern pike, native to interior Alaska, have been introduced and become established throughout the Susitna River drainage, Kenai Peninsula, and into Southeast Alaska, and their range is continuing to expand. In 2002, this species was identified as the species of greatest immediate concern in the Alaska Aquatic Nuisance Species Management Plan (Fay 2002) due to their ability to spread and establish quickly and their adverse affects to native trout and salmonid stocks. Hundreds of thousands of Atlantic salmon raised in fish farms in British Columbia and Washington state have escaped from their pens, some reaching waters near Ketchikan and Yakutat and as far north as the Bering Sea. If this species successfully spawns and becomes established, it could compete for limited food and spawning habitat with native fishes such as steelhead, cutthroat trout, Dolly Varden (*Salvelinus malma*), and coho salmon (*Oncorhynchus kisutch*; UCS 2005). Similarly, introduced yellow perch can compete with native fish species and are known to restrict salmon reproduction (UCS 2005).

## Invasiveness Ranking Background

Based on the best available information, twenty non-native or invasive animal species have been catalogued in Alaska's National Forests (Schrader and Hennon 2005). Since many animal introductions are still limited in distribution, managers may have the opportunity to avoid ecological disasters by containing problem species before they become well established and spread. However, before successful management efforts towards invasive species can be implemented, information must be gathered to identify where these species occur and which species pose the greatest risk to native ecosystems.

Over the past decade, a wide variety of invasiveness assessment models have been produced (Heffernan et al. 2001, Robertson et al. 2003, Warner et al. 2003, Morse et al. 2004, Carlson et al. 2008) to provide an objective and systematic mechanism to predict invasiveness. These models generally contain a series of questions for evaluating individual species based on both spatial and biological characteristics, known or potential impacts, and management difficulty (Carlson et al. 2008). Scores for each question are totaled to produce a final evaluation, which is either numerical or categorical (e.g., highly invasive, moderately invasive).

### Objectives

In an effort to provide forest managers with the most up-to-date information regarding invasive terrestrial and aquatic species, we developed an invasiveness ranking system for non-native animal and invertebrate species in Alaska's National Forests. This ranking system can serve as a tool to help set priorities for research and control efforts for invading bird, fish, invertebrate, mammal, and amphibian species. The need to evaluate and rank non-native species is a prerequisite before expensive management is attempted, so that the most threatening species may be addressed first.

Specific objectives were to:

1. Update the existing list of non-native and invasive species known to occur on National Forest lands in Alaska (see Schrader and Hennon 2005).
2. Conduct a thorough literature review of existing animal invasiveness ranking systems.
3. Develop a single invasiveness ranking system for terrestrial and aquatic vertebrate and invertebrate animals that generates a numerical rank for each species.
4. Compile and synthesize information regarding the biology, modes of dispersal, documented impacts, control options, and distribution of species to be ranked.
5. Rank all known or potential animal invaders of concern in Alaska's National Forests and create a short ranking summary report for each species with the rational and information sources used for ranking.

## Methods

### Development of the Ranking System

A thorough review of both published and gray literature revealed numerous examples of invasiveness ranking systems for plants (Hiebert and Stubbendieck 1993, Pheloung et al. 1999, Heffernan et al. 2001, Warner et al. 2003, Morse et al. 2004, Carlson et al 2008), but there was no equivalent body of knowledge for animal invaders. Copp et al. (2005) produced a risk assessment protocol for non-native fishes in the UK, and Bomford et al. (2005) developed a ranking protocol to help state governments assess and manage risks posed by importing and keeping exotic vertebrates. However, neither of these systems was suitable for assessing the overall invasiveness of both terrestrial and aquatic animals due to differences in scope, purpose, and emphasis. Therefore, in addition to the methods proposed by Copp et al. (2005) and Bomford et al. (2005), we also referred to criteria from several non-native plant invasiveness ranking systems to help identify those components that could be included as attributes in the design of an animal invasiveness ranking system. We evaluated four plant systems, including: "Invasiveness Ranking System for Non-native Plants in Alaska" (Carlson et al. 2008), "An Invasive Species Assessment Protocol: Evaluating Non-native Plants for their Impact on Biodiversity" (Morse et al. 2004), "Handbook for Ranking Exotic Plants for Management and Control" (Hiebert and Stibbendieck 1993), and "Ranking Invasive Exotic Plant Species in Virginia" (Heffernan et al. 2001).

We created a ranking system that incorporated components of the four plant systems mentioned above by identifying criteria that were both relevant and realistic for invasive species in Alaska and that could be modified and then applied to invasive animals. To provide justification for inclusion of each criterion, we compiled literature on factors used to predict invasiveness of animals based on life history traits and distribution. The ranking system was designed to work across taxonomic groups that occur in both terrestrial and aquatic environments.

## Description of the Protocol

The Alaska Invasive Animal Ranking System includes 16 assessment questions, grouped into four sections: 1) distribution, 2) biological characteristics and dispersal ability, 3) ecological impacts, and 4) feasibility of control. Scores are given to each question and the overall point total determines the invasiveness category. This system requires clear documentation for answers to each question, but allows for species to be evaluated when some information is lacking. Outcomes from the system should generally agree with present knowledge and understanding.

## Assessment Questions

### *Section 1. Distribution*

This section consists of four questions that address the species global and North American distribution, climatic tolerances, and ability to establish in disturbed and pristine sites (Table 1). This section is based on the premise that species with widespread ranges are more likely to establish additional populations than species with restricted ranges. Also, species that are able to establish in undisturbed natural areas are more of a threat to native biodiversity than those species that are restricted to human disturbed sites. Lastly, this section takes into consideration the climatic similarity between locations where the species is already established and those where it could potentially establish in Alaska. Although a species may be globally widespread, if it is unable to survive and successfully reproduce in climates similar to Alaska, than its invasive threat is greatly reduced. This question is particularly useful for predicting the threat of potential invaders that may already be at the climatic edge of their range in the northwestern United States and western Canada.

### *Section II. Biological Characteristics and Dispersal Ability*

This section contains six questions which address core life history characteristics that are commonly associated with the potential ability of a species to spread and become established (Table 2). Species that have generalist dietary and habitat needs are more likely to survive and thrive in new areas. Additionally, species that reproduce throughout the year and have a high population growth rate are more likely to quickly produce offspring creating a viable population in the new area. Species with biological traits that allow them to easily spread both naturally and by human activities are more likely to be invasive because of the number of times and individuals that are repeatedly introduced to a new area.

Management strategies are oftentimes quite different for species that occur on land versus those that live in water. To enable users of the system easy access to information, we included a sorting variable in this section to provide a mechanism to separate the overall invasiveness scores for terrestrial and aquatic species.

### *Section III. Ecological Impacts*

This section contains three questions that address the severity of the threat of invasive species to native species and communities (Table 3). The three questions are divided based on impacts to individual populations, natural communities of several species, and ecosystem processes. The impacts of invasive species on native ecological systems is often complex and answers to these questions may seem inter-related. However, this section was designed to help land managers determine to what degree biotic and abiotic systems may change.  The first criterion focuses on the impact of the invasive species on native populations (not assemblages of native species).  These types of impacts typically include changes to life history characteristics, fitness, morphology, survival, and abundance. The second question focuses on impacts to communities or assemblages of native species where multiple species are impacted.  The third criterion focuses on ecosystem level changes that are often abiotic, such as changes to nutrient availability and cycling, sedimentation, and water quality.

***Section IV. Feasibility of Control***

This section contains three questions that consider the feasibility of controlling a species once it becomes invasive (Table 4).  This section addresses information needed to determine the difficulty of control, including the number and extent of populations in Alaska, the importance of areas inhabited and species threatened, and overall general management difficulty based on current knowledge of eradication and removal techniques.

Table 1. Distribution ranking criteria and scoring.

| 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. | |

Table 2. Biological characteristics and dispersal ability ranking criteria and scoring.

| 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.

Table 3. Ecological impacts ranking criteria and scoring.

| 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 threatened 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. | |

Table 4. Feasibility of control ranking criteria and scoring.

| **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. | |

***Overall Invasiveness Score***

We adopted a scoring system similar to the one described in the "Invasiveness Ranking System for Non-Native Plants in Alaska" (Carlson et al. 2008). Answers to individual questions were assigned a point value, and the points were used to calculate subranks for each of the four sections. The maximum possible total score for a species, if all questions were answered, was 100 points. If a question could not be answered because not enough information was available, the criterion was scored as "unknown" and the number of points for that question were subtracted from the total number of "possible points" for that section.

The four sections were weighted differently to reflect their relative contribution to the overall ranking system (Table 5). Distribution, biological characteristics and dispersal ability, and ecological impacts sections were each weighted equally as 30% of the total score, while feasibility of control was weighted as 10% of the total score. Although the feasibility of control section is important to land managers, it is not generally listed in the literature (such as in Bomford 2003) as being highly correlated with a species ability to become invasive, and was therefore not given as much importance as the other sections.

The final invasiveness score is assigned based on the "relative maximum score" (points accrued as a percent of the maximum possible points for questions that could be answered). For example, if the maximum possible points for the questions that could be answered are 80 (suggesting that two questions with 10 points were scored as unknowns), and the species received an outcome score of 60, then the species "relative maximum score" would be 60/80 or 75. Calculating the relative maximum score helps to account for uncertainty in the response to each question. Hence, species are evaluated only on information that is known rather than artificially depressing scores of poorly understood species. A higher relative maximum score corresponds to an increased likelihood of a species potential to become invasive (see Appendix 1 for a blank ranking form with the ranking criteria and steps to calculate the overall invasiveness rank).

Table 5. Explanation of the four major sections of the 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 |

To determine the impact of category weighting on the overall invasiveness score, we recalculated the ranks using several different weighting scenarios including those used by Carlson et al. (2008) in "Invasiveness Ranking System for Non-native Plants in Alaska" (25% distribution, 25% biological characteristics, 40% ecological impacts, and 10% feasibility of control) and by Heffernan et al. (2001) in "Ranking Exotic Plant Species in Virginia" (10% distribution, 30% biological characteristics, 40% ecological impacts, and 20% feasibility of control). Additionally, we ran scenarios where all sections were weighted equally (25% each), where the weight of the ecological impacts section was reduced (30% distribution, 30% biological characteristics, 10% ecological impacts, and 30% feasibility of control), and where the weighting of the feasibility of control section was increased (20% distribution, 20% biological characteristics, 20% ecological impacts, and 40% feasibility of control). We then calculated ranks for six different species using the above mentioned scenarios. In general, changing the weights for individual sections had little impact on the overall invasiveness scores (Figure 1).

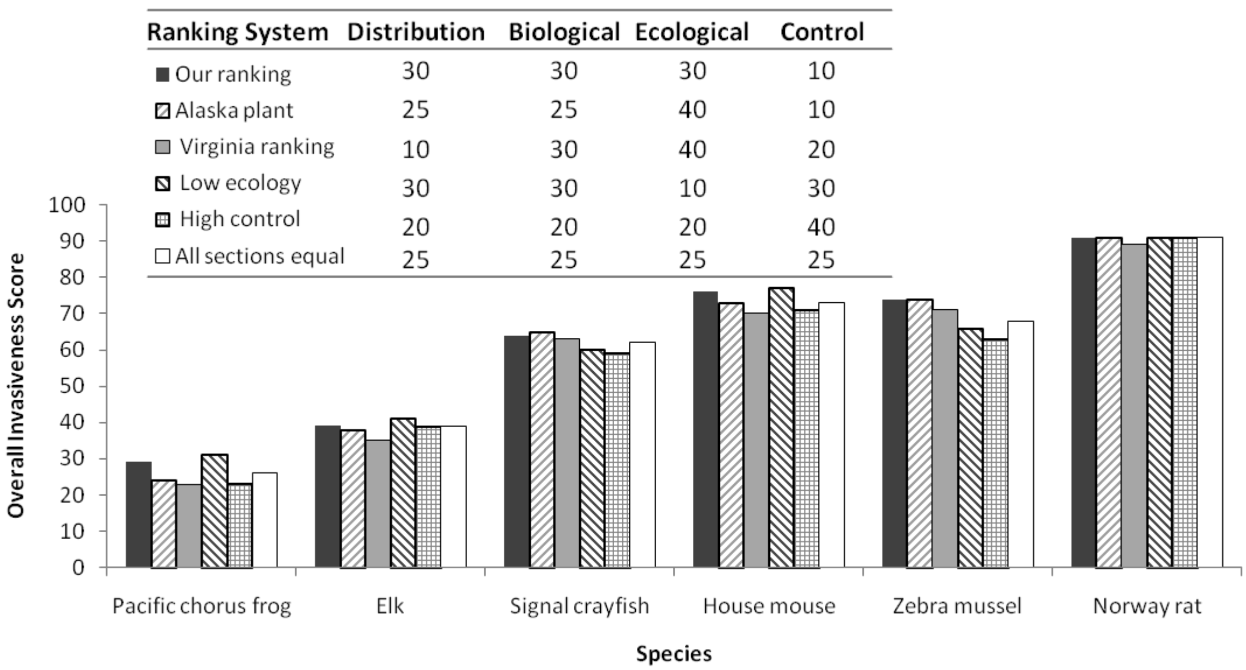



Figure 1. Comparison of overall invasiveness scores for six species when categorical weighting scenarios for distribution, biology, ecology and control sections were modified. Weighting scenarios, presented as percentages, are listed in the legend above the graph.

To provide users of the ranking system with an alternative mechanism than just using straight scores to make determinations about what is considered "highly invasive" vs. "moderately invasive," we adopted categories from Carlson et al. (2008) that divided the numerical scores into six groups based on intensity of invasiveness potential (Table 6). Species ranked as “Extremely Invasive” or "Highly Invasive" are considered very threatening to ecosystem integrity in Alaska and require more attention. Species ranked as "Moderately Invasive" or "Modestly Invasive" also pose significant threats to ecosystems and should be watched. 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 species.

Table 6. Description of the categories used to group numerical scores into six different levels based on intensity of invasiveness potential (adapted from Carlson et al. 2008).

| **Relative Maximum Score** | **Level of Invasiveness** |
|---|---|
| ≥80 | Extremely Invasive |
| 70 – 79 | Highly Invasive |
| 60 – 69 | Moderately Invasive |
| 50 – 59 | Modestly Invasive |
| 40 – 49 | Weakly Invasive |
| < 40 | Very Weakly Invasive |

## Application of the invasiveness ranking system to Alaska's National Forests

Schrader and Hennon (2005) reviewed the literature and developed a list of invasive species considered as threats to National Forest land in Alaska. As a first step in generating a species list for this project, we updated the Schrader and Hennon (2005) list with more recent literature and added two species of invasive slugs (dusky and brown-banded slug) and one invasive crayfish (red swamp crayfish). In total, 23 non-native species identified as currently occurring or having the potential to occur in Alaska's National Forests were selected for inclusion in the ranking (Table 7). The final species list included pathogens, invertebrates, amphibians, fishes, birds, and mammals of which 13 were aquatic and 10 were terrestrial species.

Staff at the Alaska Natural Heritage Program (AKNHP) completed the initial assessment for the 23 species. Information sources used included published literature, unpublished reports, internet sources, and expert opinion from qualified ecologists and taxonomic experts from across Alaska and beyond. Once the ranking for all species was completed, all scores and associated responses were evaluated relative to each other for consistency in scoring. To determine which sections had greater explanatory power, we examined the interrelationship of the variables by calculating rank correlation coefficients for each of the section scores and overall invasiveness. To insure that questions were clearly written and would be scored similarly by multiple evaluators, three staff independently ranked two species and then compared the responses and the overall invasiveness scores. Assessment forms for individual species were reviewed by at least one expert reviewer to help answer unknowns and comment on the scoring and associated justification (see Appendix II for list of expert reviewers).

Table 7. Documented non-native species and species with the potential to invade Alaska's National Forests.

| Common name | Scientific name | Present in Alaska |
|---|---|---|
| Atlantic salmon* | *Salmo salar* | Yes |
| Brown-banded slug* | *Arion circumscriptus* | Yes |
| Chinese mitten crab | *Eriocheir sinensis* | No |
| Dusky slug* | *Arion subfuscus* | Yes |
| Elk* | *Cervis canadensis* | Yes |
| European black slug* | *Arion ater* | Yes |
| European green crab | *Carcinus maenas* | No |
| House mouse* | *Mus musculus* | Yes |
| Leopard slug* | *Limax maximus* | Yes |
| New Zealand mud snail | *Ptoamopyrgus antipodarum* | No |
| Northern pike* | *Esox lucius* | Yes |
| Norway rat* | *Rattus norvegicus* | Yes |
| Pacific chorus frog* | *Pseudacris regilla* | Yes |
| Pacific oyster* | *Crassostrea gigas* | Yes |
| Red swamp crayfish[1] | *Procambarus clarkia* | Yes |
| Red-legged frog* | *Rana aurora* | Yes |
| Rock dove* | *Columba livia* | Yes |
| Signal crayfish[2] | *Pacifastacus leniusculus* | Yes |
| Spiny water flea | *Bythotrephes longimanus* | No |
| Starling* | *Sturnus vulgaris* | Yes |
| Whirling disease parasite[3] | *Myxobolus cerebralis* | Yes |
| Yellow perch[4] | *Perca flavescens* | Yes |
| Zebra mussel | *Dreissena polymorpha* | No |

*=In National Forest (Tongass or Chugach), 1= Kenai, 2= Kodiak
3= Elmendorf Fish Hatchery, Anchorage, 4= near Nikiski, Kenai Peninsula

**Species ranking database**
A project specific Microsoft Access database was developed with built-in user friendly menus and forms to aid in the ranking of species. The database switchboard (user interface) contains a set of options where the user can edit information about a species, enter a new species, view ranking reports, and view ranking summaries based on the species presence or potential presence in Alaska and whether its' habitat is terrestrial or aquatic. For each species ranked, the database automatically produces a score and justification for each criterion, subsection scores, and a formatted report with the overall ranking score. The species report also contains a map depicting the current range of the species and a literature cited section. For species known to be invasive in Alaska, range maps were developed illustrating the species distribution throughout the state. For species not currently in the state but identified as potential invaders, range maps were produced for the region from which they would most likely spread into Alaska (e.g., Pacific Northwest, Western U.S.).

## Results

The invasiveness ranks of 23 species are summarized in Table 8 and completed ranking forms for individual species are presented in Appendix III. Of the 23 total species ranked, 18 are already considered invasive to Alaska, and five are considered a potential threat. The overall invasiveness scores ranged from 29 to 91 (of a possible 1 to 100). The mean score was 63 and median score was 64 (sd = 14.3). The overall invasiveness scores for the 23 species were normally distributed (Figure 2).

The distribution of the scores for the terrestrial species ranked (n = 10) ranged from 21 (Pacific chorus frog, least invasive) to 91 (Norway rat, most invasive). The Pacific chorus frog was originally grouped with the aquatic species, but one expert reviewer suggested moving this species to the terrestrial category based on habitat preferences. The most invasive species, the Norway rat, ranked high in all four sections (e.g., distribution, biological characteristics and dispersal ability, ecological impacts, and feasibility of control). All terrestrial species evaluated have been documented as occurring in Alaska.

Invasiveness scores for the aquatic species (n = 13) ranged from 45 (Chinese mitten crab, least invasive) to 84 (Northern pike, most invasive). Five of the 13 aquatic species evaluated have not yet been recorded in Alaska. These include the New Zealand mudsnail (score 75), zebra mussel (74), spiny waterflea (65), European green crab (64), and Chinese mitten crab (45).

Scores for each section (distribution, biological characteristics and dispersal ability, ecological impacts, and feasibility of control) were positively correlated with the overall invasiveness score ($r > 0.50$; Table 9), with ecological impacts and distribution having the strongest associations ($r = 0.84$ and $r = 0.70$, respectively). Between variables, there was a strong association between the distribution and control sections ($r = 0.69$) and a moderately strong association between the ecology and control sections ($r = 0.43$; Table 9).

Table 8. Summary scores of invasiveness ranking of 23 non-native animal species, sorted by aquatic and terrestrial habit and ordered by overall invasiveness score. Total possible points for distribution, biology, and ecology section were 30 points per section; 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 | Biology | Ecology | Control | Invasiveness Score[1] | Level[2] |
|---|---|---|---|---|---|---|
| **Aquatic** | | | | | | |
| Northern pike | 30 | 18 | 27 | 9 | 84 | Extreme |
| Whirling disease | 27 | 20 | 24 | 7 | 78 | High |
| New Zealand mudsnail* | 24 | 25 | 21 | 5 | 75 | High |
| Zebra mussel* | 23 | 23 | 24 | 4 | 74 | High |
| Red swamp crayfish | 27 | 19 | 17 | 5 | 68 | Moderate |
| Spiny water flea* | 16 | 24 | 21 | 4 | 65 | Moderate |
| European green crab* | 20 | 23 | 17 | 4 | 64 | Moderate |
| Yellow perch | 20 | 19 | 21 | 4 | 64 | Moderate |
| Signal crayfish | 19 | 19 | 21 | 5 | 64 | Moderate |
| Atlantic salmon | 27 | 18 | 6 (20) | 7 | 61 | Moderate |
| Pacific oyster | 18 | 23 | 6 | 3 | 50 | Modest |
| Red-legged frog | 10 | 12 (25) | 7 (10) | 4 | 49 | Weak |
| Chinese mitten crab* | 13 | 20 | 9 | 3 | 45 | Weak |
| **Terrestrial** | | | | | | |
| Norway rat | 30 | 25 | 27 | 9 | 91 | Extreme |
| House mouse | 27 | 26 | 17 | 6 | 76 | High |
| Dusky slug | 24 | 25 | 13 | 4 (7) | 68 | Moderate |
| Rock dove | 27 | 24 | 6 | 5 | 62 | Moderate |
| European black slug | 13 | 25 | 17 | 7 | 62 | Moderate |
| Brown-banded slug | 17 | 25 | 13 | 4 | 59 | Modest |
| Leopard slug | 21 | 20 | 14 | 3 | 58 | Modest |
| Starling | 25 | 16 | 6 | 7 | 54 | Modest |
| Elk | 17 | 9 | 6 (20) | 4 | 39 | Very weak |
| Pacific chorus frog | 10 | 18 | 0 | 1 | 29 | Very weak |

* = Species not present in Alaska, considered potential invader.

[1]Invasiveness score is a relative maximum score calculated from the total points earned divided by the possible points.

[2]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 (Carlson et al. 2008).

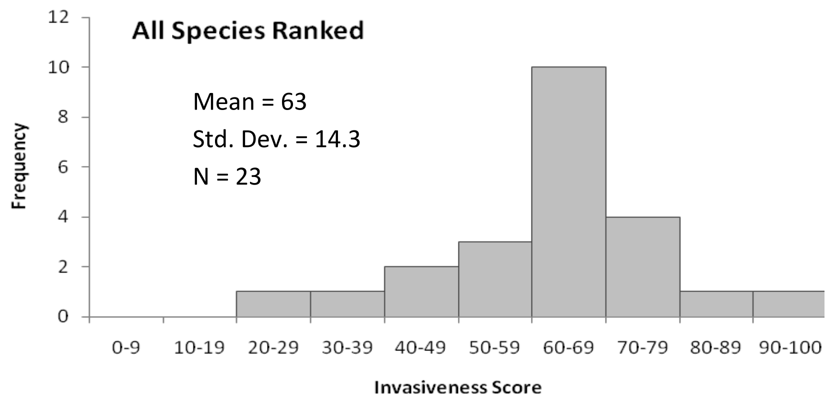



Figure 2: Frequency distribution of invasiveness scores for 23 species ranked.

Table 9: Spearman rank correlations among four sections of the invasiveness ranking system.

| | Distribution | Biology | Ecology | Control | Invasiveness |
|---|---|---|---|---|---|
| **Distribution** | 1.000 | 0.212 | 0.367 | 0.687 ** | 0.701** |
| **N** | | 23 | 23 | 23 | 23 |
| **Biology** | | 1.000 | 0.321 | 0.091 | 0.517* |
| **N** | | | 23 | 23 | 23 |
| **Ecology** | | | 1.000 | 0.431* | 0.844** |
| **N** | | | | 23 | 23 |
| **Control** | | | | 1.000 | 0.586** |
| **N** | | | | | 23 |
| **Invasiveness** | | | | | 1.000 |

**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level.

The accuracy and consistency of ranking systems, no matter how objective the selection criteria, are largely dependent on the skill and rigor of the assessor. To evaluate how clearly questions were presented and assess if they would be answered similarly by multiple evaluators, we had three independent assessors answer criteria and score two species, the rock dove and New Zealand mudsnail. Overall, there was general agreement in the scores assigned by independent assessors to both individual section scores as well as the overall score, suggesting the ranking system can be used by multiple independent assessors to produce consistent results (Figure 3).

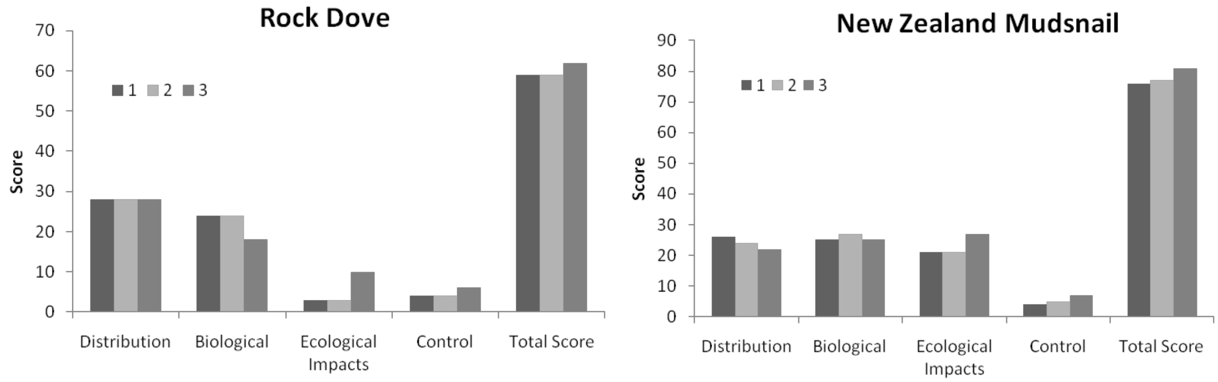



Figure 3: Comparison of scores produced by 3 independent assessors (1-3 in legend) for two species.

We contacted expert reviewers for each of the 23 species ranked, and received comments back for 21 species (Appendix II). Expert comments greatly improved the quality of the responses to specific questions and the consequent scores.

## Discussion

The Invasiveness Ranking System for Non-native Animals in Alaska was developed as a tool to categorize invasive species of greatest threat to Alaska's National Forests. The ranking system was designed to be objective and efficient, rely upon available information and expert opinion, and to provide outputs that are useful to invasive species management. This study reviewed 23 known or potential animal invaders on Forest Service lands in Alaska using ranking criteria comprised of 16 assessment questions that focused on a species potential for introduction, establishment, damage and control.

Our initial review of the ranking literature revealed no other comparable invasiveness ranking systems for animals, especially one that was inclusive of both terrestrial and aquatic species. As a consequence, our ranking system relied heavily on criteria borrowed from several invasive plant ranking systems. However, during the expert review of our ranking system, it was brought to our attention that the Washington Invasive Species Council (http://invasivespecies.wa.gov) had developed an "Invasive Species Impact and Prevention/ Early Action Assessment Tool", with similar goals to our own ranking system. The Washington ranking system uses similar criteria to evaluate ecological impacts, invasive potential and difficulty of control for both plants and animals. The major difference between the two systems is the Washington system also includes a large economic component that addresses impacts to agriculture/aquaculture, the forestry products industry, physical infrastructure, and the recreational sector. This type of economic information is generally lacking for Alaska; therefore, we did not feel compelled to add additional economic questions to our ranking system beyond those already included under the feasibility of control section.

Scores for the four sections of the ranking system were generally positively related to each other. For example, species that were more difficult to control were also generally more widely distributed and had larger ecological impacts. The distribution and ecology sections appeared to be the best predictors of the overall invasiveness ranking score. Scores for the biological characteristics and dispersal section were all relatively high, were not well distributed across the range of possible scores, and thus were not as highly correlated to the overall invasiveness ranking scores as other sections were. Our ranking was biased toward species that are already known or potential invaders, hence, species already recognized as having a high propensity for establishment. We anticipate that as more, possibly less threatening invasive species are ranked, the biological scores would become more normally distributed.

We found the ecological impacts section the most difficult to develop criteria for and also the most difficult to find answers for. It was challenging to select criteria for this section that were not highly correlated and inter-related to each other. In an effort to formulate questions that were independent, we focused on the impacts of the invasive species on three components of ecological systems: effects at the individual species level, impacts at the community level, and impacts (primarily abiotic) to ecosystem processes. Since little to no research has been conducted in Alaska in relation to invasive species impacts, scores for this section were generally low, and may increase as new information becomes available.

**Implications for management of non-native species in Alaska's National Forests**

Results of the Animal Invasiveness Ranking System can now be used as a decision support tool to identify those invasive species considered the most threatening. The strengths of the Animal Invasiveness Ranking System include: answers to criteria are transparent and repeatable, ranks can be updated as better information becomes available, consistent criteria were used to score all taxa, and there is flexibility in setting priorities as a result of separate section subscores and sorting mechanisms. Additionally, all species scorecards and associated justification were expert reviewed, which enabled us to capture the most up-to-date information regarding many of the species ranked.

The overall invasiveness scores are instructive, but we encourage managers and landowners to also consider the categorical ranks when using the ranking system to develop an action plan for invasive species. The categories provide managers with a list of species to consider for action with similar invasiveness traits, yet allow for greater flexibility in selection than just straight invasiveness scores.

***High Risk***

Of the 23 total species ranked, 6 (26%) scored between 100 and 79 (extremely invasive to highly invasive), suggesting these species have the highest invasiveness potential and, thus, the greatest capacity to cause harm to native species or ecosystem processes. These species have severe ecological impacts on ecosystems, and plant and animal communities. Their reproductive biology and other attributes are conducive to moderate to high rates of dispersal and establishment. These species are usually widely distributed ecologically, both among and within ecosystems. Not only do these species pose serious threats to ecosystem health, they are also generally hard to control. These include the Norway rat, northern pike, house mouse, whirling disease, New Zealand mudsnail, and zebra mussel. The latter two species do not yet occur in Alaska, but have high potential for invasion.

Norway rats are invasive worldwide and in Alaska are particularly a threat in the Aleutian Islands and islands of Southeast, where there have been multiple infestations documented on islands in the Tongass National Forest. Rats likely became established along Alaska coastal islands following shipwrecks of early European explorers (Schrader and Hennon 2005). Seaports continue to be major points of entry today (Jarrell et al. 2001). This species ranked at the top of our list because of its wide distribution, especially in northern latitudes, generalist habitat and food needs, fast reproductive rate, and ability to hitch-hike with humans to new locations. Eradication of rats is expensive, involves continual monitoring, and this species can easily be re-introduced back to areas they were previously eradicated from. It is unknown what impacts rats may be having on nesting shorebirds of forested islands and other coastal habitats in Southeast Alaska.

The northern pike is native to interior Alaska, but has been introduced throughout drainages in Cook Inlet, as well as drainages in Prince William Sound, within the Chugach National Forest. Northern pike have many characteristics of a successful invader, such as the ability to inhabit cold shallow waters, a generalist diet, and the ability to reproduce quickly. This species has significant impacts on salmon production in systems that it invades. Once an introduction spreads into interconnected bodies of water, it is virtually impossible to control or eradicate.

The house mouse is a cosmopolitan species worldwide and in Alaska is found in major human centers and on several islands. It has been documented on several islands and the mainland in the Tongass National Forest. The species is not known to occur on the Chugach National Forest, but has been documented in the nearby communities of Anchorage and Eagle River. This species ranked high because its biological characteristics are well adapted for invasion of new locations, such as a generalist diet and habitat, fast reproductive rate, and ability to spread via human transport in cargo. House mice likely have more of an impact on islands without predators, and cause moderate impacts feeding on vegetation and seabirds. Eradication of house mice is difficult, but has been successfully undertaken on several islands.

Whirling disease is widespread worldwide, and has been documented in at least 25 U.S. states. In Alaska, there has been a single detection of the parasite in rainbow trout at the Elmendorf Fish Hatchery in Anchorage (2006). Whirling disease is able to spread naturally and with the help of humans, especially in infected fish that are transported to stocked lakes. Whirling disease alternates between two obligate hosts, salmonids and oligochaete worms. In the western U.S., whirling disease has caused declines in salmonid populations, resulting in cascading changes to native fish communities. More sampling is needed in Alaska to make certain that whirling disease is absent from the state.

Of the potential invaders to Alaska, the New Zealand mudsnail is the top ranking. Potential ecological impacts associated with this species are the ability to reduce the abundance of macroinvertebrates, algae and primary producers, and thus, reduce the fitness of fish that feed on these species. In the western U.S., the New Zealand mudsnail has become the most productive taxon in numerous rivers, constituting 65-92% of the total invertebrate productivity and is responsible for causing significant changes in community composition. Eradication of this species in large water bodies is difficult and often involves eliminating many native species.

***Moderate Risk***

Oftentimes, the most problematic groups of non-native animal species are those with poorly understood and intermediate impacts and those newly arriving to the state (Carlson et al. 2008). 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 invasiveness scores. These species have substantial and apparent but generally not severe ecological impacts on ecosystems, plant and animal communities. They have the capacity for moderate to rapid expansion in natural settings, yet they are currently at low population sizes (D'Antonio and Meyerson 2002) and distribution may range from limited to widespread. This group of species is generally easier to control than species ranked as highly invasive. Thirteen (56%) of the 23 species scored between 69 and 50, and were categorized as moderately or modestly invasive. Many of these species had relatively high scores for distribution and biology but low scores for both ecology and control sections. Low scores in these two sections were attributed to lack of available data on the ecological or community effects of most species in Alaska or similar ecosystems elsewhere and the relative lack of available literature on control methods. Examples of moderately to modestly invasive species include the Atlantic salmon, Pacific oyster, yellow perch, leopard slug, and the brown-banded slug.

The impacts of moderately invasive species and those not present in Alaska are often not well understood, yet they could still affect natural systems and interfere with land management goals (Carlson et al. 2008). 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 moderate to modest risk categories to assess changes to range sizes and threats to native species and natural systems. Control measures for the majority of species classified as intermediate risk are generally not recommended. These species are generally data deficient and a more detailed understanding of their distribution and ecological role is required before effective control measures can be considered. However, if monitoring or research provides evidence of significant ecological impacts or 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 elk, red-legged frog, Pacific chorus frog, and Chinese mitten crab (potential invader). The ecological impacts of these species to natural areas and native species are generally considered minor and in most cases, invasions are localized (recognizing that localized invasions can be persistent and problematic), or in the case of potential invaders, the climate in Alaska is currently too cold for survival and reproduction. Because distribution is restricted, these species are also generally easier to control. Overall, weakly invasive species do not require as much attention as the other categories.

## Conclusion

The ranking system presented here closely compliments the Invasiveness Ranking System for Non-native Plants in Alaska (Carlson et al. 2008), which has been enormously useful in helping to set priorities for control of exotic plants within the state. We hope that the Invasiveness Ranking System for Non-native Animals in Alaska will be equally successful as a management tool to raise awareness of the threat of invasive animal species on National Forest lands and beyond, to provide information about species that have been identified as invasive or potentially invasive, to identify data gaps in our understanding, and to help set priorities for research and control efforts of invading bird, mammal, fish, amphibian, and aquatic and terrestrial invertebrate species. We also hope that use of the ranking system will increase awareness of potential vectors for introduction, which in turn, could help prevent their future spread.

Deciding which species or group of species in which areas need to be targeted for control is not easy. The invasiveness ranking system can be used as a tool to help set priorities for research and control efforts, but decisions should be based on more information than solely ranks. The ranking system provides managers and landowners with a list of species to consider for action and also provides them with sufficient information to help guide those decisions. Other considerations should include knowledge of the geographic extent of the invasion, the cost vs. effectiveness of various control scenarios, and whether or not sensitive or rare native species are impacted. The ranking system also provides managers with background information to defend a decision, should management action be recommended.

Ecological systems are highly dynamic and the distribution, abundance, and level and type of impacts for individual species will change over time and space. Thus, the ranks presented here should be viewed as a work in progress, and updated as newer information becomes available. The system can be used to rank additional invasive animal species, as many known invaders were not included in the initial ranking since the project focus was on National Forest lands. Lastly, the ranking system can be modified to meet individual agency or landowner needs by modifying the weights of the four main criteria sections.

## Acknowledgements

This project was funded by the U.S. Forest Service, Alaska Region. We are especially grateful to Michael Goldstein and Barbara Schrader, USFS, for their support and guidance throughout the duration of the project. We would also like to thank members of the Alaska Invasive Species Working Group who provided comments during the development of the ranking system. Denny Lassuy, Mary Stensvold, and Jeff Heys made particularly insightful comments that greatly improved the usefulness of the ranking system. We would like to acknowledge the contribution of Tamara Fields, who provided guidance during the framing of the ranking questions. We would also like to thank all the expert reviewers who shared valuable knowledge and comments on their species of expertise.

## Literature Cited

Beisel, J.N. 2001. The elusive model of biological invasion process: time to take differences among aquatic and terrestrial ecosystems into account? Ethology, Ecology & Evolution 13: 193-195.

Blackburn, T.M. and R.P. Duncan. 2001. Determinants of establishment success in introduced birds. Nature 414: 195-197.

Bomford, M. 1991. Importing and keeping exotic vertebrates in Australia: criteria for the assessment of risk. Bureau of Rural Resources Bulletin 12. Australian Government Publishing Service, Canberra.

Bomford, M. 2003. Risk assessment for the import and keeping of exotic vertebrates in Australia. Bureau of Rural Sciences, Canberra.

Bomford, M., F. Kraus, M. Braysher, L. Walter, and L .Brown. 2005. Risk assessment model for the import and keeping of exotic reptiles and amphibians. Bureau of Rural Sciences for the Department of Environment and Heritage, Canberra.

Bomford, M. and J. Glover. 2004. Risk assessment model for the import and keeping of exotic freshwater and estuarine finfish. Bureau of Rural Science, Canberra.

Brooks, T. 2001. Are unsuccessful avian invaders rarer in their native range than successful invaders? J.L. Lockwood and M.L. McKinney, eds. Biotic Homogenization. Kluwer Academic, New York, NY.

Brown, J.H. 1989. Patterns, modes and extents of invasion s by vertebrates. Pp. 85-109 in J.A. Drake, H.A. Mooney, F. di Castri, R.H. Groves, F.J. Kruger, M. Rejmánek, and M. Williamson, eds. Biological Invasions: a Global Perspective. John Wiley & Sons, Chichester.

Carlson, M. L., I. V. Lapina, M. Shephard, J. S. Conn, R. Densmore, P. Spencer, J. Heys, J. Riley, and J. Nielsen. 2008. Invasiveness ranking system for non-native plants in Alaska. Technical Paper R10-TP-143. USDA Forest Service, Alaska Region.

Cassey, P. 2002. Life history and ecology influences establishment success of introduced land birds. Biological Journal of the Linnaean Society 76: 465-480.

Copp, G.H., R. Garthwaite, and R.E. Gozlan. 2005. Risk identification and assessment of non-native freshwater fishes: concepts and perspectives on protocols for the UK. UK. Sci. Ser. Tech Rep., Cefas Lowestoft, 129.

D'Antonio, C.M. and L. Meyerson. Exotic species and restoration synthesis and research needs. Restoration Ecology 10: 703-713.

Davis, A.J., L.S. Jenkinson, J.H. Lawton, B. Shorrocks, and S. Wood. 1998. Making mistakes when predicting shifts in species range in response to global warming. Nature 391: 783-786.

Davis, M.A. 2009. Invasion Biology. Oxford University Press, New York, NY.

Dean, W.R.J. 2000. Alien birds in southern Africa: what factors determine success? South African Journal of Science 96: 9-14.

di Castri, F. 1991. The biogeography of Mediterranean animal invasions. Pp. 439-452 in R.H. Groves and F. di Castri, eds. Biogeography of Mediterranean Invasions. Cambridge University Press, Cambridge.

Duncan, R.P., M. Bomford, D.M. Forsyth, and L. Conibear. 2001. Correlates of introduction success and geographical range size in introduced Australian bird. Journal of Animal Ecology 70: 621-632.

Ebbert, S.E. and G.V. Byrd. 2002. Eradications of invasive species to restore natural biological diversity on Alaska Maritime National Wildlife Refuge. Pp. 102-109 In C R. Veitch and M.N. Clout (eds). Turning the tide: the eradication of invasive species. IUCN SCC Invasive Species Specialist Group. Gland, Switerland.

Eberhard, T. 1988. Introduced birds and mammals and their ecological effects. Swedish Wildlife Research Viltrevy 13: 1-107.

Ehrlich, P.R. 1989. Attributes of invaders and the invading process: vertebrates. Pp 315-328 in J.A. Drake, H.A. Mooney, F. di Castri, R.H. Grooves, F.J. Kruger, M. Rejmanek, and M.W. Williamson, eds. Biological Invasions. A Global Perspective. John Wiley and Sons, Chichester.

Executive Order 13112. 1999 Feb. 3. Invasive Species. http://www.invasivespecies.gov/laws/execorder.shtml. Accessed 10 January 2007.

Fay, V. 2002. Alaska aquatic nuisance species management plan. Alaska Department of Fish and Game, Juneau, AK.

Forsyth, D.M., R.P. Duncan, M. Bomford, and G. Moore. 2004. Climatic suitability, life-history traits, introduction effort and the establishment and spread of introduced mammals in Australia. Conservation Biology 18: 557-569.

Gherardi, F. 2007. Biological invasions in inland waters: an overview. Pp. 3-25 in F. Gherardi, ed. Biological invaders in inland water: profiles, distribution and threats. Invading Nature: Springer Series in Invasion Ecology, volume 2. J.A. Drake, series ed. Springer, Dordrecht, Netherlands.

Griffith, B., J.M. Scott, J.W. Carpenter, and C. Reed. 1989. Translocation as a species conservation tool: status and strategy. Science 245: 477-480.

Heffernan, K. E., P. P. Coulling, J. F. Townsend, and C. J. Hutto. 2001. Ranking invasive exotic plant species in Virginia. Natural Heritage Technical Report 01-13. Virginia Department of Conservation and Recreation, Division of Natural Heritage, Richmond, VA.

Hiebert, R. D. and J. Stubbendieck. 1993. Handbook for ranking exotic plants for management and control. Natural Resources Report NPS/NRMWRO/NRR-93/08. U.S. Department of Interior National Park Service, Denver, CO.

Jarrell, G.H., S.O. MacDonald and J.A. Cook. 2001. Checklist of Mammals of Alaska. University of Alaska.

Javis, P.J. 1980. The biogeography and ecology of introduced species. Department of Geography, University of Birmingham Working Paper Series No. 1: 1-40.

Keller, R.P. and D.M. Lodge. 2007. Species invasions from commerce in live aquatic organisms: problems and possible solutions. Bioscience 57: 428-436.

Kinlan, B.P. and A. Hastings. 2005. Rates of population spread and geographic range expansion. What species tell us. Pp. 381-419 in D.F. Sax, J.J. Stachowicz, and S.D. Gaines, eds. Species Invasions. Insights into Ecology, Evolution, and Biogeography. Sinauer Associates, Inc. Publishers, Sunderland, MA.

Kolar, C.S. and D.M. Lodge. 2001. Progress in invasion biology: predicting invaders. Trends in Ecology and Evolution 16: 199-204.

Kolar, C.S. and D.M. Lodge. 2002. Ecological predictions and risk assessment for alien fishes in North America. Science 298: 1233-1236.

Kurle, C.M., D.A. Croll, and B.R. Tershy. 2008. Introduced rats indirectly change marine rocky intertidal communities from algae- to invertebrate-dominated. PNAS 105: 3800-3804.

Lidicker, W.Z. 1991. Introduced mammals in California. Pp. 263-271 in R.H. Groves and F. di Castri, eds. Biogeography of Mediterranean Invasions. Cambridge University Press, Cambridge.

Lockwood, J.L., M.F. Hoopes, and M.P. Marchetti. 2007. Invasion Ecology. Blackwell Publishing, Malden, MA.

Lodge, D.M. 1993. Biological invasions: lessons for ecology. Trends in Ecology and Evolution 8: 113-137.

Long, J.L. and P.R. Mawson. 1991. Species of introduced birds in Mediterranean Australia. Pp. 365-375 in R.H. Groves and F. di Castri, eds. Biogeography of Mediterranean Invasions. Cambridge University Press, Cambridge.

MacDonald, S.O. 2003. The amphibians and reptiles of Alaska: a field handbook. Available at: http://www.alaskaherps.info. (Last accessed 20 November 2009).

Mack, R.N. 1996. Predicting the identity and fate of plant invaders: emergent and emerging properties. Biological Conservation 78: 107-121.

Major, H.L. and I.L. Jones. 2005. Distribution, biology, and prey selection of the introduced Norway rat *Rattus norvegicus* at Kiska Island, Aleutian Islands, Alaska. Pacific Conservation Biology 11: 105-113

Marchetti, M.P., P.B. Moyle, and R. Levine. 2004. Invasive species profiling? Exploring the characteristics of non-native fishes across invasion stages in California. Freshwater Biology 49: 646-661.

Maron, J.L., J.A. Estes, D.A. Croll, E.M. Danner, S.C. Elmendorf, and S.L. Buckelew. 2006. An introduced predator alters Aleutian Island plant communities by thwarting nutrient subsides. Ecological Monographs 76: 3-24.

Mayr, E. 1965. Summary. Pp. 553-563 in H.G. Baker and G.L. Stebbins, eds. The Genetics of Colonizing Species. Academic Press, New York, NY.

McClory, J. and T. Gotthardt. 2008. Non-native and invasive animals of Alaska: A comprehensive list and select species status reports. Prepared for the Alaska Department of Fish and Game, Invasive Species Program. Alaska Natural Heritage Program, University of Alaska Anchorage, Anchorage , AK.

Morse, L. E., J. M. Randall, N. Benton, R. Hiebert, and S. Lu. 2004. An invasive species assessment protocol: evaluating non-native plants for their impact on biodiversity. Version 1. NatureServe, Arlington, VA.

Myers, N. 1997. Global biodiversity II: Losses and threats. G. K. Meffe and C. R. Carroll, eds . Principles of Conservation Biology. Sinauer Associates, Sunderland, MA.

NatureServe. 2006. Conservation Issues: Invasive species. http://www.natureserve.org/consIssues/invasivespecies.jsp. Accessed 20 March 2007.

Nix, H. and A.J. Waphere. 1986. Origins of invading species. Pp. 155 in R.H. Groves and J.J. Burdon, eds. Ecology of Biological Invasions: An Australian Perspective. Australian Academy of Science, Canberra.

O'Connor, R.J. 1986. Biological characteristics of invaders among bird species in Britain. Philosophical Transactions of the Royal Society, London B 314: 583-598.

Pauchard, A. and K. Shea. 2006. Integrating the study of non-native plant invasions across spatial scales. Biological Invasions 8: 399-413.

Pheloung, P.C. 1996. CLIMATE: a system to predict the distribution of an organism based on climate preference. Agriculture Western Australia, Perth.

Pheloung, P.C., P.A. Williams, and S.R. Halloy. 1999. A weed risk assessment model for use as a biodiversity tool evaluating plant introduction. Journal of Environmental Management 57: 239-251.

Pimm, S. L. and M. E. Gilpin. 1989. Theoretical issues in conservation biology. J. Roughgarden, R. May, and S. A. Levin, eds. Perspectives in Ecological Theory. Princeton Univerity Press, Princeton, NJ.

Robertson, M.P., M.H. Villet, D.H.K. Fairbanks, L. Henderson, S.I. Higgins, J.H. Hoffman, D.C. Le Mairte, A.R. Palmer, I. Riggs, C.M. Shackleton, and H.G. Zimmermann. 2003. A proposed prioritization system for the management of invasive alien plants in South Africa. South African Journal of Science 99: 1-7.

Ruiz, G.M. and J.T. Carlton. 2003. Invasion vectors: a conceptual framework for management. Pp. 459-504 in G.M. Ruiz and J.T. Carlton, eds. Invasive Species: Vectors and Management Strategies. Island Press, Washington, D.C.

Sakai, A.K., F.W. Allendorf, J.S. Holt, D.M. Lodge, J. Molofsky, K.A. With, S. Baughman, R.J. Cabin, J.E. Cohen, N.C. Ellstrand, D.E. McCauley, P. O'Neil, I.M. Parker, J.N. Thompson, and S.G. Weller. 2001. The population biology of invasive species. Annual Review of Ecology and Systematics 32: 305-332.

Schrader, B. and P. Hennon. 2005. Assessment of Invasive Species in Alaska and its National Forests. U.S. Forest Service, Alaska Region.

Shine, S., N. Williams, and L. Gundlings. 2000. A guide to designing legal institutional frameworks on alien invasive species. IUCN, Gland, Switzerland, Cambridge and Bonn.

Sol, D. and L. Lefebvre. 2000. Behavioural flexibility predicts invasion success in birds introduced to New Zealand. Oikos 90: 599-605.

Stein, B., L. Kutner, and J. Adams. 2000. Precious heritage: the status of biodiversity in the United States. Oxford University Press, Oxford.

Swincer, D.E. 1986. Physical characteristics of sites in relation to invasions. Pp 67-76 in R.H. Groves and J.J. Burdon, eds. Ecology of Biological Invasions: An Australian Perspective. Australian Academy of Science, Canberra.

Union of Concerned Scientists (UCS). 2005. Invasive species: Alaska. Available online at: http://www.ucsusa.org/invasive_species/state-invasion-portfolios.html.

U.S. Congress, Office of Technology Assessment. 1993. Harmful non-indigenous species in the United States. OTA-F-565. U.S. Government Printing Office, Washington, D.C.

Vermeij, G.J. 2005. Invasion as expectation: a historical fact of life. Pp. 315-339 in D.F. Sax, J.J. Stachowicz, and S.D. Gaines, eds. Species Invasions: Insights into Ecology, Evolution and Biogeography. Sinauer Associates, Inc., Sunderland, MA.

Warner, P.J., C.C. Bossard, M.L. Brooks, J.M. DiTomaso, J.A. Hall, A.M. Hawald, D.W. Johnson, J.M. Randall, C.L. Roye, M.M. Ryan, and A.E. Stanton. 2003. Criteria for categorizing invasive non-native plants that threaten wildlands. California Exotic Pest Plant Council and Southwest Vegetation Management Association.

Williamson, M. 1996. Biological Invasions. Chapman & Hall, London.

Williamson, M. 1999. Invasions. Ecography 22: 5-12.

# Appendices

## Appendix I: Blank Invasiveness Ranking Template

### Alaska Invasive Animal Ranking Form

Scientific name:
Common name:
Assessor(s):
Reviewer(s):
Date:

Present in Alaska: Yes or No

**Ranking Summary**

| Category | Weight (%) | Potential Max[1] | Actual Score |
|---|---|---|---|
| Distribution | 30 | | |
| Biological characteristics | 30 | | |
| Ecological impacts | 30 | | |
| Feasibility of control | 10 | | |
| | **Total** | b | a |
| | **Invasiveness Score [2]** | | |

[1] For questions answered as "unknown" do not include point value for that question in section total.
[2] Relative maximum score, calculated as a/b × 100 when there are no unknowns. If there are unknowns take actual score divided by potential max for each section than multiple by weighting factor for that section. Then add up all sections to get overall invasiveness score.

**Alaska Invasion/Introduction History:**

| **1. Distribution** | **Score** |
|---|---|
| **1.1. Current global distribution (includes current invasive and native range).** | |
| 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. | |

**Documentation**
Justification:

| **1.2. Extent of the species US range and/or occurrence of formal state or provincial listings.** | |
|---|---|
| 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. | |

**Documentation**
Justification:

**1.3. Role of anthropogenic and natural disturbance in establishment.**

| | |
|---|---|
| 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. | |

**Documentation**
Justification:

**1.4. Climatic similarity between site of origin and release.**

| | |
|---|---|
| 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. | |

**Documentation**
Justification:

| | |
|---|---|
| **Total Possible** | |
| **Total** | |

## 2. Biological characteristics and dispersal ability — Score

**2.1. Invasive elsewhere?**

| | |
|---|---|
| a. No, not invasive in areas outside of Alaska. | 0 |
| b. Yes, invasive in areas outside of Alaska. | 5 |
| u. Unknown. | |

**Documentation**
Justification:

**2.2. Dietary specialization.**

| | |
|---|---|
| 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. | |

**Documentation**
Justification:

**2.3. Habitat specialization.**

| | |
|---|---|
| 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. | |

**Documentation**
Justification:

**2.4. Average number of reproductive events (e.g. clutches, litters) per female per year.**

| | |
|---|---|
| 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. | |

**Documentation**
Justification:

**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).**

| | |
|---|---|
| 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. | |

**Documentation**
Justification:

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

| | |
|---|---|
| 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. | |

**Documentation**

Justification:

**2.7. Terrestrial or aquatic species.** **No point value**

a. Terrestrial.
b. Aquatic.
u. Unknown.

**Documentation**
Justification:

| | |
|---|---|
| **Total Possible** | |
| **Total** | |

## 3. Ecological impacts

| | Score |
|---|---|
| **3.1. Impact on population dynamics of other species, including animal, fungi, plant, microbe, and other organisms.** | |
| 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 threatened 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. | |

**Documentation**
Justification:

| | |
|---|---|
| **3.2. Impact on natural community composition.** | |
| 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. | |

**Documentation**
Justification:

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

| | |
|---|---|
| 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. | |

**Documentation**

Justification:

| | |
|---|---|
| **Total Possible** | |
| **Total** | |

## 4. Feasibility of control

**Score**

**4.1. Number and extent of populations in Alaska.**

| | |
|---|---|
| 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. | |

**Documentation**

Justification:

**4.2. Significance (economic and conservation value) of the natural areas and native species threatened.**

| | |
|---|---|
| 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. | |

**Documentation**

Justification:

**4.3. General management difficulty.**

| | |
|---|---|
| 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. | |

**Documentation**

Justification:

| | |
|---|---|
| **Total Possible** | |
| **Total** | |
| **Total Possible for all sections** | |
| **Total for all sections** | |

## References

## Appendix II: List of expert reviewers

| Common name | Scientific name | Expert reviewer(s) and affiliation |
|---|---|---|
| Atlantic salmon | *Salmo salar* | None |
| Brown-banded slug | *Arion circumscriptus* | Robert Forsyth, Royal BC Museum |
| Chinese mitten crab | *Eriocheir sinensis* | Matthias Herborg, BC Ministry of Government; Robyn Draheim, Portland State University |
| Dusky slug | *Arion subfuscus* | Robert Forsyth, Royal BC Museum |
| Elk | *Cervus elaphus* | Larry van Daele, Alaska Department of Fish and Game |
| European black slug | *Arion ater* | Robert Forsyth, Royal BC Museum |
| European green crab | *Carcinus maenas* | Matthias Herborg, BC Ministry of Government |
| House mouse | *Mus musculus* | Gary Witmer, USDA National Wildlife Research Center, Fort Collins |
| Leopard slug | *Limax maximus* | Robert Forsyth, Royal BC Museum |
| New Zealand mud snail | *Ptoamopyrgus antipodarum* | Robert Hall, University of Wyoming |
| Northern pike | *Esox lucius* | Kristine Dunker, Alaska Department of Fish and Game |
| Norway rat | *Rattus norvegicus* | Stephen MacLean, The Nature Conservancy |
| Pacific chorus frog | *Pseudacris regilla* | Lisa Hallock, Washington Natural Heritage Program |
| Pacific oyster | *Crassostrea gigas* | Jennifer Ruesink, University of Washington |
| Red swamp crayfish | *Procambarus clarkia* | James Fetzner Jr., Carnegie Museum of Natural History |
| Red-legged frog | *Rana aurora* | Lance Lerum, U.S. Forest Service |
| Rock dove | *Columba livia* | Rick Sinnott, formerly with Alaska Department of Fish and Game |
| Signal crayfish | *Pacifastacus leniusculus* | Theo Light, Shippensburg University;  James Fetzner Jr., Carnegie Museum of Natural History |
| Spiny water flea | *Bythotrephes longimanus* | Norman Yan, York University |
| Starling | *Sturnus vulgaris* | Rick Sinnott, formerly with Alaska Department of Fish and Game |
| Whirling disease | *Myxobolus cerebralis* | Barry Nehring, Colorado Division of Wildlife; Jerri Bartholomew, Oregon State University |
| Yellow perch | *Perca flavescens* | None |
| Zebra mussel | *Dreissena polymorpha* | Hugh MacIssac, Great Lakes Institute for Environmental Research; Dianna Padilla, State University of New York Stony Brook |

**Scientific name: *Rattus norvegicus*** **Common name: Norway rat**

**Alaska invasion/introduction history**

Norway rats spread to the Aleutian Islands and the Alaska Maritime National Wildlife Refuge on cargo ships during WWII (Murie 1959, Ebbert and Byrd 2002).

| Ranking Summary | | |
|---|---|---|
| | Potential Max | Score |
| Distribution | 30 | 30 |
| Biological Characteristics | 30 | 25 |
| Ecological Impact | 30 | 27 |
| Feasibility of Control | 10 | 9 |
| Total | 100 | 91 |
| **Invasiveness (out of 100) =** | 91 **Extremely invasive** | |

| **Distribution** | **Score** |
|---|---|
| *Current global distribution (0-10)* | 10 |

The Norway rat is native to Asia, but introduced worldwide, and is more common in cold climates (Kucheruk 1990, Nagorsen 1990).

*Extent of the species US range and/or occurrence of formal state or provincial listings (0-10)* 10

Norway rats are invasive in all U.S. states and the majority of the Canadian provinces and territories (Patterson 2003, Nature Serve 2009).

*Role of anthropogenic and natural disturbance in establishment (0-5)* 5

This species is typically commensal with humans and readily establishes in urban areas (Vignieri 2009). However, once introduced, Norway rats establish in undisturbed habitats on islands and along beaches (MacDonald and Cook 2009).

*Climatic similarity between site of origin and release (0-5)* 5

Norway rats are more common in cold climates and occur in northern latitiudes with similar climatic zones to those found in Alaska (Kucheruk 1990, MacDonald and Cook 2009).

Total for distribution 30 /30

| **Biological Characteristics and Dispersal** | **Score** |
|---|---|
| *Invasive elsewhere (0-5)* | 5 |

Norway rats are invasive worldwide (Nagorsen 1990).

*Dietary specialization (0-5)* 5

Norway rats are omnivorous, eating a wide variety of plant and animal material (Johnson 2008). Rats prey on nesting birds (adults, nestlings, and eggs), intertidal invertebrates, seeds, berries, other plant parts, and food scrapes left by humans (Landry 1970, Moors 1990, Drever and Harestad 1998, Major et al. 2006, Johnson 2008).

*Habitat specialization (0-5)* 5

Norway rats nest in burrows, which can be created in the ground, trees, rock piles, buildings, and natural cervices (Johnson 2008). These rats are often commensal with humans and can easily find suitable habitats in urban areas (Johnson 2008, Vignieri 2009).

*Average number of reproductive events per adult female per year (0-5)* 5

Females have 3-6 litters per year, with 2-13 offspring (average of 7 offspring) per litter (Vignieri 2009).

*Potential to be spread by human activities (0-5)* 5

Norway rats hitch-hike to new locations on ships and airplanes via physically walking aboard and by hiding in cargo (Fritts 2007, Johnson 2008). Norway rats are commensal with humans, so as fisheries, tourism, and the human populations increase in Alaska, chances for accidental introduction of rats from increased human traffic rises (Ebbert and Byrd 2002).

*Innate potential for long distance dispersal (0-5)* 0

Norway rats do not have any mechanisms for long distance dispersal, limited by daily movements of up to several kilometers on land and several hundred meters in water (Taylor et al. 2000, NatureServe 2009).

Total for biological characteristics 25 / 30

| **Ecological Impact** | **Score** |
|---|---|
| *Impact on population dynamics of other species (0-10)* | 10 |

Norway rats are known to severly reduce or extirpate native ground nesting seabirds, burrow nesting seabirds, and shorebirds (storm petrels, puffins, auklets, gulls, Black Oystercatchers, and Rock Sandpipers) by feeding on individual birds and disturbing nesting adults (Ebbert and Byrd 2002, Major and Jones 2005, Kurle et al. 2008).

*Impact on natural community composition (0-10)* 10

Norway rats reduce the biodiversity of insular avifauna by greatly reducing and/or extirpating many ecologically important bird species (Ebbert and Byrd 2002, Major and Jones 2005, Kurle et al. 2008). Additionally, Norway rats provide supplemental prey to introduced foxes which also prey on native bird species (Ebbert and Byrd 2002). Indirectly, Norway rats impact marine intertidal communities by reducing the densities of intertidal foraging birds, which in turn shifts the intertidal community from algae to invertebrate dominated because the marine herbivores are released from predation (Kurle et al. 2008). Additionally, a reduction in seabirds may reduce the nutrient flow into terrestrial soils, thus impacting below-ground invertebrate communities (Towns et al. 2009).

*Impact on natural ecosystem processes (0-10)* 7

The indirect impact of Norway rats changing marine rocky intertidal communities can cascade to changes in ecosystem processes (Kurle et al. 2008, Simberloff 2009). Marine birds connect the marine and terrestrial communities and ecosystems, and as bird densities decrease, the productivity changes as invertebrates (not algae) dominate intertidal communities (Kurle et al. 2008). A reduction in birds means a reduction in guano inputs into terrestrial and marine ecosystems, resulting in a change to the nutrient cycling of the ecosystem (Kurle et al. 2008). The reduction of nutrients from seabirds can cause changes in soil fertility, which in turn impacts belowground organisms (Fukami et al. 2006).

Total for ecological impact 27 /30

| Feasibility of control | Score |
|---|---|

*Number of populations in Alaska (0-3)* 2

Populations of Norway rats are on many Aleutian Islands and in southeast Alaska (MacDonald and Cook 2009).

*Significance of the natural area(s) and native species threatened (0-3)* 3

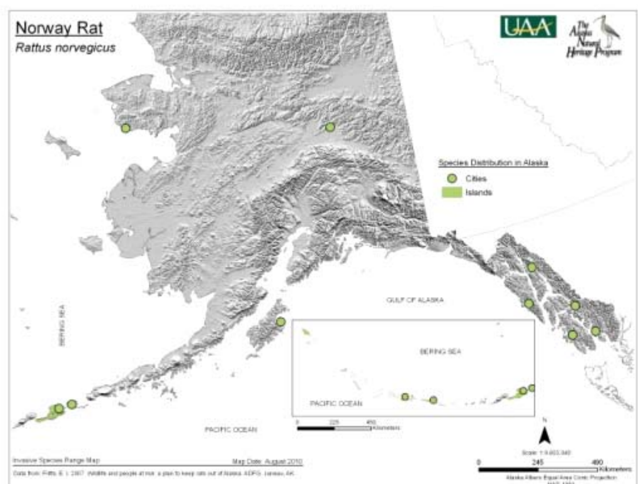
The insular communities that Norway rats invade are often refuges and source populations for large colonies of birds, such as the Least Auklet and Ancient Murrelet (Bertram 1995, Major and Jones 2005). Predation by invasive species is the second highest cause (after habitat destruction) of the endangerment, extirpation, and extinction of island birds, which places a high conservation value on Alaskan insular avifauna communities (King 1985).

*General management difficulty (0-4)* 4

Eradication of rats on islands is expensive (Ebbert and Byrd 2002) and involves continued monitoring, but is possible and has been done on many islands (Taylor et al. 2000, Fritts 2007, Howald et al. 2007). The following are prevention and control methods that are possible in Alaska. To prevent new introductions, public education events have been held to spread awareness, and bait and trap stations (often referred to as "rat spill") are set up at ports to catch rats as they arrive from docking and shipwrecked vessels. Also, rodenticides are used in some communities (Fritts 2007). Removing clutter off the ground of ports by relocating objects that create shelter and concealed transport corridors for rats (e.g., old crate material, excess shrubs), is an inexpensive way to prevent and control rats (Johnson 2008).

Total for feasibility of control 9 / 10

**Range Map**




**References**

Bertram, D.F. 1995. The role of introduced rats and commercial fishing in the decline of ancient murrelets on Langara Island, British Columbia. Conservation Biology 9: 865-872.

Drever, M.C. and A.S. Harestad. 1998. Diets of Norway Rat, Rattus norvegicus, on Langara Island, Queen Charlotte Islands, British Columbia: implications for conservation of breeding seabirds. Canadian Field Naturalist 112: 676-683.

Ebbert, S.E. and G.V. Byrd. 2002. Eradications of invasive species to restore natural biological diversity on Alaska Maritime National Wildlife Refuge. Pp. 102-109 in Turning the tide: the eradication of invasive species. C.R. Veitch and M.N. Clout (eds). IUCN SCC Invasive Species Specialist Group. Gland, Switzerland.

Fritts, E.I. 2007. Wildlife and people at risk: a plan to keep rats out of Alaska. Alaska Department of Fish and Game, Juneau, Alaska. 190 p.

Fukami, T., D.A. Wardle, P.J. Bellingham, C.P.H Mulder, D.R. Towns, G.W. Yeates, K.I. Bonner, M.S. Durrett, M.N. Grant-Hoffman, and W.M. Williamson. 2006. Above- and below-ground impacts of introduced predators in seabird-dominated island ecosystems. Ecology Letters 9: 1299-1307.

Howald, G., C. J. Donlan, J. P. Galvan, J. C. Russell, J. Parkes, A. Samaniego, Y. Wang, D. Veitch, P. Genovesi, M. Pascal, A. Saunders, and B. Tershy. 2007. Invasive rodent eradication on islands. Conservation Biology 21: 1258-1268.

Johnson, T. 2008. Rat control for Alaska waterfront facilities. Alaska Sea Grant College Program, University of Alaska Fairbanks, Fairbanks, Alaska.

King, W. B. 1985. Island birds: Will the future repeat the past? Pp. 3-15 in Conservation of Island Birds. P J. Moors(ed). International Council for Bird Preservation Technical Publication, no. 3. International Council for Bird Preservation, Cambridge, United Kingdom.

Kucheruk, V.V. 1990. Areal [Range]. In Seraya krysa: Sistematika, ekologiya, reguliatsiya chislennosti [Norway rat: systematics, ecology, and population control]. V.E. Sokolov and E.V. karasjova (eds). Nauka, Moscow. P. 34-84. (in Russian).

Kurle, C.M., D.A. Croll, and B.R. Tershy. 2008. Introduced rats indirectly change marine rocky intertidal communities from algae- to invertebrate-dominated. PNAS 105: 3800-3804.

Landry, S.O. Jr. 1970. The rodentia as omnivores. The Quarterly Review of Biology 45: 351-372.

MacDonald, S.O. and J.A. Cook. 2009. Recent mammals of Alaska. University of Alaska Press, Fairbanks, Alaska.

Major, H.L. and I.L. Jones. 2005. Distribution, biology, and prey selection of the introduced Norway rat Rattus norvegicus at Kiska Island, Aleutian Islands, Alaska. Pacific Conservation Biology 11: 105-113.

Major, H. L., I. L. Jones, M. R. Charette, and A. W. Diamond. 2006. Variations in the diet of introduced Norway rats (Rattus norvegicus) inferred using stable isotope analysis. Journal of Zoology 271: 463-468.

Moors, P.J. 1990. Norway Rat. Pp. 192-206 in The Handbook of New Zealand Mammals. C.M. King (ed). Oxford University Press, Auckland.

Murie, O.J. 1959. Fauna of the Aleutian Islands and Alaska Penninsula. North American Fauna, Volume 61. US Fish and Wildlife Service, Washington D.C.

Nagorsen, D.W. 1990. The mammals of British Columbia: A taxonomic catalogue. Memoir No. 4, Royal British Columbia Museum.

NatureServe. 2009. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. (Accessed: October 22, 2009 ).

Patterson, B.D., G. Ceballos, W. Sechrest, M.F. Tognelli, T. Brooks, L. Luna, P. Ortega, I. Salazar, and B.E. Young. 2003. Digital Distribution Maps of the Mammals of the Western Hemisphere, version 1.0. NatureServe, Arlington, Virginia, USA.

Simberloff, D. 2009. Rats are not the only introduced rodents producing ecosystem impacts on islands. Biological Invasions 11: 1735-1742.

Taylor, R.H., G.W. Kaiser and M.C. Drever. 2000. Eradication of Norway rats for recovery of seabird habitat on Langara Island, British Columbia. Restoration Ecology 8: 151-160.

Towns, D. R., D. A. Wardle, C. P. H. Mulder, G. W. Yeates, B. M. Fitzgerald, G. R. Parrish, P. J. Bellingham, and K. I. Bonner. 2009. Predation of seabirds by invasive rats: multiple indirect consequences for invertebrate communities. Oikos 118: 420-430.

Vignieri, S.N. 2009. Black rat Rattus rattus, Norway rat Rattus norvegicus. Pp. 184-185 in Invasive Species in the Pacific Northwest. P.D. Boersma, S.H. Reichard, and A.N. Van Buren (eds). University of Washington Press, Seattle, Washington.

## Acknowledgements

*Authors:* K. M. Walton and T. A. Gotthardt, Alaska Natural Heritage Program, University of Alaska Anchorage.

*Reviewer(s):* Stephen MacLean, The Nature Conservancy.

**Scientific name: *Esox lucius*** **Common name: Northern pike**

**Alaska invasion/introduction history**

Northern pike are native to watersheds in Bristol Bay and north and west of the Alaska range. Pike were illegally transported to Bulchitna Lake (Yenta drainage) in the 1950s, to Derk's Lake (Soldotna Creek drainage) in the 1970s, into Anchorage lakes in the late 1980s or early 1990s, and into the Yakutat "village pond system" (SANPCC 2007). In the summer of 2010, northern pike were reported in Hall Lake near Soldotna (Cella 2010).

| Ranking Summary | | |
|---|---|---|
| | Potential Max | Score |
| Distribution | 30 | 30 |
| Biological Characteristics | 30 | 18 |
| Ecological Impact | 30 | 27 |
| Feasibility of Control | 10 | 9 |
| Total | 100 | 84 |
| **Invasiveness (out of 100) =** | 84 **Extremely invasive** | |

| Distribution | Score |
|---|---|
| *Current global distribution (0-10)* | 10 |

Northern pike occur in North America, Europe, Asia, and Africa (Crossman 1979, Welcomme 1988, Lever 1996).

*Extent of the species US range and/or occurrence of formal state or provincial listings (0-10)* 10

Northern pike occur in watersheds outside of its native range in at least 38 states (SANPCC 2007) and is native in at least 15 states and 11 provinces/ territories (NatureServe 2009).

*Role of anthropogenic and natural disturbance in establishment (0-5)* 5

Northern pike were illegally introduced in disturbed and undisturbed lakes for sport fishing and have spread to numerous pristine lakes and through connected water bodies via rivers, streams, and sloughs (SANPCC 2007).

*Climatic similarity between site of origin and release (0-5)* 5

Northern pike naturally inhabit cold waters (SANPCC 2007). The sites of release have similar climates to region in the northern pike's native range north of the Alaska Range, in the Ahrnklin River drainage (Mecklenburg et al. 2002), and throughout Canada.

Total for distribution 30 /30

| Biological Characteristics and Dispersal | Score |
|---|---|
| *Invasive elsewhere (0-5)* | 5 |

Northern pike are invasive in watersheds in at least 38 states (SANPCC 2007), in Spain, Portugal, Ireland, and six African countries (Welcomme 1988, Lever 1996).

*Dietary specialization (0-5)* 5

Northern pike are opportunistic predators, primarily feeding on other fish, but have been known to feed on invertebrates, amphibians, and small vertebrates, such as waterfowl, mice, and muskrats (Solman 1945, Scott and Crossman 1973, Morrow 1980, Mecklenburg et al. 2002, Pierce et al. 2003, SANPCC 2007).

*Habitat specialization (0-5)* 2

Northern pike require shallow water with emergent vegetation and a muddy bottom covered in aquatic vegetation mats for spawning (Inskip 1982). The remainder of the time, northern pike can utilize a variety of habitats where prey is available (Chapman and Mackay 1984) and can use less desirable habitats as travel corridors to disperse to more favorable spawning locations (K. Dunker pers. comm.).

*Average number of reproductive events per adult female per year (0-5)* 0

Females spawn once per year and can lay 2,000-600,000 eggs (Morrow 1980).

*Potential to be spread by human activities (0-5)* 3

Humans primarily spread northern pike by illegally stocking fish in lakes (SANPCC 2007).

*Innate potential for long distance dispersal (0-5)* 3

Northern pike primarily migrate between spawning and nonspawning habitats; however, a study on the Minto Flats found 36% of fish observed moved >16 km during one summer (Cheney 1971 in Morrow 1980). Once introduced to an open system, northern pike often spread on their own in pursuit of prey and more favorable spawning habitat (K. Dunker pers. comm.).

Total for biological characteristics 18 / 30

| Ecological Impact | Score |
|---|---|
| *Impact on population dynamics of other species (0-10)* | 10 |

Numerous lakes in the Northern Cook Inlet

Management Area, Kenai Peninsula, and southeast Alaska that contained healthy populations of native fish, including valuable salmon, are now pike dominated and the abundance of those native fish populations has substantially decreased or been eliminated (SANPCC 2007). A weakly armoured population of threespine stickleback in Prator Lake, Alaska, went extinct after the introduction of northern pike (Patankar et al. 2006).

*Impact on natural community composition (0-10)* 10

Northern pike has destroyed fish communities in many lakes because of its ability to prey upon all the native fish present. Diversity is reduced, with lakes becoming pike dominated (SANPCC 2007).

*Impact on natural ecosystem processes (0-10)* 7

The loss of salmon species in lakes causes a loss of nutrient inputs from decaying carcasses and an overall reduction in ecosystem productivity (SANPCC 2007).

| Total for ecological impact | 27 /30 |
|---|---|

| Feasibility of control | Score |
|---|---|

*Number of populations in Alaska (0-3)* 3

Numerous populations are found in open and closed lake systems in the Matanuska-Susitna Valley, Anchorage, parts of the Kenai Peninsula, and parts of Yakutat (Yakutat population was eradicated in 2008/2009; Schrader and Hennon 2005). In the summer of 2010, northern pike were found in Hall Lake, an open lake system connected to the Kenai River near Soldonta (Cella 2010).

*Significance of the natural area(s) and native species threatened (0-3)* 3

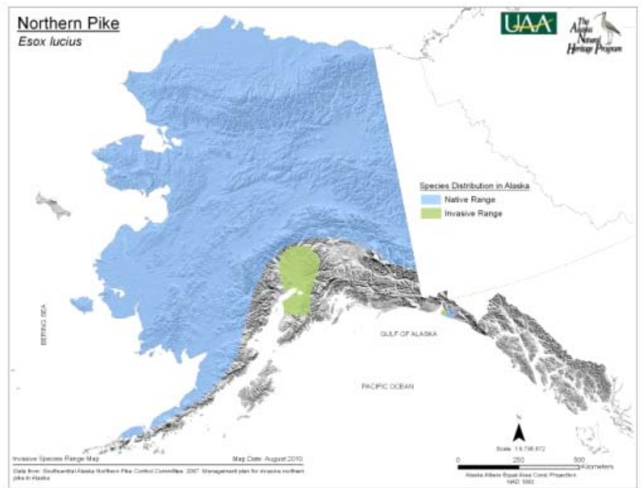
The Alaska Department of Fish and Game spends substantial amounts of money stocking lakes with rainbow trout to reduce angling pressure on native stocks (ADF&G 2006). Northern pike consume rainbow trout, jeopardizing stocking investments (Hyvarinen and Vehanen 2004, SANPCC 2007). Northern pike also consume native species, which reduce populations of value to commercial, personal use, sport, and subsistence fisheries (SANPCC 2007).

*General management difficulty (0-4)* 3

The large extent of lakes inhabited by northern pike makes total eradication a large undertaking, especially in open systems where eradication would impact other species. Eradication of individual populations in Alaska has been successful using rotenone, and more eradications are planned. Current management techniques also focus on preventing further introduction and movement of pike through public education and increasing bag limits to reduce the number of pike in certain lakes (SANPCC 2007).

| Total for feasibility of control | 9 / 10 |
|---|---|

**Range Map**




**References**


Alaska Department of Fish and Game (ADF&G). 2006. Statewide Stocking Plan for Recreational Fisheries. Alaska Department of Fish and Game, Division of Sport Fisheries. 125 p.

Cella, T. 2010. Invasive fish threaten Kenai: Fish and Game biologists discover northern pike in Hall Lake. Peninsula Clarion, Monday August 16, 2010.

Chapman, C. A. and W. C. Mackay. 1984. Direct observations of habitat utilization by northern pike. Copeia, 1984 225-258.

Crossman , E. J. 1979. Esox lucius, Northern Pike. Pp. 133 134 in Lee, D.S., C.R. Gilbert, C.H. Hocutt, R.E. Jenkins, D.E. McAllister and J.R. Stauffer, Jr. 1980. Atlas of North American Freshwater Fishes. North Carolina State Museum of Natural History. Raleigh, N.C. 854 p.

Hyvarinen, P., and T. Vehanen. 2004. Effect of brown trout body size on post-stocking survival and pike predation. Ecology of Freshwater Fish 13: 77-84.

Inskip, P. D. 1982. Habitat suitability index model: northern pike. U.S. Dept. Int., Fish and Wildlife Service, FWS/OBS-82/10.17. 40 p.

Lever, C. 1996. Naturalized fishes of the world. Academic Press, California. 408 p.

Mecklenburg, C.W., T.A. Mecklenburg, and l.K. Thorstein. 2002. Fishes of Alaska. American Fisheries Society. Bethesda, MD. 1037 p.

Morrow, J.E. 1980. The freshwater fishes of Alaska. Alaska Northwest Publishing Co., Anchorage, AK. 248 p.

NatureServe. 2009. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. Accessed: 6 October 2009.

Patankar, R., F.A. Von Hippel, and M.A. Bell. Extinction of a weakly armoured threespine stickleback (Gasterosteus aculeatus) population in Prator Lake, Alaska. Ecology of Freshwater Fish 15: 482-487.

Pierce, R. B., C. M. Tomcko, and M. T. Drake. 2003. Population dynamics, trophic interactions and production of northern pike in a shallow bog lake and their effects on simulated regulation strategies. North American Journal of Fisheries Management 23: 323-330.

Southcentral Alaska Northern Pike Control Committee (SANPCC). 2007. Management plan for invasive northern pike in Alaska. Alaska Department of Fish and Game, Sport Fish Division, Anchorage, AK.

Schrader, B. and P. Hennon. 2005. Assessment of invasive species in Alaska and its national forests. US Forest Service report.

Scott, W. B. and E. J. Crossman. 1973. Freshwater Fishes of Canada. Department of Fisheries and Oceans Scientific Information and Publications Branch. Ottawa, Canada. 966 p.

Solman, V. E. 1945. The ecological relations of pike, Esox Lucius L., and waterfowl. Ecology 26: 157-170.

Welcomme, R. L. 1988. International Introductions of Inland Aquatic Species. FAO Fisheries Technical Paper No.294. Food and Agriculture Organization of the United Nations, Rome, Italy. 318 p.

## Acknowledgements

*Authors:* K. M. Walton and T. A. Gotthardt, Alaska Natural Heritage Program, University of Alaska Anchorage.

*Reviewer(s):* Kristine Dunker, Alaska Department of Fish and Game

**Scientific name: *Myxobolus cerebralis*** **Common name: Whirling disease**

**Alaska invasion/introduction history**

Whirling disease was first detected in 2006 in rainbow trout at the Elmendorf fish hatchery (Arsan et al. 2007). Salmonid fish (such as rainbow trout) are one of the two obligate hosts that Myxobolus cerebralis alternates between, the other host being an oligochaete worm (Tubifex tubifex, certain mitochondrial lineages are more susceptible; Arsan and Bartholomew 2008).

| Ranking Summary | | |
|---|---|---|
| | Potential Max | Score |
| Distribution | 30 | 27 |
| Biological Characteristics | 30 | 20 |
| Ecological Impact | 30 | 24 |
| Feasibility of Control | 10 | 7 |
| Total | 100 | 78 |
| **Invasiveness (out of 100) =** | 78 **Highly invasive** | |

| **Distribution** | **Score** |
|---|---|
| *Current global distribution (0-10)* | 10 |

Whirling disease is widespread, with occurrences in North America, South America, Europe, Asia, and island countries, such as Japan and New Zealand (Bartholomew and Reno 2002).

*Extent of the species US range and/or occurrence of formal state or provincial listings (0-10)* 7

Whirling disease is invasive in 25 states (Bartholomew and Reno 2002).

*Role of anthropogenic and natural disturbance in establishment (0-5)* 5

Prior to 1990, whirling disease was primarily a problem in hatcheries (Gilbert and Granath 2003); however, whirling disease is now found in natural areas.

*Climatic similarity between site of origin and release (0-5)* 5

TAM release may be delayed at colder temperatures, but is not reduced in magnitude. In Colorado, TAM release peaks have been documented in the late-fall to early winter in a stream where the primary or sole salmonid host present was brown trout. Myxospores were washed downstream by spring snow-melt in April - June and settled onto sedimented eddies containing worms in April -June. TAM release can be virtually non-existent during the warm months of summer and early fall, then begins to pick up in late October, early November, peaks during December-January (under ice cover) and then subsides to non-detectible levels in March-April as spring warm-up occurs (B. Nehring pers comm.). Additionally, Nehring (2010) found there is no elevation or thermal barrier prohibiting the establishment of whirling disease in Colorado, with both hosts occuring in cold high elevation streams (Nehring 2010), meaning it could likely establish in Alaska (B. Nehring pers comm.).

Total for distribution 27 /30

| **Biological Characteristics and Dispersal** | **Score** |
|---|---|
| *Invasive elsewhere (0-5)* | 5 |

Whirling disease is invasive throughout the United States and in Africa, Asia, New Zealand, Japan, South America, and parts of Europe (Bartholomew and Reno 2002).

*Dietary specialization (0-5)* 2

Whirling disease alternates between living in two obligate hosts, salmonid fish and oligochaete worms, in two spore stages. The myxospore stage of the life cycle is dependent on an oligochaete worms for nutrients, the worm then releases the triactinomyxon (TAM) stage, which enters the salmonid fish and feeds on the cartilage (El-Matbouli et al. 1995).

*Habitat specialization (0-5)* 2

Since whirling disease is dependant on two hosts, a salmonid fish and an aquatic oligochaete worm (Tubifex tubifex), suitable habitat is where there is spatial temporal overlap of the hosts (Arsan and Bartholomew 2008). Upon initial survey of southeast and southcentral Alaska, the probability of finding areas with abundant oligochaetes of the susceptible lineage and rainbow trout (more susceptible to infection than other salmonids) are low (Bartholomew and Reno 2008). However, the lack of T. tubifex worm sampling in Alaska does not mean they do not occur, and if T. tubifex worms are present, there is likely an abundant amount of habitat available in salmonid spawning streams.

*Average number of reproductive events per adult female per year (0-5)* 5

In laboratory experiments, ingestion of 50 myxospores/worm results in 1 million to 20 million TAMs produced over a 200 - 230 day release period once TAM maturation (1,000 degree-days post-ingestion) has occurred. Likewise, a dosage of 100 TAMs (which is very low in the natural environment) for a susceptible salmonid fry will result in a cranial myxospore concentration of 100,000 - 1,000,000 myxospores once the parasite life cycle has runs its course (B. Nehring pers comm.).

*Potential to be spread by human activities (0-5)* 3

Humans can spread whirling disease through importation of frozen fish (speculated pathway for initial introduction into U.S.; Hoffman 1962), use of contaminated fish heads as bait, attachment and transfer on recreational equipment (e.g. waders), and stocking of infected samonid fish and contaminated water (Arsan and Bartholomew 2008).

*Innate potential for long distance dispersal (0-5)* 3

Spores can naturally disperse in water, even traveling through interdrainage canals and underground springs (Wilson 2006). Rainbow trout can spread whirling disease; however, trout typically do not migrate long distances (Morrow 1980). Other salmonid fish (including steelhead, the anandromus form of rainbow trout) can be infected, spreading whirling disease greater distances during migration (Arsan and Bartholomew 2008).

Total for biological characteristics 20 / 30

| **Ecological Impact** | **Score** |
|---|---|

*Impact on population dynamics of other species (0-10)* 10

The impacts of whirling disease on other organisms is highly variable, with negligible changes in native salmonid abundance seen in the eastern United States to severe declines in native trout in Colorado, Wyoming, and Montana (Elwell et al. 2009). Whirling disease causes mortality in salmonids (especially young fish) by concentrating in the head and spinal cartilage which causes abnormal swimming behavior, and difficulty feeding and avoiding predators (Elwell et al. 2009). The effect of whirling disease on oligochaete populations is unclear, but possibly detremental, as infected worms often have circular areas of discoloration in the intestines (Gilbert and Granath 2003).

*Impact on natural community composition (0-10)* 7

As stated above, the ecological impacts of whirling disease are highly variable. The parasite has the potential to alter fish communities by reducing trout (and other salmonid) abundance, which could in turn alter food chains for species dependent on and preyed upon by those salmonids (Elwell et al. 2009).

*Impact on natural ecosystem processes (0-10)* 7

The impacts of whirling disease on ecosystem processes not fully understood, but this species has the potential to change nutrient cycling. In Yellowstone National Park, cutthroat trout populations and spawning runs have been greatly reduced from historical numbers (B. Nehring pers comm.), this in turn can impact nutrient input and cycling in the stream and surrounding areas.

Total for ecological impact 24 /30

| **Feasibility of control** | **Score** |
|---|---|

*Number of populations in Alaska (0-3)* 1

Whirling disease has only been detected at the Elmendorf fish hatchery near Anchorage (Arsan et al. 2007).

*Significance of the natural area(s) and native species threatened (0-3)* 3

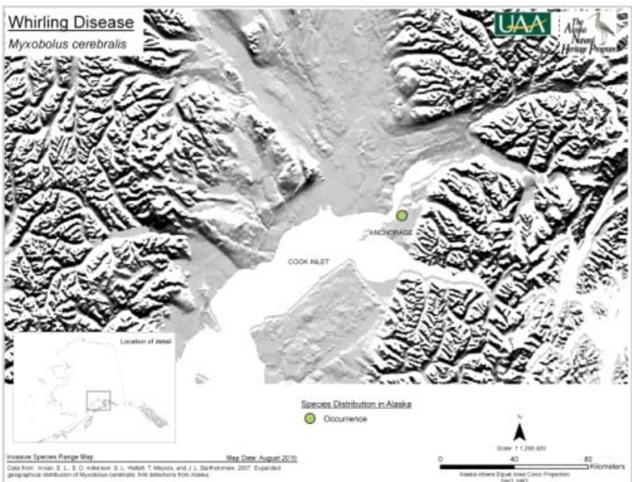
The impact of whirling disease on salmonids is variable, with the potential to cause declines in native salmonid populations (especially rainbow trout). In Alaska, rainbow trout are a highly valued sport fish, that occur naturally and some regions have supplemental stocking (Dean 1994). Declines in rainbow trout could cause economic loss due to a reduction in anglers and a waste of hatchery effort to raise and stock fish that may become infected. If other salmonid species become infected the economic and conservation loss would be even greater.

*General management difficulty (0-4)* 3

Since whirling disease is not widespread in Alaska, and the single reported case has been in a hatchery, management and prevention of future whirling disease introduction can be accomplished with moderate effort. More sampling is necessary to make sure whirling disease is actually absent for the rest of the state. Improvement to hatchery facilities, such as converting earthen-bottomed ponds and raceways to concrete (Markiw 1992) and switching from a surface water to a groundwater sources, would help prevent whirling disease spread. If the parasite spreads to lakes, stocking of larger fish can reduce spore counts (Ryce et al. 2004). However, prevention of whirling disease spread to natural areas through public education and stocking only disease free fish is often the most cost efficient method to control whirling disease (Elwell et al. 2009).

Total for feasibility of control 7 / 10

### Range Map




### References

Arsan, E.L. and J.L. Bartholomew. 2008. Potential for dissemination of the nonnative salmonid parasite Myxobolus cerebralis in Alaska. Journal of Aquatic Animal Health 20: 136-149.

Arsan, E.L., S.D. Atkinson, S.L. Hallett, T. Meyers, and J.L. Bartholomew. 2007. Expanded geographical distribution of Myxobolus cerebralis: first detections from Alaska. Journal of Fish Diseases 30: 483-491.

Bartholomew, J.L. and P.W. Reno. 2002. The history and dissemination of whirling disease. American Fisheries Society Symposium 29: 3-24.

Dean, A. 1994. Rainbow trout: Alaska wildlife notebook series. Alaska Department of Fish and Game, Juneau, AK.

El-Matbouli, M.Y., T. Fisher-Scherl, and C. Mandok. 1995. Light and electron microscopic observations on the route of the triactinomyxon-sporoplasm of Myxobolus cerebralis from epidermis to rainbow trout cartilage. Journal of Fish Biology 46: 919-935.

Elwell, L.C.S, K.E. Stromberg, E.K.N. Ryce, and J.L. Bartholomew. 2009. Whirling disease in the United States: a summary of progress in research and management 2009. Available: http://whirlingdisease.montana.edu/resources/publications.htm (Last accessed 5 November 2009).

Gilbert, M.A. and W.O. Granath Jr. 2003. Whirling disease of salmonid fish: life cycle, biology, and disease. Journal of Parasitology 89: 658-667.

Hoffman, G.L. 1962. Whirling disease of trout. U.S. Fish and Wildlife Service, Fishery Leaflet 508.

Markiw, M. E. 1992. Salmonid whirling disease. United States Fish and Wildlife Service, Leaflet 17, Washington, D.C.

Morrow, J.E. 1980. The freshwater fishes of Alaska. Alaska Northwest Publishing, Anchorage, AK.

Nehring, B.R. 2010. Whirling Disease Investigations. Colorado Department of Natural Resources, Division of Wildlife. Federal Aid Project F-237R-17, Fort Collins, CO.

Ryce, E. K. N., A. V. Zale, and E. MacConnell. 2004. Effects of fish age and development of whirling parasite dose on the disease in rainbow trout. Diseases of Aquatic Organisms 59:225-233.

Wilson, J.C. 2006. Whirling disease: What we've learned in the last 15 years. Wildlife Review. Utah Division of Wildlife Resources,
Summer 2006.

### Acknowledgements

*Authors:* K. M. Walton and T. A. Gotthardt, Alaska Natural Heritage Program, University of Alaska Anchorage.

*Reviewer(s):* Barry Nehring, Colorado Division of Wildlife. Jerri Bartholomew, Oregon State University.

**Scientific name: *Mus musculus*** **Common name: House mouse**

**Alaska invasion/introduction history**

The introduction and spread of house mice are poorly documented in Alaska. Historical records indicate mice in Wrangell and Sitka around 1891 (MacDonald and Cook 2007), in Juneau forests in 1895 (MacDonald and Cook 2009), and mice were first recorded on St. Paul Island in 1872 (Manville and Young 1965). More recent records indicate mice living in most urban areas and several islands throughout Alaska (MacDonald and Cook 2009).

| **Ranking Summary** | | |
|---|---|---|
| | Potential Max | Score |
| Distribution | 30 | 27 |
| Biological Characteristics | 30 | 26 |
| Ecological Impact | 30 | 17 |
| Feasibility of Control | 10 | 6 |
| Total | 100 | 76 |
| **Invaseness (out of 100) =** | 76 **Highly invasive** | |

| **Distribution** | **Score** |
|---|---|
| *Current global distribution (0-10)* | 10 |

House mice are cosmopolitan, occurring in Europe, Asia, Australia, Africa, North America, South America, and many Oceanic islands (GISD 2009).

*Extent of the species US range and/or occurrence of formal state or provincial listings (0-10)* 10

House mice occur throughout the entire United States and Canada (GISD 2009, NatureServe 2009).

*Role of anthropogenic and natural disturbance in establishment (0-5)* 2

House mice are commensal, typically occurring in human disturbed areas, but feral populations can exist in natural areas (Pocock et al. 2004).

*Climatic similarity between site of origin and release (0-5)* 5

House mice survive at similar latitudes and climatic conditions to those in Alaska throughout their worldwide range.

Total for distribution 27 /30

| **Biological Characteristics and Dispersal** | **Score** |
|---|---|
| *Invasive elsewhere (0-5)* | 5 |

House mice are invasive throughout the world.

*Dietary specialization (0-5)* 5

House mice are omnivorous, feeding on plant material, insects, human food, and even man-made household materials (e.g., glue, soap; GISD 2009).

*Habitat specialization (0-5)* 5

House mice often live in close association with humans, in buildings, as well as in fields, croplands, and sometimes in low elevation forests and along beaches (NatureServe 2009).

*Average number of reproductive events per adult female per year (0-5)* 5

Females have 5-10 litters per year, giving birth to an average of 5-6 young per litter (GISD 2009).

*Potential to be spread by human activities (0-5)* 5

House mice can stowaway in grain storage units that are transported extensively. Baker (1994) estimated that tens of thousands of mice leave the U.S each year as stowaways in cargo (grain, straw, and hay shipments). Mice are repeatedly introduced to islands after sucessful eradication.

*Innate potential for long distance dispersal (0-5)* 1

Commensal house mice do not typically move long distances, with occasional dispersal events due to habitat disturbances, social interactions, or overcrowding (Pocock et al. 2004). Feral house mice have slightly higher dispersal tendencies due to changing habitat and environmental conditions (Pocock et al. 2004).

Total for biological characteristics 26 / 30

| **Ecological Impact** | **Score** |
|---|---|
| *Impact on population dynamics of other species (0-10)* | 7 |

Ecological impacts of house mice populations on islands are fairly well documented, especially those lacking other invasive mammals, while impacts of non-insular populations are poorly documented. Several Oceanic islands where mice are the only invasive mammal present have reported a reduction in native vegetation due to seed predation, extinction or reduction of several invertebrate species, and mortality of healthy seabird chicks from mice predation (Angel et al. 2009). Investive rodents have also been vectors of disease to native mammals, and a few studies have shown mice impacting the abundance of native small mammals (Traveset et al. 2009). In systems where other invasive mammals or predators are present, the threat of mice to other organisms is reduced from dominance, competition, and predation (Courchamp et al. 1999, Wanless et al. 2007, Harris and Macdonald 2007, Quillfeldt et al. 2008, Angel et al. 2009).

*Impact on natural community composition (0-10)* 7

The following are predicted impacts of house mice on island communities, particularly those that lack other invasive mammals; the impacts of mice on inland habitats and islands with other invasive mammals and predators are likely to be reduced. Mice could potentially change vegetation communities by consuming and interferring with the dispersal of native species (Angel et al. 2009), which may in turn favor the establishment of invasive plant species (Traveset et al. 2009). House mice could potentially alter invertebrate communities by predation, applying selective pressure on large invertebrates, and reducing plant resources that may be important for developmental stages of an invertebrate's lifecycle (Angel et al. 2009). In turn, changes in the invertebrate communities and abundance may alter bird foraging patterns (Crafford and Scholtz 1987, Rowe-Rowe et al. 1989).

*Impact on natural ecosystem processes (0-10)* 3

If seabirds densities are reduced, nitrogenous fertilization will decrease, resulting in lower productivity (Croll et al. 2005, Fukami et al. 2006). Nutrient cycling and mineralization processes could change if food webs are altered, particularly if soil invertebrate abundance is reduced (Crafford 1990, Chown and Smith 1993, Smith et al. 2002). Changes in vegetation communities may caused increased rates of erosion (Traveset et al. 2009).

| Total for ecological impact | 17 /30 |
|---|---|

| **Feasibility of control** | **Score** |
|---|---|

*Number of populations in Alaska (0-3)* 2

House mice have been recently reported from Mendenhall Wetlands, Kasilof, Anchorage, Eagle River, Chugiak, Palmer, Fairbanks, Kodiak Island, Hog Island, Unalaska Island, Kiska Island, and St. Paul Island (see references in MacDonald and Cook 2009).

*Significance of the natural area(s) and native species threatened (0-3)* 1

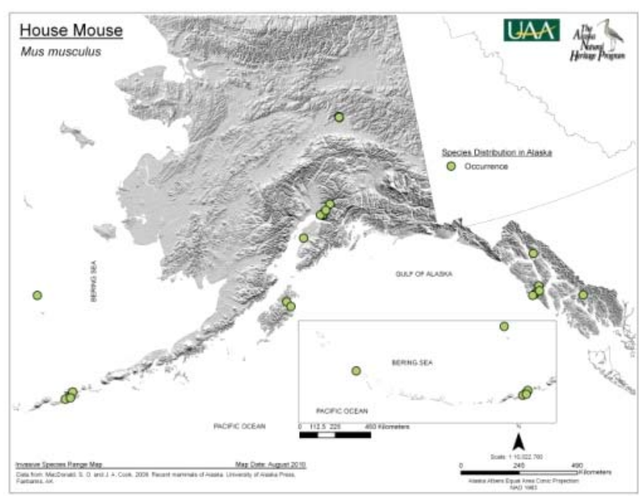
House mice usually inhabit disturbed areas and have not been reported to threaten any valuable native species. Insular populations of mice are more likely to impact natural areas and native species (Angel et al. 2009). No impacts to that degree have been reported in Alaska, with one report on St. Paul Island indicating mice were only living in the community area and dump (Ebbert and Byrd 2002).

*General management difficulty (0-4)* 3

In urban areas mouse control involves population reduction, by means of traps, toxicants, repellants, and fumigants (GISD 2009). Anticoagulant poison was used to successfully eradicate mice from 28 islands (MacKay et al. 2007). Eliminating house mice can be difficult, and the same approach does not fit all infestations (Witmer and Jojola 2006). An eradication project in Australia noted that with careful planning, specifically using specially designed bait stations that native animals can not access and an intensive short term investment in human resources, the control of mice is possible (Moro 2001).

| Total for feasibility of control | 6 / 10 |
|---|---|

**Range Map**



## References

Angel, A., R.M. Wanless, and J. Cooper. 2009. Review of impacts of the introduced house mouse on islands in the Southern Ocean: are mice equivalent to rats? Biological Invasions 11: 1743-1754.

Baker, A.E.M. 1994. Stowaway transport rates of house mice (Mus domesticus) and deermice (Peromyscus maniculatus). Pp. 106-112 In W.S Halverson, and A.C. Crabb (eds). Proceedings of the 16th vertebrate pest conference. Davis, CA, University of California.

Chown, S.L. and V.R. Smith. 1993. Climate change and the short-term impact of feral house mice at the sub-Antarctic Prince Edward Islands. Oecologia 96: 508-516.

Courchamp, F., M. Langlais, and G. Sugihara. 1999. Cats protecting birds: modeling the mesopredator release effect. Journal of Animal Ecology 68: 282-292.

Crafford, J.E. 1990. The role of feral house mice in ecosystem functioning on Marion Island. Pp. 359-364 in K.R. Kerry and G. Hemperl (eds). Antarctic ecosystems. Ecological change and conservation. Springer-Verlag, Berlin.

Crafford, J.E., and C.H. Scholtz. 1987. Quantitative differences between the insect faunas of the Subantarctic Marion and Prince Edward islands: a result of human intervention? Biological Conservation 40: 255-262.

Croll, D.A., J.L. Maron, J.A. Estes, E.M. Danner, and G.V. Byrd. 2005. Introduced predators transform subarctic islands from grassland to tundra. Science 307: 1959-1961.

Ebbert, S.E. and G.V. Byrd. 2002. Eradications of invasive species to restore natural biological diversity on Alaska Maritime National Wildlife Refuge. Pp. 102-109 In C.R. Veitch and M.N. Clout (eds). Turning the tide: the eradication of invasive species. IUCN SCC Invasive Species Specialist Group. Gland, Switzerland.

Fukami, T., D.A. Wardle, P.J. Bellington, C.P.H. Mulder, D.R. Towns, G.W. Yeates, K.I. Bonner, M.S. Durett, M.N. Grant-Hoffman, and W.M. Williamson. 2006. Above- and below-ground impacts of introduced predators in seabird-dominated island ecosystems. Ecology Letters 9: 1299-1307.

Harris, D.B. and D.W. Macdonald. 2007. Interference competition between introduced black rats and endemic Galapagos rice rats. Ecology 88: 2330-2344.

MacDonald, S.O. and J.A. Cook. 2007. Mammals and amphibians of Southeast Alaska. The Museum of Southwestern Biology, Special Publication 8: 1-191.

MacDonald, S.O. and J.A. Cook. 2009. Recent mammals of Alaska. University of Alaska Press, Fairbanks, AK.

MacKay, J.W.B., J.C. Russell, and E.C. Murphy. 2007. Eradicating house mice from islands: successes, failures and the way forward. Pp. 294-304 In K.A. Fagerstone and G.W. Witmer (eds). Managing vertebrate invasive species: an international symposium. USDA, National Wildlife Research Center, Fort Collins, CO.

Manville, R.H., and S.P. Young. 1965. Distribution of Alaskan mammals. U.S. Fish and Wildlife Service Circular 211.

Moro, D. 2001. Evaluation and cost-benefits of controlling house mice (Mus domesticus) on islands: an example from Thevenard Island, Western Australia. Biological Conservation 99: 355-364.

NatureServe. 2009. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available at: http://www.natureserve.org/explorer. (Last accessed 16 November 2009 ).

Pocock, M.J.O., H.C. Hauffe, and J.B. Searle. 2004. Dispersal in house mice. Biological Journal of the Linnean Society 84: 565–583.

Quillfeldt, P., I. Schenk, R.A.R. McGill, I.J. Strange, J.F. Masello, A. Gladbach, V. Roesch, and R.W. Furness. 2008. Introduced mammals coexist with seabirds at New Island, Falkland Islands: abundance, habitat preferences, and stable isotope analysis of diet. Polar Biology 31: 333-349.

Rowe-Rowe, D.T., B. Green, and J.E. Crafford. 1989. Estimated impact of feral house mice on Subantarctic invertebrates at Marion Island. Polar Biology 9: 457-460.

Smith, V.R., N.L. Avenant, and S.L. Chown. 2002. The diet and impact of house mice on a Subantarctic island. Polar Biology 25: 703-715.

Traveset, A., M. Nogales, J. A. Alcover, J. D. Delgado, M. Lopez-Darias, D. Godoy, J. M. Igual, and P. Bover. 2009. A review on the effects of alien rodents in the Balearic (western Mediterranean Sea) and Canary Islands (eastern Atlantic Ocean). Biol Invasions 11: 1653-1670.

Wanless, R.M., A. Angel, R.J. Cuthbert, G. Hilton, and P.G. Ryan. 2007. Can predation by invasive mice drive seabird extinction? Biology letters 3: 241-244.

Witmer, G. and S. Jojola. 2006. What's up with house mice? - a review. Proc. Vertebrate Pest Conference 22: 124-130.

## Acknowledgements

*Authors:* K. M. Walton and T. A. Gotthardt, Alaska Natural Heritage Program, University of Alaska Anchorage.

*Reviewer(s):* Gary Witmer, USDA National Wildlife Research Center, Fort Collins, CO.

**Alaska invasion/introduction history**

Not present in Alaska. Two separate populations have independently established in the United States, one in the Snake River in 1987 (in both Idaho and Wyoming; Taylor 1987, Bowler 1991, Richards 2002) and the other in Lake Ontario and the St. Lawrence River in 1991 (Zaranko et al. 1997).

| Ranking Summary | | |
|---|---|---|
| | Potential Max | Score |
| Distribution | 30 | 24 |
| Biological Characteristics | 30 | 25 |
| Ecological Impact | 30 | 21 |
| Feasibility of Control | 10 | 5 |
| Total | 100 | 75 |
| **Invaziveness (out of 100) =** | 75 **Highly invasive** | |

| Distribution | Score |
|---|---|
| *Current global distribution (0-10)* | 10 |

Native to New Zealand, the mudsnail is now invasive in Australia, North America, Japan, and Europe (Anderson 2006, NZMMC 2007).

*Extent of the species US range and/or occurrence of formal state or provincial listings (0-10)* 7

New Zealand mudsnails are in most western states, Lake Ontario, Lake Superior, Lake Erie, and Ontario, Canada (NZMMC 2007, Benson and Kipp 2009).

*Role of anthropogenic and natural disturbance in establishment (0-5)* 5

Although mudsnail abundance was positively correlated with human land use and flow disturbance in several Australian streams (Schreiber et al. 2003), mudsnails have also been documented in relatively pristine areas in the western U.S. (Richards et al. 2001).

*Climatic similarity between site of origin and release (0-5)* 2

In laboratory experiments, the New Zealand mudsnail was able to survive and reproduce at 12°C (Dybdahl and Kane 2005), and in winter field experiments in Yellowstone, snails were able to reproduce at 7°C (Dybdahl unpublished). In southcentral Alaska, temperature briefly get above 12°C (Kyle and Brabets 2001). In northern Europe, mudsnails survive in freshwater (Bondesen and Kaiser 1949) where mean temperature are around 0°C for 3-4 months (Kerans et al. 2005) and in the Glen Canyon of Arizona, the water is realtively cold, with a mean range of 8.0-16.1°C (2003-2008; Cross et al. 2010).

Total for distribution 24 /30

| Biological Characteristics and Dispersal | Score |
|---|---|
| *Invasive elsewhere (0-5)* | 5 |

New Zealand mudsnails are invasive in Australian, Europe, North America, and Japan (Anderson 2006).

*Dietary specialization (0-5)* 5

New Zealand mudsnails are generalist feeders (grazing herbivore and detritivore; Haynes and Taylor 1984).

*Habitat specialization (0-5)* 5

New Zealand mudsnails have a broad range of environmental tolerances, living in a variety of habitats that have a wide range of temperatures, osmotic concentrations, flows, substrates, and disturbance regimes (NZMMC 2007).

*Average number of reproductive events per adult female per year (0-5)* 2

Most invasive populations are comprised of almost entirely females that reproduce clonally (NZMMC 2007) and in the United States females typically bear young in the summer and autumn (GISD 2005, Anderson 2006).

*Potential to be spread by human activities (0-5)* 5

Humans can potentially spread mudsnails on watercraft and trailers, recreational equipment (e.g. on waders, in bait bucket), in sand and gravel mining operations, in the aquatic plants, and by stocking fish with mudsnails in their digestive tracts or in contaminated hatchery water (NZMMC 2007).

*Innate potential for long distance dispersal (0-5)* 3

The spread of mudsnails can be facilitated by fish, with one study observing a live snail passing through the gut of a fish and reproducing within an hour (Haynes et al. 1985). Vinson and Baker (2008) found 54% of snails recovered in the feces of fish passed through the digestive system alive. Snails can spread by attaching to the feet and feathers of birds (Boycott 1936, Talling 1951, Lassen 1975) and attaching to the fur of animals walking along riparian areas (NZMMC 2007). Snails can attach to floating vegetation mats (NZMMC 2007) and are capable of moving at speeds greater than 1 m/hour, facilitating spread within a watershed (Richards 2002).

| Total for biological characteristics | 25 / 30 |
|---|---|

| Ecological Impact | Score |
|---|---|

*Impact on population dynamics of other species (0-10)* — 7

Mudsnails can reduce abundance of several species of macroinvertebrates (Kerans et al. 2005), algae, and primary producers (through grazing; Hall et al. 2003). They can also reduce the fitness of fish that feed on New Zealand mudsnails because of their poor nutritional quality (Vinson et al. 2007, Vinson and Baker 2008). In Polecat Creek in Yellowstone and Grand Tetons National Parks, interactions between the New Zealand mudsnail and a native snail has resulted slower growth rates of the native snail due to the superior competitive ability of New Zealand mudsnails (Riley et al. 2008).

*Impact on natural community composition (0-10)* — 7

In Wyoming, New Zealand mudsnails have become the most productive taxon in several rivers, constituting 65-92% of the total invertebrate productivity (Hall et al. 2006); therefore, causing a significant change in community composition. Kerans et al. (2005) observed the macroinvertebrate community composition and structure covaried with New Zealand mudsnail abundance, when the mudsnail density increased, macroinvertebrate density decreased. Some species of fish have started to consume New Zealand mudsnails in the Green River (Utah and Wyoming). Bioenergetic simulations suggested that mudsnails do not provide enough energy for proper fish growth (Vinson et al. 2007) and may affect these higher trophic levels if they become a dominant component of fish diets (Vinson and Baker 2008). Mudsnails could also alter fish communities that feed on invertebrates and algae (Anderson 2006).

*Impact on natural ecosystem processes (0-10)* — 7

Hall et al. (2003) reported mudsnails in Polecat Creek, northwest Wyoming, altered carbon and nitrogen fluxes by consuming a large proportion of the daily gross primary production and excreting a large fraction of the ammonium present in the system.

| Total for ecological impact | 21 /30 |
|---|---|

| Feasibility of control | Score |
|---|---|

*Number of populations in Alaska (0-3)* — 0

No populations in Alaska.

*Significance of the natural area(s) and native species threatened (0-3)* — 2

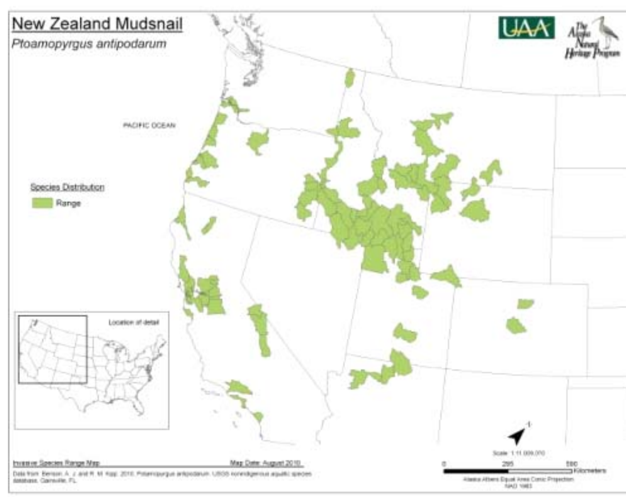
New Zealand mudsnails often inhabit disturbed habitats (Schreiber et al. 2003), but also invade pristine areas, such as spring streams, and become the dominate invertebrate taxon (Hall et al. 2003). When this occurs not only can invertebrate communities change, but also the fish communities (potentially of high economic and conservation value) that rely on those macroinvertebrates.

*General management difficulty (0-4)* — 3

Public education is used to help prevent initial introductions and help control spread of snails once introduced. Eradication of New Zealand mudsnails is possible in small waterbodies that are isolated and can be chemically treated or completely drained (NZMMC 2007); however, other organisms are typically killed as well. When eradication is not feasible, chemical treatment and desiccation of the waterbody can still be used to help control the population, along with proper cleaning of boats, trailers, and recreational equipment (NZMMC 2007).

| Total for feasibility of control | 5 / 10 |
|---|---|

**Range Map**



## References


Anderson, T.R. 2006. New Zealand mudsnail Potomopyrgus antipodarum. Pp. 102-103 in P.D. Boersma, S.H. Reichard, and A.N. Buren (eds). Invasive Speices in the Pacific Northwest. University of Washington Press, Seattle, WA.

Benson, A. J. and R. M. Kipp. 2009. Potamopyrgus antipodarum. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. <http://nas.er.usgs.gov/queries/FactSheet.asp?speciesID=1008 (Accessed 5 November 2009).

Bondesen, P. and E. W. Kaiser. 1949. Hydrobia (Potamopyrgus) jenkinsi (Smith) in Denmark illustrated by its ecology. Oikos 1:252-281.

Bowler, P. 1991. The rapid spread of the freshwater hydrobiid snail Potamopyrgus antipodarum (Gray) in the middle Snake River, southern Idaho. Proceedings of the Desert Fishes Council 21:173-182.

Boycott, A. C. 1936. The habitats of freshwater mollusca in Britain. Journal of Animal Ecology 5:111-186.

Cross, W.F., E.J. Rosi-Marshall, K.E. Behn, T.A. Kennedy, R.O. Hall Jr., A.E. Fuller, and C.V. Baxter. 2010. Invasion and production of New Zealand mud snails in the Colorado River, Glen Canyon. Biological Invasions 12: 3033-3043.

Dybdahl, M.F. and S.L. Kane. 2005. Adaptation vs. phenotypic plasticity in the success of a clonal invader. Ecology 86: 1592-1601.

Global Invasive Species Database (GISD). 2005. Potamopygrus antipodarum (Mollusc). Available online at: http://www.invasivespecies.net.

Hall, R.O. Jr, J.L. Tank, and M.F. Dybdahl. 2003. Exotic snails dominate nitrogen and carbon cycling in a highly productive stream. Frontiers in Ecology and the Environment 1: 407-411.

Hall, R.O. Jr, M.F. Dybdahl, and M.C. Vanderloop. 2006. Extremely high secondary production of introduced snails in rivers. Ecological applications 16: 1121-1131.

Haynes, A., and B. J. R. Taylor. 1984. Food finding and food preference in Potamopyrgus jenkinsi (E.A. Smith) (Gastropoda: Prosobranchia). Archiv fur Hydrobiologie 100:479–491.

Haynes, A., B. J. R. Taylor, and M. E. Varley. 1985. The influence of the mobility of Potamopyrgus jenkinsi (Smith, E.A.) (Prosobranchia: Hydrobiidae) on its spread. Archiv fur Hydrobiologie 103:497–508.

Kerans, B.L., M.F. Dybdahl, M.M. Gangloff, and J.E. Jannot. 2005. Potamopyrgus antipodarum: distribution, density, and effects on native macroinvertebrate assemblages in the Greater Yellowstone Ecosystem. Jounral of the North American Benthological Society 24: 123-138.

Kyle, R.E. and T.P. Brabets. 2001. Water temperature of streams in the Cook Inlet Basin, Alaska, and implications of climate change. Water-Resources Investigations Report 01-4109, USGS, Anchorage, AK

Lassen, H.H. 1975. The diversity of freshwater snails in view of the equilibrium theory of island biogeography. Oecologia 19:1-8.

New Zealand Mudsnail Management and Control Working Group (NZMMC). 2007. National management and control plan for the New Zealand mudsnail (Potamopyrgus antipodorum). Prepared for the Aquatic Nuisance Species Task Force. Available: http://www.anstaskforce.gov/Documents/NZMS_MgmtControl_Final.pdf

Richards, D.C. 2002. The New Zealand mudsnail invades the western United States. Aquatic Species Digest 4: 42-44.

Richards, D.C., L.D. Cazier, and G.T. Lester. 2001. Spatial distribution of three snail species, including the invader Potamopyrgus antipodarum, in a freshwater spring. Western North American Naturalist 61: 375-380.

Riley, L.A., M.F. Dybdahl, and R.O. Hall Jr. 2008. Invasive species impact: asymmetric interactions between invasive and endemic freshwater snails. J. N. Am. Benthol. Soc. 27: 509-520.

Schreiber, E.S.G., G.P. Quinn, and P.S. Lake. 2003. Distribution of an aquatic snail in relation to flow variability, human activities, and water quality. Freshwater Biology 48: 951-961.

Talling, J. F. 1951. The element of chance in pond populations. The Naturalist 1951: 157- 170.

Taylor, D.W. 1987. Thousand Springs threatened or endangered snails. Unpublished report submitted to The Nature Conservancy of Idaho summerizing a 2-5 September 1987 survey.

Vinson, M.R. and M.A. Baker. 2008. Poor growth of rainbow trout fed New Zealand mud snails Potamopyrgus antipodarum. North American Journal of Fisheries Management 28: 701-709.

Vinson, M., T. Harju, and E. Dinger. 2007. Status of New Zealand mudsnails (Potamopyrgus antipodarum) in the Green River downstream from Flaming Gorge Dam: current distribution; habitat preference and invertebrate changes; food web and fish effects; and predicted distributions. USDI Bureau of Land Management & Utah State University National Aquatic Monitoring Center.

Zaranko, D.T., D.G. Farara, and F.G. Thompson. 1997. Another exotic mollusk in the Laurentian Great Lakes: the New Zealand native Potamopyrgus antipodarum (gray 1843)(Gastropoda, Hydrobiidae). Canadian Journal of Fisheries and Aquatic Sciences 54: 809-814.


## Acknowledgements

**Scientific name:** ***Potamopyrgus antipodarum*** **Common name: New Zealand mudsnail**

*Authors:* K. M. Walton and T. A. Gotthardt, Alaska Natural Heritage Program, University of Alaska Anchorage.
*Reviewer(s):* Robert Hall, University of Wyoming.

**Scientific name: *Dreissena polymorpha*** **Common name: Zebra mussel**

**Alaska invasion/introduction history**

Zebra mussels do not occur in Alaska, but were likely introduced into North America around 1988 in the ballast water of a cargo vessel traveling from the Black Sea to the Great Lakes (McMahon 1996).

| Ranking Summary | | |
|---|---|---|
| | Potential Max | Score |
| Distribution | 30 | 23 |
| Biological Characteristics | 30 | 23 |
| Ecological Impact | 30 | 24 |
| Feasibility of Control | 10 | 4 |
| Total | 100 | 74 |
| **Invasiveness (out of 100) =** | 74 **Highly invasive** | |

| **Distribution** | **Score** |
|---|---|
| *Current global distribution (0-10)* | 6 |

The zebra mussel is native to southern Russia and the Caspian and Black Sea Basin, and invasive in Asia, Europe, and North America (Ludyanskiy et al. 1993, D. Padilla pers comm.).

*Extent of the species US range and/or occurrence of formal state or provincial listings (0-10)* 10

The zebra mussel have been reported (although not always a persistant established population) in over half of the U.S. states, primarily in the Great Lakes watershed and large navigable rivers in the eastern U.S. (Benson and Raikow 2009).

*Role of anthropogenic and natural disturbance in establishment (0-5)* 5

Zebra mussels can establish in both disturbed and natural areas, as seen by the attachment of mussels to both human constructed and natural surfaces (Ludyanskiy et al. 1993).

*Climatic similarity between site of origin and release (0-5)* 2

The lower limit for survival is 0°C (Karatayev et al. 1998). For fertilization of eggs to occur, water temperatures must be higher than 12°C (Ludyanskiy et al. 1993). In lakes and streams in the Cook Inlet watershed, water temperatures can briefly warm above 12°C during the summer (Kyle and Brabets 2001), indicating that zebra mussels would be at the extreme of their climatic range in Alaska. Zebra mussels are able to reproduce in Belaurus, Lithuania, and other northern countries, so would likely be able to survive in southeast Alaska (D. Padillla pers comm).

Total for distribution 23 /30

| **Biological Characteristics and Dispersal** | **Score** |
|---|---|
| *Invasive elsewhere (0-5)* | 5 |

Zebra Mussels are invasive in the Great Lakes watershed, large rivers in the eastern U.S, and throughout Eurasia (Benson and Raikow 2009).

*Dietary specialization (0-5)* 5

Zebra mussels are suspension feeders and primarily consume phytoplankton and suspended organic matter (Ludyanskiy et al. 1993). Also consumes small zooplankton (H. MacIsaac pers comm.).

*Habitat specialization (0-5)* 5

Zebra mussels attach to almost any solid substrate, including macrophytes, other mussels, clams, rocks, and artifical surfaces (Benson and Raikow 2009). They will also live on soft substrate if conditions are quiescent (H. MacIsaac pers comm.). The upper salinity limit is 6%, minimuim temperature for reproduction is 12-15°C, lower pH limit is 7.3-7.5, lower calcium limit is 25-28 mg/L, and lower oxygen limit (at 20°C) is 1.8-2.4 (Karatayev et al. in review).

*Average number of reproductive events per adult female per year (0-5)* 0

Although females can spawn 2-5 times a year, in North America females typically spawn once a year (D. Padilla pers comm), releasing more than one million eggs per spawning event (Sprung 1990, 1993, Waltz 1973, 1978).

*Potential to be spread by human activities (0-5)* 5

Carlton (1993) stated there are 20 human related dispersal mechanisms that can transport zebra mussels overland, upstream, and downstream. Adults attach to boat hulls, motors, anchors, and external surfaces and are transported in waterways and overland on recreational boats and trailers (Johnson and Carlton 1996). Additionally, larvae can reside in water that is transported by boats and recreational users (Johnson and Carlton 1996).

*Innate potential for long distance dispersal (0-5)* 3

Carlton (1993) stated zebra mussels have several natural dispersal mechanisms. Veliger larva can be transported long distances on water currents and to a lesser degree adults can attach to waterfowl and other aquatic organisms for transport (Morton 1993).

| Total for biological characteristics | 23 / 30 |
|---|---|

| **Ecological Impact** | **Score** |
|---|---|
| *Impact on population dynamics of other species (0-10)* | 7 |

Karatayev et al. (in review) sorted through the literature and reported the following ecological impacts. Phytoplankton and zooplankton biomass often decrease from suspension feeding. Unionid bivalues are typically negeatively impacted, decreasing in abundance, while other benthic invertebrates often increase in biomass including amphipods, isopods, leeches, turbellarians, hydrozoans, and some oligochaetes and chironomids. In Lake Erie, Holland (1993) found diatoms decreased by 81-91%.

| | |
|---|---|
| *Impact on natural community composition (0-10)* | 7 |

Zebra mussels can shift a lake from phytoplankton to macrophyte dominated by clarifying the water (Scheffer et al. 1993). When zebra mussels reduce phytoplankton biomass, significant changes casade throughout many food webs. Zooplankton populations that feed on phytoplankton experience declines, which in turn increases competition and decreases the survival of planktivorous fish (MacIsaac 1996, Benson and Raikow 2009). Benthic feeding fishes may increase because of the increase in biomass of benthic invertebrates (Karatayev et al. in review) In higher trophic levels, such as waterfowl, zebra mussels can cause biomaginification of metals and contaminants, which can reduce fitness (de Kock and Bowmer 1993). Additonally, as zebra mussel cause an energy shift to benetic communities, the diversity of invertebrates can increase beyond the native level (MacIsaac 1996).

| | |
|---|---|
| *Impact on natural ecosystem processes (0-10)* | 10 |

Zebra mussels enhance water clarity by excreting particles to the benthic environment, which causes increased light penetration, macrophyte growth, and possibly increased water temperature (Skubinna et al. 1995). Lakes with zebra mussels often have decreased dissolved oxygen contents (Raikow 2002) and altered water chemisty and nutrient cycling (Heath et al. 1995).

| Total for ecological impact | 24 /30 |
|---|---|

| **Feasibility of control** | **Score** |
|---|---|
| *Number of populations in Alaska (0-3)* | 0 |

There are no populations of zebra mussels in Alaska.

| | |
|---|---|
| *Significance of the natural area(s) and native species threatened (0-3)* | 2 |

Zebra musssels have the potential to change highly valued aquatic systems and the unionids, other invertebrate, and fish communities within them. As zebra mussels filter particles out of the water column, they accumulate contaminants and metals in their bodies, which can be passed on to higher trophic levels (Ludyanskiy et al. 1993), such as waterfowl and eventually humans that hunt those birds. Also the turbidity, water chemistry, and nutrient cycling can be altered of important natural areas (Heath et al. 1995).

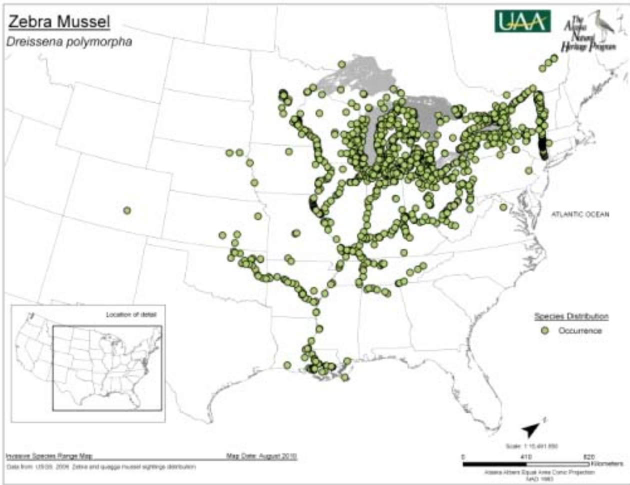
| | |
|---|---|
| *General management difficulty (0-4)* | 2 |

Since zebra mussels are not present in Alaska, management involves prevention of introductions, which is a minor investment. If zebra mussels are introduced, then a major investment will be required. Once a waterbody is infested, control is difficult and often few management options are viable. Many techniques are harmful to other organisms, such as draining of the entire waterbody, chemical treatments, and thermal heating of the water to kill zebra mussels. If only a few mussels are present, physically removing individuals is effective and does not harm native species (DRC 2005). Currently there is no environmentally friendly method to eradicate dense infestations of zebra mussels (Ludyanskiy et al. 1993).

| Total for feasibility of control | 4 / 10 |
|---|---|

## Scientific name: *Dreissena polymorpha* Common name: Zebra mussel

### Range Map




### References


Benson, A. J. and D. Raikow. 2009. Dreissena polymorpha. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. Available http://nas.er.usgs.gov/queries/FactSheet.asp?speciesID=5 (Accessed 3 Nov 2009).

Carlton, J.T. 1993. Dispersal mechanisms of the zebra mussel (Dreissena polymorpha). Pp. 677-697 in T.F. Nalepa and D.W. Schloesser (eds). Zebra mussels: biology, impacts, and control. Lewis Publication, Chelsea, MI

de Kock, W.C., and C.T. Bowmer. 1993. Bioaccumulation, biological effects, and food chain transfer of contaminants in the zebra mussels (Dreissena polymorpha). Pp. 503-533 in T.F. Nalepa and D.W. Schloesser (eds). Zebra mussels: biology, impacts, and control. Lewis Publishers, Chelsea, MI.

DRC. 2005. Rapid response plan for the zebra mussel (Dreissena polymorpha) in Massachusetts. Massachusetts Department of Conservation and Recreation, Boston, MA.

Heath, R.T., G.L. Fahnenstiel, W.S. Gardner, J.F. Cavaletto, and S.J. Hwang. 1995. Ecosystem-level effects of zebra mussels (Dreissena polymorpha): an enclosure experiment in Saginaw Bay, Lake Huron. Journal of Great Lakes Research 21: 501-516.

Holland, R.E. 1993. Changes in planktonic diatoms and water transparency in Hatchery Bay, Bass Island Area, Western Lake Erie since establishment of the zebra mussel. Journal of Great Lakes Research 19: 617-624.

Johnson, L.E. and J.T. Carlton. 1996. Post-establishment spread in large-scale invasions: dispersal mechanism of the zebra mussel Dreissena polymorpha. Ecology 77: 1686-1690.

Karatayev, A. Y., L. E. Burlakova, and D. K. Padilla. 1998. Physical factors that limit the distribution and abundance of Dreissena polymorpha (Pall.). Journal of Shellfish Research 17: 1219-1235.

Karatayev, A. Y., L. E. Burlakova, and D. K. Padilla. In review. Spread, population dynamics, and ecosystem impacts of zebra mussels versus Quagga mussels: what we know and what we do not.

Kyle, R.E. and T.P. Brabets. 2001. Water temperature of streams in the Cook Inlet Basin, Alaska, and implications of climate change. Water-Resources Investigations Report 01-4109, USGS, Anchorage, AK.

Ludyanskiy, M.L., D. McDonald, and D. MacNeill. 1993. Impact of the zebra mussel, a bivalve invader. BioScience 43: 533-544.

MacIsaac, H.J. 1996. Potential abiotic and biotic impacts of zebra mussels on the inland waters of North America. American Zoologist 36: 287-299.

McMahon, R. F. 1996. The physiological ecology of the zebra mussel, Dreissena polymorpha, in North America and Europe. American Zoologist 36:339-363.

Morton, B.S. 1993. The anatomy of Dreissena polymorpha and the evolution and success of the hetermyarian form in Dreissenoidea. Pp. 185-215 in T.F. Nalepa and D.W. Schloesser (eds). Zebra mussels: biology, impacts, a and control. Lewis Publications, Chelsea, MI.

Raikow, D.F. 2002. How the feeding ecology of native and exotic mussels affects freshwater ecosystems. Doctoral dissertation, Michigan State University.

Scheffer, M., S.H. Hosper, M-L. Meijer, B. Moss, and E. Jeppesen. 1993. Alternative equalibria in shallow lakes. Trends in Ecology and Evolution 8: 275-279.

Skubinna, J.P., T.G. Coon, and T.R. Batterson. 1995. Increased abundance and depth of submersed macrophytes in response to decreased turbidity in Saginaw Bay, Michigan. Journal of Great Lakes Research 21: 476-488.

Sprung, M. 1990. Costs of reproduction: a study on metabolic requirements of the gonads and fecundity of the bivalve Dreissena polymorpha. Malacologia 32: 267-274.

Sprung, M. 1993. The other life: an account of present knowledge of the larval phase of Dreissena polymorpha. Pp. 39-53 in T.F. Nalepa and D.W. Schloesser (eds). Zebra mussels: biology, impacts, and control. Lewis Publications, Chelsea, MI.

Waltz, N. 1973. Studies on the biology of Dreissena polymorpha in Lake Constance. Arch. Hydrobiol. Suppl. 42: 452-482.

Waltz, N. 1978. The energy balance of the freshwater mussel Dreissena polymorpha in laboratory experiments and in Lake Constance. 2. Reproduction. Arch. Hydrobiol. Suppl. 55: 106-119.

## Acknowledgements

*Authors:* K. M. Walton and T. A. Gotthardt, Alaska Natural Heritage Program, University of Alaska Anchorage.

*Reviewer(s):* Hugh MacIssac, Great Lakes Institute for Environmental Research; Dianna Padilla, State University of New York Stony Brook.

**Scientific name: *Arion subfuscus*** **Common name: Dusky slug**

**Alaska invasion/introduction history**

The invasion history in Alaska is unknown, surveys have found this species around Kodiak, Haines, Juneau, Ketchikan, Sitka, Wrangell, Valdez, and Girdwood (Ferguson and Knight 2010).

| Ranking Summary | | |
|---|---|---|
| | Potential Max | Score |
| Distribution | 30 | 24 |
| Biological Characteristics | 30 | 25 |
| Ecological Impact | 30 | 13 |
| Feasibility of Control | 7 | 4 |
| Total | 97 | 66 |
| **Invasiveness (out of 100) =** | 68 | **Moderately invasive** |

| **Distribution** | **Score** |
|---|---|
| *Current global distribution (0-10)* | 10 |

The dusky slug is native to Europe and introduced to North America, South America, Asia (Forsyth 2004, McDonnell et al. 2009).

*Extent of the species US range and/or occurrence of formal state or provincial listings (0-10)* 7

Between 21-50% of the states and several Canadian provinces (NF, NS, ON, BC) have invasive dusky slugs (Pinceel et al. 2005), but there are large gaps of under-studied areas (R. Forsyth pers comm).

*Role of anthropogenic and natural disturbance in establishment (0-5)* 2

In British Columbia, distributed near human settlements (Forsyth 2004) and in natural sites in close proximity to disturbed areas (R. Forsyth pers comm).

*Climatic similarity between site of origin and release (0-5)* 5

The dusky slug lives in both temperate and polar regions, with Eurasian populations occurring in cold climates, such as in Moscow and the Murmansk region (near Russian border with northern Finland; Zotin and Ozernyuk 2002). Also found in interior and extreme northern regions of Scandinavia (Kerney and Cameron 1979).

Total for distribution 24 /30

| **Biological Characteristics and Dispersal** | **Score** |
|---|---|
| *Invasive elsewhere (0-5)* | 5 |

The dusky slug is invasive in the continental United States and several Canadian provinces (NatureServe 2009).

*Dietary specialization (0-5)* 5

This species of slug is a generalist, feeding on fungi, decaying or yellowed foliage, unprotected plant parts (flower petals and sepals), and occasionally animal feces, dead or injured earthworms, insect larvae, and rarely intact foliage (Beyer and Saari 1978).

*Habitat specialization (0-5)* 5

The dusky slug is a habitat generalist, found in wooded habitats, grasslands, ecotones, and dumps (Chichester and Getz 1973, Beyer and Saari 1978).

*Average number of reproductive events per adult female per year (0-5)* 5

Slugs can lay eggs multiple times a year, as seen by a similar Arion species (A. lusitanicus), which laid between 56-58 batches of eggs from mid June to the end of November in an Austrian study (Grimm 1996). Quick (1960) noted mating in March, April, May and perhaps other months in Britain.

*Potential to be spread by human activities (0-5)* 5

Slugs are commonly transported in horticultural and plant materials and spread to woodland areas when gardeners dump garden refuse and compost in such areas (Rollo and Wellington 1975). Other methods of transport likely similar to other slugs, such as on boats, trailers, pallets, in ice chests, and trail construction materials (R. Forsyth pers comm).

*Innate potential for long distance dispersal (0-5)* 0

The dusky slug does not have any innate long distance dispersal mechanism.

Total for biological characteristics 25 / 30

| **Ecological Impact** | **Score** |
|---|---|
| *Impact on population dynamics of other species (0-10)* | 3 |

Willows that are susceptible to dusky slug herbivory alter their leaf chemistry to reduce the palatability of their leaves to slugs. Additionally, dusky slugs can cause a decrease in the abundance of willow seedlings, which have not yet built up their chemical defenses (Fritz et al. 2001) and can cause leaf damage to newly emerged herbaceous plants (Rathcke 1985).

*Impact on natural community composition (0-10)* 3

Slugs have the potential to alter community composition and plant diversity by restricting seedling recruitment in early stage communities (Buschmann et al. 2005) and communities of young herbaceous plants that emerge when slugs are highly active (Rathcke 1985).

*Impact on natural ecosystem processes (0-10)* 7

Slugs process decaying plant and fecal material, helping to recycle organic matter and nutrients back into a form that can be used by other organisms. Additionally, this process aids in the maintenance of soil fertility. The mucus from slug activity is also known to accelerate nutrient cycling (e.g. C, N and P) (Theenhaus and Scheu 1996). Also, dusky slugs have the potential to impact the dynamics of plant succession in early stage communities by feeding on seedlings (Buschmann et al. 2005).

Total for ecological impact 13 /30

| Feasibility of control | Score |
|---|---|

*Number of populations in Alaska (0-3)* 1

Although the exact number and extent of populations is unknown, has been found around Kodiak, Haines, Juneau, Ketchikan, Sitka, Wrangell, Valdez, and Girdwood (Ferguson and Knight 2010).

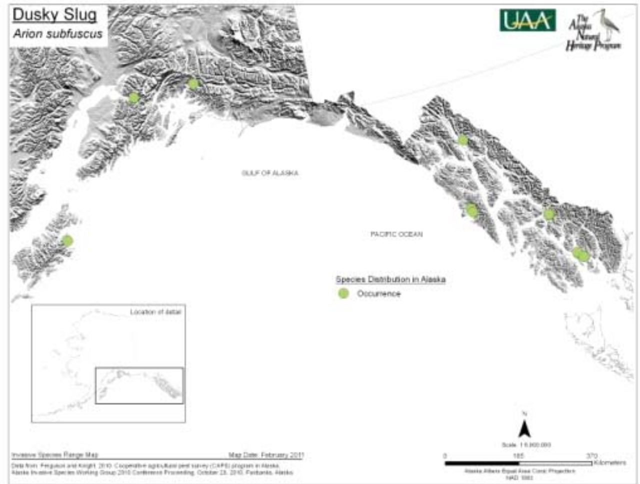
*Significance of the natural area(s) and native species threatened (0-3)* u

*General management difficulty (0-4)* 3

Absolute eradication is unlikely. The most effective management option includes a combination of prevention of spread, early detection and rapid response, and control. To prevent slugs from spreading, public education can raise awareness to reduce human mediated spread of slugs. Early detection and rapid response would most likely involve a watch program allowing biologist and the public to report sightings and control would involve physically removing slugs or possibly chemical treatments (Gotthardt 2010).

Total for feasibility of control 4 / 7

**Range Map**




**References**

Beyer, W. N. and D. M. Saari. 1978. Activity and ecological distribution of the slug, Arion subfuscus (Draparnaud) (Stylommatophora, Arionidae). The American Midland Naturalist 100: 359-366.

Buschmann, H., M. Keller, N. Porret, H. Dietz and P.J. Edwards. 2005. The effect of slug grazing on vegetation development and plant species diversity in an experimental grassland. Functional Ecology 19: 291-298.

Chichester, L.F. and L.L. Getz. 1973. The terrestrial slugs of northeastern North America. Sterkiana 51: 11-42.

Ferguson, A. and C. Knight. 2010. Cooperative agricultural pest survey (CAPS) program in Alaska. Alaska Invasive Species Working Group 2010 Conference Proceeding. October 28, 2010, Fairbanks, Alaska.

Forsyth, R. G. 2004. Land snails of British Columbia. Royal BC Museum, Victoria, Canada.

Fritz, R.S., C.G. Hochwender, D.A. Lewkiewicz, S. Bothwell, and C.M. Orians. 2001. Seedling herbivory by slugs in a willow hybrid system: developemental changes in damage, chemical defense, and plant performance. Oecologia 129: 87-97.

Gotthardt, T. 2010. European black slug risk assessment for the Copper River Delta area, Alaska. Alaska Natural Heritage Program, Prepared for USDA Forest Service. Anchorage, AK.

Grimm, B. 1996. A new method for individually marking slugs (Arion lustanicus (Mabille)) by magnetic transponders. Journal of Molluscan Studies 62: 477-482.

Kerney, M.P., and R.A.D. Cameron. 1979. A field guide to the land snails of Britain and north-west Europe. London: Collins. 288 p., 24 pl.

McDonnell, R.J., T.D. Paine, and M.J. Gormally. 2009. Slugs: a guide of the invasive and native fauna of California. University of California Division of Agriculture and Natural Resources. Publication 8336.

NatureServe. 2009. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available at: http://www.natureserve.org/explorer. (Last accessed: 8 January 2010 ).

Pinceel, J., K. Jordaens, N. Van Houtte, G. Bernon, and T. Backeljau. 2005. Population genetics and identity of an introduced slug: Arion subfuscus s.l. in the north-east USA (Gastropoda, Pulmonata, Arionidae). Genetica 125: 155-171.

Quick, H.E. 1960. British slugs (Pulmonata: Testacellidae, Arionidae, Limacidae). Bulletin of the British Museum (Natural History) Zoology 6: 105-226.

Rathcke, B. 1985. Slugs as generalist herbivores: a test of three hypotheses on plant choices. Ecology 66: 828-836.

Rollo, C.D. and W.G. Wellington. 1975. Terrestrial slugs in the vicinity of Vancouver, British Columbia. The Nautilus 89: 107-115.

Theenhaus, A. and S. Scheu. 1996. The influence of slug (Arion rufuf) mucuc and cast material addition on microbial biomass, respiration, and nutrient cycling in beech leaf litter. Biol. Fertil. Soils 23:80-85.

Zotin, A.A and N.D Ozernyuk. 2002. Thermal compensation of respiration in Pulmonate snails (Pulmonata) of Arion and Deroceras genera living in polar and temperate climatic zone. Biology Bulletin 29: 468-472.

## Acknowledgements

*Authors:* K. M. Walton and T. A. Gotthardt, Alaska Natural Heritage Program, University of Alaska Anchorage.

*Reviewer(s):* Robert Forsyth, Royal BC Museum.

**Scientific name: *Procambarus clarkii*** **Common name: Red swamp crayfish**

**Alaska invasion/introduction history**

A red swamp crayfish was collected in the city of Kenai in May of 2004 (Tunseth 2004) and from the Kenai River in a drift net in July of 2007 (Dunker 2008). No other crayfish of this species have been found since and no known populations have established.

| Ranking Summary | | |
|---|---|---|
| | Potential Max | Score |
| Distribution | 30 | 27 |
| Biological Characteristics | 30 | 19 |
| Ecological Impact | 30 | 17 |
| Feasibility of Control | 10 | 5 |
| Total | 100 | 68 |
| **Invasiveness (out of 100) =** | 68 **Moderately invasive** | |

| Distribution | Score |
|---|---|
| *Current global distribution (0-10)* | 10 |

Invasive on all continents except Australia and Antarctica (Hobbs et al. 1989).

*Extent of the species US range and/or occurrence of formal state or provincial listings (0-10)* 7

The USGS nonindigenous species occurrence list for the red swamp crayfish shows occurrences in 23 states (USGS 2011).

*Role of anthropogenic and natural disturbance in establishment (0-5)* 5

Habitat requirements indicate this species can establish independent of disturbance.

*Climatic similarity between site of origin and release (0-5)* 5

In an article about the crayfish caught in the Kenai River, Robert Romaire and Ray McClaine, aquaculture professors with Louisiana State University, commented that red swamp crayfish have been introduced to places with similar climates to southcentral Alaska (Dunker 2008), although its naitve range is in a much warmer climate in the gulf coast and Mississippi River basin.

Total for distribution 27 /30

| Biological Characteristics and Dispersal | Score |
|---|---|
| *Invasive elsewhere (0-5)* | 5 |

Invasive on all continents except Australia and Antarctica (Hobbs et al. 1989).

*Dietary specialization (0-5)* 5

Omnivore. A diet study in Portugal found that red swamp crayfish guts were filled with a variety of food and had the highest percentage of plant material, followed by animal, then amorphous material, and lastly, sand. The animal component was comprised of fish, other crayfish, mollusca, diptera, ephemeroptera, coleoptera, hemiptera, and odonata. Other studies in different locations have found a similar diet (Perez-Bote 2005).

*Habitat specialization (0-5)* 5

Inhabits sloughs, swamps, roadside ponds, and flowing water. Tolerant of low oxygen and can be found in most habitat types in sluggish streams and lentic situations (NatureServe 2010). In cool regions of Europe, it prefers small permanent ponds. The red swamp crayfish is able to tolerate dry periods of up to four months (Global Invasive Species Database 2011).

*Average number of reproductive events per adult female per year (0-5)* 0

Depending on the size of the adult female, she can produce 100- 500 eggs. In places with a long flooding period (not Alaska), there may be at least 2 reproductive periods (Global Invasive Species Database 2011).

*Potential to be spread by human activities (0-5)* 3

Can spread by anglers as bait, through the pet/aquarium trade, aquaculture, biological supply trade, illegal stocking, and as live food, such as for cooking Cajun dishes (Global Invasive Species Database 2011, Lodge et al. 2000).

*Innate potential for long distance dispersal (0-5)* 1

Males can locally disperse along watercourse (Lodge et al. 2000) and migrate over several miles of dry area (NatureServe 2010).

Total for biological characteristics 19 / 30

| Ecological Impact | Score |
|---|---|
| *Impact on population dynamics of other species (0-10)* | 7 |

Invasive crayfish often reduce the abundance of thin-shelled, small-bodied snails and other invertebrates. Consumes and damages (fragments) hydrophytes, often reducing their abundance and biomass (Gherardi and Acquistapace 2007). Also, can reduce the abundance of algae from direct consumption and by destructing marcophytes algae grow on (Lodge et al. 2000). Red swamp crayfish can also be a vector of disease that attacks native crayfish (Moore 2006), although Alaska does not have native crayfish. Impacts on native fishes and amphibians are less studied, but reductions do occur (Lodge et al. 2000).

*Impact on natural community composition (0-10)* 7

Destruction and consumption of hydrophyte biomass can in turn impact other organisms by reducing protective cover, substratum, and breeding sites. Additionally, in nutrient-rich lakes, hydrophyte destruction causes the lake to switch from clear to turbid dominated by microalgae (Gherardi and Acquistapace 2007). Consumption of invertebrates and destruction of hydrophytes can impact other trophic levels in the food web, such as competion with native fish that feed on invertebrates (Lodge et al. 2000).

*Impact on natural ecosystem processes (0-10)* 3

The Red swamp crayfish is an aggressive burrower, causing damage to rice fields in California (Moore 2006) and degrading river banks (Global Invasive Species Database 2011).

| Total for ecological impact | 17 /30 |
|---|---|

| **Feasibility of control** | **Score** |
|---|---|

*Number of populations in Alaska (0-3)* 1

Has been found twice near Kenai (Dunker 2008, Tunseth 2004).

*Significance of the natural area(s) and native species threatened (0-3)* 2

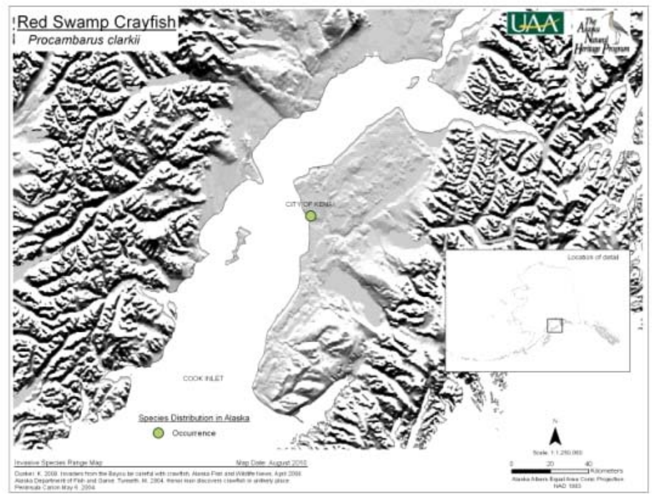
One of the major threats of invasive crayfish is their ability to reduce native crayfish populations through competition, predation, reproductive interference, and disease (Lodge et al. 2000); however, there are no native crayfish in Alaska. Could indirectly compete with native salmon and trout by altering plant and invertebrate communities (Dunker 2008).

*General management difficulty (0-4)* 2

Since few invasive crayfish have been found in Alaska, prevention of further introductions is the primary management option. After finding the crayfish in 2008, the Alaska Department of Fish and Game recommended keeping both live and dead crayfish out of Alaska's waters (Dunker 2008).

| Total for feasibility of control | 5 / 10 |
|---|---|

**Range Map**




**References**


Dunker, K. 2008. Invaders from the Bayou be careful with crawfish. Alaska Fish and Wildlife News, April 2008. Alaska Department of Fish and Game.

Gherardi, F. and P. Acquistapace. 2007. Invasive crayfish in Europe: the impact of Procambarus clarkii on the littoral community of a Mediterranean lake. Freshwater Biology 52: 1249-1259.

Global Invasive Species Database. 2011. Procambarus clarkii (crustacean). Available at: http://www.issg.org/.

Hobbs III, H. H., J. P. Jass, and J. V. Huner. 1989. A review of global crayfish introductions with particular emphasis on two North American species (Decapoda, Cambaridae). Crustaceana 56: 299-316.

Lodge, D. M., C. A. Taylor, D. M. Holdich, and J. Skurdal. 2000. Non-indigenous crayfishes threaten North American freshwater biodiversity: lessons from Europe. Fisheries 25: 7-20.

Moore, J. W. 2006. Red swamp crayfish (Procambarus clarkii), rusty crayfish (Orconectes), virile crayfish (Orconectes virilis). Pp. 100-101 in P.D. Boersma, S.H. Reichard, and A.N. Buren (eds). Invasive Speices in the Pacific Northwest. University of Washington Press, Seattle, WA.

NatureServe. 2010. NatureServe explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. (Accessed: January 20, 2011 ).

Perez-Bote, J. L. 2005. Feeding ecology of the exotic red swamp crayfish, Procambarus clarkii (Girard, 1985) in the Guadiana River (SW Iberian Peninsula). Crustaceana 77: 1375-1387.

Tunseth, M. 2004. Kenai man discovers crawfish in unlikely place. Peninsula Carion May 6, 2004.

United States Geological Survey (USGS). 2011. Procambarus clarkii. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. Http://nas.er.usgs.gov/queries/factsheet.aspx?SpeciesID=217 RevisionDate: 11/16/2009.

## Acknowledgements

*Authors:* K. M. Walton and T. A. Gotthardt, Alaska Natural Heritage Program, University of Alaska Anchorage.

*Reviewer(s):* James Fetzner Jr., Carnegie Museum of Natural History

**Scientific name: *Bythotrephes longimanus*** **Common name: Spiny water flea**

**Alaska invasion/introduction history**

Spiny water fleas are not found in Alaskan waters. In the 1980's the spiny water flea was introduced into the Great Lakes Region probably via ballast water (Sprules et al. 1990, MacIsaac et al. 2004), and has since spread to inland lakes in adjacent regions (MacIsaac et al. 2000, Therriault et al. 2002).

| Ranking Summary | | |
|---|---|---|
| | Potential Max | Score |
| Distribution | 30 | 16 |
| Biological Characteristics | 30 | 24 |
| Ecological Impact | 30 | 21 |
| Feasibility of Control | 10 | 4 |
| Total | 100 | 65 |
| **Invasiveness (out of 100) =** | 65 **Moderately invasive** | |

| **Distribution** | **Score** |
|---|---|

*Current global distribution (0-10)* 6

The spiny water flea, Bythotrephes longimanus, occurs in Europe, Asia, and North America (Rivier 1998, GISD 2009).

*Extent of the species US range and/or occurrence of formal state or provincial listings (0-10)* 3

The spiny water flea occurs in all the Great Lakes and has spread to approximately 140 inland lakes in Ontario and several inland lakes in New York, Michigan, Wisconsin, Ohio and Minnesota (GISD 2009, Liebig and Benson 2009, N. Yan pers comm.).

*Role of anthropogenic and natural disturbance in establishment (0-5)* 2

Spiny water fleas do not require disturbance to establish, but are often spread by human activities (Weisz and Yan 2010).

*Climatic similarity between site of origin and release (0-5)* 5

The spiny water flea is found in cool lakes in northern Europe (e.g., Finland) and Russia (MacIsaac et al. 2000), which are in similar climatic zones to those in Alaska. Additionally, in laboratory experiments, Garton et al. (1990) reported relatively low mortality of Bythotrephes at 5°C, indicating this species ability to survive in cold waters.

Total for distribution 16 /30

| **Biological Characteristics and Dispersal** | **Score** |
|---|---|

*Invasive elsewhere (0-5)* 5

Bythotrephes is invasive in regions of Europe, Asia, and the Great Lakes basin and neighboring regions of the United States and Canada (GISD 2009).

*Dietary specialization (0-5)* 5

Zooplankton are the primary food source for this species (Hatton 2008).

*Habitat specialization (0-5)* 5

In Europe, Bythotrephes longimanus is found in a wide range of lakes (Grigorovich et al. 1998; Therriault et al. 2002), and in North America, this species commonly occurs in large, deep, oligotrophic lakes (MacIsaac et al. 2000; Weisz and Yan 2010).

*Average number of reproductive events per adult female per year (0-5)* 5

The number of reproductive events per female is >3 (N. Yan pers comm.; Kim and Yan 2010).

*Potential to be spread by human activities (0-5)* 3

Scientists hypothesize that spiny water fleas were originally transported to the Great Lakes basin in ballast water (Sprules et al. 1990) and spread throughout the Canadian Shield is correlated to lakes with human activity (Weisz and Yan 2010). Since the spiny water flea is a freshwater species, the probability of being transported in ballast water is low, but possible (Berg 1992). Transport on recreational equipment, such as in bait buckets, on angling gear, and on boats, is the primarily mode of dispersal in North American (Boudreau and Yan 2004).

*Innate potential for long distance dispersal (0-5)* 1

In North America, spiny water fleas are primarily spread via boaters and anglers (Jarnagin et al. 2000, MacIsaac et al. 2004), but diapausing eggs can occasionally undergo rare, natural long distance (>100 km) dispersal events (MacIsaac et al. 2004).

Total for biological characteristics 24 / 30

| **Ecological Impact** | **Score** |
|---|---|

*Impact on population dynamics of other species (0-10)* 7

Declines in abundance of native cladoceran species (Boundreau and Yan 2003) and shifts in size structure in zooplankton species has occurred (Barbiero and Tuchman 2004). Bythotrepes could compete with

native invertebrates and planktivorous fish for food resources (Boudreau and Yan 2003, Foster and Sprules 2009).
The long caudal spine causes ingestion difficulties in small fish (Schneeberger 1991, Baker et al. 1992, Mills et al. 1992, Barnhisel and Harvey 1995), and can disrupt foraging behavior (Barnhisel and Kerfoot 2004). In small lakes,abundance and therefore impacts of Bythotrephes may be reduced by fish predation (Stenson 1972, Nilsson 1979).

*Impact on natural community composition (0-10)* 7

The Great Lakes have experienced large declines in zooplankton species richness (16% decline in Lake Erie, 28% decline in Lake Michigan) and shifts in size structure of zooplankton communities (Barbiero and Tuchman 2004). More specifically, densities of cladocera species have declined in many lakes (Boudreau and Yan 2003) and Bythotrephes has consumed more zooplankton than most other predatory invertebrates, resulting in a 300% higher total consumption (Foster and Sprules 2009). Reductions in zooplankton abundance and biomass can release phytoplankton from grazing pressure (Elser and Goldman 1991) and increase competition among small zooplanktivorous fish for reduced food resources (Boudreau and Yan 2003). Rotifer densities could increased due to indirect impacts on food webs (Hovius et al. 2006).

*Impact on natural ecosystem processes (0-10)* 7

Many lakes with spiny water fleas did not have altered primary productivity, whole water column secondary productivity, or water chemistry (Strecker and Arnott 2008). But epilimnion zooplankton production has declined significantly, resulting in less secondary production available to zooplanktivorous species in that water column strata. Additionally, the spiny water flea may impact energy flow in freshwater systems by diverting energy away from native predators (Strecker and Arnott 2008).

| Total for ecological impact | 21 /30 |
|---|---|

| Feasibility of control | Score |
|---|---|
| *Number of populations in Alaska (0-3)* | 0 |

Not present in Alaska.

*Significance of the natural area(s) and native species threatened (0-3)* 2

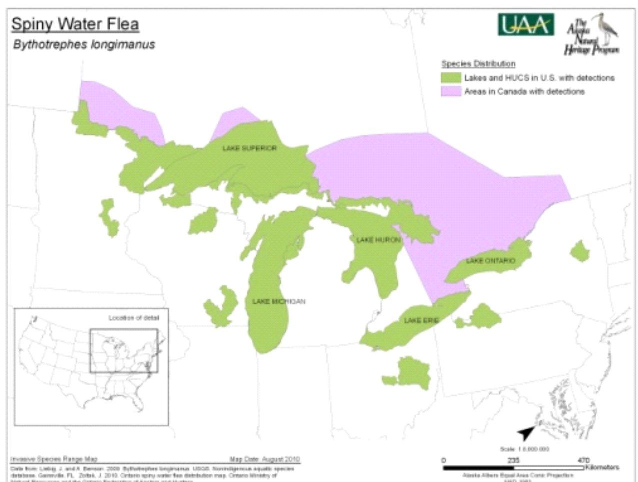
Spiny water fleas may compete with juvenile zooplanktivorous fish, including sport fish (Massachusetts DCR 2009). In Alaska, salmonids, particularly juvenile sockeye salmon, feed on zooplankton (ADF&G 2004) and may be sensitive to changes in abundance and richness.

*General management difficulty (0-4)* 2

Management of the spiny water fleas primarily involves preventing its spread. In the Great Lakes basin and neighboring lakes, many organizations are actively educating the public about the impacts of the spiny water flea and encouraging recreational users to properly clean and dry recreational equipment and boats between outings (Sikes 2002).

| Total for feasibility of control | 4 / 10 |
|---|---|

**Range Map**




**References**

Alaska Department of Fish and Game (ADF&G). 2004. Sockeye Salmon. Alaska Department of Fish and Game Wildlife Notebook Series. Available at: http://www.adfg.state.ak.us/pubs/notebook/notehome.php.

Baker, E. A., S.A. Tolentino, and T.S McComish. 1992. Evidence for yellow perch predation on Bythotrephes cederstroemi in southern Lake Michigan. Journal of Great Lakes Research 18: 190-193.

Barbiero, R.P., and M.L. Tuchman. 2004. Changes in the crustacean communities of Lakes Michigan, Huron, and Erie following the invasion of the predatory cladoceran Bythotrephes longimanus. Canadian Journal of Fisheries and Aquatic Sciences 61: 2111-2125.

Barnhisel, D. R., and H.A. Harvey. 1995. Size-specific fish avoidance of the spined crustacean Bythotrephes: field support for laboratory predictions. Canadian Journal of Fisheries and Aquatic Sciences 52: 768-775.

Barnhisel, D.R., and W.C. Kerfoot. 2004. Fitting into food webs: behavioral and functional response of young lake trout (Salvelinus namaycush) to an introduced prey, the spiny cladoceran (Bythotrephes cederstroemi). Journal of Great Lakes Research 30 (Supplement 1): 300-314.

Berg, D. J. 1992. The spiny water flea, Bythotrephes cederstroemi, another unwelcome newcomer to the Great Lakes. Ohio Sea Grant, College Program: FS-049.

Boudreau, S.A., and N.D. Yan. 2003. The differing crustacean zooplankton communities of Canadian Shield lakes with and without the nonindigenous zooplanktivore Bythotrephes longimanus. Canadian Journal of Fisheries and Aquatic Sciences 60: 1307-1313.

Boudreau, S. A., and N. D. Yan. 2004. Auditing the accuracy of a volunteer-based surveillance program for an aquatic invader, Bythotrephes. Environmental Monitoring and Assessment, 91:17-26.

Elser, J.J., and C.R. Goldman. 1991. Zooplankton effects on phytoplankton in lakes of contrasting trophic status. Limnology and Oceanography 36: 64-90.

Foster, S.E., and W.G. Sprules. 2009. Effects of the Bythotrephes invasion on native predatory invertebrates. Limnology and Oceanography 54: 757-769.

Garton, D.W., D.J. Berg, and R.J. Fletcher. 1990. Thermal tolerances of the predatory cladocerans Bythotrephes cederstroemi and Leptodora kindti: relationship to seasonal abundance in Western Lake Erie. Canadian Journal of Fisheries and Aquatic Sciences 47: 731–738.

Global Invasive Species Database (GISD). 2009. Bythotrephes longimanus (crustacean). Available at: http://www.invasivespecies.net.

Grigorovich, I.A., O.V. Pashkova, Y.F. Gromova, and C.D.A. van Overdijk. 1998. Bythotrephes longimanus in the Commonwealth of Independent States: variability, distribution and ecology. Hydrobiologia 379: 183–198.

Hatton, E.C. 2008. The role of invasive Bythotrephes longimanus in lake food webs. Master's Thesis. Queen's University, Ontario, Canada.

Hovius, J.T., B.E. Beisner, and K.S. McCann. 2006. Epilimnetic rotifer community responses to Bythotrephes longimanus invasion in Canadian Shield lakes. Limnology and Oceanography 51: 1004-1012.

Jarnagin, S.T., B.K. Swan and W.C. Kerfoot. 2000. Fish as vectors in the dispersal of Bythotrephes cederstroemi: diapausing eggs survive passage through the gut. Freshwater Biology, 43: 579-589.

Kim, N., and N. Yan. 2010. Methods for rearing the invasive zooplankter Bythotrephes in the laboratory. Limnology and Oceanography: Methods 8: 552-561.

Liebig, J. and A. Benson. 2009. Bythotrephes longimanus. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. Available at: http://nas.er.usgs.gov/queries/FactSheet.asp?speciesID=162. (Last accessed 2 December 2009).

MacIsaac, H.J., J.V.M. Borbely, J.R. Muirhead, and P.A. Graniero. 2004. Backcasting and forecasting biological invasions of inland lakes. Ecological Applications 14:773-783.

MacIsaac, H.J., H.A.M. Ketelaars, I.A. Grigorovich, C.W. Ramcharan, and N.D. Yan. 2000. Modeling Bythotrephes longimanus invasions in the Great Lakes basin based on its European distribution. Archiv für Hydrobiologie 149: 1-21.

Massachusetts Department of Conservation and Recreation (DCR). 2009. Spiny water flea alert. Available at: http://www.mass.gov/dcr/watersupply/watershed/spinywaterflea.htm. (Last accessed 7 December 2009).

Mills, E. L., R. O'Gorman, J. DeGisi, R.F. Heberger, and R.A. House. 1992. Food of the alewife (Alosa pseudoharengus) in Lake Ontario before and after the establishment of Bythotrephes cederstroemi. Canadian Journal of Fisheries and Aquatic Sciences 49: 2009-2019.

Nilsson, N.-A, 1979. Food and habitat of the fish community of the offshore region of Lake Vanern, Sweden. Institute of Freshwater Research 58:126-139.

Rivier I. K. 1998. The predatory Cladocera (Onychopoda: Podonidae, Polyphemidae, Cercopagidae) and Leptodorida of the world. Guides to the identification of the micro-invertebrates of the continental waters of the world. Backhuys Publishing, Leiden, 13: 213 pp.

Schneeberger, P.J. 1991 Seasonal incidence of Bythotrephes cederstroemi in the diet of yellow perch (ages 0–4) in Little Bay de Noc, Lake Michigan, 1988. Journal of Great Lakes Research 17: 281–285.

Sikes, B.A. 2002. Invader of the month (June 2002). Spiny water flea. Institute for Biological Invasions. Available at: http://invasions.bio.utk.edu/invaders/flea.html. (Last accessed 3 December 2009).

Sprules, W.G., H.P. Riessen, and E.H. Jin. 1990. Dynamics of the Bythotrephes invasion of the St. Lawrence Great Lakes. Journal of Great Lakes Research 16: 346-351.

Stenson, J. 1972. Fish predation effects on the species composition of the zooplankton community in eight small forest lakes. Institute of Freshwater Research 52: 132-148.

Strecker, A.L., and S.E. Arnott. 2008. Invasive predator, Bythotrephes, has varied effects on ecosystem function in freshwater lakes. Ecosystems 11: 490-503.

Therriault, T.W., I.A. Grigorovich, M.E. Cristescu, H.A.M. Ketelaars, M. Viljanen, D.D. Heath, and H.J. MacIsaac. 2002. Taxonomic resolution of the genus Bythotrephes Leydig using molecular markers and re-evaluation of its global distribution. Divers. Distrib. 8: 67–84.

Weisz, E.J. and N.D. Yan. 2010. Relative value of limnological, geographic, and human use variables as predictors of the presence of Bythotrephes longimanus in Canadian Shield lakes. Can. J. Fish. Aquat. Sci. 67: 462-472.

## Acknowledgements

*Authors:* K. M. Walton and T. A. Gotthardt, Alaska Natural Heritage Program, University of Alaska Anchorage.

*Reviewer(s):* Norman Yan, York University.

**Scientific name: *Carcinus maenas L.*** **Common name: European green crab**

**Alaska invasion/introduction history**

European green crab are not in Alaska; however, they arrived in California and the pacific northwest in the 1990's (Cohen et al. 1995, McDonald 2009).

| Ranking Summary | | |
|---|---|---|
| | Potential Max | Score |
| Distribution | 30 | 20 |
| Biological Characteristics | 30 | 23 |
| Ecological Impact | 30 | 17 |
| Feasibility of Control | 10 | 4 |
| Total | 100 | 64 |
| **Invasiveness (out of 100) =** | 64 **Moderately invasive** | |

| Distribution | Score |
|---|---|
| *Current global distribution (0-10)* | 10 |

European green crabs are native to Europe and possibly northern Africa and invasive in North America, southern Africa, South America, Asia, and Australia (Fulton and Grant 1900, Christiansen 1969, Zeidler 1978, 1988, Le Roux et al. 1990, Cohen et al. 1995, Carlton and Cohen 2003, Hidalgo et al. 2005).

*Extent of the species US range and/or occurrence of formal state or provincial listings (0-10)* 3

European green crabs are known to occur in Bristish Columbia, California, Oregon, Washington, Maine, Massachusetts, New York, and New Jersey (Audet et al. 2003, Carlton and Cohen 2003).

*Role of anthropogenic and natural disturbance in establishment (0-5)* 5

European green crabs do not need disturbance to establish, allowing them to thrive on pristine shores and in highly modified harbors (McDonald 2009).

*Climatic similarity between site of origin and release (0-5)* 2

Cohen et al. (1995) predicted that based on winter water temperature tolerances, the European green crab's potential range could extend into southern Alaska (Sverdrup et al. 1947). Hines et al. (2004) reported that several locations along the Alaskan coast from Sitka in Southeast Alaska to Sand Point in the Aleutian Islands have at least 60 days of water temperatures above 10°C, which is necessary of larvae development.

Total for distribution 20 /30

| Biological Characteristics and Dispersal | Score |
|---|---|
| *Invasive elsewhere (0-5)* | 5 |

European green crabs are invasive on the east and west coasts of North America, and in Asia, Africa and Australia (Fulton and Grant 1900, Zeidler 1978, 1988, Le Roux et al. 1990, Cohen et al. 1995, Carlton and Cohen 2003).

*Dietary specialization (0-5)* 5

European green crabs diet can consist of a large variety of prey, including organisms from at least 104 families and 158 genera in 5 plant, 5 protist, and 14 animal phyla (Cohen et al. 1995). Major prey organisms are bivalves, gastropods, crustaceans, polychaetes, and algae (Cohen et al. 1995).

*Habitat specialization (0-5)* 5

European green crabs utilize a variety of habitat types in protected marine and estuarine areas, including rocky shores, mud, sand, and rock substrates, and in tidal pools and marshes. This species is also euryhaline, allowing individuals to live in waters with salinities ranging from 5 to 33% (Naylor 1962, Christiansen 1969, Crothers 1969, 1970, Berrill and Berrill 1981, Cohen et al. 1995, Grosholz and Ruiz 1995). It is reasonally tolerant of low oxygen conditions and is able to survive in water temperatures from 0 to over 35°C (Klassen and Locke 2007).

*Average number of reproductive events per adult female per year (0-5)* 2

Females can produce more than one clutch of eggs a year and each clutch typically consists of 185,000 or more eggs (Grosholz and Ruiz 2002).

*Potential to be spread by human activities (0-5)* 5

Humans probably aided in the dispersal of all introduced populations of European green crabs (Cohen et al. 1995, Carlton and Cohen 2003). Humans spread this species via attachement to ship hulls, ballast water, solid ballast (e.g., rocks), fouled seawater pipes, semisubmersible exploratory drilling platforms, commercial fisheries products, educational/research supplies, and private release for fisheries purposes (Cohen et al. 1995, Carlton and Cohen 2003).

*Innate potential for long distance dispersal (0-5)* 1

Although European green crab larvae can be transported by water currents, long distance dispersal events are infrequent by this mode of transport (Cohen et al. 1995, PWSRCAC 2004).

| Total for biological characteristics | 23 / 30 |
|---|---|

| Ecological Impact | Score |
|---|---|

*Impact on population dynamics of other species (0-10)* 7

In laboratory experiments, European green crabs have competed with juvenile Dungeness crab for food, shelter, and space; however, it has been suggested that less competition would occur in the natural environment due to spatial separation (McDonald et al. 2001). European green crabs will also compete and prey upon other crabs, shrimp, invertebrates, bird, and fish, which could decrease the abundance of these species and change their morphology, behavior, and life history traits (Cohen et al. 1995, Grosholz and Ruiz 1995). Green crabs have been shown to disturb eelgrass beds, which promotes the establishment of algae in place of the eelgrass (Klassen and Locke 2007).

*Impact on natural community composition (0-10)* 7

European green crabs have the potential to negatively impact communities by altering food webs. The crabs could reduce invertebrate species, which could then affect other organisms that depend on those invertebrates (Grosholz and Ruiz 1995), and change the grazing pressure those invertebrates put on primary producers (Klassen and Locke 2007).

*Impact on natural ecosystem processes (0-10)* 3

European green crabs can disturb the sediment by digging through the top 15 cm, which can cause changes in infaunal populations (Cohen et al. 1995). In an experimental study, European green crabs caused lower levels of sediment chlorophyll a, total sediment organic material, and redox compared with control areas lacking crabs (Neira et al. 2006).

| Total for ecological impact | 17 /30 |
|---|---|

| Feasibility of control | Score |
|---|---|

*Number of populations in Alaska (0-3)* 0

No populations have established in Alaska.

*Significance of the natural area(s) and native species threatened (0-3)* 2

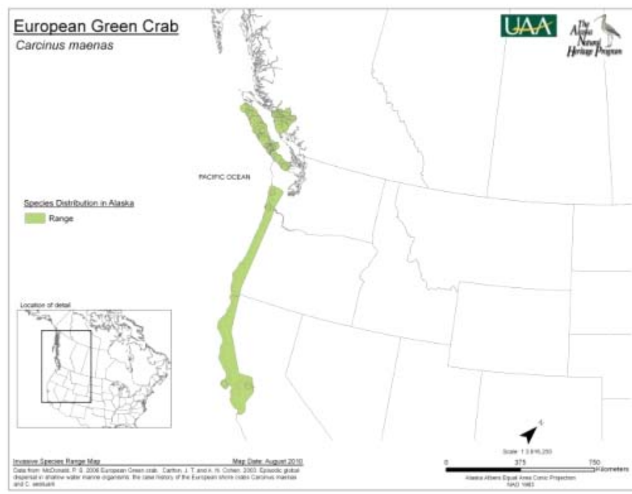
European green crabs have the potential to impact the shellfish industry by competing with and reducing the food available for economically important shellfish species (Jamieson et al. 1998, McDonald et al. 2001). In the western United States, European green crabs have indirectly reduced abundances of shorebirds, which impacts bird watching (Lovell et al. 2007).

*General management difficulty (0-4)* 2

Since there are no populations of European green crabs in Alaska, management involves public education and monitoring of sites in order to rapidly detect a new invasion. If a new population is rapidly detected, eradication is possible by trapping, which involves moderate effort (Grosholz and Ruiz 2002).

| Total for feasibility of control | 4 / 10 |
|---|---|

**Range Map**




**References**

Audet, D., D.S. Davis, G. Miron, M. Moriyasu, K. Benhalima, and R. Campbell. 2003. Geographical expansion of a nonindigenous crab, Carcinus maenas (L.), along the Nova Scotian shore into the southeastern Gulf of St. Lawrence, Canada. Journal of Shellfish Research 22:255-262.

Berrill, M. and D. Berrill. 1981. A Sierra Club naturalist's guide: the North Atlantic coast. Sierra Club Books, San Francisco, California.

Carlton, J.T. and A.N. Cohen. 2003. Episodic global dispersal in shallow water marine organism: the case history of the European shore crabs Carcinus maenas and C. aestuarii. Journal of Biogeography 30:1809-1820.

Christiansen, M.E. 1969. Crustacea Decapoda Brachyura. Marine Invertebrates of Scandinavia. Vol.2, Universitetsforlaget, Oslo, Norway, p 49-51.

Cohen, A.N., J.T. Carlton, and M.C. Fountain. 1995. Introduction, dispersal and potential impacts of the green crab Carcinus maenas in San Francisco Bay, California. Marine Biology 122:225-237.

Crothers, J.H. 1969. The distribution of crabs in Dale Roads (Milford Haven, Pembrokeshire) during summer. Field Studies 3:109-124.

Crothers, J.H. 1970. The distribution of crabs on rocky shores around Dale Peninsula. Field Studies 3:263-274.

Fulton, S.W. and F.E. Grant. 1900. Note on the occurrence of the European crab, Carcinus maenas, Leach, in Port Phillip. Victorian Naturalist 27:147-148.

Grosholz, E.D. and G.M. Ruiz. 2002. Management plan for the European green crab. Aquatic Nuisance Species task Force. 55p.

Hines, A.H., G.H. Ruiz, N.G. Hitchcock, and K. deRiveria. 2004. Projecting range expansion of invasive European green crabs (Carcinus maenas) to Alaska: temperature and salinity tolerance of larvae. Research Report. Prince William Sound Regional Citizens' Advisory Council.

Jamieson, G.S., E.D. Grosholz, D.A. Armstrong, and R.W. Elner. 1998. Potential ecological implications from the introduction of the European green crab, Carcinus maenas (Linnaeus), to British Columbia, Canada, and Washington, USA. Journal of Natural History 32:1587-1598.

Klassen, G. and A. Locke. 2007. A biological synopsis of the European green crab, Carcinus maenas. Can. Manuscr. Rep. Fish. Aquat. Sci. no. 2818: vii+75 pp.

Le Roux, P.J., G.M. Branch, M.A.P. Joska. 1990. On the distribution, diet, and possible impact of the invasive European shore crab Carcinus maenas (L.) along the South African coast. South African Journal of Marine Science 9:85-92.

Lovell, S., E. Besedin, and E. Grosholz. 2007. Modeling economic impacts of the European green crab. American Agricultural Economics Association Annual Meeting, Portland, Oregon, July 29-August 1, 2007. 40 p.

McDonald, P.S. 2009. European green crab Carcinus maenas. In P.D. Boersma, S.H. Reichard, and A.N. Van Buren (eds) Invasive species in the Pacific Northwest. University of Washington Press, Seattle, Washington. 110-111 p.

McDonald, P.S., G.C. Jensen, and D.A. Armstrong. 2001. The competitive and predatory impacts of the nonindigenous crab Carcinus maenas (L.) on early benthic phase Dungeness crab Cancer magister Dana. Journal of Experimental Marine Biology and Ecology 258:39-54.

Naylor, E. 1962. Seasonal changes in a population of Carcinus maenas (L.) in the littoral zone. Journal of Animal Ecology 31:601:609.

Neira, C., E.D. Grosholz, L.A. Levin, and R. Blake. 2006. Mechanisms generating modification of benthos following tidal flat invasion by a Spartina hybrid. Ecological Applications 16:1391-1404.

Prince William Sound Regional Citizens' Advisory Council (PWSRCAC). 2004. Non-indigenous aquatic species of concern for Alaska. Green crab fact sheet. Available at http://www.pwsrcac.org/projects/ NIS/factsheets.html. Last accessed 14 October 2009.

Sverdrup, H.U., M.W. Johnson, and R.H. Flemming. 1947. The oceans. Their physics, chemistry, and general biology. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Zeidler, W. 1978. Note on the occurrence of the European shore crab, Carcinus maenas (Linn., 1758) in Australia. South Australian Naturalist 53:11-12.

Zeidler, W. 1988. The European shore crab, Carcinus maenas in the Coorong – a potential threat to fisheries. Transactions of the Royal Society of Australia 112:181-182.

## Acknowledgements

*Authors:* K. M. Walton and T. A. Gotthardt, Alaska Natural Heritage Program, University of Alaska Anchorage.

*Reviewer(s):* Matthias Herborg, BC Ministry of Government.

**Scientific name: *Pacifastacus leniusculus*** **Common name: Signal crayfish**

**Alaska invasion/introduction history**

A single individual has been found in the Buskin River on Kodiak Island (Fay 2002, USGS 2009), but no breeding populations have been reported in Alaska.

| Ranking Summary | | |
|---|---|---|
| | Potential Max | Score |
| Distribution | 30 | 19 |
| Biological Characteristics | 30 | 19 |
| Ecological Impact | 30 | 21 |
| Feasibility of Control | 10 | 5 |
| Total | 100 | 64 |
| **Invasiveness (out of 100) =** | 64 **Moderately invasive** | |

| Distribution | Score |
|---|---|
| *Current global distribution (0-10)* | 6 |

Signal crayfish are native to North America and invasive in Europe and Japan (Hobbs 1989, NatureServe 2009).

*Extent of the species US range and/or occurrence of formal state or provincial listings (0-10)* 3

Signal crayfish are distributed throughout the western U.S (California, Oregon, Washington, Montana, Idaho, Nevada, Utah, Wyoming, Alaska, and southern British Columbia (NatureServe 2009).

*Role of anthropogenic and natural disturbance in establishment (0-5)* 5

Signal crayfish occur in natural undisturbed areas.

*Climatic similarity between site of origin and release (0-5)* 5

Signal crayfish inhabit aquatic ecosystems as far north as Finland (Bondar et al. 2003), which is of a similar latitude and climate as Alaska.

Total for distribution 19 /30

| Biological Characteristics and Dispersal | Score |
|---|---|
| *Invasive elsewhere (0-5)* | 5 |

Signal crayfish are invasive in Europe, Japan, and regions outside of its native range in North America (NatureServe 2009).

*Dietary specialization (0-5)* 5

Signal crayfish are omnivorous and can be predatory (Mason 1974, Guan and Wiles 1998, Freeman et al. 2009). Their diet includes algae, benthic insects, vascular detritus, woody debris, and other crayfish (Mason 1974, Guan and Wiles 1998), with feeding habits changing with the availability of resources (Bondar et al. 2003).

*Habitat specialization (0-5)* 5

Signal crayfish inhabit rocky bottomed fresh and brackish waters, including lakes, rivers, ponds, and estuaries (Miller 1960, Goldman and Rundquist 1977, Shimizu and Goldman 1983, GISD 2009, NatureServe 2009). Crayfish prefer water temperatures below 25°C (Hogger 1988), high dissolved oxygen content (Nyström 2002), high calcium content (above 5mg/L; Lowery and Holdich 1988), and a pH above 6 (Bondar et al. 2003).

*Average number of reproductive events per adult female per year (0-5)* 0

It is controversial if signal crayfish spawn every year once mature or if some years are skipped (Miller 1960, Abrahamsson and Goldman 1970). Spawning occurs in the fall and females lay one clutch of 100-400 eggs (Kirjavaienen and Westman 1999).

*Potential to be spread by human activities (0-5)* 3

Humans have mediated the spread of signal crayfish through aquaculture, stocking (Holdich and Reeve 1991, Gherardi 2007), and baitbucket transport (DiStephano et al. 2009).

*Innate potential for long distance dispersal (0-5)* 1

Most crayfish move relatively short distances, with a small number of individuals moving larger distances (maximum distance recorded was 375 m over a 21 day study period; Bubb et al. 2006). Upstream dispersal of > 1 km/year is known in Finland and the UK (Johnsen and Taugbøl 2010) and Light (2003) recorded upstream movements of 120 m/day.

Total for biological characteristics 19 / 30

| Ecological Impact | Score |
|---|---|
| *Impact on population dynamics of other species (0-10)* | 7 |

Signal crayfish can compete with benthic fish for shelter, causing shifts in fish behavior, increased susceptibility to predation, and decreased abundance, as seen in bullheads in Northern England and Atlantic salmon in Scotland (Griffiths et al. 2004, Bubb et al. 2009). In Alaska, many fish, including salmon parr, sculpin, long nose suckers, and trout utilize shelter in benthic habitats during at least one life stage and therefore could be displaced from their shelter by crayfish. Crayfish could compete with fish for food, and prey on fish eggs and juvenile fish (Ribbens and Graham 2004). In California, crayfish have contributed to the decline of amphibians (Kats et al. 2006) by increasing mortality on eggs and larvae (Kats and Ferrer 2003). Crayfish are also carriers of a variety of diseases and potenitally harmful organisms , that can be especially harmful to native crayfish (Longshaw 2011), although there are no native crayfish in Alaska. Additionally, crayfish can exert grazing pressure, reducing the cover of detritus and macrophytes (Maitland et al. 2001, Gherardi 2007).

*Impact on natural community composition (0-10)* 7

Signal crayfish can reduce biodiversity and impact ecological communities by altering the food webs of other species, which in turn cascades to higher trophic levels (Gherardi 2007). Changes in species richness and biomass result from increased foraging pressure by crayfish on detritus, macrophytes, and invertebrates (including snails; Gherardi 2007). A reduction in macrophytes composition and abundance can change littoral habitats and the macrophyte-associated taxa (Nyström et al. 1996). Additionally, a reduction in snail abundance releases microalgae from grazing pressure (crayfish can not efficiently feed on microalgae), allowing increased colonization of water surfaces by microalgae (Rodríguez et al. 2003). Changes to lower trophic levels, such as the ones mentioned above, can cascade to alterations in food availability for predators, such as large predatory fish, birds, and mammals (Gherardi 2007).

*Impact on natural ecosystem processes (0-10)* 7

During burrowing and locomotory activity (walking and tail flipping), crayfish can cause bioturbation that increases total suspended solids and water turbidity, which in turn changes littoral habitats by reducing light penetration and plant productivity (Anastácio and Marques 1997, Angeler et al. 2001, Rodríguez et al. 2003). Although not considered a burrowing species, in Europe, signal crayfish burrow extensively resulting in changes to the stream bank morphology and even collapse (Guan 1994, Sibley 2000). Crayfish can also change energy cycling by consuming large amounts of energy from the detritus pool (lower trophic level) and transferring it directly to higher trophic levels (Gherardi 2007).

| Total for ecological impact | 21 /30 |
|---|---|

| **Feasibility of control** | **Score** |
|---|---|

*Number of populations in Alaska (0-3)* 1

A signal crayfish was collected in the Buskin River on Kodiak Island (Fay 2002, Schrader and Hennon 2005, USGS 2009).

*Significance of the natural area(s) and native species threatened (0-3)* 2

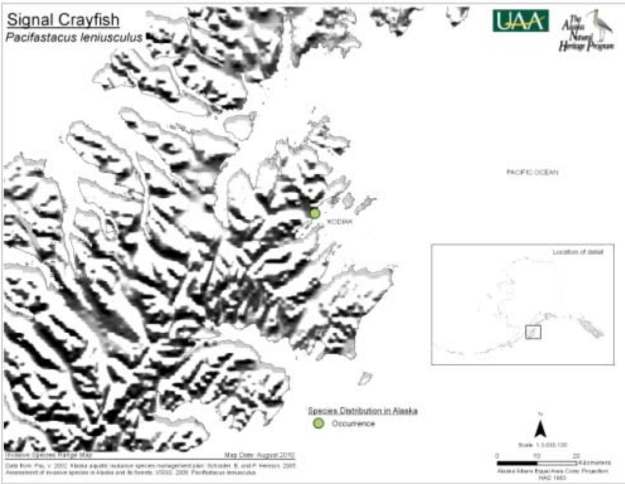
Field and laboratory experiments in the U.K. have reported crayfish displacing benthic fish, including salmonids (Griffiths et al. 2006, Bubb et al. 2009). If signal crayfish increase in abundance in Alaska, they could compete with fish, such as salmon parr, sculpin, long nose suckers, and trout, which all utilize benthic habitats during at least one life stage. Additionally, signal crayfish could alter littoral habitats, which are of importance to aquatic ecosystems.

*General management difficulty (0-4)* 2

Since only a few individual crayfish have been found in Alaska, control may include removal of individuals and prevention of further introductions through public education. However, once established, eradication is difficult without negatively impacting native fauna or causing environmental damage, making containment of existing populations the most feasible management option (Corkum 2004, Genovesi 2005, Freeman et al. 2009).

| Total for feasibility of control | 5 / 10 |
|---|---|

## Range Map




## References

Abrahamsson, S.A.A. and C.R. Goldman. 1970. Distribution, density, and production of the crayfish Pacifastacus leniusculus (Dana) in Lake Tahoe, California-Nevada. Oikos 21: 83-91.

Anastácio, P.M. and J.C. Marques. 1997. Procambarus clarkii, effects on initial stages of rice growth in the lower Mondego River valley (Portugal). Freshwater crayfish 11: 608-617.

Angeler, D.G., S. Sánchez-Carrillo, G. García, and M. Alvarez-Cobelas. 2001. The influence of Procambarus clarkii (Cambaridae, Decapoda) on water quality and sediment characteristics in a Spanish floodplain wetland. Hydrobiologia 464: 9-98.

Bondar, C., Y. Zhang, J. S. Richardson, and D. Jesson. 2003. The conservation status of the freshwater crayfish, Pacifastacus leniusculus, in British Columbia. Ministry of Water, Land and Air Protection Province of British Columbia, Fisheries Management Report.

Bubb, D.H., T.J. Thom, and M.C. Lucas. 2006. Movement patterns of the invasive signal crayfish determined by PIT telemetry. Canadian Journal of Zoology 84: 1202-1209.

Bubb, D.H., O.J. O'Malley, A.C. Gooderham, and M.C. Lucas. 2009. Relative impacts of native and non-native crayfish on shelter use by indigenous benthic fish. Aquatic Conservation: Marine and Freshwater Ecosystems 19: 448-455.

Corkum, L.D. 2004. Pheromone signaling in conservation. Aquatic Conservation: Marine and Freshwater Ecosystems 14: 327-331.

DiStephano, R.J., M.E. Litvan, and P.T. Horner. 2009. The bait industry as a potential vector for alien crayfish introductions: problem recognition by fisheries agencies and a Missouri evaluation. Fisheries 34: 586-597.

Fay, V. 2002. Alaska aquatic nuisance species management plan. Alaska Department of Fish and Game, Juneau, AK.

Freeman, M.A., J.F. Turnbull, W.E. Yeomans, and C.W. Bean. 2009. Prospects for management strategies of invasive crayfish populations with an emphasis on biological control. Aquatic Conservation: Marine and Freshwater Ecosystems. In Press.

Genovesi, P. 2005. Eradications of invasive alien species in Europe: a review. Biological Invasions 7: 127-133.

Gherardi, F. 2007. Understanding the impact of invasive crayfish. Pp. 507-542 In F. Gherardi (ed). Biological invaders in inland waters: profiles, distribution and threats. Springer, Dordrecht, Netherlands.

Goldman, C.R. and J.C. Rundquist. 1977. A comparative ecological study of the Californian crayfish P. leniusculus (Dana) from two subalpine lakes. Freshwater Crayfish 3: 51-80.

Griffiths, S.W., P. Collen, and J.D. Armstrong. 2004. Competition for shelter among over-wintering signal crayfish and juvenile Atlantic salmon. Journal of Fish Biology 65: 436-447.

Guan, R-Z. 1994. Burrowing behaviour of signal crayfish, Pacifastacus leniusculus (Dana), in the River Great Ouse, England. Freshwater Forum 4: 155-168

Guan, R. and P.Wiles. 1998. Feeding ecology of the signal crayfish Pacifastacus leniusculus in a British lowland river. Aquaculture 169: 177-193.

Hobbs, H. Jr. 1989. An illustrated checklist of the American crayfishes (Decapoda: Astacidae, Cambaridae & Parastacidae). Smithsonian Contributions to Zoology 480. Smithsonian Institute Press, Washington, D. C. 236 pp.

Hogger, J.B. 1988. Ecology, population biology and behavior. Pp. 114-144 In D.M. Holdich and R.S. Lowery (eds). Freshwater crayfish: biology, management and exploitation. Croom Helm, London.

Holdich, D.M., and I.D. Reeve. 1991. Distribution of freshwater crayfish in the British Isles, with particular reference to crayfish plague, alien introductions and water quality. Aquatic Conservation: Marine and Freshwater Ecosystems 1: 139-158.

Johnsen, S.I. and Taugbøl, T. 2010. NOBANIS – invasive alien species fact sheet – Pacifastacus leniusculus. Online Database of the North European and Baltic Network on Invasive Alien Species – NOBANIS. Available at: www.nobanis.org, last accessed 1/27/2011.

Kats, L.B. and R.P. Ferrer. 2003. Alien predators and amphibian declines: review of two decades of science and the transition to conservation. Diversity and Distribution 9: 99-110.

Kats, L., L. Pintor, A. Sih, and J. Kerby. 2006. Aquatic Nuisance Species: A multi-stage approach to understanding the invasion ecology of exotic crayfish in Northern and Southern California. UC San Diego: California Sea Grant College Program. Available at: http://www.escholarship.org/uc/item/9vv2r9t4. (Last accessed 24 November 2009).

Light, T. 2003. Success and failure in a lotic crayfish invasion: the roles of hydrologic variability and habitat alteration. Freshwater Biology 48(10):1886-1897.

Longshaw, M. 2011. Diseases of crayfish: A review. Journal of Invertebrate Pathology 106: 54-70.

Lowery, R.S. and D.M. Holdich. 1988. Pacifastacus leniusculus in North America and Europe, with details of the distribution of introduced and native crayfish species in Europe. Pp. 283-308 In D.M. Holdich and R.S. Lowery (eds). Freshwater Crayfish: Biology, Management and Exploitation, Croom Helm, London.

Maitland, P.S., C. Sinclair, and C.R. Doughty. 2001. The status of freshwater crayfish in Scotland in the year 2000. Glasgow Naturalist 23: 26-32.

Mason, J.C. 1974. Aquaculture potential of the freshwater crayfish, (Pacifastacus). I. studies during 1970. Fisheries Research Board of Canada. Technical Report 440.

Miller, G.C. 1960. Taxonomy and certain biological aspects of the crayfish of Oregon and Washington. Master's thesis, Oregon State University.

NatureServe. 2009. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, VA. Available at: http://www.natureserve.org/explorer. (Last accessed: 24 November 2009).

Nyström, P. 2002. Ecology. Pp. 192-235 In D.M. Holdich (ed). Biology of freshwater crayfish. Blackwell Science, London.

Nyström, P., C. Brönmark, and W. Granéli. 1996. Patterns in benthic food webs: a role for omnivorous crayfish? Freshwater Biology 36: 631-646.

Ribbens, J.C.H. and J.L. Graham. 2004. Strategy for the containment and possible eradication of American signal crayfish (Pacifastacus leniusculus) in the River Dee catchment and Skyre Burn catchment, Dumfries and Galloway. Scottish Natural Heritage, Commissioned Report No. 014.

Rodríguez, C.L., E. Bécares, and M. Ferández-Aláez. 2003. Shift from clear to turbid phase in Lake Chozas (NW Spain) due to the introduction of the American red swamp crayfish (Procambarus clarkii). Hydrobiologia 506-509:421-426.

Schrader, B. and P. Hennon. 2005. Assessment of invasive species in Alaska and its national forests. U.S. Forest Service Report.

Shimizu, S.J. and C.R. Goldman. 1983. Pacifastacus leniusculus (Dana) production in the Sacramento River. Freshwater Crayfish 5: 210-228.

Sibley, P. 2000. Signal crayfish management in the River Wreake catchment. Pp. 95-108 in D. Rogers and J. Brickland (Eds). Crayfish Conference Leeds. Environment Agency, Leeds, England.

United States Geological Survey (USGS). 2009. Pacifastacus leniusculus. USGS nonindigenous aquatic species database, Gainesville, FL. Available at: http://nas.er.usgs.gov. (Last accessed 24 November 2009).

## Acknowledgements

*Authors:* K. M. Walton and T. A. Gotthardt, Alaska Natural Heritage Program, University of Alaska Anchorage.

*Reviewer(s):* Theo Light, Shippensburg University. James Fetzner Jr., Carnegie Museum of Natural History.

**Scientific name: *Perca flavescens*** **Common name: Yellow perch**

**Alaska invasion/introduction history**

A population of yellow perch was illegally introduced to an unnamed lake near Nikiski on the Kenai Peninsula. In 2000, the Alaska Department of Fish and Game eradicated this population using rotenone (Fay 2002, USGS 2008, ADF&G undated). No other known populations of yellow perch exist in Alaska.

| Ranking Summary | | |
|---|---|---|
| | Potential Max | Score |
| Distribution | 30 | 20 |
| Biological Characteristics | 30 | 19 |
| Ecological Impact | 30 | 21 |
| Feasibility of Control | 10 | 4 |
| Total | 100 | 64 |
| **Invasiveness (out of 100) =** | 64 **Moderately invasive** | |

| **Distribution** | **Score** |
|---|---|
| *Current global distribution (0-10)* | 0 |

Yellow perch occur in North America (Schindler and Carter 2006).

*Extent of the species US range and/or occurrence of formal state or provincial listings (0-10)* 10

Yellow perch occur in the majority of the U.S. states and Canada, with populations in the western U.S. establishing from illegal introductions and stocking events (Schindler and Carter 2006, NatureServe 2009).

*Role of anthropogenic and natural disturbance in establishment (0-5)* 5

Yellow perch are not dependent on disturbance for establishment.

*Climatic similarity between site of origin and release (0-5)* 5

Yellow perch occur in aquatic systems throughout the boreal forests of Canada and in areas adjacent to southeast Alaska in British Columbia (Schindler and Carter 2006, NatureServe 2009); indicating perch occupy climatic zones similar to those that exist in Alaska.

Total for distribution 20 /30

| **Biological Characteristics and Dispersal** | **Score** |
|---|---|
| *Invasive elsewhere (0-5)* | 5 |

Yellow perch have been introduced into many drainages in the western U.S. (Schindler and Carter 2006).

*Dietary specialization (0-5)* 5

After hatching, larval perch feed on zooplankton in open waters and by late summer transition to feeding on benthic insects along the shoreline. Adults are omnivorous, feeding on zooplankton, benthic insects, mollusks, and small fishes (Schindler and Carter 2006).

*Habitat specialization (0-5)* 5

Yellow perch live in lakes with relatively clear water and aquatic vegetation to provide cover and structure to lay eggs on (Schindler and Carter 2006).

*Average number of reproductive events per adult female per year (0-5)* 0

Females spawn once a year in the spring (Schindler and Carter 2006).

*Potential to be spread by human activities (0-5)* 3

There are many accounts of humans intentionally introducing yellow perch to lakes for angling and the accidental release from bait buckets (Schindler and Carter 2006).

*Innate potential for long distance dispersal (0-5)* 1

Perch are not typically long distance dispersers, only making local migrations from lakes to tributaries to spawn (Scott and Crossman 1973). Mansueti (1960) reported that while resident yellow perch may have limited movements, stocked perch traveled farther from their release site and have the ability to distribute themselves throughout neighboring drainages.

Total for biological characteristics 19 / 30

| **Ecological Impact** | **Score** |
|---|---|
| *Impact on population dynamics of other species (0-10)* | 7 |

In the Klamath River, California, 35 out of 44 yellow perch had fingerling Chinook salmon in their stomachs (Dill and Cordone 1997). Bonar et al. (2004) found only a few Coho salmon in the stomach contents of yellow perch from shallow lakes in Washington. When the habitat of yellow perch and trout overlaps, perch can compete for food, thus reducing the survival and growth of native trout (Moyle 2002). In Phillips Reservoir, Oregon, competition between juvenile yellow perch and several species of gamefish resulted in the reduction of zooplankton and gamefish abundances (Schrader 2000).

*Impact on natural community composition (0-10)* 7

Yellow perch have been known to shift zooplankton communities from large bodied to small bodied species (Schindler and Carter 2006). In one community, calanoid copepods and daphnia declined from 15 and 39% of the zooplankton community to 2 and 24% respectively (Schrader 2000). In Oregon, the depletion of large bodied zooplankton caused a decline in juvenile gamefish from competition for a limited resource (Schrader 2000). Native fish abundance and biodiversity can be further impacted from predations by yellow perch (Schindler and Carter 2006).

*Impact on natural ecosystem processes (0-10)* 7

In aquatic systems, invasive species that alter food webs also typically alter ecosystem productivity and nutrient cycling by consuming energy (such as zooplankton) that would have otherwise been directed towards native species (Schrader 2000).

| Total for ecological impact | 21 /30 |
|---|---|

| Feasibility of control | Score |
|---|---|

*Number of populations in Alaska (0-3)* 0

There are currently no populations of yellow perch in Alaska. In 2000, the only known population near Nikiski on the Kenai Peninsula was eradicated (Fay 2002, USGS 2008, ADF&G undated).

*Significance of the natural area(s) and native species threatened (0-3)* 2

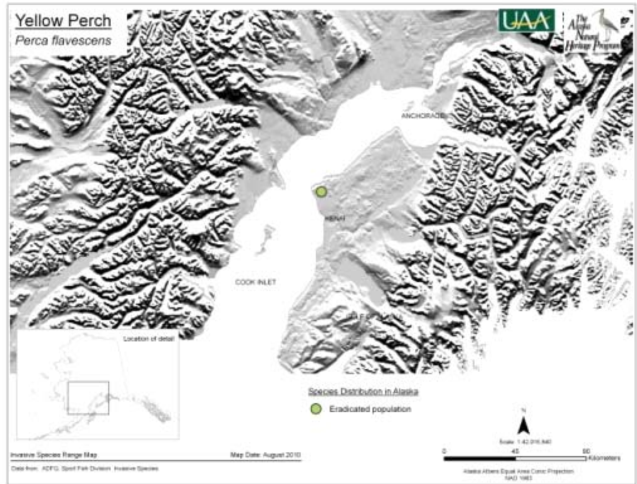
If introduced, yellow perch could impact salmon populations (Dill and Cordone 1997, Bonar et al. 2004) which are of high economic and conservation value to Alaska.

*General management difficulty (0-4)* 2

The population of yellow perch on the Kenai Peninsula was successfully eradicated using rotenone (ADF&G undated). For relatively small isolated populations (likely scenario in Alaska), rotenone is an effective management option (ADF&G undated).

| Total for feasibility of control | 4 / 10 |
|---|---|

**Range Map**




**References**

Alaska Department of Fish and Game (ADF&G). Undated. Recent Rotenone projects in Alaska. Available at: http://www.sf.adfg.state.ak.us/Statewide/InvasiveSpecies/index.cfm/FA/rotenone.projects. (Last accessed 10 November 2009).

Bonar, S.A., B.D. Bolding, M. Divens, and W. Meyer. 2004. Effects of introduced fishes on wild juvenile coho salmon using three shallow western Washington lakes. Washington Department of Fish and Game. Available at: http://wdfw.wa.gov/fish/warmwater/library/fpt04-03.pdf

Dill, W.A. and A.J. Cordone. 1997. History and status of introduced fishes in California, 1871-1996. Fish Bulletin 178.

Fay, Virginia. 2002. Alaska aquatic nuisance species management plan. Alaska Department of Fish and Game, Juneau, AK.

Mansueti, R. 1960. Comparison of the Movements of Stocked and Resident Yellow Perch, Perca flavescens, in Tributaries of Chesapeake Bay, Maryland. Cheasapeake Science 1: 21-35.

Moyle, P.B. 2002. Inland fishes of California revised and expanded. University of Caifornia Press, Los Angeles, CA.

NatureServe. 2009. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. (Accessed: November 9, 2009 ).

Schindler, D.E. and J.L. Carter. 2006. Yellow perch Perca flavescens. Pp. 168-169 in P.D. Boersma, S.H. Reichard, and A.N. Van Buren (eds). Invasive species in the Pacific Northwest. University of Washington Press, Seattle, WA.

Schrader, T. 2000. Effects of invasive yellow perch on gamefish and zooplankton populations of Phillips Reservoir. Oregon Department of Fish and Game, Information Report 2000-03, Portland OR.

Scott, W. B., and E. J. Crossman. 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada, Bulletin 184.

USGS. 2008. Nonindigenous species fact sheet: Perca flavescens. Available at: http://nas.er.usgs.gov/queries/specimenviewer.asp?SpecimenID=26208 (Last accessed 10 Novermber 2009).

## Acknowledgements

*Authors:* K. M. Walton and T. A. Gotthardt, Alaska Natural Heritage Program, University of Alaska Anchorage.

*Reviewer(s):*

**Scientific name:** ***Arion ater*** **Common name: European black slug**

**Alaska invasion/introduction history**

Arion ater was previously considered two species A. ater and A. rufus (Quick 1947, 1949). In Alaska, the taxonomic status of the European black slug (A. ater) is still under debate. European black slugs have been reported around Anchorage, Cordova, Yakutat, Gustavus, Juneau, Sitka, Tenakee Springs, Ketchikan, and Kodiak Island (see references in Gotthardt 2010), with the suspected mode of introduction being from nursery plants or potting soil (Wittwer 2004, Meyers 2006), or adhered to pallets or totes delivered to fish canneries from elsewhere.

| Ranking Summary | | |
|---|---|---|
| | Potential Max | Score |
| Distribution | 30 | 13 |
| Biological Characteristics | 30 | 25 |
| Ecological Impact | 30 | 17 |
| Feasibility of Control | 10 | 7 |
| Total | 100 | 62 |
| **Invasiveness (out of 100) =** | 62 **Moderately invasive** | |

| Distribution | Score |
|---|---|
| *Current global distribution (0-10)* | 6 |

The European black slug is native to western and central Europe and is invasive in southeastern Australia and North America (Featherstone 2006).

*Extent of the species US range and/or occurrence of formal state or provincial listings (0-10)* — 3

In the United States, black slugs have been introduced into Alaska and the Pacific Northwest. Additionally, black slugs are found in Newfoundland and British Columbia (Featherstone 2006, Forsyth 2004).

*Role of anthropogenic and natural disturbance in establishment (0-5)* — 2

In the Cordova area, black slugs are typically found near disturbed soils and close to human populations, but are occasionally found in less disturbed areas (Meyers and Harris 2005, Meyers 2006).

*Climatic similarity between site of origin and release (0-5)* — 2

Native to western and central Europe (Forsyth 2004). Introduced slugs inhabit British Columbia, which is of similar climate to southeastern Alaska. Slugs are moderately tolerant of cold temperatures (Mellanby 1961), but severe winters may limit their distribution farther north (Wittwer 2004).

Total for distribution 13 /30

| Biological Characteristics and Dispersal | Score |
|---|---|
| *Invasive elsewhere (0-5)* | 5 |

European black slugs are invasive in southern British Columbia, the Pacific Northwest, and southeastern Australia (Featherstone 2006).

*Dietary specialization (0-5)* — 5

Black slugs are omnivorous eating fungi, carrion, lichens, earthworms, leaves, stems, live and decomposing vegetation, and feces (Forsyth 1999).

*Habitat specialization (0-5)* — 5

Slugs live in moist, cool soil in areas such as road cutbanks, fields, gardens, campgrounds, and other disturbed areas with patches of shade (Gotthardt 2010).

*Average number of reproductive events per adult female per year (0-5)* — 5

Slugs can lay eggs multiple times a year, as seen by a similar Arion species (A. lusitanicus), which laid between 56-58 batches of eggs from mid June to the end of November in an Austrian study (Grimm 1996).

*Potential to be spread by human activities (0-5)* — 5

Humans spread adult slugs and eggs in nursery plants (including balled-burlap shrubs), on canoes, boats trailers, pallets, fish totes, in ice chests, and in trail construction materials (Gotthardt 2010).

*Innate potential for long distance dispersal (0-5)* — 0

Black slugs do not have any mechanisms for innate long distance dispersal.

Total for biological characteristics 25 / 30

| Ecological Impact | Score |
|---|---|
| *Impact on population dynamics of other species (0-10)* | 7 |

Slugs can restrict seedling recruitment in favored species (Hanley et al. 1996). When slugs are abundant, favored food items can become rare or extirpated in an area, but Meyer (2006) did not notice heavy herbivory of any one species around Cordova. Seeds and spores can be dispersed by slugs. The impact of black slugs on native slugs in Alaska is unknown, but in Vancouver, British Columbia, the native banana slug was displaced by non-native slugs (Busch 2007).

*Impact on natural community composition (0-10)* 3

Slugs have the potential to alter community composition and plant diversity by restricting seedling recruitment in early stage communities and by reducing dominant plants in later successional stage forests (Buschmann et al. 2005). In 2006, a slug survey by Meyer did not report any ecological damage caused by the black slugs around the Cordova area (Meyer 2006).

*Impact on natural ecosystem processes (0-10)* 7

Slugs process decaying plant and fecal material, helping to recycle organic matter and nutrients back into a form that can be used by other organisms. Additionally, this process aids in the maintenance of soil fertility. The mucus from slug activity is also known to accelerate nutrient cycling (e.g. C, N and P) (Theenhaus and Scheu 1996). Also, black slugs have the potential to impact the dynamics of plant succession in both early and later stage communities by feeding extensively on plant material of both seedlings and mature plants (Buschmann et al. 2005).

Total for ecological impact 17 /30

| Feasibility of control | Score |
|---|---|

*Number of populations in Alaska (0-3)* 2

European black slugs have been reported around Anchorage, Cordova, Yakutat, Gustavus, Juneau, Sitka, Tenakee Springs, Ketchikan, and Kodiak Island (see references in Gotthardt 2010).

*Significance of the natural area(s) and native species threatened (0-3)* 2

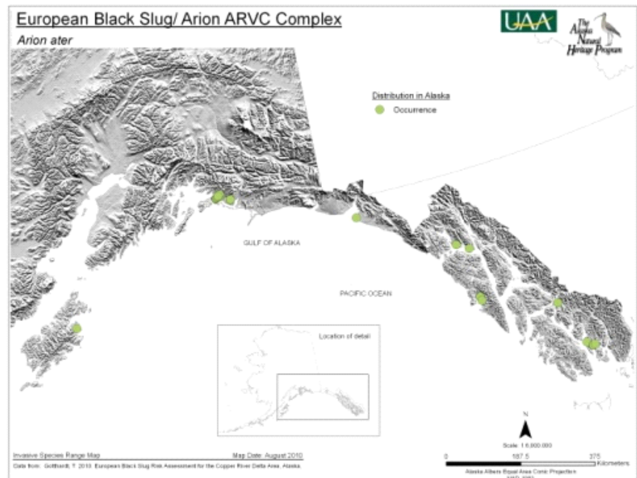
In some places, black slugs have been reported damaging lilies and orchids. In British Columbia, they have impacted plant species at risk, including deltoid balsamroot (Balsamorhiza deltoidea) and yellow montane violet (Viola praemorsa) (Gary Oak Ecosystem Recovery Team 2003).

*General management difficulty (0-4)* 3

Absolute eradication is unlikely. The most effective management option includes a combination of prevention of spread, early detection and rapid response, and control. To prevent slugs from spreading, public education can raise awareness to reduce human mediated spread of slugs. Early detection and rapid response would most likely involve a watch program allowing biologists and the public to report sightings and control would involve physically removing slugs or possibly chemical treatments (Gotthardt 2010).

Total for feasibility of control 7 / 10

**Range Map**




**References**

Busch, D.S. 2007. Black arion (Arion ater), black garlic glass-snail (Oxychilus alliarius), brown gardensnail (Cornu aspersum), gray fieldslug (Deroceras reticulatum), leopard slug (Limax maximus). Pp. 144-145 In: P.D. Boersma, S.H. Reichard, and A.N. Van Buren (eds). Invasive species in the pacific northwest. University of Washington Press, Seattle, WA.

Buschmann, H., M. Keller, N. Porret, H. Dietz, and P.J. Edwards. 2005. The effect of slug grazing on vegetation development and plant species diversity in an experimental grassland. Functional Ecology 19: 291-298.

Featherstone, A.W. 2006. Caledonian Forest – Species Profile: European black slug (Arion ater). Available at: www.treesforlife.org.uk. Last accessed 6 October 2009.

Forsyth, R. G. 1999. Terrestrial gastropods of the Columbia basin, British Columbia. Victoria, B.C. Available at: www.livinglandscapes.bc.ca/cbasin/mollusks /arionidae.html. Last accessed 6 October 2009.

Forsyth, R. G. 2004. Land snails of British Columbia. Royal BC Museum Handbook, Victoria, Canada.

Gary Oak Ecosystem Recovery Team. 2003. Invasive species in Gary Oak and associated ecosystems in British Columbia. Gary Oak Recovery Team, Victoria, B.C.

Gotthardt, T. 2010. European black slug risk assessment for the Copper River Delta area, Alaska. Alaska Natural Heritage Program, Prepared for USDA Forest Service. Anchorage, AK.

Grimm, B. 1996. A new method for individually marking slugs (Arion lustanicus (Mabille)) by magnetic transponders. Journal of Molluscan Studies 62: 477-482.

Hanley, M. E., M. Fenner and P. J. Edwards. 1996. The effect of mollusc grazing on seedling recruitment in artificially created grassland gaps. Oecologia. 106: 240-246.

Mellanby, K. 1961. Slugs at low temperatures. Nature. 189: 944.

Meyers, P. 2006. European black slug distribution and habitat use on the Chugach National Forest, Cordova Ranger District. Draft Report. USDA Forest Service, Chugach National Forest, Cordova Ranger District.

Meyers, P. and G. Harris. 2005. European black slug distribution and habitat use on the Chugach National Forest, Cordova Ranger District. Draft Report. USDA Forest Service, Chugach National Forest, Cordova Ranger District.

Quick, H.E. 1947. Arion ater (L.) and A. rufus (L.) in Britain and their specific differences. Journal of Conchology 22:249-261.

Quick, H.E. 1949. Synopsis of the British fauna. No. 8. Slugs (Mollusca). (Testscellidae, Arionidae, Limacidae). Linnean Society of London 8: 29 pp.

Theenhaus, A. and S. Scheu. 1996. The influence of slug (Arion rufus) mucus and cast material addition on microbial biomass, respiration, and nutrient cycling in beech leaf litter. Biology and Fertility of Soils 23: 80-85.

Wittwer, D. (compiler). 2004. Forest health conditions in Alaska – 2003. General Technical Report R10-TP-123. USDA Forest Service and State of Alaska Department of Natural Resources. 82 pp.

## Acknowledgements

*Authors:* K. M. Walton and T. A. Gotthardt, Alaska Natural Heritage Program, University of Alaska Anchorage.

*Reviewer(s):* Robert Forsyth, Royal BC Museum.

**Scientific name: *Columba livia*** **Common name: Rock dove**

**Alaska invasion/introduction history**

Rock Doves were introduced in downtown Anchorage in the late 1960s (ADF&G 2000) and are commonly reported in Fairbanks, Kodiak, and southeast and southcentral Alaska (National Audubon Society 2009).

| Ranking Summary | | |
|---|---|---|
| | Potential Max | Score |
| Distribution | 30 | 27 |
| Biological Characteristics | 30 | 24 |
| Ecological Impact | 30 | 6 |
| Feasibility of Control | 10 | 5 |
| Total | 100 | 62 |
| **Invasiveness (out of 100) =** | 62 **Moderately invasive** | |

**Distribution** — **Score**

*Current global distribution (0-10)* 10

Rock Doves are native to Eurasia and distributed worldwide (NatureServe 2009).

*Extent of the species US range and/or occurrence of formal state or provincial listings (0-10)* 10

Rock Doves occur throughout the entire U.S. and Canada (Ridgely et al. 2003).

*Role of anthropogenic and natural disturbance in establishment (0-5)* 2

Rock Doves are often commensal with humans and are commonly found in disturbed urban habitats (Williams and Corrigan 1994), but can inhabit natural areas (NatureServe 2009).

*Climatic similarity between site of origin and release (0-5)* 5

Rock Doves already inhabit areas of southeast, southcentral, and interior Alaska, indicating their ability to survive in many climatic regions of Alaska.

Total for distribution 27 /30

**Biological Characteristics and Dispersal** — **Score**

*Invasive elsewhere (0-5)* 5

Rock Doves are invasive worldwide (NatureServe 2009).

*Dietary specialization (0-5)* 5

Rock Doves primarily eat grains and seeds, but will feed on garbage, livestock manure, insects, and human food scraps (Williams and Corrigan 1994).

*Habitat specialization (0-5)* 5

Rove Doves often roost, loaf, and nest in farm yards, feed mills, parks, city buildings, bridges, cliffs, and other structures with openings or ledges (Williams and Corrigan 1994, NatureServe 2009).

*Average number of reproductive events per adult female per year (0-5)* 5

Rock Doves have 4-5 broods of chicks per year (Link 2004)

*Potential to be spread by human activities (0-5)* 3

Humans have intentionally introduced Rock Doves as a food source (Eguchi and Amano 2004). Doves have also escaped from fanciers, who have transported rock doves extensively for homing and racing competitions (Robbins 1995).

*Innate potential for long distance dispersal (0-5)* 1

Rock Doves are not migratory and urban dwelling doves typically have limited movements (Murton et al. 1972); however, Rock Doves can travel in excess of 50 km from roosting to feeding areas (Johnston and Janiga 1995).

Total for biological characteristics 24 / 30

**Ecological Impact** — **Score**

*Impact on population dynamics of other species (0-10)* 3

Rock Doves can carry and spread diseases to people, livestock, and native birds, such as pigeon ornithosis, encephalitis, Newcastle disease, cryptococcosis, toxoplasmosis, and salmonella food poisoning. In recent winters, salmonella has killed redpolls and grosbeaks at birdfeeders and Rock Doves may have been agents in the nurturing and spread of the disease in urban area (ADF&G 2000). Additionally Rock Doves carry ectoparasites, including fleas, lice, mites, ticks, and other biting insects, that are considered pests to humans and livestock (Williams and Corrigan 1994). In cities, Rock Doves may potentially compete with native ravens and magpies in the winter when food is scarce (ADF&G 2000).

*Impact on natural community composition (0-10)* 3

Literature does not indicate the presence of Rock Doves impacting natural communities, but may impact urban communities of birds (R. Sinnott pers comm.).

*Impact on natural ecosystem processes (0-10)* 0

Other then potentially adding droppings to the nutrient cycling of an ecosystem, no other ecosystem impacts have been documented.

| Total for ecological impact | 6 /30 |
|---|---|

| Feasibility of control | Score |
|---|---|
| *Number of populations in Alaska (0-3)* | 2 |

Populations of Rock Doves are patchy throughout Alaska, typically occurring in urban areas.

*Significance of the natural area(s) and native species threatened (0-3)* 0

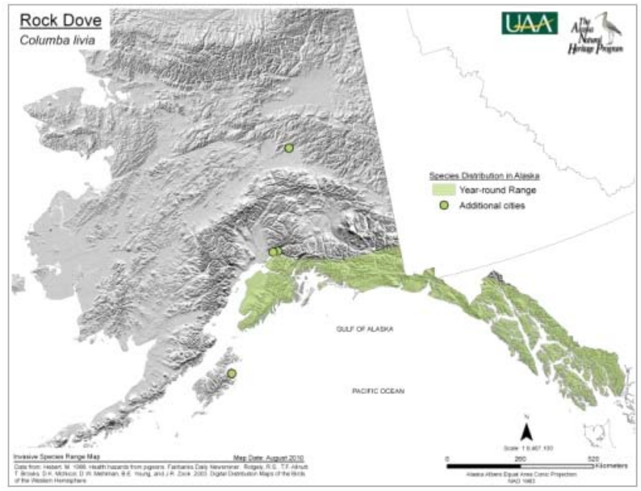
Rock Doves typically occur in human disturbed habitats and have not been documented to threaten any native species.

*General management difficulty (0-4)* 3

The USDA Wildlife Services office in Palmer spends $8,750 per year on Rock Dove control (ADF&G 2000). Most control measures are implemented to reduce the nuisance Rock Doves cause to humans by defecating on and living in buildings. Rock Doves can be excluded from buildings by blocking access to roosting sites and attaching objects to ledges that change the angle to 45° or more. Rock Doves can also be trapped, shot, or poisoned to eliminate individuals (William and Corrigan 1994), but it is difficult to entirely elimate Rock Doves, and many building owners are not willing to spend the time and effort required to do so (R. Sinnott pers comm.).

| Total for feasibility of control | 5 / 10 |
|---|---|

**Range Map**




**References**

Alaska Department of Fish and Game (ADF&G). 2000. Living with wildlife in Anchorage: a cooperative planning effort. Available at: http://www.wildlife.alaska.gov/index.cfm?adfg=planning.anchorage#comm.

Eguchi, K. and H.E. Amano. 2004. Spread of exotic birds in Japan. Ornithological Science 3:3-11.

Johnston, R.F. and M. Janiga. 1995. Feral pigeons. Oxford University Press, New York, NY.

Link, R. 2004. Living with wildlife in the pacific Northwest. University of Washington Press, Seattle, WA.

Murton, R.K., R.J.P. Thearle, and J. Thompson. 1972. Ecological studies of the feral pigeon Columba livia var. I. Population, breeding biology, and methods of control. Journal of Applied Ecology 9: 835-874.

National Audubon Society. 2009. Historical Results. Available at: http://www.audubon.org/bird/cbc/hr/. (Last accessed: 10 November 2009).

NatureServe. 2009. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. (Accessed: 11 November 2009 ).

Ridgely, R.S., T.F. Allnutt, T. Brooks, D.K. McNicol, D.W. Mehlman, B.E. Young, and J.R. Zook. 2003. Digital Distribution Maps of the Birds of the Western Hemisphere, version 1.0. NatureServe, Arlington, VA.

Robbins, C. S. 1995. Non-native birds. Pp. 437-440 in E.T. LaRoe, G.S. Farris, C.E. Puckett, P.D. Doran, and M.J. Mac (eds). Our Living Resources. National Biological Service, Washington D.C.

Williams, D.E. and R.M. Corrigan. 1994. Pigeons (rock doves). Pp. 87-96 in S.E. Hygnstorm , R.M. Timm, and G.E. Larson (eds) Prevention and control of wildlife damage. University of Nebraska, Lincoln, NE.

## Acknowledgements

*Authors:* K. M. Walton and T. A. Gotthardt, Alaska Natural Heritage Program, University of Alaska Anchorage.

*Reviewer(s):* Rick Sinnott, formerly with Alaska Department of Fish and Game.

**Scientific name: *Salmo salar*** **Common name: Atlantic salmon**

**Alaska invasion/introduction history**

In the 1980's farming of imported Atlantic salmon began in British Columbia and Washington. Since, thousands of Atlantic salmon have been deliberately and accidentally released into the wild, many of which have migrated to and established in Alaskan waters (ADF&G 2002).

| Ranking Summary | | |
|---|---|---|
| | Potential Max | Score |
| Distribution | 30 | 27 |
| Biological Characteristics | 30 | 18 |
| Ecological Impact | 20 | 6 |
| Feasibility of Control | 10 | 7 |
| Total | 90 | 58 |
| **Invasiveness (out of 100) =** | 61 **Moderately invasive** | |

| **Distribution** | **Score** |
|---|---|
| *Current global distribution (0-10)* | 10 |

Atlantic salmon are native in the Atlantic ocean along the coast of Europe, Russia, and the United States, and are invasive in the Pacific ocean along the coast of the United States and Canada (NatureServe 2009). Additionally, Atlantic salmon have small invasive populations in Australia, New Zealand, Singapore, Chile, and the French Southern Territories (GISD 2009).

*Extent of the species US range and/or occurrence of formal state or provincial listings (0-10)* 7

Atlantic salmon occur in New England, eastern Canada, the Great Lakes region, and in the western United States and Canada (NatureServe 2009).

*Role of anthropogenic and natural disturbance in establishment (0-5)* 5

Once Atlantic salmon escape, they can survive in and migrate to pristine areas, as well as establishing in predisturbed niches (Gross 1998).

*Climatic similarity between site of origin and release (0-5)* 5

Atlantic salmon inhabit coastal regions and drainages of southern British Columbia, which has a similar climate to southeast Alaska. Additionally, Atlantic salmon are native at high latitudes in Canada and Norway.

Total for distribution 27 /30

| **Biological Characteristics and Dispersal** | **Score** |
|---|---|
| *Invasive elsewhere (0-5)* | 5 |

Atlantic salmon are invasive in regions of Canada, New Zealand, Australia, Singapore, Chile, and the French Southern Territories (GUID 2009). Farmed fish have also escaped in waters where wild Atlantic salmon populations occur in Europe and New England (Gross 1998).

*Dietary specialization (0-5)* 5

Young salmon living in freshwater are generalized insectivores, primarily eating aquatic insect larvae and terrestrial insects (Scott and Crossman 1973). Once in salt water, Atlantic salmon feed opportunistically on pelagic prey and the diet may change with food availability along migration routes (Lacroix and Knox 2005).

*Habitat specialization (0-5)* 2

Adult Atlantic salmon can utilize a variety of marine habitats and prefer to migrate through slow flowing rivers to travel between spawning and nonspawning regions. Spawning occurs in water less than 50°F, preferably in gravel substrate. In freshwater, young inhabit gravel bottoms and with age utilize large rocks for cover before migrating to marine waters (Nature Serve 2009).

*Average number of reproductive events per adult female per year (0-5)* 0

Females are iteroparous and spawn once a year laying 8,000-26,000 eggs (Palen 2006).

*Potential to be spread by human activities (0-5)* 1

Historically, intentional dispersal of Atlantic salmon fry did not produce viable populations in the wild (Palen 2006, Gross 1998). However, Atlantic salmon farms have transported individuals of all life stages to new locations, where they are repeatedly released, which increases their chance of establishment (Gross 1998).

*Innate potential for long distance dispersal (0-5)* 5

The Atlantic salmon can quickly travel thousands of kilometers between spawning and nonspawning habitats and are strong swimmers and jumpers (Bisson 2006, NatureServe 2009). Farmed fish often have lower homing precision, causing them to migrate up and spawn in non natal rivers (Jonsson and Jonsson 2006).

**Scientific name: *Salmo salar*** **Common name: Atlantic salmon**

| Total for biological characteristics | 18 / 30 |
|---|---|

| Ecological Impact | Score |
|---|---|

*Impact on population dynamics of other species (0-10)* 3

There is no empirical evidence that Atlantic salmon are causing significant reductions in native species abundance (Bisson 2006); however, the following are potential ecological impacts. Atlantic salmon have the potential to compete with native salmonids for food and habitat resources, and potentially transmit diseases, parasites, and pathogens to wild fish (Wing et al. 1992, Volpe et al. 2000, Bisson 2006). Freshwater juvenile salmon could prey on other juveniles of native species, such as chum and pink fry (ADF&G 2002). Concern is especially high in areas where native salmonid runs are below historic levels and could face even larger declines from competition with Atlantic salmon (ADF&G 2002). Also, the niche of juvenile steelhead overlaps with Atlantic salmon; however, Volpe et al. (2001) showed that resident steelhead are able to outcompete Atlantic salmon.

*Impact on natural community composition (0-10)* 3

There is no empirical evidence that Atlantic salmon significantly alter communities (Bission 2006), but the following changes could occur. Atlantic salmon have the potential to alter the abundances of multiple salmonid species, which could reduce the salmonid biodiversity of these aquatic systems and overwhelm native fish communities by force of numbers (ADF&G 2002).

*Impact on natural ecosystem processes (0-10)* u

Ecosystem impacts are generally unknown; however, if Atlantic salmon reduce salmonid densities and biodiversity, a reduction in nutrients from salmon carcasses may occur.

| Total for ecological impact | 6 /20 |
|---|---|

| Feasibility of control | Score |
|---|---|

*Number of populations in Alaska (0-3)* 2

Atlantic salmon occurrences are patchy with individuals primarily documented throughout southeast Alaska and rarer cases in the Aleutian Islands and Bering Sea (Wing et al. 1992, Brodeur and Busby 1998, Gross 1998).

*Significance of the natural area(s) and native species threatened (0-3)* 2

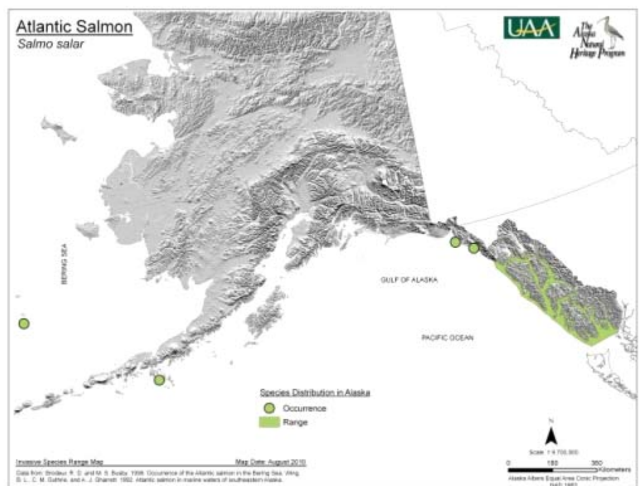
Atlantic salmon may have the potential to threaten native salmonids of economic and conservation value through competition for resources and predation (AFD&G 2002).

*General management difficulty (0-4)* 3

To prevent additional farm raised salmon from escaping, stricter oversight of marine based farming is necessary or operations need to become solely land based (ADF&G 2002, Palen 2006). Public education can help fishermen identify and report Atlantic salmon in order to monitor invasion locations. When Atlantic salmon are found, the watershed should be intensively surveyed to determine the appropriate control action (Bission 2006).

| Total for feasibility of control | 7 / 10 |
|---|---|

**Range Map**




**References**


Alaska Department of Fish and Game (ADF&G). 2002. Atlantic salmon white paper. Juneau, Alaska.

Bisson, P. A. 2006. Assessment of the risk of invasion of national forest streams in the Pacific Northwest by farmed Atlantic salmon. General Technical Report PNW-GTR-697. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 28 p.

Brodeur, R.D. and M.S. Busby. 1998. Occurrence of the Atlantic salmon Salmo salar in the Bering Sea. Alaska Fishery Research Bulletin 5: 64-66.

Global invasive species database (GISD). 2009. Salmo sonar. Available from: http://www.issg.org/database/species/distribution.asp?si=376&fr=1&sts=&lang=EN. (Accessed 27 October 2009).

Gross, M.R. 1998. One species with two biologies: Atlantic salmon (Salmo salar) in the wild and in aquaculture. Canadian Journal of Fisheries and Aquatic Sciences 55: 131-144.

Lacroix, G. L., and Knox, D. 2005. Distribution of Atlantic salmon (Salmo salar) post smolts of different origins in the Bay of Fundy and Gulf of Maine and evaluation of factors affecting migration, growth, and survival. Canadian Journal of Fisheries and Aquatic Sciences, 62: 1363e1376.

NatureServe. 2009. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. (Accessed: October 26, 2009 ).

Scott, W. B., and E. J. Crossman. 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada, Bulletin 184. 966 pp.

Palen, W.J. 2006. Atlantic salmon Salmo salar. Pp. 170-171 in Invasive species in the pacific northwest. P.D. Boersm, S.H. Reichard, and A.N. Buren (eds). University of Washington Press, Seattle, Washington.

Volpe, J.P., E.B. Taylor, D.W. Rimmer, and B.W. Glickman. 2000. Evidence of natural reproduction of aquaculture-escaped Atlantic salmon in a coastal British Columbia river. Conservation Biology 14:899-903.

Volpe, J.P., B.R. Anholt, and B.W. Glickman. 2001. Competition among juvenile Atlantic salmon (Salmo salar) and steelhead (Oncorhynchus mykiss): relevance to invasion potential in British Columbia. Canadian Journal of Fisheries and Aquatic Sciences 58: 197-207.

Wing, B.L., C.M. Guthrie, and A.J. Gharrett. 1992. Atlantic salmon in marine waters of southeastern Alaska. Transactions of the American Fisheries Society 121: 814-818.

## Acknowledgements

*Authors:* K. M. Walton and T. A. Gotthardt, Alaska Natural Heritage Program, University of Alaska Anchorage.

*Reviewer(s):*

**Scientific name:** ***Arion circumscriptus*** **Common name: Brown-banded slug**

**Alaska invasion/introduction history**

The date and mode of introduction of brown-banded slugs in Alaska is unknown. Recent slug surveys in Southeast Alaska reported this species presence in Sitka (Ferguson and Knight 2010).

| Ranking Summary | | |
|---|---|---|
| | Potential Max | Score |
| Distribution | 30 | 17 |
| Biological Characteristics | 30 | 25 |
| Ecological Impact | 30 | 13 |
| Feasibility of Control | 10 | 4 |
| Total | 100 | 59 |
| **Invasiveness (out of 100) =** | 59 **Modestly invasive** | |

| **Distribution** | **Score** |
|---|---|

*Current global distribution (0-10)* 6

Arion circumscriptus is native to Europe and invasive in North America (Forsyth 2004).

*Extent of the species US range and/or occurrence of formal state or provincial listings (0-10)* 7

The brown-banded slug is found in approximately 24% percent of the United States and in many Canadian provinces and territories (NatureServe 2009), including British Columbia, Ontario, Quebec, Prince Edward Island, New Brunswick, Newfoundland, and Alberta (R. Forsyth pers comm).

*Role of anthropogenic and natural disturbance in establishment (0-5)* 2

In British Columbia, this species is found in gardens, disturbed areas, woods close to human settlements (Forsyth 2004), but also have penetrated into natural areas (Grimm et al. 2010).

*Climatic similarity between site of origin and release (0-5)* 2

Widespread in native range in Europe, mainly found in coastal areas of Scandinavia (Kerney and Cameron 1979). The brown-banded slug occurs throughout British Columbia, which has a similar climate to regions of Alaska. However, this species is not extremely cold tolerant as noted by Getz (1959). When slugs were inadvertently left out in temperatures below freezing and when slugs were exposed to -8°C for five hours, death of all slugs resulted.

Total for distribution 17 /30

| **Biological Characteristics and Dispersal** | **Score** |
|---|---|

*Invasive elsewhere (0-5)* 5

This species of slug is invasive throughout Canada and the United States.

*Dietary specialization (0-5)* 5

The brown-banded slug feeds on humus, decaying leaf mold, and live and decaying vegetation (Getz 1959).

*Habitat specialization (0-5)* 5

This species is found under objects or below vegetation in gardens, disturbed sites, and wooded areas close to human settlement (Forsyth 2004).

*Average number of reproductive events per adult female per year (0-5)* 5

Predominately reproduces by self-fertilization (Jordaens et al. 2002). Slugs can lay eggs multiple times a year during the warm season, as seen by a similar Arion species (A. lusitanicus), which laid between 56-58 batches of eggs from mid-June to the end of November in an Austrian study (Grimm 1996).

*Potential to be spread by human activities (0-5)* 5

Slugs are commonly spread between and within continents on plant and horticultural material, such as nursery and greenhouse plants (Getz and Chichester 1971). Also can be spread via similar methods as other invasive slugs, such as on boats, trailers, pallets, in ice chests, and trail construction materials (R. Forsyth pers comm).

*Innate potential for long distance dispersal (0-5)* 0

Slugs do not have any innate mechanism for long distance dispersal.

Total for biological characteristics 25 / 30

| **Ecological Impact** | **Score** |
|---|---|

*Impact on population dynamics of other species (0-10)* 3

No information could be found on the impacts of brown-banded slugs on other populations of organisms, but impacts are probably minimal since this species is found in urban areas (Getz and Chichester 1971). Other Arion species have damaged young plant leaves and induced increased chemical defenses in willow plants (Rathcke 1985, Fritz et al. 2001).

**Scientific name:** ***Arion circumscriptus*** **Common name: Brown-banded slug**

| | |
|---|---|
| *Impact on natural community composition (0-10)* | 3 |

No information could be found on the impacts of the brown-banded slug on community composition. Since this species is often found in association with humans, serious interactions with native communities is unlikely (Getz and Chichester 1971). Other Arion species have the potential to alter seedling community composition by feeding on newly emerged young plants (Rathcke 1985).

| | |
|---|---|
| *Impact on natural ecosystem processes (0-10)* | 7 |

Slugs process decaying plant and fecal material, helping to recycle organic matter and nutrients back into a form that can be used by other organisms. Additionally, this process aids in the maintenance of soil fertility. The mucus from slug activity is also known to accelerate nutrient cycling (e.g. C, N and P) (Theenhaus and Scheu 1996).

| | |
|---|---|
| Total for ecological impact | 13 /30 |

| Feasibility of control | Score |
|---|---|
| *Number of populations in Alaska (0-3)* | 1 |

Brown-banded slugs occur in Sitka (Ferguson and Knight 2010).

| | |
|---|---|
| *Significance of the natural area(s) and native species threatened (0-3)* | 0 |

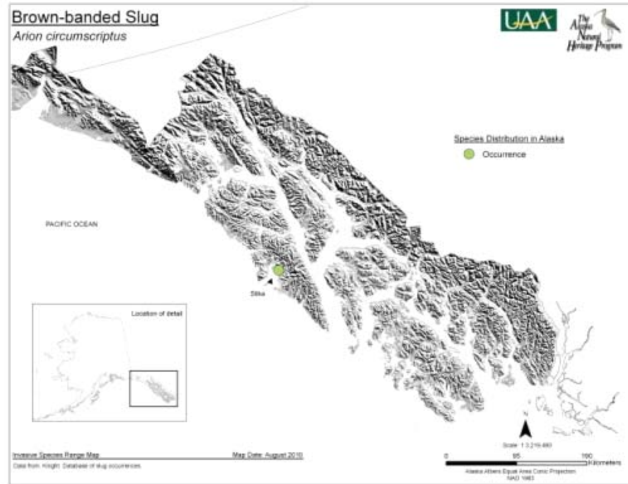
Since this species is found primarily in human disturbed areas, natural areas and vulnerable species are not likely to be threatened.

| | |
|---|---|
| *General management difficulty (0-4)* | 3 |

Absolute eradication is unlikely. The most effective management option includes a combination of prevention of spread, early detection and rapid response, and control. To prevent slugs from spreading, public education can raise awareness to reduce human mediated spread of slugs. Early detection and rapid response would most likely involve a watch program allowing biologists and the public to report sightings, and control would involve physically removing slugs or possibly chemical treatments (Gotthardt 2010).

| | |
|---|---|
| Total for feasibility of control | 4 / 10 |

**Range Map**




**References**


Ferguson, A. and C. Knight. 2010. Cooperative agricultural pest survey (CAPS) program in Alaska. Alaska Invasive Species Working Group 2010 Conference Proceeding. October 28, 2010, Fairbanks, Alaska.

Forsyth, R.G. 2004. Land snails of British Columbia. Royal BC Museum, Victoria, Canada.

Fritz, R.S., C.G. Hochwender, D.A. Lewkiewicz, S. Bothwell, and C.M. Orians. 2001. Seedling herbivory by slugs in a willow hybrid system: developmental changes in damage, chemical defense, and plant performance. Oecologia 129: 87-97.

Getz, L.L. 1959. Notes on the ecology of slugs: Arion circumscriptus, Deroceras reticulatum, and D. laeve. The American Midland Naturalist 61: 485-498.

Getz, L.L. and L.F. Chichester. 1971. Introduced European slugs. The Biologist 53: 118-127.

Gotthardt, T. 2010. European black slug risk assessment for the Copper River Delta area, Alaska. Alaska Natural Heritage Program, Prepared for USDA Forest Service. Anchorage, AK.

Grimm, B. 1996. A new method for individually marking slugs (Arion lustanicus (Mabille)) by magnetic transponders. Journal of Molluscan Studies 62: 477-482.

Grimm, F.W., R.G. Forsyth, F.W. Schueler, and A. Karstad. 2010. Identifying land snails and slugs in Canada: introduced species and native genera. Ottawa: Canadian Food Inspection Agency. Iv + 168 p. Dated 2009, published 2010.

Jordaens, K., S. van Dongen, P. van Riel, S. Geenan, R. Verhagen, and T. Backeljau. 2002. Multivariate morphometrics of soft body parts in terrestrail slugs: comparison between two datasets, error assessment and taxonomic implications. Biological Journal of the Linnean Society 75: 533-542.

Kerney, M.P., and R.A.D. Cameron. 1979. A field guide to the land snails of Britain and north-west Europe. London: Collins. 288 p., 24 pl.

NatureServe. 2009. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available at: http://www.natureserve.org/
explorer. (Last accessed: 12 January 2010 ).

Rathcke, B. 1985. Slugs as generalist herbivores: tests of three hypotheses on plant choices. Ecology 66: 828-836.

Theenhaus, A. and S. Scheu. 1996. The influence of slug (Arion rufuf) mucuc and cast material addition on microbial biomass, respiration, and nutrient cycling in beech leaf litter. Biol. Fertil. Soils 23:80-85.

## Acknowledgements

*Authors:* K. M. Walton and T. A. Gotthardt, Alaska Natural Heritage Program, University of Alaska Anchorage.

*Reviewer(s):* Robert Forsyth, Royal BC Museum.

**Scientific name:** ***Limax maximus*** **Common name: Leopard slug**

**Alaska invasion/introduction history**

The timing and mode of introduction of leopard slugs, also known as gaint garden slug, in Alaska is unknown. It has been reported in Wrangell, and likely occurs in other Southeast Alaska communities (Ferguson and Knight 2010). In 2010, a large slug was found in Kodiak, which may have been this species (C. Knight pers comm).

| Ranking Summary | | |
|---|---|---|
| | Potential Max | Score |
| Distribution | 30 | 21 |
| Biological Characteristics | 30 | 20 |
| Ecological Impact | 30 | 14 |
| Feasibility of Control | 10 | 3 |
| Total | 100 | 58 |
| **Invasiveness (out of 100) =** | 58 **Modestly invasive** | |

| **Distribution** | **Score** |
|---|---|
| *Current global distribution (0-10)* | 10 |

Leopard slugs are fairly cosmopolitan, occurring in Europe, Asia, Africa, North America, South America, Australia, and New Zealand (NatureServe 2009).

*Extent of the species US range and/or occurrence of formal state or provincial listings (0-10)* — 7

Limax maximus has been reported in just under 50% of the states and in several Canadian provinces (BC, ON, NF, NS; NatureServe 2009)

*Role of anthropogenic and natural disturbance in establishment (0-5)* — 2

The leopard slug primarily lives near human settlement (Forsyth 2004), but can occasionally be found in wooded areas and fields not associated with anthropogenic disturbance (Rollo and Wellington 1975).

*Climatic similarity between site of origin and release (0-5)* — 2

Leopard slugs are native to Europe, North Africa, and Asia minor, which are at lower latitudes than Alaska; however, this species is able to survive in British Columbia and more northern states in the US.

Total for distribution — 21 /30

| **Biological Characteristics and Dispersal** | **Score** |
|---|---|
| *Invasive elsewhere (0-5)* | 5 |

Leopard slugs are invasive in North America, South America, Australia, and New Zealand (Forsyth 2004).

*Dietary specialization (0-5)* — 5

Leopard slugs primarily eats decaying plant material, fungi and pet feces. Green plants are not are major part of this species diet (Forsyth 2004), but can damage vegetable crops (Barker 1999).

*Habitat specialization (0-5)* — 0

This species primarily inhabits human modified habitats, such as in gardens, hedgerow, roadsides, and other sheltered damp places (Barker 1984, Forsyth 2004).

*Average number of reproductive events per adult female per year (0-5)* — 5

Eggs are laid in clusters of a several dozen throughout the warm season (Pilsbry 1948).

*Potential to be spread by human activities (0-5)* — 5

In New Zealand, human activities have been attributed to the dispersal of the leopard slug throughout the country (Barker 1984).

*Innate potential for long distance dispersal (0-5)* — 0

The leopard slug does not have any long distance dispersal mechanism.

Total for biological characteristics — 20 / 30

| **Ecological Impact** | **Score** |
|---|---|
| *Impact on population dynamics of other species (0-10)* | 7 |

Elsewhere, the leopard slug has displaced native banana slugs through competition for food resources (Busch 2007). In New Zealand, leopard slugs are aggressive towards other slugs and will attack and drive off intruding slugs through repeated biting (Barker 1984). Leopard slugs can reduce the reproductive success of non-aggressive slugs and increase mortality (Rollo 1983).

*Impact on natural community composition (0-10)* — 0

Leopard slugs are primarily associated with human activity and therefore are less likely to have serious interactions with native communities (Getz and Chichester 1971).

**Scientific name: *Limax maximus*** **Common name: Leopard slug**

*Impact on natural ecosystem processes (0-10)* 7

Slugs process decaying plant and fecal material, helping to recycle organic matter and nutrients back into a form that can be used by other organisms. Additionally, this process aids in the maintenance of soil fertility. The mucus from slug activity is also known to accelerate nutrient cycling (e.g. C, N and P) (Theenhaus and Scheu 1996).

Total for ecological impact 14 /30

| Feasibility of control | Score |
|---|---|
| *Number of populations in Alaska (0-3)* | 1 |

Leopard slugs most likely occur scattered throughout southeast Alaska; however, surveys have not been completed for all regions of the state. This species has been found in Wrangell and possibly in Kodiak (Ferguson and Knight 2010, C. Knight pers comm).

*Significance of the natural area(s) and native species threatened (0-3)* 0

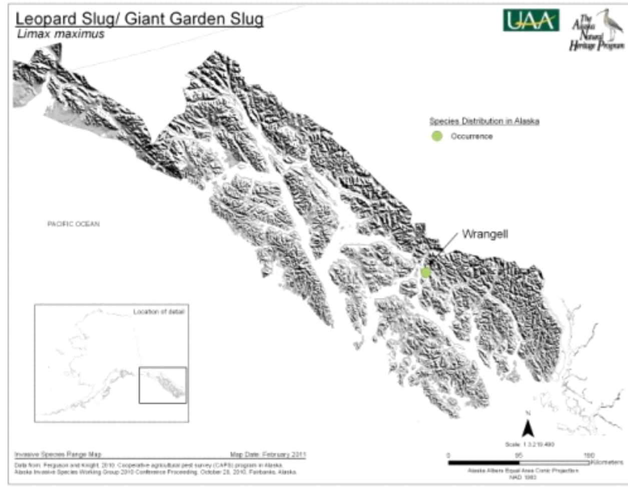
Leopard slugs are typically found in human disturbed areas and therefore are not known to impact vulnerable species or habitats.

*General management difficulty (0-4)* 2

As with other slug species, absolute eradication is unlikely. The most effective management option includes a combination of prevention of spread, early detection and rapid response, and control. To prevent slugs from spreading, public education can raise awareness to reduce human mediated spread of slugs. Early detection and rapid response would most likely involve a watch program allowing biologists and the public to report sighting and control would involve physically removing slugs or possibly chemical treatments (Gotthardt 2010).

Total for feasibility of control 3 / 10

**Range Map**




**References**

Barker, G.M. 1999. Naturalised terrestrial Stylommatophora (Mollusca: Gastropoda). Fauna of New Zealand / Ko te Aitanga Pepeke o Aotearoa 38. 253 p. http://www.landcareresearch.co.nz/research/biosystematics/invertebrates/faunaofnz/Extracts/FNZ38/documents/FNZ38Barker19991150.pdf

Barker, G.M. and R.A. McGhie. 1984. The biology of introduced slugs (Pulmonatna) in New Zealand. 1. Introduction and notes on Limax maximus. New Zealand Entomologist 8: 106-111.

Busch, D.S. 2007. Black arion (Arion ater), black garlic glass-snail (Oxychilus alliarius), brown gardensnail (Cornu aspersum), gray fieldslug (Deroceras reticulatum), leopard slug (Limax maximus). Pp. 144-145 In: P.D. Boersma, S.H. Reichard, and A.N. Van Buren (eds). Invasive species in the pacific northwest. University of Washington Press, Seattle, WA

Ferguson, A. and C. Knight. 2010. Cooperative agricultural pest survey (CAPS) program in Alaska. Alaska Invasive Species Working Group 2010 Conference Proceeding. October 28, 2010, Fairbanks, Alaska.

Forsyth, R.G. 2004. Land snails of British Columbia. Royal BC Museum , Victoria, Canada

Getz, L.L. and L.F. Chichester. 1971. Introduced European slugs. The Biologist 53: 118-127.

Gotthardt, T. 2010. European black slug risk assessment for the Copper River Delta area, Alaska. Alaska Natural Heritage Program, Prepared for USDA Forest Service. Anchorage, AK.

NatureServe. 2009. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available at: http://www.natureserve.org/explorer. (Last accessed: 4 January 2010).

Pilsbry, H.A. 1948. Land mollusca of North America (North of Mexico). The Academy of Natural Sciences of Philadelphia Monograph No. 3, Vol. 2, Part 2.

Rollo, D.C. 1983. Consequences of competition on the reproduction and mortality of three species of terrestrial slugs. Researches on Population Ecology 25: 20-43.

Rollo, C.D. and W.G. Wellington. 1975. Terrestrial slugs in the vicinity of Vancouver, British Columbia. The Nautilus. 89: 107-115.

Theenhaus, A. and S. Scheu. 1996. The influence of slug (Arion rufus) mucus and cast material addition on microbial biomass, respiration, and nutrient cycling in beech leaf litter. Biology and Fertility of Soils 23: 80-85.

## Acknowledgements

*Authors:* K. M. Walton and T. A. Gotthardt, Alaska Natural Heritage Program, University of Alaska Anchorage.

*Reviewer(s):* Robert Forsyth, Royal BC Museum.

**Scientific name: *Sturnus vulgaris*** **Common name: Starling**

**Alaska invasion/introduction history**

Starlings were released in New York City in the 1890's and have since spread to Alaska, with many reported occurrences in interior Alaska by 1979 (Kessel 1979).

| Ranking Summary | | |
|---|---|---|
| | Potential Max | Score |
| Distribution | 30 | 25 |
| Biological Characteristics | 30 | 16 |
| Ecological Impact | 30 | 6 |
| Feasibility of Control | 10 | 7 |
| Total | 100 | 54 |
| **Invasiveness (out of 100) =** | 54 **Modestly invasive** | |

| **Distribution** | **Score** |
|---|---|

*Current global distribution (0-10)* 10

Starlings are native in Europe and Asia with wintering populations extending into northern Africa, and are introduced in North America, Australia and adjacent islands, South Africa, and some of the West Indies (Lever 1987, Barndt 2006, NatureServe 2009).

*Extent of the species US range and/or occurrence of formal state or provincial listings (0-10)* 10

Starlings are invasive in all U.S. states and the majority ofCanadian provinces/territories (NatureServe 2009).

*Role of anthropogenic and natural disturbance in establishment (0-5)* 0

Starlings primarily occur in habitat types that have human disturbance because of their preference for open areas (Barndt 2006).

*Climatic similarity between site of origin and release (0-5)* 5

Starlings inhabit subarctic climates in its native range in Eurasia (Barndt 2003).

Total for distribution 25 /30

| **Biological Characteristics and Dispersal** | **Score** |
|---|---|

*Invasive elsewhere (0-5)* 5

Starlings are invasive in North America, Australia and adjacent islands, South Africa, and some of the West Indies (Lever 1987, NatureServe 2009).

*Dietary specialization (0-5)* 5

Starlings eat invertebrates, fruit, and grains (Barndt 2006, NatureServe 2009).

*Habitat specialization (0-5)* 2

Starlings are cavity nesters, requiring natural or man-made openings for breeding, and open areas for foraging. In human disturbed areas suitable nesting and foraging habitat is readily available; however, in undisturbed areas optimal habitat can be sparse (Barndt 2006).

*Average number of reproductive events per adult female per year (0-5)* 0

Elsewhere in their range, Starlings produce up to 3 broods a year, with 4-9 eggs in each clutch (NatureServe 2009); however, north of 48 degrees latitude, only one brood is typically attempted (Cabe 1993).

*Potential to be spread by human activities (0-5)* 1

Initial populations of Starlings were introduced by humans (Adeney 2001), but the literature does not indicate that humans are continuing to disperse the species (they are migrating on their own) to new locations.

*Innate potential for long distance dispersal (0-5)* 3

Since the Starling introduction in New York in the 1890's, birds have migrated rapidly throughout North America (Barndt 2006).

Total for biological characteristics 16 / 30

| **Ecological Impact** | **Score** |
|---|---|

*Impact on population dynamics of other species (0-10)* 3

Starlings compete with native birds for nest sites and may evict other birds from cavities and destroy the eggs and nest (Kessel 1979, Koenig 2003, Barndt 2006). The degree of detrimental impact from competition and eviction of native species is often predicted as relatively high; however, several scientific studies have shown these activities have little effect on the survival and abundance of native birds (Koenig 2003, Barndt 2006). Starlings can carry many diseases and parasites, whenever, their importance as vectors to other animals is unknown (Cabe 1993).

*Impact on natural community composition (0-10)* 3

Many species of birds are displaced for nesting sites; however, this displacement causes only minor alternations to communities because abundance of native species is not changed substantially (Koenig 2003, Barndt 2006). Additionally, Starlings can cause minor alternations to plant communities by spreading invasive weeds, such as blackberry via its fleshy fruit (Barndt 2006).

*Impact on natural ecosystem processes (0-10)* 0

Starlings enrich soil through droppings (NPMA 2009), but are not known to change ecosystem processes.

Total for ecological impact 6 /30

| **Feasibility of control** | **Score** |
|---|---|
| *Number of populations in Alaska (0-3)* | 2 |

Populations of Starlings are patchy throughout the state and are mainly located in cities (Kessel 1979).

*Significance of the natural area(s) and native species threatened (0-3)* 2

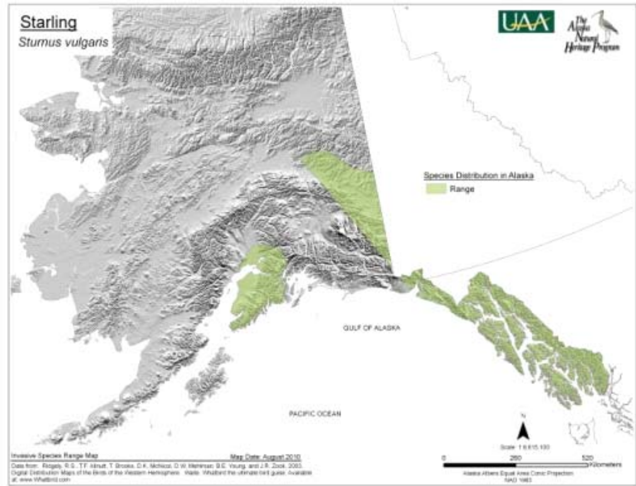
Starlings in Fairbanks are predicted to displace the Common Flicker and several species of swallows from nesting cavities and the Alaska Department of Fish and Game has documented concern about Starlings competing with native birds in Anchorage (Kessel 1979, ADF&G 2000).

*General management difficulty (0-4)* 3

Since Starlings do not appear to be causing significant declines in native bird densities and are found in disturbed habitats, efforts to control this species may be a lower priority than other invasives (Koenig 2003). Once Starlings are established, reduction is difficult (ADF&G 2000); however, enclosures, habitat modifications, frightening, trapping, shooting, and repellants can be used with moderate effort (Johnson and Glahn 1994), but many not be very effective because starlings from nearby areas will just recolonize (R. Sinnott pers comm.).

Total for feasibility of control 7 / 10

**Range Map**




**References**

Adeney, J.M. 2001. European starling. Columbia University Center for Environmental Research and Conservation. Available http://www.columbia.edu/itc/cerc/danoff-burg/invasion_bio/inv_spp_summ/. (Accessed: 7 October 2009).

Alaska Department of Fish and Game (ADF&G). 2000. Living with wildlife in Anchorage: a cooperative planning effort. Available http://www.wc.adfg.state.ak.us /index.cfm?adfg=planning.anchorage (Accessed: 15 October 2009).

Barndt, J.K. 2006. European starling Sturnus vulgaris. In P.D. Boersma, S.H. Reichard, and A. N. Van Buren (eds) Invasive species in the Pacific Northwest. University of Washington Press, Seattle, WA. 180-181 p.

Cabe, P.R. 1993. European starling (Sturnus vulgaris). In: The birds of North America, No. 48 (A. Poole and F. Gills, eds.) Philadelphia: The Academy of Natural Sciences; Washington, D.C.: The American Ornithologists' Union.

Johnson, R.J. and J.F. Glahn. 1994. European Starling. In S.E. Hygnstrom, R.M. Timm, and G.E. Larson (eds) Internet center for wildlife damage management. The handbook: prevention and control of wildlife damage. University of Nebraska, Lincoln, Nebraska.

Kessel, B. 1979. Starlings become established at Fairbanks, Alaska. Condor 81:437-438.

Koenig, W.D. 2003. European starlings and their effect on native cavity-nesting birds. Conservation Biology 17, 1134-1140.

Lever, C. 1987. Naturalized birds of the world. Longman Scient. And Tech., Essex, England.

NatureServe. 2009. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. (Accessed: October 7, 2009).

National Pest Management Association Inc. (NPMA). 2009. European starling Sturnus vulgaris. Available http://www.pestworld.org/for-consumers/Pest-Guide/Pest/European-Starling (Accessed 15 October 2009).

## Acknowledgements

*Authors:* K. M. Walton and T. A. Gotthardt, Alaska Natural Heritage Program, University of Alaska Anchorage.

*Reviewer(s):* Rick Sinnott, formerly with Alaska Department of Fish and Game.

**Scientific name: *Crassostrea gigas*** **Common name: Pacific oyster**

**Alaska invasion/introduction history**

As early as 1939, Pacific oysters were cultivated in Ketchikan and now oyster spat is commonly imported for aquatic farming in Southeast and coastal southcentral Alaska (PWSRCAC 2004). Currently wild populations of Pacific oysters are very uncommon in Southeast and southcentral Alaska because water temperatures are too low for reproduction (ADF&G 2009).

| Ranking Summary | | |
|---|---|---|
| | Potential Max | Score |
| Distribution | 30 | 18 |
| Biological Characteristics | 30 | 23 |
| Ecological Impact | 30 | 6 |
| Feasibility of Control | 10 | 3 |
| Total | 100 | 50 |
| **Invasiveness (out of 100) =** | 50 **Modestly invasive** | |

| **Distribution** | **Score** |
|---|---|
| *Current global distribution (0-10)* | 10 |

Pacific oysters are found on all continents, except Antarctica (GISD 2009).

*Extent of the species US range and/or occurrence of formal state or provincial listings (0-10)* 3

Pacific oyster farms are present in Alaska, Washington, Oregon, California, and British Columbia (PSMFC 2009).

*Role of anthropogenic and natural disturbance in establishment (0-5)* 5

Pacific oysters are typically introduced by humans; however, they do not require any type of disturbance to establish.

*Climatic similarity between site of origin and release (0-5)* 0

Pacific oysters can survive but not reproduce in cold waters. Therefore, self sustaining populations are not typically found at high latitudes. Optimal recruitment occurs in water temperatures between 23-25°C (Kobayashi et al. 1997), but sporadic recruitment can occur at 18°C (Spencer et al. 1994, Mann 1979). In Alaska, water temperatures do not consistently reach 18°C or above making a self sustaining population unlikely in current conditions (PWSRCAC 2004). Carrasco and Baron (2010) found Alaska fell outside of the expected range of naturalization when using a climate envelope approach.

Total for distribution 18 /30

| **Biological Characteristics and Dispersal** | **Score** |
|---|---|
| *Invasive elsewhere (0-5)* | 5 |

Pacific oysters are invasive in North and South America, Africa, Australia, and Europe (Buhle 2006).

*Dietary specialization (0-5)* 5

Oysters are filter feeders, and will ingest bacteria, protozoa, diatoms, invertebrate larvae, and detritus (Nehring 2006).

*Habitat specialization (0-5)* 5

Adult Pacific oysters can be found in a wide range of habitats including firm mud, sand, gravel, and rocky substrates (PWSRCAC 2004). For survival (not reproduction) water temperatures need to be between 4-35°C (Nehring 2006).

*Average number of reproductive events per adult female per year (0-5)* 2

An adult Pacific oyster can release 50-100 million eggs over several spawning events (PWSRCAC 2004). In Korea, oysters are reported to spawn at least 2 times a year, but at higher latitudes the number of spawning events can be reduced (Kang et al. 2003).

*Potential to be spread by human activities (0-5)* 3

Oysters are very commonly imported for aquaculture and larvae can be transported in ballast water and adults on ship hulls (PWSRCAC 2004, Nehring 2006).

*Innate potential for long distance dispersal (0-5)* 3

Larvae are planktonic for 3-4 weeks and can be carried by tides and currents (PWSRCAC 2004). Spat has been reported spreading up to 1,300 km on ocean currents (GISD 2009).

Total for biological characteristics 23 / 30

| **Ecological Impact** | **Score** |
|---|---|
| *Impact on population dynamics of other species (0-10)* | 3 |

Since the Pacific oyster is unlikely to reproduce in Alaskan waters, direct impacts on populations of native species are not likely (PWSRCAC 2004). Diseases can be imported with Pacific oyster shipments and may impact other species (PWSRCAC 2004). Oysters can cause paralytic shellfish posioning in humans resulting in illness or death (RaLonde 1996). If water temperatures rise in the future, oyster populations may naturalize and produce reefs that would provide refuge for an increased abundance of epifaunal species and cause a decrease in abundance of native mussel species through competition for resources (Ruesink et al. 2005).

*Impact on natural community composition (0-10)* 0

Under current conditions, Pacific oysters are unlikely to directly change community composition because reproduction is not likely. Pacific oyster shipments may contain other marine invasive species that could alter community composition (PWSRCAC 2004). In the future, if oyster populations do become self sustaining, the diversity of epifauna communities around oyster beds may increase. Extensive oyster reefs could displace native organisms (including plant communities; Ruesink et al. 2005) and completely change the composition of species utilizing an area.

*Impact on natural ecosystem processes (0-10)* 3

Pacific oysters are not currently impacting ecosystem processes. If water temperatures warm, hard substrate biogenic reefs may form, which alter water flow and sediment deposition rates. Oysters can decrease carbon and chlorophyll concentrations in the water column and increase water clarity. Additionally, deposition of fecal pellets can alter the inorganic content of sediment (Ruesink et al. 2005).

Total for ecological impact 6 /30

| **Feasibility of control** | **Score** |
|---|---|
| *Number of populations in Alaska (0-3)* | 1 |

Pacific oyster farms are scattered throughout southeast and southcentral Alaska and escaped oysters could be in neighboring natural areas.

*Significance of the natural area(s) and native species threatened (0-3)* 0

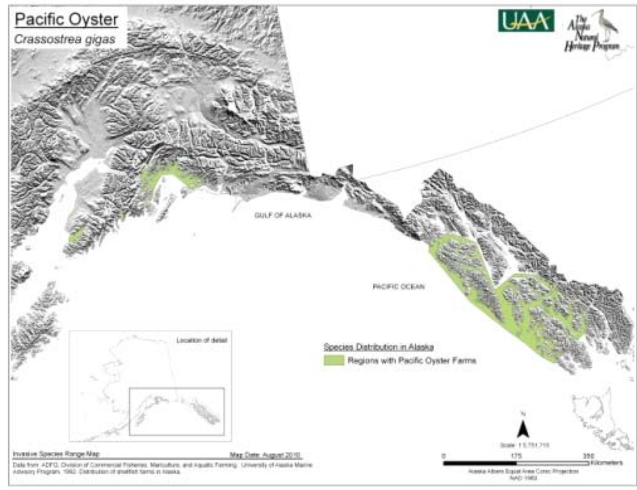
Because pacific oysters are not known to reproduce in Alaskan waters, current densities are low and unlikely to impact other valuable species or habitats (PWSRCAC 2004).

*General management difficulty (0-4)* 2

Current management may involve preventing the introduction of additional species that often hitch-hike with oysters (PWSRCAC 2004). Since Alaska does not currently have self sustaining populations of pacific oysters, management may be less of a priority compared to other invasive species.

Total for feasibility of control 3 / 10

**Range Map**




**References**


Alaska Department of Fish and Game (ADF&G). 2009. Frequently asked questions mariculture. Available at: http://www.cf.adfg.state.ak.us/geninfo/enhance/maricult/mari_faq.php

Buhle, E.R. 2006. Pacific oyster Crassostrea gigas. Pp. 124-125 in P.D. Boersma, S.H. Reichard, and A.N. Van Buren. Invasive Species in the pacific northwest. University of Washington Press, Seattle, WA.

Carrasco, M. F. and P. J. Baron. 2010. Analysis of the potential geographic range of the Pacific oyster Crassostrea gigas (Thunberg, 1793) based on surface seawater temperature satellite data and climatic charts: the coast of South America as a study case. Biol Invasions 12: 2597-2607.

Global Invasive Species Database (GISD). 2009. Crassostrea gigas (mollusc). Available at: http://www.invasivespecies.net.

Kang, S.-G., K.-S. Choi, A.A. Bulgakov, Y. Kim, and S.-Y. Kim. 2003. Enzyme-linked immunosorbent assay (ELISA) used in quantification of reproductive output in the pacific oyster, Crassostrea gigas, in Korea. Journal of Experimental Marine Biology and Ecology 282: 1-21.

Kobayashi, M., E.E. Hofman, E.N. Powell, J.M. Klinck, and K. Kusaka. 1997. A population dynamics model for the Japanese oyster, Crassostrea gigas. Aquaculture 149: 285-321.

Mann, R. 1979. Some biochemical and physiological aspects of growth and gametogenesis in Crassostrea gigas and Ostrea edulis grown at sustained elevated temperatures. Journal of the Marine Biological Association of the United Kingdom 59: 95-100

Nehring, S. 2006. NOBANIS - Invasive alien species fact sheet - Crassostrea gigas. Online Database of the Northern European and Baltic Network on Invasive Alien Species. Available at: www.nobanis.org.

Pacific States Marine Fisheries Commission (PSMFC). 2009. Pacific oyster. Available at: http://www.psmfc.org/.

Prince William Sound Regional Citizens' Advisory Council (PWSRCAC). 2004. Non-indigenous aquatic species of concern for Alaska. Fact sheet 3, Pacific (Japanese) oyster. Available at: www.pwsrcac.org.

RaLonde, R. 1996. Paralytic shellfish posioning: the Alaska problem. Marine Advisory Program University of Alaska. Alaska's Marine Resources 8 (2): 1-20.

Ruesink, J.L., H.S. Lenihan, A.C. Trimble, K.W. Heiman, F. Micheli, J.E. Byers, and M.C. Kays. 2005. Introduction of non-native oysters: ecosystem effects and restoration implications. Annual Review of Ecology, Evolution, and Systematics 36: 643-689.

Spencer, B.E., D.B. Edwards, M.J. Kaiser, and C.A. Richardson. 1994. Spatfalls of the non-native pacific oyster, Crassostrea gigas, in British waters. Aquatic Conservation 4:203-217.

## Acknowledgements

*Authors:* K. M. Walton and T. A. Gotthardt, Alaska Natural Heritage Program, University of Alaska Anchorage.

*Reviewer(s):* Jennifer Ruesink, University of Washington.

**Scientific name: *Rana aurora*** **Common name: Red-legged frog**

**Alaska invasion/introduction history**

In 1982, a school teacher released several dozen froglets into a pond southeast of Hoonah on Chichagof Island in Southeast Alaska. Since that time, the frogs have become established, reproduced and dispersed to adjacent wetlands (Hodge 2004).

| **Ranking Summary** | | |
|---|---|---|
| | Potential Max | Score |
| Distribution | 30 | 10 |
| Biological Characteristics | 25 | 12 |
| Ecological Impact | 10 | 7 |
| Feasibility of Control | 10 | 4 |
| Total | 75 | 33 |
| **Invasiveness (out of 100) =** | 49 **Weakly invasive** | |

| **Distribution** | **Score** |
|---|---|
| *Current global distribution (0-10)* | 0 |

Red-legged frogs occur only in North America (NatureServe 2009).

*Extent of the species US range and/or occurrence of formal state or provincial listings (0-10)* 3

Red-legged frogs are currently found in Alaska, California, Oregon, Washington, and British Columbia (MacDonald 2003, NatureServe 2009).

*Role of anthropogenic and natural disturbance in establishment (0-5)* 5

Red-legged frogs are not dependent on disturbance to establish, and are often found in remote natural areas (Ovaska et al. 2002, Hodge 2005).

*Climatic similarity between site of origin and release (0-5)* 2

Pauly et al. (2008) concluded that the Chichagof population is at the extreme limits of the red-legged frog's range based on a habitat suitability model. The model has the following two assumptions, that the niche model accurately predicts ecological tolerances and requirements and that the niche of R. aurora will be conserved in the extralimital populations and these frogs will not adapt to the novel and changing future conditions. However, in southeast Alaska, R. aurora may be adapting or finding this new habitat very conducive to their viabillity (even compared to ther native habitat; L. Lerum pers. Comm.).

Total for distribution 10 /30

| **Biological Characteristics and Dispersal** | **Score** |
|---|---|
| *Invasive elsewhere (0-5)* | u |

Ovaska et al. (2002) first reported red-legged frogs on Graham Island in the Queen Charlotte Islands, British Columbia. It is unknown if red-legged frogs are indigenous to Queen Charlotte Island or introduced (Ovaska et al. 2002).

*Dietary specialization (0-5)* 5

Tadpoles are herbivorous, feeding on algae, organic debris, plant tissue, and other small organisms. Adults are insectivores, but may occasional feed on small vertebrates (NatureServe 2009).

*Habitat specialization (0-5)* 5

Adults and juveniles live along water and in forests (Orchard 1984, Corkran and Thoms 1996). Little is known about habitat requirements for hibernation sites in winter. Adults breed in ponds, lakes, slow moving streams, marshes, bogs, and swamps that are at least 50 cm deep and have aquatic vegetation (Leonard et al. 1993, Corkran and Thoms 1996). The upper and lower thermal tolerance limits for embyros are 4° and 21°C respectively, but they can survive short periods of time at colder temperatures (Licht 1971).

*Average number of reproductive events per adult female per year (0-5)* 0

Females breed once in a 1-2 week breeding period between March and July (NatureServe 2009).

*Potential to be spread by human activities (0-5)* 1

Humans are unlikely to aid in the dispersal of red-legged frogs; however, intentional translocations do occur (Hodge 2004) and have been recorded several times in Alaska.

*Innate potential for long distance dispersal (0-5)* 1

Chan-McLeod (2003) radio tracked red-legged frogs and found them to be relatively sedentary, remaining within 36 m of a stream. The largest documented movement is 2.4 km between capture points in Oregon (Hayes et al. 2001). However, on Chichagof Island the population has spread to over 6000 contiguous hectares of suitable habitat (Lerum and Piehl 2007).

Total for biological characteristics 12 / 25

**Scientific name: *Rana aurora*** **Common name: Red-legged frog**

| Ecological Impact | Score |
|---|---|
| *Impact on population dynamics of other species (0-10)* | 7 |

The impact of red-legged frogs on Chichagof ecosystems is unknown (Scrader and Hennon 2005). Chytrid fungus, which has caused worldwide declines in amphibians (Daszak et al. 1999), is known to occur in some Ranid species (Pearl et al. 2007), and could cause a delcine in other frog species if transmitted. An enclosure study reported tadpoles can alter algae abundance in waterbodies (Dickman 1968). The impact of red-legged frogs on other amphibians is unknown, but this species ability to persist and spread across Chichagof drainages could displace native wood frogs and western toads through competion for resources (Schrader and Hennon 2005).

*Impact on natural community composition (0-10)* u

Unknown.

*Impact on natural ecosystem processes (0-10)* u

Unknown.

Total for ecological impact 7 /10

| Feasibility of control | Score |
|---|---|
| *Number of populations in Alaska (0-3)* | 1 |

One population of red-legged frogs occurs on Chichagof Island (Hodge 2004).

*Significance of the natural area(s) and native species threatened (0-3)* 1

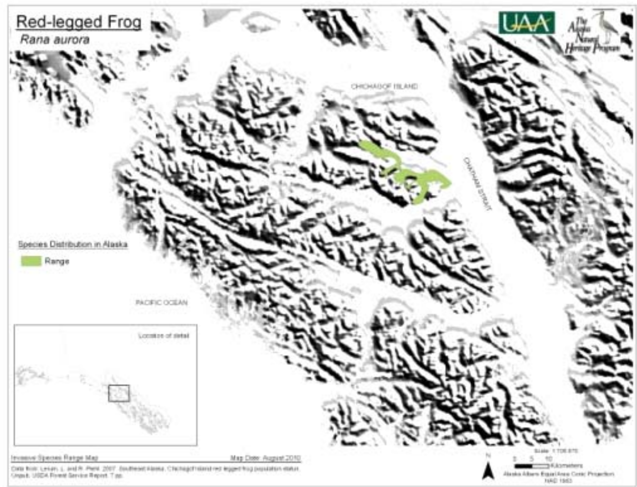
The western toad is declining throughout its range for unknown reasons (MacDonald 2003) and could potentially be impacted by invasive red-legged frogs through competition for resources.

*General management difficulty (0-4)* 2

Two general management options exists, either eradication or monitoring and control of red-legged frog dispersal. Pauly et al. (2008) states that eradication would be expensive and probably unsuccessful due to the remote location of the population. The latter management option may be more feasible and would involve monitoring the impacts and spread of the current population, and raising public awareness of the hazards of translocating frogs (Pauly et al. 2008). Red-legged frog populations are declining in the majority of its native range, so allowing the Chichagof Island population to persist may be a strategy for the conservation of this species in the future (Pauly et al. 2008).

Total for feasibility of control 4 / 10

**Range Map**




**References**

Chan-McLeod, A.C.A. 2003. Refining the funnel trapping protocol for monitoring amphibians and movement patterns of red-legged frogs. Unpublished progress report prepared for Weyerhaueser Company, Nanaimo, BC.

Corkran, C.C. and C.R. Thomas. 1996. Amphibians of Oregon, Washington, and British Columbia. Lone Pine Publishing, Vancouver, B.C.

Daszak, P., L. Berger, A.A Cunningham, A.D. Hyatt, D.E. Green, and R. Speare. 1999. Emerging infectious diseases and amphibian population declines. Emerging Infectious Diseases 5:735–748.

Dickman, M. 1968. The effect of grazing by tadpoles on the structure of a periphyton community. Ecology 49: 1188-1190.

Hayes, M.P., C.A. Pearl, and C.J. Rombough. 2001. Rana aurora aurora (northern red-legged frog). Movement. Herpetological Review 32:35-36.

Hodge, R.P. 2004. Geographic distribution. Rana aurora (red-legged frog). Herpetological Review 35: 79.

Leonard, W.P., H.A. Brown, L.L.C. Jones, K.R. McAllister, and R.M. Storm. 1993. Amphibians of Washington and Oregon. Seattle Audubon Society, Seattle, WA.

Lerum, L. and R. Piehl. 2007. Southeast Alaska, Chichagof Island redlegged frog population status. Unpub. USDA Forest Service Report. 7 pp.

Licht, L.E. 1971. Breeding habits and embryonic thermal requirements of the frogs, Rana aurora aurora and Rana pretiosa pretiosa, in the Pacific Northwest. Ecology 52: 116-124.

MacDonald, S.O. 2003. The amphibians and reptiles of Alaska: A field handbook. Available at: http://www.alaskaherps.info. (Last accessed 20 November 2009).

NatureServe. 2009. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available at: http://www.natureserve.org/ explorer. (Last accessed: 19 November 2009 ).

Orchard, S.A. 1984. Amphibians and reptiles of B.C.: an ecological review. Research Branch, Ministry of Forests. WHR-15. Victoria, B.C.

Ovaska, K., L. Hyatt, and L. Sopuck. 2002. Rana aurora (red-legged frog). Herpetological Review 33: 318.

Pauly, G.B., S.R. Ron, and L. Lerum. 2008. Molecular and ecological characterization of extralimital populations of red-legged frogs from Western North America. Journal of Herpetology 42: 668-679.

Pearl, C.A., E.L. Bull, D.E. Green, J. Bowerman, M.J. Adams, A. Hyatt, and W.H. Wente. 2007. Occurrence of the amphibian pathogen Batrachochytrium dendrobatidis in the Pacific Northwest. Journal of Herpetology 41: 145-149.

Schrader, B. and P. Hennon. 2005. Assessment of invasive species in Alaska and its national forests. US Forest Service Report.

## Acknowledgements

*Authors:* K. M. Walton and T. A. Gotthardt, Alaska Natural Heritage Program, University of Alaska Anchorage.

*Reviewer(s):* Lance Lerum, U.S. Forest Service.

**Scientific name: *Eriocheir sinensis*** **Common name: Chinese mitten crab**

**Alaska invasion/introduction history**

Chinese mitten crabs are not present in Alaska. In 1992, a shrimp trawler reported Chinese mitten crabs in San Francisco Bay and by 1996 crabs had spread to the southern delta of the north bay (Hieb 1997, Siegfried 1999).

| Ranking Summary | | |
|---|---|---|
| | Potential Max | Score |
| Distribution | 30 | 13 |
| Biological Characteristics | 30 | 20 |
| Ecological Impact | 30 | 9 |
| Feasibility of Control | 10 | 3 |
| Total | 100 | 45 |
| **Invasiveness (out of 100) =** | 45 **Weakly invasive** | |

| Distribution | Score |
|---|---|

*Current global distribution (0-10)* 6

Chinese mitten crabs are native to the Yellow Sea region bordering China and Korea in eastern Asia and invasive in Europe and North America (Panning 1939, Ralston 2006).

*Extent of the species US range and/or occurrence of formal state or provincial listings (0-10)* 0

The only established population of Chinese mitten crabs in the United States are in the San Francisco Bay area and neighboring drainages (Rudnick et al. 2000, Benson and Fuller 2009). Individual crabs were collected in the Mississippi River (Horwath 1989) and Great Lakes- St. Lawrence River basin (Nepszy & Leach 1973), but these individuals showed no evidence of breeding because they were too far from saltwater (Benson and Fuller 2009), except for three specimens in the St. Lawrence estuary that were found in suitable reproductive brackish waters (Veilleux and de Lafontaine 2007). There is no established population on the eastern seaboard, but specimens have been collected from the Chesapeake Bay, Delaware Bay, and Hudson River (Veilleux and de Lafontaine 2007).

*Role of anthropogenic and natural disturbance in establishment (0-5)* 5

Chinese mitten crabs are not dependent on disturbance for establishment.

*Climatic similarity between site of origin and release (0-5)* 2

Hanson and Sytsma (2005) reported that Alaskan waters do not get above 9°C for a long enough period of time (125 days) to support larvae development. The Lake Maerlaren area of Sweden has an established population that survives extended periods of freezing and there have been repeated reports from the Finnlands Lake District and Russia (Herborg et al. 2003, Herborg et al. 2007).

Total for distribution 13 /30

| Biological Characteristics and Dispersal | Score |
|---|---|

*Invasive elsewhere (0-5)* 5

Chinese mitten crabs are invasive in Europe and North America (Panning 1939, Ralston 2006).

*Dietary specialization (0-5)* 5

Juvenile crabs are herbivorous for several months until they develop adult feeding habits. Adult are omnivorous and opportunistic scavengers, consuming aquatic vegetation, invertebrates, fish eggs, and other items if presented (Tan 1984, Rudnick et al. 2003).

*Habitat specialization (0-5)* 2

Adults inhabit estuarine and freshwater habitats, including tidal mud flats, rocky shores, wetlands, lakes, ponds, streams, and rivers finding refugia in weeds, rocks, and other benthic structures (Veldhuizen and Hieb 1998, Rudnick et al. 2000). Larvae need a more specialized habitat to survive and develop, including an estuary with a low flushing rate (Hanson and Sytsma 2005), water temperatures above 12°C , and salinities between 15 and >30 %S are easily tolerable for the first zoea stage in suitable temperature conditions (Anger 1991). Salinity tolerances change throughout zoeal stages, with zoea I tolerant of euryhaline conditions and subsequent stages with decreasing tolerances to low salinities and eventually a clear preference for seawater, tolerance for low salinity then increase during the final larval stage and metamorphosis (Anger 1991).

*Average number of reproductive events per adult female per year (0-5)* 0

Females typically reproduce once, carrying up to one million eggs under their abdominal flap (Panning 1939, Ralston 2006).

*Potential to be spread by human activities (0-5)* 5

Humans disperse Chinese mitten crabs primarily through ballast water and intentional release (mitten crabs are a delicacy in Asian markets; CMCWG 2003, Ralston 2006). Additionally, there are many known instances of Chinese mitten crabs being smuggled into the U.S. for personal use and black market trade (USFWS 1999). It is largely accepted that the worldwide spread of Chinese mitten crabs was likely due to human-mediated activities (Veileux and de Lafontaine 2007).

*Innate potential for long distance dispersal (0-5)* 3

Chinese mitten crabs are capable of traveling thousands of kilometers in a lifetime. Crabs migrate up and down rivers, with reports of individuals walking on land to navigate past obstacles (Ralston 2006). In China, Chinese mitten crabs have traveled 1,000 km (Panning 1939) and in the Czech Republic, crabs have migrated 800 km (Normant et al. 2000).

Total for biological characteristics 20 / 30

| **Ecological Impact** | **Score** |
|---|---|
| *Impact on population dynamics of other species (0-10)* | 3 |

The impact of mitten crabs on native species is not well documented, but if this species is at the extreme of its climatic range the potential impacts are likely reduced. Chinese mitten crabs may reduce invertebrate abundance. Crabs can potentially consume the eggs of salmon, but quantitative evidence is lacking (Veilleux and de Lafontaine 2007) and compete with clams and mussels (Ralston 2006). Crabs are known to inhabit agricultural ditches and bioaccumulate contaminants that can be passed up the food chain to predators (CMCWG 2003). Chinese mitten crabs are the secondary host of the Asian lung fluke (Yang 2000), which can infect mammals; however the snail host is circumtropical (Veilleux and de Lafontaine 2007) this fluke has not been reported in U.S. Chinese mitten crabs (CMCWG 2003).

*Impact on natural community composition (0-10)* 3

Since Chinese mitten crabs may be at its climatic limit in Alaska, impacts on communities could be minor. In other locations, Chinese mitten crabs have altered food webs by competing with and preying upon invertebrate and crustacean communities (Ralston 2006). When Chinese mitten crabs feed on organic detritus they make it less available to other aquatic organisms, resulting in alterations to freshwater benthic food webs (Veilleux and de Lafontaine 2007).

*Impact on natural ecosystem processes (0-10)* 3

Impacts on ecosystems is likely minor in Alaska because of cool water temperatures. Elsewhere Chinese mitten crabs have burrowed extensively causing increased sediment load, bank/levee erosion, and bank slumping in aquatic systems (Panning 1939). Alterations to food webs could impact nutrient cycling in aquatic systems and erosion could eventually increase water turbidity and general water quality (Veilleux and de Lafontaine 2007).

Total for ecological impact 9 /30

| **Feasibility of control** | **Score** |
|---|---|
| *Number of populations in Alaska (0-3)* | 0 |

No populations in Alaska.

*Significance of the natural area(s) and native species threatened (0-3)* 1

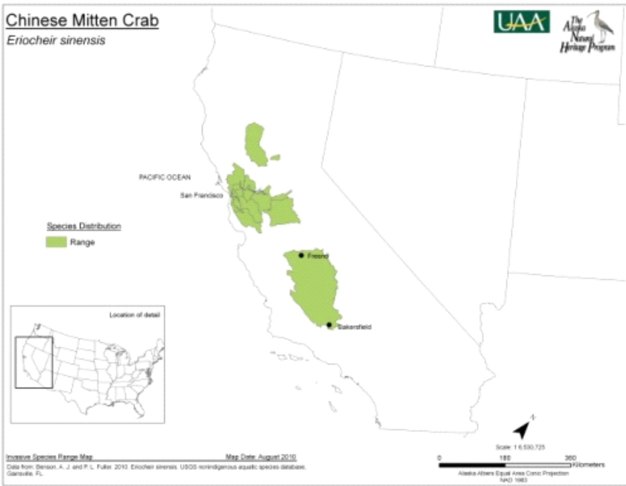
In other locations, mitten crabs have been reported to disturb and be a nuisance to shrimp fisheries by entangling in nets and damaging shrimp in the nets (CMCWG 2003). Chinese mitten crabs can also alter natural riparian areas, which may be of importance, by increasing erosion and slumping of streambanks (Panning 1939). However, cool water temperatures in Alaska may limit reproduction and impacts on other species and natural areas.

*General management difficulty (0-4)* 2

Prevention of invasion by mitten crabs is the most cost effective management option, since this species is difficult to control once established (Rudnick et al. 2003). In Germany, crabs are trapped when they reach migration barriers (Panning 1939) and electrical screens are placed in areas where crabs congregate and pulses are used to disable and kill individuals (Halsband 1968 cited in USFWS 1989). The general management difficulty in Alaska would likely be lower than other locations because of cold water temperature limiting Chinese mitten crab establishment.

Total for feasibility of control 3 / 10

## Range Map




## References

Anger, K. 1991. Effects of temperature and salinity on the larval development of the Chinese mitten crab Eriocheir sinensis (Decapoda: Grapsidae). Marine Ecology Progress Series 73: 103-110.

Benson, A. J. and P. L. Fuller. 2009. Eriocheir sinensis. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. Available at: http://nas.er.usgs.gov/queries/FactSheet.asp?speciesID=182 (Last accessed 13 November 2009).

Chinese Mitten Crab Working Group (CMCWG). 2003. National management plan for the genus Eriocheir (mitten crabs). Aquatic Nuisance Species Task Force.

Global Invasive Species Database (GISD). 2009. Eriocheir sinensis (crustacean). Available at: http://www.invasivespecies.net.

Hanson, E. and M. Sytsma. 2005. The potential for mitten crab colonization of estuaries on the west coast of North America. Final Report. Prepared for the Pacific States Marine Fisheries Commission and Alaska Department of Fish and Game.

Heib, K. 1997. Chinese mitten crabs in the delta. IEP Newsletter 10: 14-15.

Herborg L.-M., S. P. Rushton, A. S. Clare, and M. G. Bentley. 2003. Spread of the Chinese mitten crab (Eriocheir sinensis, H. Milne Edwards) in continental Europe: analysis of a historical data set. Hydrobiologia 503: 21-28.

Herborg L.-M., D. Rudnick, Y. Silang, D. M. Lodge, and H. J. MacIsaac. 2007. Predicting the range of Chinese mitten crabs in Europe. Conservation Biology 21: 1316-1323.

Horwath, J.L. 1989. Importation or shipment of injurious wildlife: mitten crabs. U.S. Fed Reg 54: 22286-22289.

Nepszy, S. and J. Leach. 1973. First records of the Chinese mitten crab, Eriocheir sinensis, (Crustacea: Brachyura) from North America. Journal of the Fisheries Research Board of Canada 30: 1909–1910.

Normant, M., A. Wiszniewska, and A. Szaniawska. 2000. The Chinese mitten crab Eriocheir sinensis (Decopda: Grapsidae) from Polish waters. Oceanologia 42: 375-383.

Panning, A. 1939. The Chinese mitten crab. Smithsonian Institution Annual Report for 1938, Washington, D.C.

Ralston, C.L. 2006. Chinese mitten crab Eriocheir sinensis. Pp. 206-207 in P.D. Boersma, S.H. Reichard, and A.N. Van Buren. Invasive Species in the Pacific Northwest. University of Washington Press, Seattle, WA.

Rudnick, D.A., K.M. Halat, and V.H. Resh. 2000. Distribution, Ecology and Potential Impacts of the Chinese Mitten Crab (Eriocheir sinensis) in San Francisco Bay. University of California Water Resource Center, Technical Completion Report Project Number: UCAL-WRC-W-881.

Rudnick, D., K. Hieb, K. Grimmer, V. Resh. 2003. Patterns and processes of biological invasion: the Chinese mitten crab in San Francisco Bay. Basic Applied Ecology 4: 1-14.

Siegfried, S. 1999. Notes on the invasion of the Chinese mitten crab (Eriocheir sinensis) and their entrainment at the Tracy fish collection facility. IEP Newsletter 12: 24-25.

Tan, Q. 1984. The ecological study of the anadromous crab Eriocheir sinensis going upstream. Tung wu hsueh tsa chih (Chinese Journal of Zoology) 6: 19-22.

U.S. Fish and Wildlife Service (USFWS). 1989. Importation or shipment of injurious wildlife: mitten crabs. Federal Register 54: 22286-22289.

U.S. Fish and Wildlife Service (USFWS). 1999. U.S. Fish & Wildlife Service Division of Law Enforcement Annual Report FY 1999. Available at: http://www.fws.gov/le/pdffiles/99rept.pdf

Veilleux, E. and Y. de Lafontaine. 2007. Biological synopsis of the Chinese mitten crab (Erocheir sinensis). Can. Manusc. Rep. Fish. Aquat. Sci. 2812: vi + 45p.

Veldhuizen, T. and K. Hieb. 1998. What difference can one crab species make? The ongoing tale of the Chinese mitten crab and the San Francisco estuary. Outdoor California 59: 19-21.

Yang, J., C. Ming-gang, F. Zheng, and D. Blair. 2000. Paragonimus and Paragonimiasis in China: A review of the literature. Chinese Journal of Parasitology and Parasitic Diseases.

## Acknowledgements

*Authors:* K. M. Walton and T. A. Gotthardt, Alaska Natural Heritage Program, University of Alaska Anchorage.

*Reviewer(s):* Matthias Herborg, BC Ministry of Government;

Robyn Draheim, Portland State University.

**Scientific name: *Cervis canadensis*** **Common name: Elk**

**Alaska invasion/introduction history**

Eight Roosevelt elk were introduced to Afognak Island in the 1920's (Batchlelor 1965). In 1985 Alaska legislature passed a law requiring the introduction of 50 elk to Etolin Island and two years later both Roosevelt and Rocky Mountain elk were introduced to Etolin Island (ADF&G 1999).

| Ranking Summary | | |
|---|---|---|
| | Potential Max | Score |
| Distribution | 30 | 17 |
| Biological Characteristics | 30 | 9 |
| Ecological Impact | 20 | 6 |
| Feasibility of Control | 10 | 4 |
| Total | 90 | 36 |
| **Invasiveness (out of 100) =** | 39 | **Very weakly invasive** |

| Distribution | Score |
|---|---|
| *Current global distribution (0-10)* | 0 |

Elk occur in regions of the conterminous U.S., Canada, and Mexico, other subspecies (which are not used to determine ranking) occur in Asia and northern Africa (Nowak 1991).

*Extent of the species US range and/or occurrence of formal state or provincial listings (0-10)* 7

Elk occur in approximately 30% of the states and at least five Canadian provinces. The majority of the elk's range is along the Rocky Mountains and western coast of the United States (Patterson et al. 2003, NatureServe 2009).

*Role of anthropogenic and natural disturbance in establishment (0-5)* 5

Once introduced to an area elk are not dependent on human activity or disturbance to establish, as seen by all successful elk populations in Alaska that have established in natural areas (Troyer 1960, ADF&G 2008).

*Climatic similarity between site of origin and release (0-5)* 5

Elk are native in the Rocky Mountains, including Colorado, Wyoming, Montana, Alberta, and British Columbia (O'Gara and Dundas 2002), which experience low temperatures similar to coastal Alaska (Cathey 1990).

Total for distribution 17 /30

| Biological Characteristics and Dispersal | Score |
|---|---|
| *Invasive elsewhere (0-5)* | 0 |

Although elk have been extensively translocated to locations outside of their native range throughout the United States and Canada, this species is not considered invasive because it was intentionally introduced and does not appear to cause harm ecologically or economically.

*Dietary specialization (0-5)* 2

Elk feed on a variety of grasses, sedges, forbs, and shrubs (MacDonald and Cook 2009). The diet of elk vary with season and the availability of food resources (Toyer 1960). On Afognak Island, Alaska, elk are dependent on willow and elderberry in the winter (Troyer 1960) and in Southeast Alaska, three species of huckleberry, western redcedar, and salal are important components of their diet (Kirchhoff and Larsen 1998).

*Habitat specialization (0-5)* 5

Elk utilize habitat types in both lowland and mountainous regions (Nowak 1991). In British Columbia, elk utilize conifer and deciduous forests, wetlands, rock outcrops, and vegetation slides (Quayle and Brunt 2003).

*Average number of reproductive events per adult female per year (0-5)* 0

Cows can start breeding while still yearlings, but the proportion of cows that successfully conceive are highly variable. By age 3.5, most cows successfully produce a single calf (rarely twins) per year (Raedeke et al. 2002).

*Potential to be spread by human activities (0-5)* 1

The accidental transport of elk to new locations does not typically occur; however, elk have been translocated by humans to create additional hunting opportunities (O'Gara and Dundas 2002, ADF&G 2008).

*Innate potential for long distance dispersal (0-5)* 1

Elk display a high fidelity to their home ranges during seasonal migrations; however, if conditions are highly unfavorable, elk may move outside of their home range and establish in new locations (Irwin 2002, NatureServe 2009). Elk have dispersed to islands adjacent to their site of release in Southeast Alaska (ADF&G 2008).

**Scientific name:** ***Cervis canadensis*** **Common name: Elk**

| | |
|---|---|
| Total for biological characteristics | 9 / 30 |

| **Ecological Impact** | **Score** |
|---|---|

*Impact on population dynamics of other species (0-10)* 3

In Southeast Alaska, Sitka black-tailed deer and elk have a high degree of dietary overlap. This overlap has a high potential to cause competition between elk and deer during severe winters or as more areas are clearcut (Kirchhoff and Larsen 1998). It is unlikely that deer will be completely displaced by elk, but deer may have to exploit foraging patches that are not accessible to elk (Hanley 1984, Jenkins and Wright 1988).

*Impact on natural community composition (0-10)* 3

In other states elk populations have heavily grazed and trampled plant communities (Lyon and Christensen 2002). Literature does not report heavy feeding as a problem in Alaska yet; however, if food resources become sparse due to logging, competition may occur between elk and Sitka black-tailed deer and vegetation communities may become highly browsed by both species (Kirchhoff and Larsen 1998, ADF&G 1999).

*Impact on natural ecosystem processes (0-10)* u

Grazing by elk can lower the biomass produced by plants and cause changes in the carbon and nitrogen dynamics in willow communities. However, these changes in ecosystem processes are not well understood and conflicting results have been obtained by different studies (Schoenecker et al. 2004).

| | |
|---|---|
| Total for ecological impact | 6 /20 |

| **Feasibility of control** | **Score** |
|---|---|

*Number of populations in Alaska (0-3)* 1

Populations of elk exist on Afognak, Raspberry, Etolin, and Zarembo islands, and possibly on neighboring islands in Southeast Alaska (ADF&G 2008).

*Significance of the natural area(s) and native species threatened (0-3)* 1

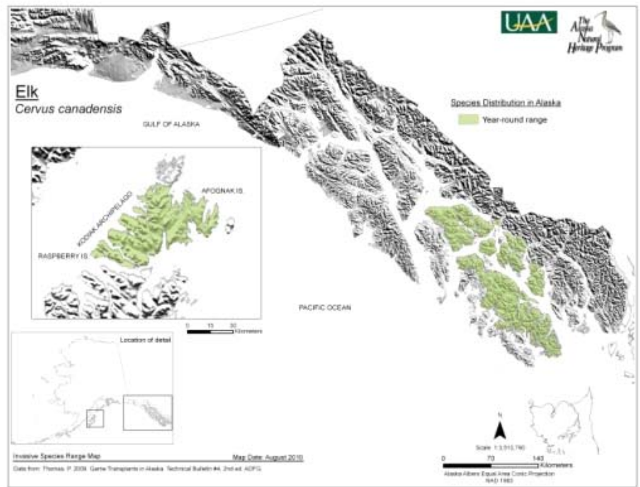
Elk have the potential to compete with native Sitka black-tailed deer. These deer are of value to recreational hunters; however, reduction in deer hunting and/ or complete displacement of by elk is unlikely (Kirchhoff and Larsen 1998, ADF&G 1999).

*General management difficulty (0-4)* 2

Management of elk in Alaska does not include eradication of the species, but managing abundances at healthy levels to provide hunting opportunities on Afognak, Raspberry, Etolin, and Zarembo islands, while limting the dispersal of individuals to adjoining islands and the mainland (ADF&G 2008).

| | |
|---|---|
| Total for feasibility of control | 4 / 10 |

**Range Map**




**References**

Alaska Department of Fish and Game (ADF&G). 1999. Draft southeast Alaska elk management plan. Juneau, Alaska.

Alaska Department of Fish and Game (ADF&G). 2008. Elk management report of survey-inventory activities 1 July 2005-30 July 2007. P. Harper (ed). Juneau, AK.

Batchlelor, R.F. 1965. The Roosevelt elk in Alaska - its ecology and management. Alaska Department of Fish and Game, Juneau, Alaska.

Cathey, H.M. 1990. USDA plant hardiness zone map. USDA Miscellaneous Publication No. 1475.

Hanley, T.A. 1984. Habitat patches and their selection by wapiti and black-tailed deer in coastal montane coniferous forest. Journal of Applied Ecology 21: 423-436.

Irwin, L.L. 2002. Migration. Pp. 493-513 in North American elk ecology and management. D.E. Toweill and J.W. Thomas (eds) Smithsonian Institution Press, Washington.

Jenkins, K.J. and R.G. Wright. 1988. Resource partitioning and competition among cervids in the northern Rocky Mountains. Journal of Applied Ecology 25: 11-24.

Kirchhoff, M.D. and D.N. Larsen. 1998. Dietary overlap between native Sitka black-tailed deer and introduced elk in southeast Alaska. Journal of Wildlife Management 62: 236-242.

Lyon, L.J. and A.G. Christensen. 2002. Elk and land management. Pp. 557-581 in North American elk ecology and management. D.E. Toweill and J.W. Thomas (eds). Smithsonian Institution Press, Washington.

MacDonald, S.O. and J.A. Cook. 2009. Recent mammals of Alaska. University of Alaska Press, Fairbanks, AK.

NatureServe. 2009. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. (Accessed: October 21, 2009 ).

Nowak, R.M. 1991. Walker's mammals of the world. Fifth edition. Johns Hopkins Press, Baltimore, MD.

O'Gara, B.W. and R.G. Dundas. 2002. Distribution: past and present. Pp. 67-119 in North American elk ecology and management. D.E. Toweill and J.W. Thomas (eds). Smithsonian Institution Press, Washington.

Patterson, B.D., G. Ceballos, W. Sechrest, M.F. Tognelli, T. Brooks, L. Luna, P. Ortega, I. Salazar, and B.E. Young. 2003. Digital Distribution Maps of the Mammals of the Western Hemisphere, version 1.0. NatureServe, Arlington, Virginia, USA

Quayle, J.F. and K.R. Brunt. 2003. Status of Roosevelt Elk (Cervus elaphus roosevelti) in British Columbia. B.C. Ministry of Sustainable Resource Management, Conservation Data Centre, and B.C. Ministry of Water, Land and Air Protection, Biodiversity Branch, Victoria, BC. 31pp.

Raedeke, K.J., J.J. Millspaugh, and P.E. Clark. 2002. Population characteristics. Pp. 449-513 in North American elk ecology and management. D.E. Toweill and J.W. Thomas (eds). Smithsonian Institution Press, Washington.

Schoenecker, K.A., F.J. Singer, L.C. Zeigenfuss, D. Binkley, and R.S.C. Menezes. 2004. Effects of elk herbivory on vegetation and nitrogen processes. Journal of Wildlife Management 68: 837-849.

Troyer, W.A. 1960. The Roosevelt elk on Afognak Island, Alaska. Journal of Wildlife Management 24: 15-21.

## Acknowledgements

*Authors:* K. M. Walton and T. A. Gotthardt, Alaska Natural Heritage Program, University of Alaska Anchorage.

*Reviewer(s):* Larry van Daele, Alaska Department of Fish and Game.

**Scientific name: *Pseudacris regilla*** **Common name: Pacific chorus frog**

**Alaska invasion/introduction history**

Around 1960, a population of Pacific chorus frogs were released into a group of muskeg ponds near Ward Lake on Revillagigedo Island (MacDonald 2003). Pacific chorus frogs were also transported on Christmas trees into the Anchorage area in December 2009, but did not successfully establish (Halpin 2009).

| Ranking Summary | | |
|---|---|---|
| | Potential Max | Score |
| Distribution | 30 | 10 |
| Biological Characteristics | 30 | 18 |
| Ecological Impact | 30 | 0 |
| Feasibility of Control | 10 | 1 |
| Total | 100 | 29 |
| **Invasiveness (out of 100) =** | 29 **Very weakly invasive** | |

| **Distribution** | **Score** |
|---|---|
| *Current global distribution (0-10)* | 0 |

The Pacific chorus frog is indigenous to North America (Somma 2009).

*Extent of the species US range and/or occurrence of formal state or provincial listings (0-10)* 3

The Pacific chorus frog is found in 9 states, including Alaska and in British Columbia, Canada (NatureServe 2009).

*Role of anthropogenic and natural disturbance in establishment (0-5)* 5

Pacific chorus frogs are able to establish in undisturbed areas, as seen by the population near Ward Lake in Alaska and by individuals inhabiting pristine areas on Queen Charlotte Island, British Columbia (Reimchen 1990).

*Climatic similarity between site of origin and release (0-5)* 2

The climate in southeast Alaska is similar to the climate in the northern part of its range in British Columbia and the Pacific Northwest.

Total for distribution 10 /30

| **Biological Characteristics and Dispersal** | **Score** |
|---|---|
| *Invasive elsewhere (0-5)* | 5 |

Pacific chorus frogs were released on the Queen Charlotte Islands, British Columbia, in 1962, and the population had increased in numbers and range (Reimchen 1990).

*Dietary specialization (0-5)* 5

Tadpoles primarily feed on algae and adults consume a variety of insects (Werner et al. 2004).

*Habitat specialization (0-5)* 5

Pacific chorus frogs inhabit a variety of habitats including clumps of grasses and sedges, pond edges, and woodland forests (MacDonald 2003).

*Average number of reproductive events per adult female per year (0-5)* 2

Perril and Daniel (1983) reported that Pacific chorus frogs have 2-3 clutches of eggs per breeding season.

*Potential to be spread by human activities (0-5)* 1

Other than humans intentionally introducing Pacific chorus frogs (Reimchen 1990), human dispersal is unlikely, although Pacific chorus frogs were transported to Anchorage Alaska on a shipment of Christmas trees from Washington state (Halpin 2009).

*Innate potential for long distance dispersal (0-5)* 0

Hylid frogs typically exhibit limited movements, with no specific mechanism for long distance dispersal and frogs have not dispersed out of the muskeg ponds in Alaska (MacDonald 2003, NatureServe 2009). In Montana, frogs move up to 400 m during the summer (Werner et al. 2004).

Total for biological characteristics 18 / 30

| **Ecological Impact** | **Score** |
|---|---|
| *Impact on population dynamics of other species (0-10)* | 0 |

Somma (2009) stated it is unlikely that Pacific chorus frogs in Alaska will impact other organisms, at least not outside the confines of their muskeg pond site. On Revillagigedo Island, native western toads and roughskin newts could potentially be impacted by the Pacific chorus frog, but negative interactions have not yet been noted (MacDonald 2003). Invasive frogs may also spread chytrid fungus to native amphibian species if they are infected or carriers of the fungus (Skerratt et al. 2007).

*Impact on natural community composition (0-10)* 0

No changes to native communities have been percieved and native amphibians are still breeding in the muskeg ponds that Pacific chorus frogs occupy (MacDonald 2003).

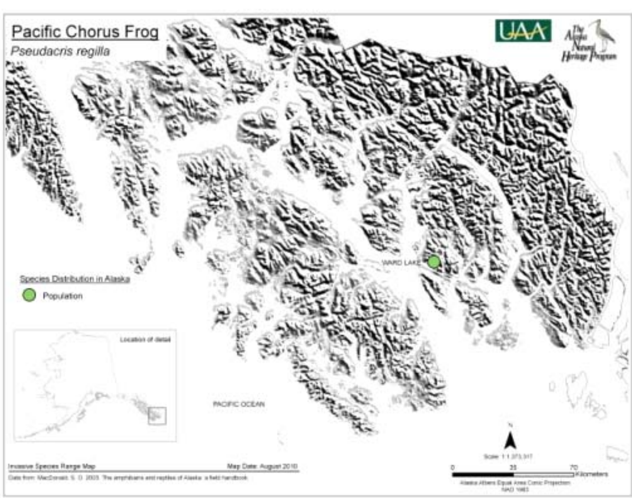
*Impact on natural ecosystem processes (0-10)* 0

There are no documented alterations of ecosystem processes and Pacific chorus frogs occur in one muskeg region. Their impacts if any are not likely to extend beyond their breeding pond (Somma 2009).

Total for ecological impact 0 /30

| Feasibility of control | Score |
|---|---|
| *Number of populations in Alaska (0-3)* | 1 |
| In Alaska, Pacific chorus frogs are found on Revillagigedo Island (MacDonald 2003). | |
| *Significance of the natural area(s) and native species threatened (0-3)* | 0 |
| Currently, the Pacific chorus frog does not seem to be impacting any valuable native species or natural areas. | |
| *General management difficulty (0-4)* | 0 |
| The population of Pacific chorus frogs does not appear to be spreading beyond its release site in the muskeg ponds. Native amphibians are still successfully breeding in the area, so management may be a low priority. | |
| Total for feasibility of control | 1 / 10 |

**Range Map**




**References**

MacDonald, S.O. 2003. The amphibians and reptiles of Alaska: a field handbook. Available http://www.alaskaherps.info (Accessed 4 November 2009).

NatureServe. 2009. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. (Accessed: November 4, 2009 ).

Perril, S.A. and R.E. Daniel. 1983. Multiple egg clutches in Hyla regilla, H. cinerea, and H. gratiosa. Copeia 1983: 513-516.

Reimchen, T.E. 1990. Introduction and dispersal of the Pacific treefrog, Hyla regilla, on the Queen Charlotte Islands, British Columbia. Canadian Field Naturalist 105: 288-290.

Skerratt, L. F., L. Berger, R. Speare, S. Cashins, K. R. McDonald, A. D. Phillott, H. B. Hines, and N. Kenyon. 2007. Spread of Chytridiomycosis has caused the rapid global decline and extinction of frogs. EcoHealth 4: 125-134.

Somma, L.A. 2009. Pseudacris regilla. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. Available http://nas.er.usgs.gov/queries/FactSheet.asp?speciesID=59 (Accessed 4 November 2009).

Werner, J.K., B.A. Maxell, P. Hendricks, and D.L. Flath. 2004. Amphibians and reptiles of Montana. Mountain Press Publishing Company, Missoula, Montana.

**Acknowledgements**

*Authors:* K. M. Walton and T. A. Gotthardt, Alaska Natural Heritage Program, University of Alaska Anchorage.

*Reviewer(s):* Lisa Hallock, Washington Natural Heritage Program