NON-NATIVE AND INVASIVE ANIMALS OF ALASKA:
A COMPREHENSIVE LIST AND SELECT SPECIES STATUS REPORTS

FINAL REPORT

Jodi McClory
Tracey Gotthardt

Alaska Natural Heritage Program

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Jodi McClory and Tracey Gotthardt

Alaska Natural Heritage Program
Environment and Natural Resources Institute
University of Alaska Anchorage
707 A Street, Anchorage AK 99501

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EXECUTIVE SUMMARY

In recent years, a number of non-native animal species have been observed in Alaska, some of which have proven to be invasive. Since animal introductions to the state are still limited in distribution, and because protecting land not yet infested by non-natives is an efficient technique for the management of invasive species, we have the opportunity to preserve Alaska's immense natural resources with careful management of invasive animal threats. However, before management efforts towards invasive species can be successful, information must be gathered to identify which non-native animal species are present in the state, where they occur, and which species pose the greatest risk to native ecosystems. In an effort to provide managers with the most up-to-date information regarding invasive animal species in Alaska, we compiled a comprehensive list of non-native animals that have been documented in the state, and also developed a list of potential future invaders based on their occurrence in neighboring states and/or provinces. We collected published and unpublished information on a number of non-native animal species that are known to pose a high risk to native ecosystems, and summarized information on their biology, modes of dispersal, documented impacts, control options, and current and historic distribution.

A total of 116 non-native animal species (including fishes, amphibians, reptiles, birds, mammals, invertebrates, parasites and pathogens) were documented as present (either historically or currently) in the state, of which 20 were designated as highly invasive species. Status reports describing biology and invasive potential were developed for 14 of the highly invasive species and are included as an appendix to this report, along with maps of their known current distribution in the state. An additional 41 species were identified as potential invaders based on their rapid spread in western North America and on their ability to disperse over large distances. Ten of the 41 potential invaders were identified as being highly invasive, and status reports were developed for 3 of those species.

The development of the first comprehensive list of non-native animals in Alaska summarizes necessary and preliminary information about the current status of these animals in the state. Information contained within the individual species status reports and associated distribution maps may be used to interpret a species' ability to spread into particular regions, and could be used in future mapping efforts to calculate rates of dispersal as well as enable prediction of future range expansions. As global climate change continues to warm the landscape, Alaska may become more susceptible to harmful invaders and the information compiled within this report could be useful in predicting and preventing animal invasions.

INTRODUCTION

Invasive species are defined in federal law as species that are both non-native (alien) to a particular ecosystem and whose introduction causes or is likely to cause economic or environmental harm, or harm to human health (Executive Order 13112 1999). In recent years, a number of non-native animal species have been observed in Alaska, some of which have proven to be invasive. Invasive species threaten native ecosystem integrity and Alaska's valuable resources in fisheries, tourism, forestry, and agriculture by the alteration and loss of natural species biodiversity and ecosystem functions. Alaska's low population and relative geographic isolation have kept introductions of new invasive species comparatively low, but increased commercial traffic, development, and changes wrought by climate change all potentially increase the risk of new introductions to the state. Since many animal introductions to the state are still limited in distribution, and because protecting land not yet infested by non-natives is an efficient technique for the management of invasive species, we have the opportunity to preserve Alaska's valuable natural resources with careful management of invasive animal threats.

Before successful management efforts towards invasive species can be implemented, information must be gathered to identify which non-native animal species are present in the state, where they occur, and which species pose the greatest risk to native ecosystems. In an effort to provide managers with the most up-to-date information regarding invasive animal species in Alaska, we compiled a comprehensive list of non-native animals that have been documented in the state, and also developed a list of potential future invaders based on their occurrence in neighboring states and/or provinces. We collected published and unpublished information on a number of non-native animal species that pose a high risk to native ecosystems, and summarized information on their biology, modes of dispersal, documented impacts, control options, and current and historic distribution.

Specific project objectives were to:

(1) Conduct a comprehensive literature review and consult with area biologists to compile a draft list of non-native animal species previously documented in Alaska. Compile a list of potential invaders to include species that have been documented in neighboring states and provinces.

(2) Through literature review and expert consultation, identify which species are accidentals and unlikely invaders in Alaska and remove these species from the list, or identify them as such.

(3) Research and synthesize information on the biology, modes of dispersal, documented impacts, and control options of listed species to identify those capable of causing the greatest impacts.

METHODOLOGY

Objective 1: To develop a comprehensive list of non-native animal species in the state, we reviewed published and unpublished information available in peer-reviewed and gray literature, museum specimen collection databases, wildlife and invasive species program websites, news reports, and personal communications with Alaska biologists and invasive

species experts for fishes, amphibians, reptiles, birds, mammals, invertebrates, parasites and pathogens. Data were compiled into two lists: 1) a preliminary list of non-native animals documented in the state (either currently or historically) and 2) a list of invasive species that have been detected in adjacent states and provinces which have the potential to spread and establish in Alaska. For animals present in Alaska, we included information about the species' status (e.g., cryptogenic, reported but not yet confirmed in the state, documented but eradicated, native but translocated). Draft lists were reviewed by local biologists and invasive species experts, and updated throughout the process of literature review and information synthesis.

Objective 2: We refined the list of non-native animal species present in Alaska by identifying those species already recognized as invasive in existing literature, reports or by experts in the state. Based on evidence in the literature, we identified a number of non-native species known to pose a high risk to native biodiversity. These "high risk" species were selected for in-depth research into their biology, ecology and possible impacts to native systems. It would require a systematic ranking scheme in order to objectively identify the highest risk species. Unfortunately, a ranking exercise was beyond the scope of this project. Instead, we selected "high-risk" species based on their widespread recognition as invasive species in the literature.

Objective 3: For select "high-risk" animal species, we summarized available information relating to the taxonomy, reproduction, feeding, habitat needs, dispersal potential, current/historic distribution, documented impacts, and control options. Maps of species' Alaskan range and/or distribution were developed using ArcGIS software.

RESULTS

The final list of non-native animal species in Alaska included 116 species documented (either historically or currently) in the state (including amphibians [3], birds [16], fishes [14], invertebrates [42], mammals [35], parasites [1], pathogens [4], and reptiles [1]; see Appendix I). An additional 41 species were identified as potential invaders based on their proximity in adjacent states and provinces and on their ability to disperse over large distances (amphibians [1], birds [1], invertebrates [37], and pathogens [2]; see Appendix II). Of those found in the state, 21 were highlighted as "high-risk" for invasiveness. Of those not yet found in the state, 10 were highlighted as "high-risk" for invasiveness. Status reports were developed for 17 species (2 amphibians, 10 invertebrates, 2 fishes and 3 mammals) and are included as Appendix III in this report.

DISCUSSION AND FUTURE DIRECTION

The majority of species listed as non-native in Alaska are not considered invasive by the formal definition. An exploration of the factors contributing to a species' invasiveness, and a systematic effort to rank species according to objective criteria would be constructive and has yet to be conducted for animals in the state. The need to evaluate and rank non-native species is a prerequisite before expensive management is attempted, so that the most threatening species are addressed first. A ranking system can help set

priorities for research and control efforts for invading bird, mammal, fish, invertebrate, and pathogenic species. Since many of the species on the Alaska non-native animal list have been documented during the last 20 years (this may be due to increased number of invasions or increased reporting and research on invasive species), there is a consensus in the invasive species community that a prioritization scheme is an important first step. Biological and ecological data summarized during this project will provide a valuable reference for future ranking efforts. These data also provide basic geographic information that could form the groundwork for development of a GIS database of non-native animal species distribution.

The development of the first comprehensive list of non-native animals in Alaska, presented here, summarizes necessary and preliminary information about the current status of these animals in the state. By making this information available to researchers and the general public, we hope it will be used to identify data gaps in our understanding and help direct targeted research. We also hope that it will serve to increase public awareness of the negative impacts of invasive species, which in turn, could help prevent their future spread. Questions that need to be addressed in the future include: Which species or groups of animals have the most invasive potential, and which have already caused the most damage to native ecosystems in the state? How can we target entire groups or dispersal pathways for prevention of non-native animal introductions? Where would financial resources prove most effective in the fight against invasions, and are there invasive populations that are already beyond our control? Information contained within the individual species status reports and associated distribution maps may be used to interpret an invasive species' ability to spread into particular regions, and could be used in future mapping efforts to calculate rates of dispersal as well as enable prediction of future range expansions (Riccardi et al. 2000). As global climate change continues to warm the landscape, Alaska may become more susceptible to harmful invaders (Union of Concerned Scientists 2005) and the information contained within this report could be useful in predicting and preventing animal invasions.

ACKNOWLEDGEMENTS

This project was generously funded by the Alaska Department of Fish and Game's Invasive Species Program. We would especially like to thank Tammy Davis, the Invasive Species Program Coordinator, for her guidance and enthusiasm throughout the duration of the project.

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APPENDIX I

List of non-native animal species documented in Alaska

Appendix 1, page 1. List of non-native animal species documented in Alaska. List includes amphibians, birds, invertebrates, mammals, pathogens and reptiles. List also include information on species status (when available), whether or not a status report was developed for that species, references, and an invasiveness rank as reported in the literature.

Taxon	Scientific Name	Common Name	Status	Status Report	Reference	Invasiveness Rank
Amphibians	*Pseudacris regilla*	Pacific chorus frog		X	Schrader and Hennon 2005, USGS 2007, MacDonald 2003, Hodge 2004	Low*
Amphibians	*Rana aurora*	Red-legged frog		X	Schrader and Hennon 2005	High*
Amphibians	*Taricha granulosa*	Roughskin newt	native but moved		USGS 2007	
Birds	*Strix varia*	Barred Owl			Rapp pers. comm.	
Birds	*Colinus virginianus*	Bobwhite Quail, Northern Bobwhite			Sinnott pers. comm.	
Birds	*Molothrus ater*	Brown-headed Cowbird			Armstrong 1995, USFWS 2007b	
Birds	*Alectoris chukar*	Chukar			Burris and McKnight 1973	
Birds	*Dendragapus obscurus*	Dusky Grouse, Blue Grouse	native but moved		Burris and McKnight 1973	
Birds	*Streptopelia decaocto*	Eurasian Collared Dove			Rapp pers. comm.	
Birds	*Carpodacus mexicanus*	House Finch			Armstrong 1995, USFWS 2007b	
Birds	*Passer domesticus*	House Sparrow			Armstrong 1995, USFWS 2007b	
Birds	*Lophura leucomelanos, others*	Other pheasants (Mongolian, Nepal, Brown-eared, Kalij, Reeves, Cheer)			Burris and McKnight 1973	
Birds	*Phasianus colchicus*	Ring-necked Pheasant			Burris and McKnight 1973	
Birds	*Columba livia*	Rock dove, rock pigeon			Schrader and Hennon 2005, GISD 2007, UCS 2005	Low*
Birds	*Bonasa umbellus*	Ruffed Grouse	native but moved		Sinnott pers. comm.	
Birds	*Falcipennis canadensis*	Spruce Grouse	native but moved		Burris and McKnight 1973	
Birds	*Sturnus vulgaris*	Starling			Schrader and Hennon 2005	Low*, High^

Appendix I, page 2. List of non-native animal species documented in Alaska.

Taxon	Scientific Name	Common Name	Status	Status Report	Reference	Invasiveness Rank
Birds	*Branta canadensis fulva*	Vancouver Canada goose	native but moved		Sinnott pers. comm.	
Birds	*Meleagris gallopavo*	Wild Turkey			Sinnott pers. comm.	
Fishes	*Dallia pectoralis*	Alaska blackfish	native but moved		USGS 2007, UCS 2005	
Fishes	*Alosa sapidissima*	American shad			USGS 2007	
Fishes	*Thymallus arcticus*	Arctic grayling	native but moved		USGS 2007, UCS 2005	
Fishes	*Salmo salar*	Atlantic salmon		X	Fay 2002, UCS 2005, USGS 2007	High*
Fishes	*Salvelinus fontinalis*	Brook trout			Fay 2002, USGS 2007, UCS 2005	Low*
Fishes	*Oncorhynchus kisutch*	Coho salmon			USGS 2007	
Fishes	*Carassius auratus*	Goldfish			Fay 2002	Low*
Fishes	*Esox lucius*	Northern pike		X	Fay 2002, UCS 2005, USGS 2007	High*
Fishes		Ornamental aquarium fish			Fay 2002	
Fishes	*Astronotus ocellatus*	Oscars			Fay 2002	
Fishes	*Oncorhynchus mykiss*	Rainbow trout			Schrader and Hennon 2005, USGS 2007	Low*, High^
Fishes	*Gasterosteus aculeatus*	Threespine stickleback			USGS 2007	
Fishes	*Gambusia affinis*	Western mosquitofish	persistence questionable		USGS 2007	High^
Fishes	*Perca flavescens*	Yellow perch	eradicated		Fay 2002, USGS 2007, UCS 2005	High*
Invertebrates	*Eriocampa ovata*	Alder woolly sawfly			Schrader and Hennon 2005, USFS 2007	Low*
Invertebrates	*Profenusa thomsoni*	Amber-marked birch leafminer		X	Schrader and Hennon 2005, UCS 2005	High*
Invertebrates	*Distaplia alaskensis*	Ascidiacean	cryptogenic species		Hines and Ruiz 2001	

Appendix I, page 3. List of non-native animal species documented in Alaska.

Taxon	Scientific Name	Common Name	Status	Status Report	Reference	Invasiveness Rank
Invertebrates	*Fenusa pusilla*	Birch leafminer		X	Schrader and Hennon 2005	Moderate*
Invertebrates	*Epinotia solandriana*	Birch leafroller			Schrader and Hennon 2005	Moderate*
Invertebrates	*Heterarthrus nemoratus*	Birch-edge leafminer			Schrader and Hennon 2005	Low*
Invertebrates	*Cliona thosina*	Boring sponge in oyster shell	reported but not yet confirmed		Hines and Ruiz 2001	
Invertebrates	*Schizoporella unicornis*	Bryozoan			Hines and Ruiz 2001	
Invertebrates	*Heteromastus filiformis*	Capitellid worm			USGS 2007	
Invertebrates	*Crassostrea gigas*	Cultured oyster			Hines and Ruiz 2001 GISD 2007	
Invertebrates	*Nematus ribesii*	Currantworm			Schrader and Hennon 2005, UCS 2005	Low*
Invertebrates	*Adelges piceae*	Eastern spruce gall aphid			Schrader and Hennon 2005	Low*
Invertebrates	*Arion ater*	European black slug			Schrader and Hennon 2005, UCS 2005	Low*
Invertebrates	*Lymantria dispar*	European gypsy moth, Asian gypsy moth		X	Schrader and Hennon 2005, UCS 2005, USFS 2007	High*, High^
Invertebrates	*Rhyacionia buoliana*	European pine shoot moth			Schrader and Hennon 2005, Kruse pers. comm.	Low*
Invertebrates	*Noctua pronuba*	European Yellow Underwing Moth			USFS 2007	
Invertebrates	*Arion sp.*	Garden slug			Schrader and Hennon 2005	Low*
Invertebrates	*Tubularia crocea*	Hydroid	reported but not yet confirmed		USGS 2007	
Invertebrates	*Bougainvilla sp. 2*	Hydroid	cryptogenic species		Hines and Ruiz 2001	
Invertebrates	*Bougainvilla sp.1*	Hydroid	cryptogenic species		Hines and Ruiz 2001	
Invertebrates	*Cuspidella grandis*	Hydroid	cryptogenic species		Hines and Ruiz 2001	
Invertebrates	*Garvia franciscana*	Hydroid			Hines and Ruiz 2001	
Invertebrates	*Opercularella lacerata*	Hydroid			Hines and Ruiz 2001	

Appendix I, page 4. List of non-native animal species documented in Alaska.

Taxon	Scientific Name	Common Name	Status	Status Report	Reference	Invasiveness Rank
Invertebrates	*Proboscidactila flavicirrata*	Hydroid			Hines and Ruiz 2001	
Invertebrates	*Venerupis philippinarum*	Japanese littleneck clam, Manila clam	reported but not yet confirmed		Hines and Ruiz 2001	
Invertebrates	*Pristiphora erichsonii*	Larch sawfly		X	Schrader and Hennon 2005, UCS 2005	High*
Invertebrates	*Limax maximus*	Leopard slug			Schrader and Hennon 2005	Low*
Invertebrates		Oysters			Fay 2002	
Invertebrates	*Polydora websteri*	Polychaete blister worm	reported but not yet confirmed		Hines and Ruiz 2001	
Invertebrates	*Procambarus clarkii*	Red swamp crayfish			USGS 2007	
Invertebrates	*Manayunkia speciosa*	Sabellid worm			USGS 2007	
Invertebrates	*Asterias amurensis*	Sea star	cryptogenic species		Hines and Ruiz 2001	
Invertebrates	*Pacifastacus leniusculus*	Signal crayfish		X	Fay 2002, GISD 2007, USGS 2007	High*
Invertebrates	*Schizoporella unicornis*	Single horn bryozoan			USGS 2007	
Invertebrates	*Pissodes strobi*	Sitka spruce weevil, white pine weevil			USFS 2007, Schrader and Hennon 2005, UCS 2005	Moderate*
Invertebrates	*Mya arenaria*	Soft-shelled clam			Hines and Ruiz 2001, USGS 2007, Powers et al. 2006	
Invertebrates	*Elatobium abietinum*	Spruce aphid			Schrader and Hennon 2005	Moderate*
Invertebrates	*Otiorhynchus ovatus*	Strawberry root weevil			Schrader and Hennon 2005, UCS 2005	Low*
Invertebrates	*Archips cerasivorana*	Uglynest caterpillar			USFS 2007, Schrader and Hennon 2005, UCS 2005	Low*
Invertebrates		Various ballast water species			Fay 2002	
Invertebrates	*Malacosoma californicum*	Western tent caterpillar		X	Schrader and Hennon 2005, UCS 2005, Kruse pers. comm.	High*
Invertebrates	*Pikonema alaskensis*	Yellow-headed Spruce Sawfly			USFS 2007	

Appendix I, page 5. List of non-native animal species documented in Alaska.

Taxon	Scientific Name	Common Name	Status	Status Report	Reference	Invasiveness Rank
Mammals	*Martes americana*	American marten	native but moved		Schrader and Hennon 2005	
Mammals	*Alopex lagopus*	Arctic fox			USFWS 2007, Ebbert and Byrd (2002).	
Mammals	*Spermophilus paryii ablusus*	Arctic ground squirrel			USFWS 2007, Ebbert and Byrd (2002).	
Mammals	*Spermophilus paryii nebulicola*	Arctic ground squirrel			USFWS 2007, Ebbert and Byrd (2002).	
Mammals	*Rangifer tarandus groenlandicus*	Barren-ground caribou	native but moved		Burris and McKnight 1973	
Mammals	*Castor canadensis*	Beaver			Brown pers. comm.	
Mammals	*Bos bison*	Bison			Burris and McKnight 1973	
Mammals	*Rattus rattus*	Black rat, Roof rat		X	USFWS 2007	High^
Mammals	*Canis latrans*	Coyote			NatureServe 2007, Sinnott pers. comm.	
Mammals	*Ovis dalli*	Dall's sheep	native but moved		Burris and McKnight 1973	
Mammals	*Peromyscus maniculatus*	Deer mouse			USFWS 2007, Ebbert and Byrd 2007	
Mammals	*Felis catus*	Domestic cat			Sinnott pers. comm.	High^
Mammals	*Canis familiaris*	Domestic dog			Rapp pers. comm.	High^
Mammals	*Mustela putorius furo*	Domestic ferret			Sinnott pers. comm.	
Mammals	*Cervus canadensis*	Elk		X	Schrader and Hennon 2005	Moderate*, High^
Mammals	*Oryctolagus cuniculus*	European rabbit			Burris and McKnight 1973, Schrader and Hennon 2005, USFWS 2007	High^
Mammals	*Canis lupus*	Gray wolf	native but moved		Burris and McKnight 1973	
Mammals	*Mus musculus*	House mouse			Schrader and Hennon 2005, UCS 2005, USFWS 2007	Low*, High^
Mammals	*Marmota caligata*	Marmot	native but moved		Sinnott pers. comm.	

Appendix I, page 6. List of non-native animal species documented in Alaska.

Taxon	Scientific Name	Common Name	Status	Status Report	Reference	Invasiveness Rank
Mammals	*Neovison vison*	Mink (from domestic stock)	native but moved		Burris and McKnight 1973	
Mammals	*Alces americanus*	Moose	native but moved		Burris and McKnight 1973	
Mammals	*Oreamnos americanus*	Mountain goat			Brown pers. comm.	
Mammals	*Puma concolor*	Mountain lion	reported but not yet confirmed		Sinnott pers. comm.	
Mammals	*Ovibos moschatus*	Muskox			Burris and McKnight 1973	
Mammals	*Ondatra zibethicus*	Muskrat			Brown pers. comm.	
Mammals	*Rattus norvegicus*	Norway rat, Brown rat		X	Schrader and Hennon 2005, UCS 2005, USFWS 2007	High*
Mammals	*Procyon lotor*	Raccoon			Schrader and Hennon 2005	
Mammals	*Vulpes vulpes*	Red Fox			USFWS 2007	High^
Mammals	*Tamiasciurus hudsonicus*	Red squirrel	native but moved		Schrader and Hennon 2005	
Mammals	*Rangifer tarandus asiaticus*	Reindeer			USFWS 2007	
Mammals	*Bos taurus*	Scottish cattle				
Mammals	*Enhydra lutris*	Sea otter	native but moved		Burris and McKnight 1973	
Mammals	*Odocoileus hemionus*	Sitka black-tailed deer	native but moved		Schrader and Hennon 2005	
Mammals	*Lepus americanus*	Snowshoe hare	native but moved		Burris and McKnight 1973, Davis 1979, Schrader and Hennon 2005	
Mammals	*Sus scrofa*	Wild boar, feral swine, feral hogs				High^
Parasites	*Trichodectes canis*	Biting dog louse			Golden et al. 1999, Griese 1999, ADFG 2005, UCS 2005	
Pathogens	*Erwinia amylovora*	Bacterial fire blight			Schrader and Hennon 2005	
Pathogens	*Apiosporina morbosa*	Black knot			Schrader and Hennon 2005	

Appendix I, page 7. List of non-native animal species documented in Alaska.

Taxon	Scientific Name	Common Name	Status	Status Report	Reference	Invasiveness Rank
Pathogens	*Myxobolus cerebralis*	Whirling disease parasite		X	WDI 2007, Arsan et al. 2007	
Pathogens	*Cronartium ribicola*	White pine blister rust			Schrader and Hennon 2005	
Reptiles	*Macrochelys temminckii*	Alligator snapping turtle			Associated Press 2002	

* = Schrader and Hennon 2005
^ = *GISD 2007*

APPENDIX II

List of non-native animal species with the potential for invasion in Alaska

Appendix II, page 1. List of non-native animal species that have been not documented in Alaska, but have the potential to enter the state. List includes amphibians, birds, invertebrates and pathogens. List also include information on species status (when available), whether or not a status report was developed for that species, references, and an invasiveness rank as reported in the literature.

Taxon	Scientific Name	Common Name	Status Report	Reference	Invasiveness Rank
Amphibians	*Rana catesbeiana*	American bullfrog		Secord et al 2005	High ^
Birds	*Carpodacus mexicanus*	House Finch			
Invertebrates	*Anoplophora glabripennis*	Asian longhorned beetle		Schrader and Hennon 2005, UCS 2005	Moderate*
Invertebrates	*Urosalpinx cinerea*	Atlantic oyster drill		Secord et al 2005	
Invertebrates	*Crepidula fornicata*	Atlantic slipper snail		Secord et al 2005	
Invertebrates	*Cliona sp.*	Boring sponge		USGS 2007	
Invertebrates	*Tetropium fuscum*	Brown spruce longhorn beetle		Schrader and Hennon 2005	High*
Invertebrates	*Bugula neritina*	Bryozoan		GISD 2007	
Invertebrates	*Eriocheir sinensis*	Chinese mitten crab	X	Fay 2002	High*, High^
Invertebrates	*Botryllus schlosseri*	Colonial sea squirt		Secord et al 2005	
Invertebrates	*Didemnum lahillei*	Colonial sea squirt		Secord et al 2005	
Invertebrates	*Ilyanassa obsoleta*	Eastern mudsnail		Secord et al 2005	
Invertebrates	*Teredo navalis*	European (naval) shipworm		Secord et al 2005	
Invertebrates	*Hemichroa crocera*	European alder sawfly		Schrader and Hennon 2005	Low*
Invertebrates	*Ips typographus*	European spruce beetle		Schrader and Hennon 2005	High*
Invertebrates	*Malacosoma disstria*	Forest tent caterpillar	X	Schrader and Hennon 2005	High*
Invertebrates	*Carcinus maenas*	Green crab, European green crab		Fay 2002, UCS 2005, Aquatic Nuisance Species Project 2007	High^
Invertebrates	*Adelges tsugae*	Hemlock woolly adelgid		Schrader and Hennon 2005	Moderate*
Invertebrates	*Diadumene lineata*	Japanese anemone		Secord et al 2005	
Invertebrates	*Musculista senhousia*	Japanese mussel		Secord et al 2005	
Invertebrates	*Ocinebrellus inornatus*	Japanese oyster drill		Secord et al 2005	
Invertebrates	*Coleophora laricella*	Larch casebearer		Schrader and Hennon 2005	Moderate*
Invertebrates	*Ips cembrae*	Larch engraver		Schrader and Hennon 2005	Moderate*
Invertebrates	*Venerupis philippinarum*	Manila clam		Secord et al 2005	
Invertebrates	*Mytilus galloprovincialis*	Mediterranean mussel		Secord et al 2005	

Appendix II, page 2. List of non-native species that have been not been positively identified in Alaska, but have been documented in adjacent states and provinces, and have the potential to invade.

Taxon	Scientific Name	Common Name	Status Report	Reference	Reported Invasiveness Rank
Invertebrates	*Batrillaria attramentaria*	Mudsnail		Secord et al 2005	
Invertebrates	*Potamopyrgus antipodarum*	New Zealand Mudsnail	X	Fay 2002, UCS 2005	High*
Invertebrates	*Lymantria monacha*	Nun moth		Schrader and Hennon 2005	High*
Invertebrates	*Alitta succinea*	Pile worm		GISD 2007	
Invertebrates	*Dendrolimus pini*	Pine moth		Schrader and Hennon 2005	High*
Invertebrates	*Nuttallia obscurata*	Purple varnish clam		Secord et al 2005	
Invertebrates	*Clathria prolifera*	Red beard sponge		Secord et al 2005	
Invertebrates	*Lymantria mathura*	Rosy gypsy moth		USFS 2007	
Invertebrates	*Botrylloides violaceus*	Sheath tunicate		USGS 2007	
Invertebrates	*Ciona savignyi*	Solitary sea squirt		Secord et al 2005	
Invertebrates	*Styela clava*	Solitary sea squirt		Secord et al 2005	
Invertebrates	*Bythotrephes cederstroemi*	Spiny water flea		Fay 2002, GLIN 2007	
Invertebrates	*Adelges abietis*	Woolly spruce aphid		Schrader and Hennon 2005	Moderate*
Invertebrates	*Dreissena polymorpha*	Zebra mussel		Fay 2002, UCS 2005	High^
Pathogens	*Chrysomyxa abietis*	Foliar spruce rust		Schrader and Hennon 2005	
Pathogens	*Bursaphelenchus xylophilus*	Pine wilt nematode		Schrader and Hennon 2005	Low*

* = Schrader and Hennon 2005
^ = *GISD 2007*

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APPENDIX III

Status reports for select non-native animal species of Alaska

Pacific Chorus Frog
Pseudacris regilla (Baird and Girard, 1852)

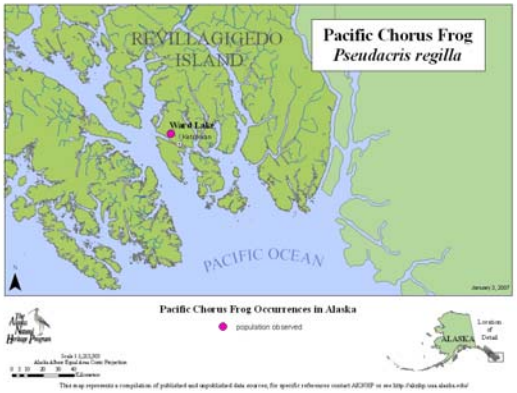
Taxonomy
Phylum Craniata, Class Amphibia, Order Anura, Family Hylidae
Other common names: Pacific Treefrog

Description
Adult dorsal color and pattern is highly variable; may be green- or brown-dominated (both have been seen in Alaska), with a conspicuous dark mask, undersides cream colored with yellowish hindquarters, prominent toe pads and limited webbing. Males have a round vocal sac that can balloon out to a size 3 times as large as the head when calling. Adult snout-vent length: 2-6 cm. Larvae are light greenish-gray (MacDonald 2003). Lifespan: maximum unknown.

Biology and Invasive Potential
Reproductive biology: breeds in permanent or ephemeral water bodies where egg masses are attached to submerged vegetation or on the bottom, January to August. May be sexually mature at less than one year, and multiple clutches have been documented in southern California (Perril and Daniel 1983).
Feeding habits: adult diet is a variety of small invertebrates, larvae feed on periphyton, benthic detritus and surface diatoms and pollen.
Habitat requirements: found in a wide variety of habitats, usually among low vegetation near water: grassland, woodland, chaparral, forests, farmland. Frogs observed in Alaska used clumps of grasses and sedges for cover adjacent to muskeg pond margins (MacDonald 2003). Breeds in marshes, lakes, ponds and slow-moving streams; sometimes breeds in weakly brackish water (Gardner 1995). Hibernates during winter in ground litter or soil; may not hibernate during mild winters on the southern coast of British Columbia (MacDonald 2003).
Dispersal potential: other hylid frogs exhibit limited movements (generally a few hundred meters or less; NatureServe 2007).
Potential to be spread by human activity: unlikely; but original Alaskan introduction of several dozen juvenile red-legged frogs (*Rana aurora*) was by a Hoonah school teacher (Hodge 2004).
Related invasive species: Red-legged frog and translocated roughskin newt (*Taricha granulosa*) are the only other introduced amphibians of Alaska; red-legged frog distribution appears to be expanding in Southeast Alaska.

Ecological Impact
Enclosure studies indicated feeding by red-legged frog tadpoles altered composition and abundance of aquatic algae, and might initiate seasonal succession of periphyton in water bodies, which in turn could result in widespread effects within the food-web (Dickman 1968). This species utilizes some habitats for breeding and foraging which are similar to native Alaskan amphibians, the wood frog (*Rana sylvatica*) and western toad (*Bufo boreas*).

Distribution and Abundance
Native and current distribution: native to western North America from Baja California to southern British Columbia, including Vancouver Island, and east to Idaho and Utah (MacDonald 2003, NatureServe 2007). Introduced from Washington State sometime around 1960 to Revillagigedo Island, Alaska, near Ward Lake, where this population has apparently remained in the



original muskeg pond system (Hodge 2004). A single individual also found recently near Juneau (Carstensen et al. 2003, AKNHP 2006). Also introduced to the Queen Charlotte Islands, British Columbia (Reimchen 1990).

Management

Management strategies have not been developed.

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Alaska Natural Heritage Program
Environment and Natural Resources Institute, University of Alaska Anchorage,
707 A Street, Anchorage, AK 99501

Updated January 2008

Red-legged Frog
Rana aurora Baird and Girard, 1852

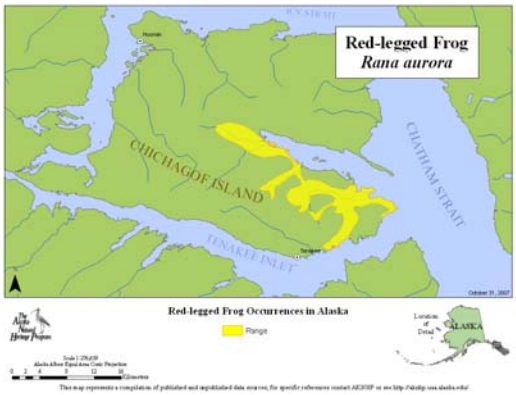
Taxonomy
Phylum Craniata, Class Amphibia, Order Anura, Family Ranidae

Description
Adult coloration is brown, gray, olive or reddish, with irregular dark spotting or blotching on the back and sides, and red coloring on lower abdomen and underside of legs. Usually has a dark mask above a whitish jaw stripe which ends before the shoulder, and is mottled blackish, red and yellow in the groin area. Legs are relatively long, eyes face outward, and dorsolateral folds are prominent. Larvae are brown with small dark spots above, creamy white flecked with spots below, and juvenile frogs may have yellow instead of red on underside of legs and in groin. Adult snout-vent length: 4-13 cm. Lifespan: maximum of 13 years in captivity (Cowan 1941).

Biology and Invasive Potential
Reproductive biology: breeds usually in permanent water bodies where eggs are attached to stiff submerged vegetation. Breeding time is March-July in northern parts of range (NatureServe 2007). Eggs hatch in 1-7 weeks and larvae metamorphose in 11-20 weeks, but may rarely overwinter in California (Fellers et al. 2001). Temperature tolerance limits for young embryos are about 4-21°C, both upper and lower limits being the lowest for any North American ranid frog (Licht 1971). Sexual maturity reached at 3-4 years of age (MacDonald 2003).
Feeding habits: adult diet primarily a wide variety of small invertebrates, larvae feed on periphyton, especially filamentous algae (COSEWIC 2004). Adults in California have preyed on mice (*Peromyscus californicus*), fish (*Gasterosteus aculeatus*) and other amphibians (*Pseudacris regilla*; Hayes and Tennant 1985).
Habitat requirements: generally in or near quiet permanent waters of streams, marshes or ponds; sometimes found in damp woods and meadows some distance from water, especially during wet weather. May also be found in ephemeral pools if water remains until late spring or summer (Biosystems Analysis 1989 *in* NatureServe 2007). In Washington, red-legged frog presence was positively correlated with wetland characteristics including shallow slopes, southern exposure, percentage of forest cover in surrounding area, and wetland complexity (ratio of coverage by emergent vegetation to open water; see sources in COSEWIC 2004). Hibernates during winter in ground litter or small mammal burrows near water (see sources in NatureServe 2007). Recent clearcuts provide significant movement barriers, especially in warm and dry conditions (Chan-McLeod 2003).
Dispersal potential: largest documented movements are 1.1, 1.2, 1.3 and 2.4 km between capture points for 4 adults in Oregon (Hayes et al. 2001 *in* NatureServe 2007).
Potential to be spread by human activity: unlikely; but original introduction of several dozen froglets was by a Hoonah school teacher (Hodge 2004).
Related invasive species: Pacific chorus frog (*Pseudacris regilla*) and translocated roughskin newt (*Taricha granulosa*) are the only other introduced amphibians of Alaska; neither appears to be expanding in distribution.

Ecological Impact
Enclosure studies indicated feeding by tadpoles altered composition and abundance of aquatic algae, and might initiate seasonal succession of periphyton in water bodies, which in turn could result in widespread effects within the food-web (Dickman 1968). This species utilizes habitats for breeding and foraging which are similar to native Alaskan amphibians, the wood frog (*Rana sylvatica*) and western toad (*Bufo boreas*).

Distribution and Abundance
Native and current distribution: native to western North America from Baja California to southwestern British Columbia (NatureServe 2007), introduced from Washington State in 1982 to Chichagof Island, Alaska, southeast of Hoonah (Hodge 2004). Also recently documented on Graham Island in the Queen Charlotte Islands, British Columbia (Ovaska et al. 2002); this is also likely an introduced population (COSEWIC 2004). Population on Chichagof Island is successfully reproducing and dispersing into adjacent wetlands (Hodge 2004). Recent surveys counted 6 adults and 2 juveniles at Pavlof Harbor and river drainage, and 1 adult at Tenakee (AKNHP 2006); surveys suggest expansion of this species (Schrader and Hennon 2005).



Management
Management strategies have not been developed.

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Environment and Natural Resources Institute, University of Alaska Anchorage,
707 A Street, Anchorage, AK 99501

Updated January 2008

Atlantic Salmon
Salmo salar Linnaeus 1758

Taxonomy
Phylum Craniata, Class Actinopterygii, Order Salmoniformes, Family Salmonidae

Description
A migratory fish (salmon). Brown, green or blue dorsally, with silver sides and white underside; black spots on back, sides and operculum. Head is small and pointed, caudal fin slightly indented. Adult total length to 150 cm, weight to 35.9 kg (Mecklenburg et al. 2002).

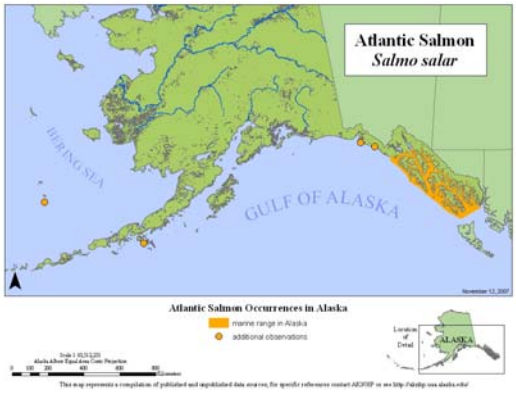
Biology and Invasive Potential
Reproductive biology: sexually mature adults (3-10 years) spawn in fall. Eggs hatch in early spring, young spend 1-3 years in stream rearing habitat, then move to sea for 1-6 years before returning to spawn; some adults may spawn in more than 1 year (Mecklenburg et al. 2002). In Europe, some large adults spawned biennially (Jonsson et al. 1991 in NatureServe 2007).
Feeding habits: young fish eat mainly aquatic insect larvae and terrestrial insects in freshwater habitat, sometimes fish eggs; adults eat fishes and crustacean zooplankton in salt water, do not feed in fresh water (NatureServe 2007).
Habitat requirements: in runs and pools of small to large rivers; young remain in gravelly streams 1-3 years, then enter the sea as smolts. Optimal migration habitat has a minimum of slow- or no-flow areas. At sea, adults may remain within estuary influence or move into open ocean. Freshwater spawning habitat is usually gravel substrate in a riffle above a pool; normal egg development requires water temperatures <50º F. Rearing habitat includes shallow riffle areas interrupted by pools and deep riffles; young fish require cover such as large rocks. Adults usually spawn in natal streams (NatureServe 2007).
Dispersal potential: capable of ranging significant distances from apparent escape sites in the Pacific: northern limit of Atlantic salmon culture is near the northern tip of Vancouver Island, but marine and freshwater recoveries are well documented in Alaska, including far into the Bering Sea (Brodeur and Busby 1998 *in* Volpe et al. 2000). In native range, migrates up to thousands of km between spawning and nonspawning habitats (NatureServe 2007).
Potential to be spread by human activity: escapes from aquaculture pens are primary source of wild fish in the Pacific; Atlantic salmon aquaculture occurs in Washington state and British Columbia (McKinnell et al. 1997).

Ecological Impact
There is potential for competition with native populations of salmonids in Alaska's freshwater and marine habitats (Wing et al. 1992, Volpe et al. 2000, Mecklenburg et al. 2002). Competition could occur between adults for food resources at sea, and for spawning habitat (between adults), juvenile habitat and food resources in freshwater (Wing et al. 1992). A study of interactions between adult Atlantic and Pacific coho salmon (*Oncorhynchus kisutch*) suggests coho salmon would be more aggressive competitors for redd sites (Gruenfeld 1977 in Wing et al. 1992), and a study of juvenile interactions between Atlantic salmon, steelhead (*O. mykiss*) and coho shows the 3 species distribute themselves differently within a stream and that coho and steelhead would likely displace Atlantic salmon parr from preferred habitats (Gibson 1981, see Wing et al. 1992 for additional sources); however, a constant flow of Atlantic salmon escapees or reproducing populations could have an important effect on native salmonids

in every habitat and lifestage. Atlantic salmon are genetically incompatible with Pacific salmonids (Wing et al. 1992), so viable hybridization is not a threat. Disease and parasite transmission, especially from hatchery escapees, may be a concern.

Distribution and Abundance

Native and current distribution: native to both sides of the North Atlantic ocean with range in the western Atlantic south to the Connecticut River (Mecklenburg et al. 2002). Introduced in the Pacific Ocean, mostly as escapees from aquaculture farms in Washington and British Columbia; first reported escape of Atlantic salmon in the Pacific occurred in 1988 (McKinnell et al. 1997), with increasing numbers of escapees annually and a reported 7,472 escapees in 1997 (Volpe et al. 2000). Well-documented in both marine and freshwater environments of Pacific coastal British Columbia and Alaska (first record in Alaska in 1990; Wing et al. 1992), with the first observation of natural reproduction occurring in British Columbia's Tsitika River in 1998 (Volpe et al. 2000).



Management

Netting, electrofishing, complete draining of a water body, and chemical (rotenone) applications are known methods for fish eradication, but all of these affect native as well as introduced species.

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707 A Street, Anchorage, AK 99501

Updated January 2008

Northern Pike
Esox lucius Linnaeus 1758

Taxonomy
Phylum Craniata, Class Actinopterygii, Order Esociformes, Family Esocidae

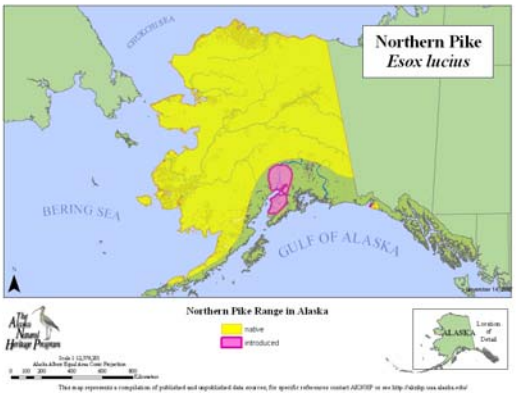
Description
An elongate, moderately compressed fish with a long, flattened snout, forked caudal fin and large prominent teeth; coloration is dark grayish green or brown dorsally, creamy white ventrally, with irregular rows of yellow spots on sides (Mecklenburg et al. 2002, SANPCC 2007).

Biology and Invasive Potential
Reproductive biology: sexually mature adults (3-5+ years of age in Alaska, 1+ years elsewhere) spawn once per year in shallow marshy areas in early spring. Spawning occurs during daylight and females lay 2,000-600,000 eggs, which hatch in 1-4 weeks (slower development in colder temperatures); young fish remain at spawning site for several weeks. Often return to same spawning site year after year (Morrow 1980, SANPCC 2007).
Feeding habits: young fish eat zooplankton and aquatic insects, then shift to fish and other small vertebrates; adults are opportunistic predators of vertebrates small enough to be engulfed: primarily fish, as well as waterfowl, amphibians, small mammals, crayfish and insects (Morrow 1980, SANPCC 2007).
Habitat requirements: usually in clear vegetated lakes, marshes, streams and small to large rivers, moving inshore or upstream to marsh areas to spawn. Spawns in marshy areas with shallow water, emergent vegetation and mud bottoms (Morrow 1980, Mecklenburg et al. 2002). Pike have broad physio-chemical tolerances and can survive in very low dissolved oxygen conditions and salt water; occur in salinities as high as 10 ppt, and reproduce in salinities as high as 7 ppt (Scott and Crossman 1973 in SANPCC 2007).
Dispersal potential: migrate locally between spawning and nonspawning habitats. A tagging study at Minto Flats, Alaska, found that 36% of fish observed moved >16 km during one summer, and one fish moved 288 km downstream in 10 months (Cheney 1971 in Morrow 1980).
Potential to be spread by human activity: anglers have illegally stocked northern pike in Alaska lake systems by hand and floatplane, and apparently continue to do so (Fay 2002).

Ecological Impact
Introduced pike establish readily in lake and river systems, prey on native fish, amphibians, waterfowl and small mammals, and have few natural predators where they are introduced (Fay 2002, Schrader and Hennon 2005, ADFG 2007). An extreme example estimated 1.5 million waterfowl were consumed by northern pike in a Michigan wildlife refuge, even though fish were their primary prey (Lagler 1956 in SANPCC 2007). In Alaska, pike consume stocked and native salmon, trout and whitefish, affecting total populations of these fish in watersheds where they have become established (ADFG 2007); reduced salmon numbers as a result of pike predation can lead to competition among native salmon predators, loss of nutrient inputs, and overall reduction in ecosystem productivity (SANPCC 2007). The Alaska Aquatic Nuisance Species Management Plan identified the northern pike as the species of greatest immediate concern (Fay 2002).

Distribution and Abundance
Native and current distribution: native to Eurasia and North America east of the continental divide; in Alaska, native to drainages north of the Alaska Range and in the Ahrnklin River drainage (Fay 2002,

Mecklenburg et al. 2002). First introduced into a lake in the Susitna River drainage via floatplane in the 1950s; now found throughout this drainage, in the Matanuska-Susitna Valley, Anchorage area, parts of the Kenai Peninsula, and a small pond system in Yakutat (Schrader and Hennon 2005). Not yet found in the Copper River system, which has much potential northern pike habitat.



Management

The Alaska Department of Fish and Game (ADFG) monitors the spread of northern pike into new areas through routine sampling of fish populations and reports from the general public. Transporting or stocking non-native fish is illegal in Alaska (State regulation 5 AAC 41.005); ADF&G works with the Alaska State Troopers' Bureau of Wildlife Enforcement to prosecute people who illegally stock fish, and has relaxed pike fishing regulations in Southcentral Alaska, encouraging anglers to catch and keep introduced pike (ADFG 2007). Public education programs may help identify recent introductions and prevent future ones. Netting, electrofishing, complete draining of a water body, and chemical (rotenone) applications are known eradication methods, with complete draining and rotenone being the only effective techniques for completely removing this species from a lake or contained system (ADFG 2007).

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Environment and Natural Resources Institute, University of Alaska Anchorage,
707 A Street, Anchorage, AK 99501

Updated January 2008

Amber-marked Birch Leafminer
Profenusa thomsoni (Konow, 1886)

Taxonomy
Phylum Arthropoda, Class Insecta, Order Hymenoptera, Family Tenthredinidae
Other common names: Amber-marked Leafminer

Description
Sawflies are closely related to bees and wasps; adults are small (1/8 to ¼ in. long), black, fly-like insects. Larvae are legless, caramel-colored with a brown head and glossy appearance (IPM of Alaska 2003, Natural Resources Canada 2007).

Biology and Invasive Potential
Reproductive biology: one generation produced per year; adults (almost always all females - likely parthenogenic reproduction) lay eggs inside small cuts made in new or fully grown leaves, which hatch several weeks later. Larvae feed on interior tissue between upper and lower leaf surfaces, creating kidney-shaped "mines". When fully grown, they drop to the ground and overwinter as prepupae in the soil layer below ground litter, to emerge as adults when trees are beginning to leaf out, in May to late June/early July (IPM of Alaska 2003, Natural Resources Canada 2007).
Feeding habits: larvae feed on leaves of all birch species occurring in Alaska (*Betula* spp.; Schrader and Hennon 2005).
Habitat requirements: prefers shaded or semi-shaded foliage on small trees (Natural Resources Canada 2007).
Dispersal potential: a mark-release-recapture experiment showed adults capable of dispersing over 100m in 2 days (McQueen 1995).
Potential to be spread by human activity: can be spread via movement of nursery-landscape stock plants as well as by "hitchhiking" on or in vehicles along road corridors; over 20% of roadways surveyed in Alaska had evidence of this species' presence, but primarily in or near major urban centers or recreation areas (USFS 2007).
Related invasive species: another birch-leafmining sawfly, *Fenusa pusilla* also attacks birch species in Alaska but is apparently still rare in occurrence (USFS 2007).

Ecological Impact
Larval feeding causes blotch "mines"; severe infestation causes brown leaves and defoliation, and infested trees may be more susceptible to infestation by other insects, but mortality of affected trees has not been proven (MacQuarrie et al. 2004, USFS 2007). Ants prey on larvae (Pezzolesi and Hagar 1994).

Distribution and Abundance
Native and current distribution: native to Europe, introduced to North America in the early 1900's likely via nursery stock. First identified in Alaska in the 1990's where it attacked urban birch trees in the Anchorage area (MacQuarrie et al. 2004). Ground surveys of major highways and many secondary roads in Alaska show the current population infesting about 140,000 acres of birch forest, similar to infestation levels of the past 2 years, with new populations found in the Fairbanks area and the Kenai Peninsula (USFS 2007).

Management

A cooperative birch leafminer biological control program was started in Anchorage in 2003, and increasing numbers of the parasitoid wasp *Lathrolestes luteolator* from Canada have been released in the last 3 years (458 individuals in 2006; MacQuarrie 2004, USFS 2007). Native wasp parasitoids likely limit leafminer populations as well, but have not stopped their spread. One study recommended use of sticky traps to catch dispersing adults in urban birch stands (McQueen 1995). Chemical control options include systemic and topical insecticides and horticultural oils (IPM of Alaska 2003). Removing leaf litter and burning or raking 1-2 in. of soil beneath infested trees helps to destroy overwintering leafminer pupae (IPM of Alaska 2003). Thousands of dollars are spent on pesticides annually to control *P. thomsoni* infestations on urban trees of Alaska (USFS 2007).

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Birch Leafminer
Fenusa pusilla (Lepeletier)

Taxonomy
Phylum Arthropoda, Class Insecta, Order Hymenoptera, Family Tenthredinidae

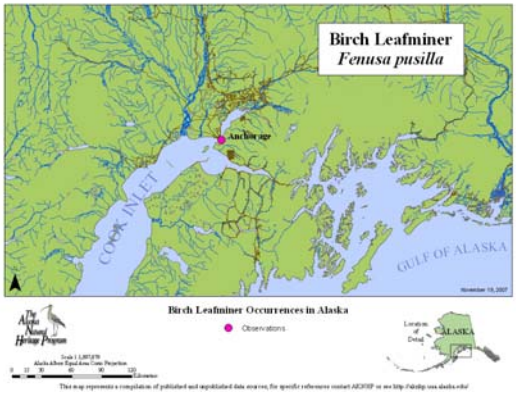
Description
Sawflies are closely related to bees and wasps; adults are small (3 mm long), black, fly-like insects. *Fenusa.pusilla* larvae are legless, about 6 mm long, flattened, and white to pale green marked with black spots on the lower side of the thorax and first abdominal segment (Furniss and Carolin 1977).

Biology and Invasive Potential
Reproductive biology: two or more generations produced per year; females lay eggs on newly expanding leaves. Larvae feed on interior tissue between upper and lower leaf surfaces, creating blotch-shaped "mines". When fully grown, they drop to the ground and overwinter as prepupae in the soil layer below ground litter, to emerge as adults when trees are beginning to leaf out, in May to June (UA 2007). Outside Alaska, a second generation of larvae emerges about 2 weeks after the first and only the last generation overwinters; there appears to be only one generation per year in AK (UA 2007).
Feeding habits: larvae feed on leaves of birch species, both wild and ornamental (*Betula* spp.; Furniss and Carolin 1977, UA 2007).
Habitat requirements: needs members of the family Betulaceae as hosts.
Dispersal potential: a mark-release-recapture experiment showed adults of another birch leafminer species (*Profenusa thomsoni*) capable of dispersing over 100 m in 2 days (McQueen 1995).
Potential to be spread by human activity: can be spread via movement of nursery-landscape stock plants as well as by "hitchhiking" on or in vehicles along road corridors.

Related invasive species: the amber-marked birch leafminer (*P. thomsoni*) also attacks birch species in North America and is much more widespread and destructive in Alaska (USFS 2007).

Ecological Impact
Larval feeding causes blotch "mines"; severe infestation causes brown leaves and defoliation, and infested trees may be more susceptible to infestation by other insects. Ants prey on larvae (Pezzolesi and Hagar 1994).

Distribution and Abundance
Native and current distribution: native to Europe, introduced to North America in the early 1900s. Birch-mining sawflies first observed in Alaska in the 1990s (primarily in the Anchorage area, also north to Fairbanks, east to Glennallen and south to Haines and Skagway); leafminer damage was assumed from *F. pusilla*, but in 2002 the major culprit was positively identified as *P. thomsoni*, and *F. pusilla* determined to be present but very rare and only found in the Anchorage area (CABI 2003).



Management
The parasitoid *Lathrolestes nigricollis* is specific to *F. pusilla* in Europe and has been released in eastern Canada and northeastern USA with excellent results (CABI 2003). A cooperative birch leafminer biological control program was started in Anchorage in

2003, and increasing numbers of the parasitoid wasp *Lathrolestes luteolator* (specific to *P. thomsoni*, not *F. pusilla*) from Canada have been released in the last 3 years (458 individuals in 2006; MacQuarrie 2004, USFS 2007). Native wasp parasitoids likely limit leafminer populations as well. One study recommended use of sticky traps to catch dispersing adults in urban birch stands (McQueen 1995). Chemical control options include systemic and topical insecticides and horticultural oils (IPM of Alaska 2003). Removing leaf litter and burning or raking 1-2 in. of soil beneath infested trees helps to destroy overwintering leafminer pupae (IPM of Alaska 2003).

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Chinese Mitten Crab
Eriocheir sinensis (Milne-Edwards, 1854)

Taxonomy
Phylum Arthropoda, Class Malacostraca, Order Decapoda, Family Varunidae

Description
A light brown crab with distinct hairy claws (of equal size) with white tips, a smooth round carapace, a notch between the eyes, 4 lateral carapace spines, and a maximum carapace width of around 80-88 mm (Normant et al. 2000, GISD 2006).

Biology and Invasive Potential
Reproductive biology: a catadromous crab; adults breed and deposit eggs (females carry 250,000-1 million eggs) in saline waters, pelagic larvae hatch in spring and metamorphose there, then migrate into brackish and fresh waters. Juveniles spend 1-5 years in freshwater streams, then migrate in autumn/winter to salt water at sexual maturity to reproduce (Rudnick et al. 2003, GISD 2006). Thought to have only one reproductive period; males die after mating, leaving females to brood eggs (NHM 2007).
Feeding habits: omnivorous; juveniles eat primarily vegetation, as they mature they increasingly prey on small invertebrates. Also consume detritus, fish and other crustaceans (GISD 2006).
Habitat requirements: Aquatic. Temperate climates, but tolerates a wide range of abiotic conditions, including water temperatures, salinities (possibly reproduce in brackish as well as saline waters), and highly modified or polluted aquatic habitats (Rudnick et al. 2003, GISD 2006).
Dispersal potential: juveniles migrate extraordinary distances in freshwater before returning to marine environments to reproduce; migrations of 1,500 km recorded in China (NHM 2007) and 800 km in the Czech Republic (Normant et al. 2000). Between 1992 and 2001, this species spread from initial introduction to an established population covering several thousand km² around the San Francisco Bay (Rudnick et al. 2003). Moves up and downstream in streams and rivers, but may also leave the water, cross dry land and enter a new river system (NHM 2007).
Potential to be spread by human activity: may be spread in ship ballast water, on hulls of ships and boats, or by illegal importation for sale as a market delicacy.
Related invasive species: Eriocheir japonicus, Eriocheir leptognathus, Eriocheir rectus (GISD 2006).

Ecological Impact
May eat and/or outcompete native freshwater crustaceans or other invertebrate species, affecting natural communities and commercial fisheries. Steals bait and damages fishing gear. Juveniles form dense colonies and create burrows in stream banks and intertidal portions of streams; this process has undermined the integrity of stream banks and levees, and even caused collapse in some areas where the crab has been introduced (Rudnick et al. 2003, GISD 2006).

Distribution and Abundance
Native and current distribution: native to China. Introduced in Europe (from Finland across Russia and down to France, with southernmost Atlantic records from Portugal and southern France) and in North America (reports from Hawaii, the Mississippi River, Lake Erie, the Columbia River Basin, and the only established population in the San

Francisco Bay area; Rudnick et al. 2003, GISD 2006). Not yet reported from Alaska, but noted as a species of concern (Schrader and Hennon 2005).

Management

Prevention and early detection of this species are key, as control is difficult due to the crab's abundance, ubiquity, high reproductive rate, and wide range of physiological tolerances (Rudnick et al. 2003). Physical trapping of crabs has not been sufficient to mitigate damage caused. In Germany, electrical screens were installed on river bottoms to prevent crab migration by pulsing the screens every 1-2 seconds to disable and kill crabs; this method met with little success (McEnnulty et al. 2001 *in* GISD 2006). Commercial targeting of mitten crabs for fishing has been proposed in England, to take pressure off native plants and animals at risk from advancing crab populations (GISD 2006).

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Forest Tent Caterpillar
Malacosoma disstria Hübner, 1820

Taxonomy
Phylum Mandibulata, Class Insecta, Order Lepidoptera, Family Lasiocampidae

Description
Larvae have a dark gray to black background body color, highlighted by broad, pale blue lines and thin, broken yellow lines extending along each side; on the back of each abdominal segment is a distinct whitish keyhole-shaped marking. Larvae have many whitish hairs, and grow to a mature length of 50-64 mm (Batzer and Morris 1978, Meeker 2001). Adult moths are stout-bodied, tan or buff-colored with 2 darker, thin parallel lines extending across mid-portion of each forewing; wingspan is 25-38 mm (Furniss and Carolin 1977, Batzer and Morris 1978). Despite its name, this species does not form a true tent, but rather larvae spin silken mats on tree branches or trunks.

Biology and Invasive Potential
Reproductive biology: one generation per year. Larvae emerge from egg masses in spring as buds form on host trees, feed gregariously and develop through 5 larval instars, then pupate in silken cocoons located in leaves or crevices over 10-14 days. Adult moths emerge, mate and females oviposit masses of 100-350 eggs encircling small twigs, where embryos develop into larvae which overwinter (Batzer and Morris 1978, Meeker 2001). In native range, populations often have cyclic outbreaks every 6 to 16 years, subsiding usually after 2 to 4 years of heavy defoliation (see sources in Meeker 2001).
Feeding habits: adults do not feed; larvae consume buds, leaves and flowers of a variety of host plants, primarily broadleaved trees. Preferred species in the northwestern United States and western Canada include members of the genera *Populus*, *Salix*, *Alnus*, *Betula*, *Prunus* and *Quercus* (Furniss and Carolin 1977, Collman and Antonelli 1996).
Habitat requirements: requires host trees or shrubs for larvae to feed, but may also consume foliage of wild and ornamental shrubs or cultivated fruits and vegetables after stripping host trees (Batzer and Morris 1978). Freezing temperatures during winter or spring can kill many larvae (e.g., a late or hard freeze following larval emergence), as can extremely high or low temperatures kill adult moths (Meeker 2001).
Dispersal potential: strong winds can carry moths many miles, and great numbers are attracted to lights (Batzer and Morris 1978).
Potential to be spread by human activity: can be spread via movement of nursery-landscape stock plants.
Related invasive species: the western tent caterpillar (*M. californicum*) has been introduced to and eradicated from the Anchorage area, Alaska, multiple times in recent years (Schrader and Hennon 2005); eastern tent caterpillar (*M. americanum*) occurs in the eastern U.S.

Ecological Impact
Larvae can substantially or completely defoliate some host trees; mortality does not usually result except where outbreaks last many years or host species exist in stressed condition or at the edge of their range (Batzer and Morris 1978, Meeker 2001). Larvae are preyed upon by insectivorous birds, parasitized by certain flies and wasps, and attacked by some viruses. Hairs of the larvae are irritating to potential predators, and there are reports of miscarriages in horses after pregnant mares consumed caterpillars on foliage (Mitton 2005).

Distribution and Abundance
Native and current distribution: similar to the western tent caterpillar, this species is native to North America and occurs in southern Canada and the continental U.S., but not yet in Alaska, although it is a likely

future invader (Furniss and Carolin 1977, Meeker 2001, USFS 2007).

Management

Most control measures are impractical for use in large-scale outbreaks. Prior to larvae emergence, branches bearing egg masses can be manually pruned and destroyed; this is the preventive and least toxic approach (Meeker 2001). Before emergence, tree trunks can be banded with sticky material such as Tanglefoot, which will trap caterpillars and prevent them from ascending and descending trees. Chemical controls are also available; evenings and early mornings are the best times to prune or spray because larvae tend to congregate in silken nests at night (WSU 1996).

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Gypsy Moth
Lymantria dispar (Linnaeus, 1759)

Taxonomy
Phylum Arthropoda, Class Insecta, Order Lepidoptera, Family Lymantriidae
Other common names: Asian gypsy moth, European gypsy moth

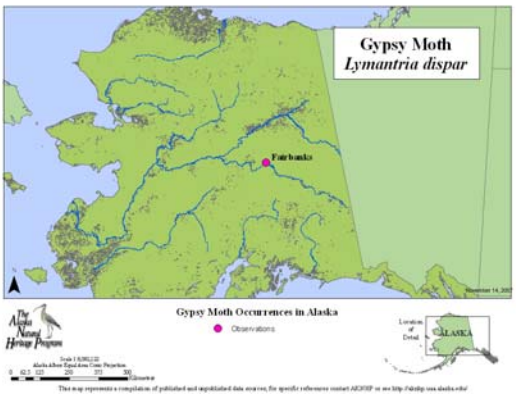
Description
Adult male moths are brown with a darker brown pattern on their wings (wingspan 35-40 mm); females are slightly larger (wingspan to 65 mm) and nearly white, with a few dark markings on their wings. Newly hatched larvae are black and hairy, later developing a mottled yellow to gray pattern with tufts of stiff hairs and 2 rows of blue then red spots along the back (mature larva length 40-65 mm; GISD 2006, Natural Resources Canada 2007).

Biology and Invasive Potential
Reproductive biology: one generation produced per year; females lay one egg mass containing 500-1,500 eggs on tree trunks, eggs overwinter and hatch in spring/early summer. Larvae go through 5 (European strains of the species) or 6-7 instars (Asian strains), then pupate in late summer (GISD 2006, Natural Resources Canada 2007). Females of Asian strains are capable of flight, but European strain females are too heavy to fly, and often deposit eggs near the pupation site.
Feeding habits: larvae feed on leaves of over 500 varieties of hardwood trees and shrubs (GISD 2006). Preferred species found in Alaska include alder, birch, aspen, poplar, willow, hemlock, larch and fir (Liebhold 2003, GISD 2006, Natural Resources Canada 2007).
Habitat requirements: temperate forests; outbreaks occur where host species comprise >20% basal area (GISD 2006). Larvae often feed at night and congregate in shady areas during the day, particularly in litter near trunks of affected trees (Natural Resources Canada 2007).
Dispersal potential: late instar larvae may crawl up to 100 m, and newly hatched caterpillars travel to tops of trees and are carried by wind, sometimes for miles (GISD 2006).
Potential to be spread by human activity: larvae may attach to people or objects; egg masses are tolerant of extreme temperatures and moisture and may be transported on logs, lawn furniture, nursery stock, pallets, shipping containers, hulls of ships, etc. (APHIS 2003 in GISD 2006).
Related invasive species: nun moth (*Lymantria monacha*) and rosy gypsy moth (*L. mathura*), neither yet found in Alaska (USFS 2007), but occur in Europe and Asia (CFIA 2007).

Ecological Impact
At low densities this species causes no discernible damage; during outbreaks (typically lasting 1-5 yrs) larval feeding may completely defoliate host trees, and cause reduced tree growth, crown dieback and tree mortality (GISD 2006). Mammal, bird and insect species diversity and composition may be altered during outbreaks through reduction in shelter, food and other benefits provided by host trees. Mammals and birds prey on adult moths, less on larvae as they are covered in dense hairs which may be irritating.

Distribution and Abundance
Native and current distribution: native to southern Europe, northern Africa, central and southern Asia and Japan. European strain has been introduced to eastern North America, and is spreading west and south (GISD 2006); also several Asian strain

populations have been discovered in the U.S and Canada recently (Liebhold 2003). A single male moth was found at a campground in south Fairbanks, Alaska in 2006 (USFS 2007).



Management

Annual surveys are conducted in the U.S. and Canada using pheromone traps (Natural Resources Canada 2007); in Alaska a cooperative monitoring program (USFS and the Animal and Plant Health Inspection Service, APHIS) is in effect and surveys several locations in the state (USFS 2007). Preventive measures include thinning stands to reduce proportion of host species, and in New Zealand, quarantining ships offshore while inspections are made for egg masses. Physical removal of egg masses and trapping of adults and larvae is possible on a small scale. Aerial spraying of pesticides is the most common method for eradicating new isolated populations and for suppressing outbreaks in low density populations. Also common is spraying of the *Bacillus thuringiensis* (Bt) bacteria, which produces a toxin that suppresses caterpillars' appetites, causing them to starve and die in usually 7-10 days (APHIS 2003 in GISD 2006). Over the last 20 years, several millions of acres of forest land have been sprayed with pesticides in the U.S. (Liebhold 2003).

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Larch Sawfly
Pristiphora erichsonii (Hartig)

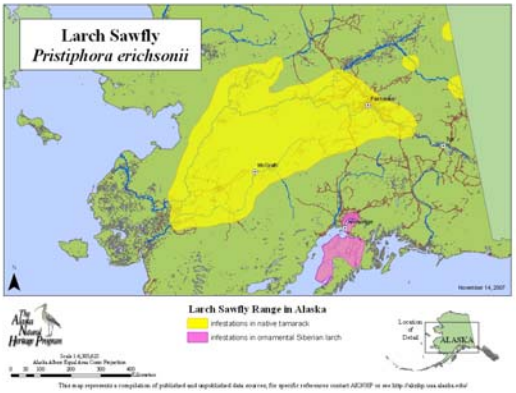
Taxonomy
Phylum Arthropoda, Class Insecta, Order Hymenoptera, Family Tenthredinidae

Description
A wasp-like insect, the adult is black with a broad orange or brownish band across the abdomen, 5-9 mm long, with black (female) or orange (male) antennae. Larvae are grayish-green above and cream-colored below, with black heads and 7 pairs of abdominal prolegs, and measure up to 18 mm long (Drooz 1960, IPM of Alaska 2003, Natural Resources Canada 2007).

Biology and Invasive Potential
Reproductive biology: primarily parthenogenetic. Adults (almost always all females) lay eggs on new shoots, which hatch in 1-2 weeks. Larvae move to older shoots to feed, then drop to the ground when mature to overwinter as prepupae in soil below the litter layer (Drooz 1960, Furniss and Carolin 1977).
Feeding habits: larvae feed in groups on leaves of larch or tamarack (*Larix* spp.). In Alaska native larch forest species may be preferred over imported ornamental trees (Rozell 1996).
Habitat requirements: larch is a shade-intolerant pioneer tree species, which grows at the edge of its range in Alaska in moist, boggy habitat. The larch sawfly has attacked larch trees of all ages in Alaska (Rozell 2000, 2007). Harsh winter weather with low snowfall and mortality from parasites during the overwintering stage are the most important natural controls for this species' populations (USFS 2001).
Dispersal potential: unknown.
Potential to be spread by human activity: can be spread via movement of nursery-landscape stock plants such as the Siberian larch (*Larix sibirica*; Rozell 2000).
Related invasive species: several species of birch leafmining sawflies have increased in Alaska recently: *Profenusa thomsoni* and *Fenusa pusilla* (USFS 2007).

Ecological Impact
Egg-laying causes shoots to curl as they grow, and larval feeding causes defoliation (although trees may refoliate after a few weeks); attacked trees may be more susceptible to infestation by other insects, and sustained infestations have caused mortality of up to 80% of the adult tamarack in Alaska in the last decade (USFS 2001, IPM of Alaska 2003, Rozell 2007). Larvae are preyed upon by insectivorous birds.

Distribution and Abundance
Native and current distribution: believed to be native to Europe, this species was first recorded from North America in 1880 and in Alaska in 1965 (Furniss and Carolin 1977, Cloutier and Filion 1991, USFS 2001). It now occurs throughout Canada and the northeastern U.S. Outbreaks first recorded in interior Alaska forests in 1993, in the Matanuska-Susitna Valley and Anchorage Bowl in 1999 (ornamental trees), Kenai Peninsula in 2001 (ornamental trees) and by 2007 the entire distribution of tamarack in the state (>1,000,000 acres) was affected, with up to 80% of trees killed (USFS 2001, Rozell 2007).



Management

Removing leaf litter and burning or raking 1-2 in. of soil beneath infested trees helps to destroy overwintering pupae (USFS 2001, IPM of Alaska 2003). High-pressure water spray or handpicking can remove larvae from needles; this is useful only for small and ornamental trees. Chemical control options include systemic and topical insecticides (IPM of Alaska 2003). USFS biologists are considering removal of some small trees for future genetic conservation and to protect against permanent decimation of Alaska's tamarack population (Rozell 2001).

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New Zealand Mudsnail
Potamopyrgus antipodarum (Gray, 1843)

Taxonomy
Phylum Mollusca, Class Gastropoda, Order Neotaenioglossa, Family Hydrobiidae
Other common names: Jenkin's spire shell


Dense population of *P. antipodarum* in the Calaveras River, CA

Description
A small aquatic snail (maximum shell length around 5 mm). Mature adult shell is light to dark brown, slightly elongate compared to many western snails, with 5 or 6 whorls, and an operculum to block the shell aperture when the snail is withdrawn into the shell (NZMMC 2007). Lifespan: observed at over 1 year in some marked individuals (Richards pers. comm.. in MSU 2004).

Biology and Invasive Potential
Reproductive biology: dioecious and bears live young. Eggs develop within the female's brood pouch and emerge as fully functional snails. Females may be either sexual or asexual in native populations of New Zealand, but introduced populations are entirely asexual and reproduce clonally, producing populations entirely of females (NZMMC 2007). Young produced every 3 months in New Zealand, but usually born in summer and autumn in North America. Each female carries 20-120 embryos, and reaches sexual maturity at 3 mm (MSU 2004, GISD 2005).
Feeding habits: mudsnails graze on attached periphyton and consume diatoms and decaying plant and animal material.
Habitat requirements: found in rivers, reservoirs, lakes and estuaries; this species has a wide range of tolerances including diverse temperature ranges, osmotic concentrations, flows, substrate types, and disturbance regimes (NZMMC 2007). In estuaries, mudsnails can tolerate up to 17-24% salinity (see sources in MSU 2004 and GISD 2005). They can also withstand desiccation. Densities are greatest in freshwater systems with high productivity, constant temperatures and constant flow, but this species is found in all river substrates: silt, sand, gravel, cobble and vegetation (GISD 2005).
Dispersal potential: mudsnails move only short distances alone, but may also attach to objects and vegetation, or be eaten by fish and pass unharmed through the digestive tract to establish elsewhere (MSU 2004, GISD 2005, NZMMC 2007).
Potential to be spread by human activity: many types of water users may spread this species; anglers, swimmers, picnickers and pets may transport individuals to new locations, as well as boats and containers in sea freight or freshwater transported overseas.

Ecological Impact
New Zealand mudsnail populations reach extremely high densities (100,000 to 800,000 per m^2 in some streams of the western U.S. and Europe, and comprising over 95% of the invertebrate biomass in a river; see sources in GISD 2005, NZMMC 2007), and impact native communities through physical displacement or crowding, and competition with other grazing invertebrates for food. Reductions in aquatic insect species diversity or abundance could diminish the food resources available to fish,

and mudsnails themselves provide as little as 2% of their nutritional value when eaten by trout (GISD 2005, NZMMC 2007). The snails can also drastically alter primary production in some streams by grazing.

Distribution and Abundance

Native and current distribution: native to New Zealand; introduced in Australia, Europe and North America, including all western United States of the lower 48. Not yet observed in Alaska (Fay 2002).

Management

Preventive measures are best; no other treatments appear effective at eliminating this species except non-selective chemical poisons that eliminate invertebrate as well as other animal and plant species (GISD 2005). Disinfectant techniques have been tested for fishing and wading gear; copper sulfate (252 mg/L Cu), benzethonium chloride (1,940 mg/L) and Formula 409 Disinfectant (50% dilution) work best under field conditions (Hosea and Finlayson 2005). Methods for cleaning gear include: 1. Disinfect: spray gear and boats with disinfectant and remove all visible snails, then rinse with tap water. 2. Freeze: freeze gear 6-8 hours. 3. Heat: dry gear in air temperatures over 112 degrees F (50 C) for 24 hours, or place in 130 degree water for 5 minutes; or let all equipment dry for several days (after doing a visual search for snails, which can survive more than a week out of water when attached to damp boots, trailer pads, etc.; USFWS 2003, CRWSG 2006). The National Park Service (no date in GISD 2005) states that "attempts at crushing or physical removal of snails may only exacerbate this problem by spreading eggs to new sites." Public education programs and prohibition under state law can help prevent introduction and spread of snails. Alaska state law prohibits live capture, possession, transport and release of native and exotic "fish" (defined to include aquatic invertebrates) or their eggs (AS 16.05.241).

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Photo credit: Calaveras River Watershed Stewardship Group,
http://www.calaverasriver.com/mudsnail.htm

Alaska Natural Heritage Program
Environment and Natural Resources Institute, University of Alaska Anchorage,
707 A Street, Anchorage, AK 99501

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Signal Crayfish
Pacifastacus leniusculus (Dana, 1852)

Taxonomy
Phylum Crustacea, Class Malacostraca, Order Decapoda, Family Astacidae
Other common names: noble crayfish, Pacific crayfish

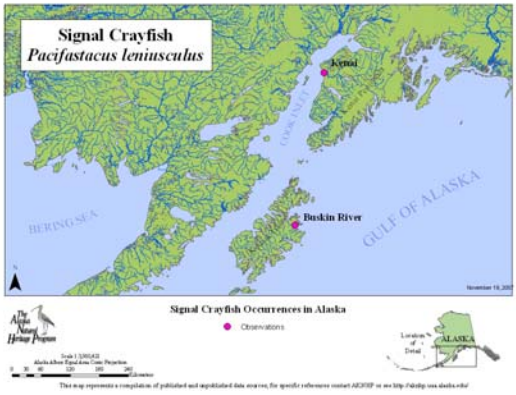
Description
A large aquatic crayfish. Reddish-brown to bluish-brown in color with large smooth claws and a white patch near the claw hinge. Primarily nocturnal. Adult carapace length: up to 15 cm.

Biology and Invasive Potential
Reproductive biology: sexually mature adults (age 3 years) mate and spawn once per year in autumn (Guan and Wiles 1999). Eggs hatch in early summer. Juveniles molt several times per year; adults molt once.
Feeding habits: omnivorous and aggressive; young crayfish eat mostly aquatic invertebrates, adults eat plant material, detritus, zoobenthos, fish and aquatic invertebrates including other crayfish (Lowery and Holdich 1988, Crawford et al. 2006).
Habitat requirements: perennial streams, rivers and lakes which offer refuges in the form of tree roots and/or rocks. Juveniles prefer shallow, fast-flowing habitat and move to slower, deeper pools as they grow (Lowery and Holdich 1988). In Lake Tahoe, California, occurs at depths of 0-40 m (most abundant from 10-20 m) where water temperatures are 4-20ºC (Lowery and Holdich 1988). Movement and activity positively correlated with water temperature (Bubb et al. 2004). Tolerates a wide range of habitats and conditions, including brackish water, but requires at least 5 mg/1 levels of dissolved calcium (Lowery and Holdich 1988).
Dispersal potential: telemetry studies showed adults moving up to 283 m upstream and 417 m downstream over several months (Bubb et al. 2004) and up to 120 m/day (Light 2003). Average rate of population expansion in the Wharfe River, northern England, was 1.5 km/year (Bubb et al. 2004). Generally greater movements made downstream and in lower gradient streams; gradient barriers and increased (bankfull) flow limit dispersal (Light 2003).
Potential to be spread by human activity: this species can be harvested and/or cultured for food, and has been deliberately introduced for this purpose as well as to reduce aquatic vegetation in lakes and streams. Also released accidentally as angling bait, and sold commonly at pet stores (Fay 2002).

Ecological Impact
This is a large, aggressive crayfish which competes with and preys upon invertebrates including smaller crayfish in its range, as well as fish eggs and fry. It carries crayfish plague (*Aphanomyces astaci*), to which it is resistant but which is lethal to European crayfish (Bubb et al. 2004). A study of 40 headwater streams in Oregon (where this species is native) found no significant relationship between crayfish densities and macroinvertebrate community attributes (Cole et al. 2003), but in Scotland an invasive population of *P. leniusculus* significantly reduced invertebrate species abundance, community richness and diversity where it occurred (Crawford et al. 2006). Native crayfish species have become threatened by established populations of non-native signals throughout Europe and in California; signal crayfish are believed to

have contributed to the extinction of California endemic *P. nigrescens* (Lowery and Holdich 1988). At high densities, this species may significantly modify stream habitats as a result of its burrowing behavior and pattern of foraging on vegetation (Crawford et al. 2006).

Distribution and Abundance
Native and current distribution: native to northwestern North America from British Columbia south to Oregon. Introduced in California, Nevada, Utah, Europe and Japan. One individual collected recently in the Buskin River, Kodiak, Alaska (Fay 2002, USGS 2007) and reported also near Kenai (Schrader and Hennon 2005); unknown if a breeding population is yet established.



Management
Focusing conservation efforts on headwater streams, and limiting dispersal by installing man-made barriers or de-regulating flow may be effective.

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Environment and Natural Resources Institute, University of Alaska Anchorage,
707 A Street, Anchorage, AK 99501

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Western Tent Caterpillar
Malacosoma californicum (Packard, 1864)

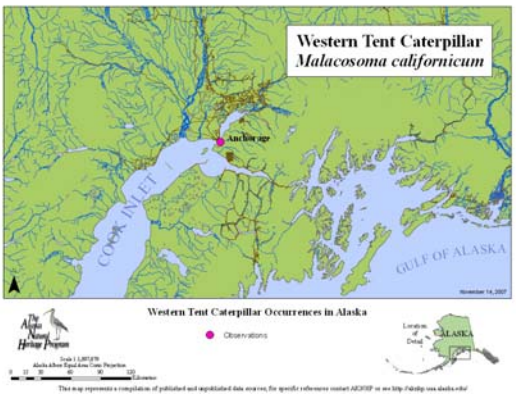
Taxonomy
Phylum Mandibulata, Class Insecta, Order Lepidoptera, Family Lasiocampidae

Description
Larvae have a dark gray to black background body color, highlighted by broad, pale blue lines and thin, broken yellow lines extending along each side; on the back of each abdominal segment is an off-white spiracular line with 2 blue patches above it. Larvae have many whitish hairs, and similar species' larvae grow to a mature length of 50-64 mm. Adults are stout-bodied, tan or buff-colored moths. Larvae form silken "tents", which they use as a shelter against predators (Furniss and Carolin 1977, Batzer and Morris 1978, Meeker 2001).

Biology and Invasive Potential
Reproductive biology: one generation per year. Larvae emerge from egg masses in spring as buds form on host trees, feed gregariously and develop through 5 larval instars, then pupate in silken cocoons located in leaves or crevices over 10-14 days. Adult moths emerge, mate and females oviposit masses of 100-350 eggs encircling small twigs, where embryos develop into larvae which overwinter (Furniss and Carolin 1977, Batzer and Morris 1978, Meeker 2001). In native range, forest tent caterpillar populations often have cyclic outbreaks every 6 to 16 years, subsiding usually after 2 to 4 years of heavy defoliation (see sources in Meeker 2001).
Feeding habits: adults do not feed; larvae consume buds, leaves and flowers of a variety of host plants, primarily broadleaved trees. Preferred species in the northwestern United States and western Canada include members of the genera *Populus*, *Salix*, *Alnus*, *Betula*, *Prunus* and *Quercus* (Furniss and Carolin 1977, Collman and Antonelli 1996).
Habitat requirements: requires host trees or shrubs for larvae to feed, but may also consume foliage of wild and ornamental shrubs or cultivated fruits and vegetables after stripping host trees (Batzer and Morris 1978). Freezing temperatures during winter or spring can kill many larvae (e.g., a late or hard freeze following larval emergence); adult moths also susceptible to extremely high or low temperatures kill (Meeker 2001).
Dispersal potential: strong winds can carry moths many miles, and great numbers are attracted to lights (Batzer and Morris 1978).
Potential to be spread by human activity: can be spread via movement of nursery-landscape stock plants.
Related invasive species: the forest tent caterpillar and eastern tent caterpillar (*M. americanum*) occur throughout North America.

Ecological Impact
Larvae of the forest tent caterpillar can substantially or completely defoliate some host trees; mortality does not usually result except where outbreaks last many years or host species exist in stressed condition or at the edge of their range (Batzer and Morris 1978, Meeker 2001). Western tent caterpillar populations may not irrupt in large outbreaks like *M. disstria*, but can still cause defoliation (Mitton 2005). Larvae are preyed upon by insectivorous birds and parasitized by certain flies and wasps, and

attacked by some viruses. Hairs of the larvae are irritating to potential predators, and there are reports of miscarriages in horses after pregnant mares consumed caterpillars on foliage (Mitton 2005).



Distribution and Abundance
Native and current distribution: native to North America in Canada and the northern and western U.S.; this species is not native to Alaska and has been introduced to and eradicated from the Anchorage area multiple times in recent years (Schrader and Hennon 2005).

Management
Most control measures are impractical for use in large-scale outbreaks. Prior to larvae emergence, branches bearing egg masses can be manually pruned and destroyed; this is the preventive and least toxic approach (Meeker 2001). Before emergence, tree trunks can be banded with sticky material such as Tanglefoot, which will trap caterpillars and prevent them from ascending and descending trees. Chemical controls are also available; evening and early morning are the best times to prune or spray because larvae tend to congregate in silken nests at night (WSU 1996).

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Environment and Natural Resources Institute, University of Alaska Anchorage,
707 A Street, Anchorage, AK 99501

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Brown Rat
Rattus norvegicus (Berkenhout, 1769)

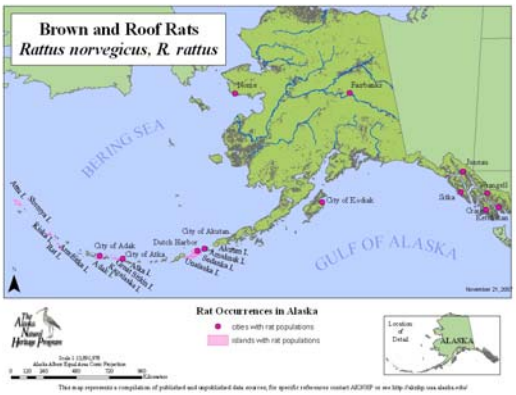
Taxonomy
Phylum Craniata, Class Mammalia, Order Rodentia, Family Muridae
Other common names: Norway rat

Description
A ground-dwelling rat with brown or gray upper pelage, lighter underside, weighing 200-400 g (Nowak 1991). Lifespan: several years in captivity, median wild survival time is 3 months (NatureServe 2007).

Biology and Invasive Potential
Reproductive biology: breeds throughout the year, especially from spring to fall. Sexual maturity is at 80-85 days, gestation period is 21-26 days, and litter size usually about 9 (2-22). Averages 6 litters per year (Nowak 1991, NatureServe 2007).
Feeding habits: a very opportunistic feeder; diet includes plant and animal matter, garbage, and carrion (NatureServe 2007). May consume large quantities of grain stored for human or livestock consumption.
Habitat requirements: a human commensal, found in buildings and other structures in cities and towns, also dumps and open or vegetated areas near abundant food. Young are born in nests in buildings, under debris, or underground. This species is most common in colder climates of high latitudes; in warmer regions, restricted to habitats highly modified by humans (NatureServe 2007).
Dispersal potential: this species is not a long-distance migrant, but can move at least several km in a day over land. Also swims well; Taylor et al. (2000) describe ocean distances of less than 300 m as "within the swimming range", and a stretch of 1 km with strong tidal currents as unlikely to be crossed without human assistance. Roof rats (*Rattus rattus*) recently documented swimming 500 m in New Zealand (see sources in GISD 2006).
Potential to be spread by human activity: accidental spread by humans is the primary method of introduction worldwide: transportation over land and water occurs through activities relating to mining, forestry, agriculture, fishing and trade, construction of roads and buildings, military occupation of remote areas, and shipwrecks (Taylor et al. 2000, Ebbert and Byrd 2002). Rats are transported in ships and vehicles, then establish populations wherever there is a food source and natural or human-constructed shelter.
Related invasive species: the roof rat is another invasive and human commensal rat.

Ecological Impact
Predation by non-native species, especially rats, is the second-most important cause (after habitat destruction) of endangerment, extirpation, and extinction of island birds (King 1985 in Major et al. 2006). By consuming eggs and young, and disturbing nesting adults, rats extirpate most species of burrow-nesting seabirds and probably reduce populations of shorebirds and other ground-nesting species where they become established (Ebbert and Byrd 2002). Introduced brown rats caused the decline of Ancient Murrelets (*Synthliboramphus antiquus*) and other seabirds breeding on Langara Island, British Columbia. (Taylor et al. 2000) and many other species where they were introduced in the Aleutian Islands, Alaska (Ebbert and Byrd 2002). Rats indirectly influence intertidal communities by keeping populations of marine birds that forage on intertidal invertebrates low (Kurle 2005). Rats likely provide supplemental

winter food to introduced foxes on Alaskan islands, thereby keeping fox populations high and increasing the impact of foxes on native birds during the breeding season; they also threaten and compete with native small mammals (Ebbert and Byrd 2002). Besides impacts to native animal communities, brown rats are known to carry diseases, destroy large quantities of food stored for humans and livestock, kill poultry and livestock, and destroy property (Nowak 1991).



Distribution and Abundance

Native and current distribution: assumed native in eastern Asia (Nowak 1991, NatureServe 2007), now introduced worldwide. In Alaska, this species was the earliest recorded accidental mammal introduction, prior to 1780, and became established on at least 16 islands in the Maritime National Wildlife Refuge (Ebbert and Byrd date); it is likely present in other coastal parts of Alaska, but little is known (Schrader and Hennon 2005).

Management

Prevention is the best protection: ship quarantine and emergency "rat spill" response plans are in effect in coastal wildlife refuges of Alaska (USFWS 2007); this involves dispersal of poison baits adjacent to a grounded wrecked vessel or on the vessel itself (Ebbert and Byrd 2002). Intensive bait dispersal programs have proven effective at eradicating brown rats from islands as large as 3,100 ha in New Zealand and Canada (Taylor et al. 2000) and roof rats from 23,000 ha in Australia (Morris 2002 in GISD 2006); however, these eradication techniques may also impact non-target organisms. Human food wastes and refuse should be collected frequently and rat access to storage facilities must be prevented to eliminate rat harborage (Schiller 1952). Current research suggests promising potential for effective rat control using contraceptive methods, including oral immunization (see sources in GISD 2006).

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Environment and Natural Resources Institute, University of Alaska Anchorage,
707 A Street, Anchorage, AK 99501

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Elk
Cervus canadensis (Linnaeus, 1758)

Taxonomy
Phylum Craniata, Class Mammalia, Order Artiodactyla, Family Cervidae
Other common names: North American wapiti

Description
A large deer (1.6-2.6 m head and body length, 0.75-2.7 m shoulder height, 75-590 kg weight), upper parts are brown or tan, underparts lighter in color, and with a prominent pale yellow or white patch on the rump. Males have a darker, dense mane, and average larger than females, with antlers of one beam plus a supernumerary tine above the brown line (Nowak 1991, Eide 1994). Lifespan: 12-15 years in the wild.

Biology and Invasive Potential
Reproductive biology: sexually mature adults (2 years of age) mate annually in early fall, and usually a single calf (sometimes twins) is born the following spring. Cows and calves congregate in large herds during summer, then males separate and defend smaller herds of females during the rut (September-October); older males do most of the mating (Nowak 1991, NatureServe 2007).
Feeding habits: herbivorous, much geographical and seasonal variation in diet. Primarily grazes grasses, but may also consume forbs and browse on shrubs where and when grasses are unavailable (Eide 1994, NatureServe 2007). A study in Southeast Alaska found high overlap between native Sitka black-tailed deer (*Odocoileus hemionus sitkensis*) and introduced elk winter diets, which is not unexpected given the low diversity of plant species in the region: red blueberry (*Vaccinium parvifolium*), western redcedar (*Thuja plicata*) and salal (*Gaultheria shallon*) together made up 40% of elk diet and 30% of deer diet (Kirchhoff and Larsen 1998).
Habitat requirements: uses open areas such as alpine meadows, marshes, river flats, and aspen/birch parkland, as well as coniferous forests, brushy clearcuts and forest edges (NatureServe 2007), as in Southeast Alaska. Kirchhoff and Larsen (1998) suggested clearcut logging creates habitat favoring elk over native deer, because elk can better negotiate deep snow accumulations in clearcuts, and process conifers and tall shrubs predominating there. Dense forest habitat is not ideal for elk.
Dispersal potential: some individuals in Wyoming migrate up to 97 km annually (Adams 1982 *in* NatureServe 2007). Home range of nonmigratory herd can be 1.8-5.3 km², animals rarely move more than 1,600 m in 1 day, and exhibit high fidelity to home ranges (NatureServe 2007).
Potential to be spread by human activity: this species was introduced to Alaska as a game animal, but transplants were not always successful (Burris and McKnight 1973).

Ecological Impact
There is potential for competition with native Sitka black-tailed deer in Southeast Alaska; severe winter weather and limited winter forage increase competition between

the species, and elk would likely outcompete deer because of their larger size, greater reach, and ability to use coarser plant material (see sources in Kirchhoff and Larsen 1998). One study predicts that increasing winter temperatures associated with global warming will cause an increase in Alaska elk populations, due to decreased snow depths and hence, increased body mass, survival and available forage (Maier and Post 2001). Increases in elk populations may lead to declines in deer where they occur together (Lowell 2004 in Schrader and Hennon 2005). Elk predators include brown and black bears (*Ursus arctos* and *U. americanus*), wolves (*Canis lupus*), coyotes (*Canis latrans*) and humans.

Distribution and Abundance

Native and current distribution: native to most of the conterminous U.S., southern Canada and northern Mexico; other species and subspecies occur throughout Asia, northern Africa, Siberia and the Himalayan region (Nowak 1991). Elk were introduced in 1926 and 1928 to Kruzof Island, Southeast Alaska, and subsequently to Afognak and Raspberry Islands of the Kodiak archipelago (ssp. *roosevelti*, or Roosevelt elk); Revillagigedo, Gravina, Etolin and Zarembo Islands (Burris and McKnight 1973, Schrader and Hennon 2005); established populations still persist on Afognak, Raspberry, Etolin and Zarembo. The population is apparently expanding in Southeast Alaska as sightings have been reported for other areas including Wrangell, Mitkof, Kupreanof, Prince of Wales and Farm Islands and the Cleveland Peninsula (Schrader and Hennon 2005, USFS 2006). The Afognak Island population was estimated at 1,200-1,500 in 1965, declined in the 1970s, and was estimated at 1,200 in the mid-1980s (Eide 1994).

Management

Elk hunting is currently allowed and managed by the Alaska Department of Fish and Game throughout the species' range (GMUs 1, 2, 3, and 8; ADFG 2007). Increasing permitted take will decrease populations in the state.

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Environment and Natural Resources Institute, University of Alaska Anchorage,
707 A Street, Anchorage, AK 99501

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Roof Rat
Rattus rattus (Linnaeus, 1758)

Taxonomy
Phylum Craniata, Class Mammalia, Order Rodentia, Family Muridae
Other common names: black rat, house rat, ship rat

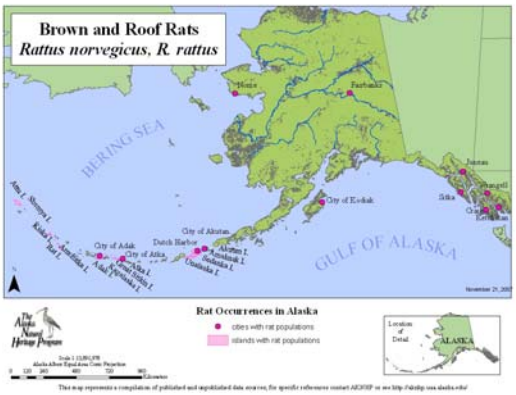
Description
A slender, gray-brown or black rat with either a similar-colored or cream-colored underside. Tail and ears are hairless, body weight usually 120-160 g (GISD 2006). Lifespan: over 4 years in captivity (Nowak 1991), likely several months in the wild.

Biology and Invasive Potential
Reproductive biology: breeds throughout the year. Sexual maturity is around 80 days, gestation period is 21-29 days, and litter size usually about 8 (6-22; Nowak 1991, NatureServe 2007). Averages 6.5 litters per year in Hawaii (NatureServe 2007).
Feeding habits: a very opportunistic feeder; diet includes plant and animal matter, garbage, carrion, and especially grain. May consume large quantities of grain stored for human or livestock consumption (NatureServe 2007). A study found this species is primarily herbivorous, but can change its food habits when food is in short supply (Yabe 2004 *in* GISD 2006).
Habitat requirements: a human commensal, found in buildings and other structures in cities and towns, also dumps, sewers, seaports; often found in the upper stories of buildings. Young are born in nests in buildings or within other cover. This species occurs in natural habitats in warmer climates, preferring dense mesic to wet forests and tall grass over open sites; often arboreal (NatureServe 2007).
Dispersal potential: rats are not long-distance migrants, but can move at least several km in a day over land, as well as climb and swim well. Recent reinvasions by this species in New Zealand involved ocean crossings of approximately 500 m in calm waters (Chappell 2004, Ward 2005 in GISD 2006).
Potential to be spread by human activity: accidental spread by humans is the primary method of introduction worldwide: transportation over land and water occurs through activities relating to mining, forestry, agriculture, fishing and trade, construction of roads and buildings, military occupation of remote areas, and shipwrecks (Taylor et al. 2000, Ebbert and Byrd 2002). Rats are transported in ships (usually in freight carried within the hull, holds and living spaces) and vehicles, then establish populations wherever there is a food source and natural or human-constructed shelter.
Related invasive species: the brown rat (or Norway rat, *R. norvegicus*) is another invasive and human commensal rat.

Ecological Impact
This species has directly caused or contributed to the extinction of many wildlife species including birds, small mammals, reptiles, invertebrates and plants, especially on islands (GISD 2006). They are believed to prey on seabirds and likely consume eggs and young and disturb nesting adults. Introduced brown rats caused the decline of Ancient Murrelets (*Synthliboramphus antiquus*) and other seabirds breeding on Langara Island, British Columbia (Taylor et al. 2000) and many other species where they were introduced in the Aleutian Islands, Alaska (Ebbert and Byrd 2002). On islands with introduced foxes in Alaska, rats likely provide supplemental winter food to foxes, which keeps fox populations high and thereby increases the impact of foxes on native birds during the breeding season; they also threaten and compete with native small mammals (Ebbert and Byrd 2002). This species is destructive to native flora on Pacific Islands (see sources in NatureServe 2007). Besides the mentioned impacts to native communities, roof rats are known to

carry diseases, destroy large quantities of food stored for humans and livestock, and destroy property (Nowak 1991).

Distribution and Abundance
Native and current distribution: native to India, now introduced worldwide (Nowak 1991, GISD 2006, NatureServe 2007). In Alaska, this species has become established on at least one island in the Maritime National Wildlife Refuge (Ebbert and Byrd 2002), but its current distribution in the state is not known.



Management
Prevention is the best protection: ship quarantine and emergency "rat spill" response plans are in effect in coastal wildlife refuges of Alaska (USFWS 2007); this involves dispersal of poison baits adjacent to a grounded wrecked vessel or on the vessel itself (Ebbert and Byrd 2002). Trapping usually fails to remove all individuals (GISD 2006), but intensive bait dispersal programs have proven effective at eradicating roof rats from islands as large as 23,000 ha in Australia (Morris 2002 in GISD 2006); these may also impact non-target organisms. Human food wastes and refuse should be collected frequently and rat access to storage facilities must be prevented to eliminate rat harborage (Schiller 1952). Current research suggests promising potential for effective control using contraceptive methods, including oral immunisation (see sources in GISD 2006).

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Whirling Disease Parasite
Myxobolus cerebralis (Hofer, 1903)

Taxonomy
Phylum Myxozoa, Class Myxosporea, Order Myxosporida, Family Myxobolidae

Description
A microscopic freshwater parasite with a 2-host life cycle. The parasite releases spores which appear differently depending on the hosts, which include species of trout, salmon and oligochaete worms (GISD 2005).

Biology and Invasive Potential
Reproductive biology: may reproduce in 3 distinct processes: asexually with the production of sporozoites, asexually where sporozoites undergo another asexual replication known as merogony, or sexually through a process called gametogamy (Melrose 2002 *in* GISD 2005).
Habitat requirements: freshwater habitats containing host species of fish and oligochaete worms. When an infected fish dies, spores are released and ingested by tubifex worms, then develop and multiply in the worm's intestine. When excreted by the worm, water-borne spores then infect susceptible fish (usually juvenile fish) by attaching to the fish's body, then migrating through skin to the central nervous system and ultimately cartilage of the fish. Spores are believed to be capable of remaining dormant in stream sediment for up to 30 years (Storey 2003 *in* GISD 2005). Tubifex worms apparently require a nutrient-rich aquatic environment, and nutrient-poor freshwater streams may not support this host for the parasite (Fay 2002).
Dispersal potential: spores themselves are not mobile, but are virtually indestructible and may be carried long distances in water currents, in the bodies of fish, or possibly in the digestive systems of fish-eating migratory birds (GISD 2005).
Potential to be spread by human activity: spread primarily through the stocking of live, infected fish; may also be spread through movement of infected water or sediment, movement of dead infected fish, and movement of spores on fishing equipment.
Related invasive species: Myxobolus lentisuturalis (GISD 2005).

Ecological Impact
Rainbow trout (*Oncorhynchus mykiss*) and cutthroat trout (*O. clarkia*) appear to be more susceptible than other trout species, and the bottom-dwelling tubifex worm, *Tubifex tubifex* is the primary oligochaete host. The parasite multiplies rapidly in the head and spinal cartilage of trout, putting pressure on the organ of equilibrium. Affected fish in later stages of the disease swim erratically (hence the name, whirling disease) and have difficulty feeding and avoiding predators. Whirling disease causes high mortalities in hatchery fry and fingerling salmonids, and has now been documented in some wild populations (GISD 2005). Some species of fish can become infected with the parasite, but are immune to the infection and show no effects externally (Fay 2002).

Distribution and Abundance
Native and current distribution: native to the Eurasian continent, introduced to North America in the late 1950s (Fay 2002). It has now been documented in a hatchery or wild fish population in 25 of the United States, including Alaska and all of the western states (WDI 2007). The first detection from Alaska was made in 2006, in a population of hatchery rainbow trout, using a polymerase chain reaction (PCR) assay and genetic sequencing (Arsan et al. 2007). None of the fish, which were hatched at the Fort Richardson hatchery and raised in Elmendorf hatchery on Ship Creek, displayed erratic swimming behavior or other signs of heavy infection (in fact, no mature spores were visually identified), but the parasite's spores were present in 12 of 60 fish tested (Arsan et al. 2007).

Management

There are no known treatments to counteract the effects of this parasite in infected organisms. Management techniques developed for fish hatcheries include rearing young fish in well water to prevent exposure until they are older and more resistant, designing ponds to reduce habitat for oligochaetes, and exposing water to ultraviolet light in order to inactivate parasite spore cells—a dose of 1300 mWs/cm² ultraviolet light can reportedly inactivate 100% of the infectious cells (GISD 2005).

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