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The findings and conclusions in this publication are those of the authors and should not be construed to represent any official USDA or U.S. Government determination or policy.

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Northwest Region

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Introduction

The Northwest region (Idaho, Oregon, and Washington; Figs. A3.1 and A3.2) contains major coastal and inland ports (Coos Bay, Lewiston, Pasco, Portland, Seattle-Tacoma, and The Dalles), waterways (Puget Sound, Columbia River Basin, and Willamette Valley), and major

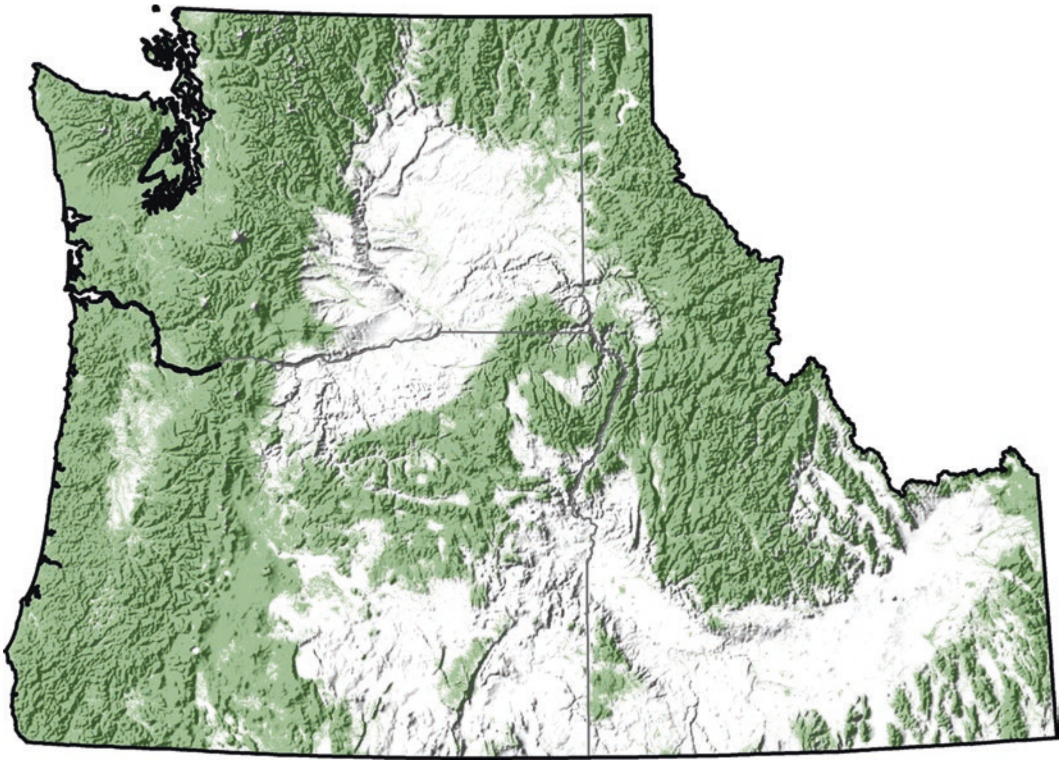

Fig. A3.1 The Northwest Region

Fig. A3.2 The Northwest region of the United States includes Idaho, Oregon, and Washington. (Figure courtesy of Daniel Ryerson, USDA Forest Service Southwestern Region, Forest Health Protection)

highway and rail arteries that provide pathways for invasive plants, pathogens, insects, and vertebrates. Two main pathways in this region for the introduction of invasive forest and horticultural pathogens and insects are shipping infrastructure, especially solid wood packing material from shipping cargo (USDA Forest Service and APHIS 2000), and the live plant trade (Liebhold et al. 2012). Temperate coastal climates, diverse and abundant native vegetation, extensive trade patterns with Pacific Rim nations, and the border with Canada and its major west coast port of Vancouver have facilitated the repeated introductions of major forest pests such as the European (also known as North American) gypsy moth (*Lymantria dispar dispar*), the Asian gypsy moth (*Lymantria dispar asiatica/japonica*), and the sudden oak death pathogen (*Phytophthora ramorum*). The region has a significant horticultural industry, extensive areas of mesic and dryland agriculture, and abundant urban and native forests whose trees can serve as adventive hosts or alternate hosts for invasive insects and pathogens as well as disturbed landscapes for invasive plants. Forested lands are regionally vital to the forest industry and are a recreational base for millions in the Northwest. Invasive species have the potential to inflict severe economic hardship on individuals, local governments, and the businesses involved in the forest, horticultural, agricultural, and tourism industries.

The Northwest region has a long history of invasive forest insects and diseases; for example, white pine blister rust, caused by *Cronartium ribicola*, was first introduced on the West Coast and was "Pest #1" on the historical "Quarantine 37" of the Plant Quarantine Act of 1912, and balsam woolly adelgid (*Adelges piceae*) was first noted in this region in the 1920s (Annand 1928; Keen 1952). More modern regulations such as the International Standards for Phytosanitary Measures No. 15 (ISPM 15), an international treaty signed by 200 nations, play a major role in protecting this region from invasive species that may arrive in solid wood packing material (FAO 2009; Strutt et al. 2013). Also, examples of the more profound impacts of climate change and invasion biology are developing in high-elevation ecosystems of this region where five-needle white pines (*Pinus* spp.) and subalpine fir (*Abies lasiocarpa*) trees are experiencing unprecedented rates of mortality (Shoal and Aubry 2006). In these instances the mountain pine beetle, *Dendroctonus ponderosae*, has been a native invader of high-elevation ecotones (Bentz et al. 2010; Logan and Powell 2001; Logan et al. 2003), whereas *C. ribicola* (on pines) and *A. piceae* (on subalpine fir) are significant non-native invaders with expanding elevational ranges (Hrinkevich et al. 2016).

Regional State government departments, interagency collaborative groups such as State Invasive Species Councils, regional USDA Forest Service personnel, and other entities have identified nearly 190 species and species groups as regional invasive or nuisance species of key concern. Altogether, the taxa identified as detected or potential invasive species fall into five categories: 78 plants; 11 plant pathogens and parasites; 93 insect species; 10 aquatic invertebrates (noninsect); and 23 vertebrates (Tables A3.1, A3.2, A3.3, A3.4 and A3.5, Bautista 2017; Flitcroft et al. 2016; Invasive Species of Idaho 2017; OIE 2018; OISC 2015; Prather et al. 2016; WISP 2009). Because of the large number of organisms (most notably plants) treated in this summary (Tables A3.1, A3.2, A3.3, A3.4 and A3.5), scientific names are only provided in the text for the most prominent species. This overview will focus on a subset of the species that are established and have caused resource damage or that have been introduced repeatedly into the Northwest region.

Plants

Aquatic invasive plants of this region (Table A3.1) include multiple species of submersed aquatic plants (i.e., *Elodea* spp., *Hydrilla* spp., milfoils, and swollen bladderwort), emergent plants (reeds, *Spartina* spp., loosestrife, rushes, giant salvinia, reed canary grass, foxtail barley, yellow flag iris, and water primrose), and floating plants (parrotfeather, curly-leaf pondweed, water chestnut, yellow floating heart, West Indian spongeplant, and dotted duckweed). Two non-plants, a cyanobacterium (toxic blue-green "alga") and a diatom (rock snot or didymo), are also included in this survey (Table A3.1). Once established, many of these taxa can cause significant impairment of water quality and navigation (by growing as dense mats) (see Chap. 2, Sect. 2.5, for additional discussion of these impacts). Furthermore, established populations may be spread by waterfowl as they move from one location to another, or by human vectors (e.g., boats and fishing gear/tackle). Marine invasive plants are not included in the survey.

Several priority aquatic plants can achieve high densities, leading to ecological problems or nuisance issues for people. Emergent plants can dominate wetland and floodplain areas (i.e., reed canary grass, water primrose, and purple loosestrife), outcompeting or displacing native species. Some invasive aquatic plants were brought initially to the region by the aquarium trade (*Elodea* spp.) or for ornamental use or seeding of wet areas for livestock or waterfowl (reed canary grass (*Phalaris arundinacea*)). Once established, cut fragments of the plants, broken by boat propellers or wildlife, can disperse for colonization. Some species such as *Elodea canadensis* have broad ecological tolerance, which make expansion and invasion a concern. Non-native and native species of water primroses (*Ludwigia* spp.) comprise a plant group whose growth has become problematic in recent years. One species, *L. grandiflora*, native to the Eastern United States, Central America, and South America, is now present in Oregon and Washington (CABI 2018). Physical and chemical alteration of the environment by *L. grandiflora* can cause severe damage to local ecosystems and biodiversity. Dense stands of this plant can reduce floodwater retention, cause hyper-sedimentation and silting, and block slow-moving waterways. The plant also gives off allelopathic elements that impact water quality throughout the year and make it detrimental to vulnerable native flora. Because it can shade out other submersed vegetation, it is generally considered a threat to biodiversity in its introduced range (CABI 2018).

Non-plant toxic "algae" are a health concern for native vertebrates and humans because they create powerful toxins known to kill fish, ducks, geese, marine mammals, and other

Table A3.1 Priority non-native invasive plants of the Northwest region

Scientific name	Common name	ID	OR	WA	R6[a]
Aquatic plants					
Lagarosiphon major	African waterweed or African elodea		x		x
Phragmites australis	Common reed	x	x	x	
Potamogeton crispus	Curly-leaf pondweed	x			x
Butomus umbellatus	Flowering rush	x	x		x
Salvinia molesta	Giant salvinia	x	x		
Hydrilla verticillata	Hydrilla, water thyme	x	x	x	x
Myriophyllum spp. including *M. spicatum, M. aquaticum*	Milfoils: Eurasian, parrotfeather	x		x	x
Lythrum salicaria, Lysimachia vulgaris	Purple loosestrife, garden yellow loosestrife	x		x	x
Phalaris arundinacea; P. arundinacea var. *picta*	Reed canary grass; ribbon grass				x
Didymosphenia geminata	Rock snot (Didymo)[b]		x		x
Chondrilla juncea	Rush skeletonweed	x		x	x
Spartina spp. including *S. alterniflora, S. densiflora*	Spartina (cordgrass)		x	x	
Prymnesium parvum, Cylindrospermopsis raciborskii	Toxic algae (golden, toxic cyanobacteria)[b]		x		
Trapa natans	Water chestnut (European)	x	x	x	
Ludwigia grandiflora	Water primrose[c]		x	x	x
Eichhornia crassipes	Water hyacinth	x			
Egeria densa, *Elodea nuttallii, E. canadensis, E. canadensis* x *E. nuttallii* hybrid	Brazilian elodea, western waterweed (elodea)	x		x	
Iris pseudacorus	Yellow flag iris	x			x
Nymphoides peltata	Yellow floating heart	x	x		x
Riparian-terrestrial plants					
Peganum harmala	African rue		x		
Alyssum corsicum, A. murale, Berteroa incana	Alyssums	x	x		x
Hyoscyamus niger	Black henbane	x			
Solanum rostratum	Buffalo bur	x			
Buddleja davidii; B. globosa	Butterfly bush			x	
Alhagi maurorum	Camelthorn		x		
Bromus tectorum	Cheatgrass				x
Tussilago farfara	Coltsfoot (European)		x		
Anchusa officinalis, A. arvensis, Echium vulgare	Common bugloss, small bugloss, viper's bugloss	x			x
Crupina vulgaris	Common crupina	x		x	x
Isatis tinctoria	Dyer's woad	x			
Linaria dalmatica, L. vulgaris	Toadflax (Dalmatian, yellow)	x		x	x
Hedera helix	English ivy				x
Ammophila arenaria	European beachgrass				x
Brachypodium sylvaticum	False brome				x
Cabomba caroliniana	Fanwort	x			
Azolla pinnata	Feathered mosquito fern	x			
Convolvulus arvensis	Field bindweed	x			
Alliaria petiolata	Garlic mustard			x	x
Geranium robertianum, G. lucidum	Geranium				x
Heracleum mantegazzianum	Giant hogweed	x	x	x	
Aegilops triuncialis, A. ovata, A. cylindrica	Goatgrasses (barbed, ovate, jointed)	x	x		x
Galega officinalis	Goatsrue		x		
Ulex europaeus	Gorse				x
Hieracium piloselloides, H. pratense, H. pilosella, H. aurantiacum, H. floribundum, H. caespitosum, H. lachenalii	Hawkweeds	x	x	x	x
Rubus armeniacus	Himalayan blackberry			x	x
Cynoglossum officinale	Houndstongue	x			x
Cuscuta japonica	Japanese dodder		x		
Sorghum halepense	Johnsongrass	x			
Centaurea virgata; C. vulgaris; C. jacea x *nigra; C. stoebe*	Knapweeds	x	x	x	x
Fallopia japonica var. *japonica; Polygonum bohemicum*	Knotweeds (Japanese, bohemian)	x		x	x
Kochia scoparia ssp. *scoparia*	Kochia			x	

(continued)

Table A3.1 (continued)

Scientific name	Common name	ID	OR	WA	R6[a]
Pueraria montana var. *lobata*	Kudzu		x	x	
Euphorbia esula	Leafy spurge	x		x	x
Nardus stricta	Matgrass	x	x		
Salvia aethiopis	Mediterranean sage	x			
Taeniatherum caput-medusae	Medusahead				x
Milium vernale	Millium	x			
Ventenata dubia	North Africa grass				x
Euphorbia oblongata	Oblong spurge		x		
Clematis vitalba	Old man's beard				x
Leucanthemum vulgare	Oxeye daisy	x			
Echium plantagineum	Paterson's curse		x		
Lepidium latifolium	Perennial pepperweed	x			
Sonchus arvensis	Perennial sowthistle	x			
Conium maculatum	Poison hemlock	x			
Impatiens glandulifera	Policeman's helmet	x			x
Tribulus terrestris	Puncturevine	x			x
Cyperus rotundus	Purple nutsedge		x		
Cytisus scoparius	Scotch broom	x		x	x
Solanum elaeagnifolium	Silverleaf nightshade		x		
Centaurea iberica, C. calcitrapa, C. solstitialis	Starthistles	x	x	x	
Potentilla recta	Sulfur cinquefoil				x
Zygophyllum fabago	Syrian bean-caper	x	x		
Tamarix spp.	Tamarix (saltcedar)	x		x	x
Senecio jacobaea	Tansy ragwort	x		x	x
Carduus nutans, C. acanthoides; Carthamus baeticus, C. lanatus; Onopordum tauricum, O. acanthium	Thistles	x	x	x	x
Bryonia alba	White bryony	x	x		
Lepidium draba	Whitetop/hoary cress	x			x

[a]R6 = USDA Forest Service Region 6 (OR, WA) priority invasive species
[b]Non-plants (diatom and cyanobacterium, respectively)
[c]Other species of *Ludwigia* (e.g., *L. palustris*) are native to the Northwest region but have become pests

Table A3.2 Priority non-native invasive plant pathogens and other parasites of the Northwest region

Scientific name	Common name	ID	OR	WA	R6[a]	Other[b]	Plant or animal host
Phytophthora lateralis	Port-Orford-cedar root disease		x		x		*Chamaecyparis lawsoniana, Taxus brevifolia*
Phytophthora ramorum	Sudden oak death	x	x		x		*Quercus* spp., *Notholithocarpus* spp., many others
Batrachochytrium dendrobatidis	Amphibian chytrid fungus (*Bd*)					x	
B. salamandrivorans	Amphibian chytrid fungus (*Bsal*)					x	
Ranavirus	Ranavirus					x	
Chronic wasting disease prion	Chronic wasting disease (CWD)		x				
Pseudogymnoascus destructans	White-nose syndrome				x		
Cronartium ribicola	White pine blister rust		x	x	x		*Pinus* spp.
Melampsora larici-populina	Eurasian poplar leaf rust		x	x			*Populus* spp.
Lachnellula willkommii	European larch canker	x					
Puccinia graminis	Black stem rust	x					

[a]R6 = US Forest Service Region 6 (OR, WA) priority invasive species
[b]Other = World Organization for Animal Health (Office International des Epizootics) priorities

Table A3.3 Non-native invasive insects of the Northwest Region include beetles, flies, aphids/adelgids, thrips, wasps, and moths

		Occurrence			Origin	Introduction		Plant or animal host
Scientific name	Common name	ID	OR	WA		Accidental	Intentional	
Coleoptera								
Agrilus cuprescens	Rose stem girdler			x	Europe	•		*Rosa* spp., *Rubus* spp.
Agriotes lineatus	Lined click beetle			x	Europe	•		Grass and plant roots, Potatoes, strawberries
Agriotes obscurus	Dusky click beetle			x	Europe	•		Grass and plant roots Potatoes, strawberries
Amphimallon majale	European chafer		x	x	Europe	•		Grass roots
Anobium punctatum	Furniture beetle			x	Europe	•		Wood products
Apion fuscirostre					Europe		•	Gorse (*Ulex europaeus*)
Apion ulicis	Gorse weevil	x	x	x	Europe		•	Gorse
Brachypterolus pulicarius	Toadflax flower-feeding beetle	x	x	x	Europe		•	Dalmatian and yellow toadflax, *Linaria* spp.
Chrysolina hyperici		x	x	x	Europe via Australia		•	Klamathweed (*Hypericum perforatum*)
Chrysolina quadrigemina	Klamathweed beetle	x	x	x	Europe via Australia		•	Klamathweed (*Hypericum perforatum*)
Cryptorhynchus lapathi	Poplar-and-willow borer	x	x	x	Europe	•		*Salix* spp. and *Populus* spp.
Cyclorhipidion bodoanum			x	x	Asia	•		Broad-leaved trees (woodborer)
Hylastes opacus			x	x	Europe	•		*Pinus*
Ips paraconfusus	California fivespined ips		O	x	California, Oregon	•		*Pinus* (invasive in Washington, native to Oregon)
Laricobius erichsonii			x	x	Europe		•	*Adelges piceae*
Larinus minutus	Lesser knapweed flower weevil	x	x	x	Europe		•	Knapweeds, *Centaurea* sp.
Larinus obtusus	Blunt knapweed flower weevil	x	x	x	Europe		•	Knapweeds, *Centaurea* sp.
Lasioderma serricorne	Cigarette beetle	x	x	x	Europe (cosmopolitan)	•		*Plant products*
Lilioceris lilii	Scarlet lily beetle			x	Eurasia	•		*Fritillaria* spp. and *Lilium* spp. leaves
Lyctus brunneus	Old World lyctus beetle	x	x	x	Europe (cosmopolitan)	•		Wood products
Lyctus linearis	European lyctus beetle	x	x	x	Europe (cosmopolitan)	•		Wood products
Mecinus janthiniformis	Dalmatian toadflax stem-mining weevil	x	x	x	Southeastern Europe		•	Dalmatian toadflax, *Linaria dalmatica*
Mecinus janthinus	Yellow toadflax stem-mining weevil	x	x	x	Eurasia		•	Yellow toadflax, *Linaria vulgaris*
Melanotus cete			x	x	Japan	•		Unknown
Micromalthus debilis	Telephone pole beetle		x	x	Eastern North America	•		Decayed wood products
Mogulones crucifer	Houndstongue root weevil	x		x	Europe	•		Houndstongue, *Cynoglossum officinale*
Nacerdes melanura	Wharf borer	x	x	x	Europe	•		Wood products
Orchestes alni	European elm flea weevil	x	x	x	Europe	•		*Ulmus* spp.
Otiorhynchus ovatus	Strawberry root weevil	x	x	x	Europe	•		Seedling conifers
Otiorhynchus rugosostriatus	Rough strawberry root weevil	x	x		Europe	•		Seedling conifers
Otiorhynchus sulcatus	Black vine weevil	x	x	x	Europe	•		Seedling conifers
Oulema melanopus	Cereal leaf beetle	x	x	x	Eurasia	•		Cereal crops, wild grasses
Phymatodes testaceus	Tanbark borer			x	Europe, Japan, Middle East, North Africa	•		Wood products/bark

(continued)

Table A3.3 (continued)

		Occurrence			Origin	Introduction		Plant or animal host
Scientific name	Common name	ID	OR	WA		Accidental	Intentional	
Pityophthorus juglandis	Walnut twig beetle	x	x	x	Arizona/New Mexico, Mexico	•		*Juglans* spp., *Pterocarya* spp.
Popillia japonica	Japanese beetle	x	x	x	Japan	•		Broad-leaved trees and many ornamentals
Pullus impexus			x		Europe		•	*Adelges piceae*
Pyrrhalta viburni	Viburnum leaf beetle			x	Eurasia	•		*Viburnum* spp.
Rhinusa antirrhini	Toadflax seed-galling weevil	x	x	x	Eurasia, Mediterranean	•		Dalmatian and yellow toadflax, *Linaria* spp.
Rhinusa neta	Toadflax seed-feeding weevil			x	Europe	•		Dalmatian and yellow toadflax, *Linaria* spp.
Saperda populnea		x	x	x	Europe	•		*Populus* spp.
Scolytus multistriatus	Smaller European elm bark beetle	x	x	x	Europe	•		*Ulmus* spp.
Scolytus rugulosus	Shot hole borer	x	x	x	Europe	•		Broad-leaved trees, Rosaceae
Scolytus schevyrewi	Banded elm bark beetle	x	x	x	Asia	•		*Ulmus* spp.
Stegobium paniceum	Drugstore beetle	x	x	x	Cosmopolitan	•		Stored products
Tenebroides mauritanicus	Cadelle	x	x	x	Cosmopolitan	•		Stored products
Trypodendron domesticum	European hardwood ambrosia beetle			x	Europe	•		Broad-leaved trees
Xanthogaleruca luteola	Elm leaf beetle	x	x	x	Europe	•		*Ulmus* spp.
Xestobium rufovillosum	Deathwatch beetle		x		Europe	•		Wood products
Xyleborinus alni = (*attenuates*)			x	x	Europe/Asia	•		Broad-leaved trees
Xyleborinus saxeseni	Fruit tree pin-hole borer	x	x	x	Europe	•		Broad-leaved trees and conifers
Xyleborus dispar	European shot hole borer	x	x	x	Europe	•		Broad-leaved trees
Xyleborus pfeili			x		Cosmopolitan	•		Broad-leaved trees
Xylosandrus crassiusculus			x		Africa/Asia	•		Broad-leaved trees
Xylosandrus germanus			x	x	Asia	•		Broad-leaved trees
Xyloterinus politus				x	Eastern North America	•		Broad-leaved trees, rare in conifers
Diptera								
Aphidoletes thompsoni			x	x	Europe		•	*Adelges piceae*
Compsilura concinnata		?	x	x	Europe		•	*Lymantria dispar* and other Lepidoptera
Cremifania nigrocellulata			x		Europe		•	*Adelges piceae*
Delia platura	Seedcorn maggot	x	x	x	Europe	•		Seedling conifers
Drosophila suzukii	Spotted wing Drosophila	x	x	x	Asia	•		Fruits/berries
Leucopis obscura			x	?	Europe		•	*Adelges piceae*
Phytomyza ilicis	Holly leafminer		x		Europe	•		*Ilex* spp.
Rhagoletis completa	Walnut husk fly	x	x	x	Eastern USA	•		*Juglans* spp., *Prunus persica*
Hemiptera								
Adelges abietis	Eastern spruce gall aphid	x	x	x	Europe	•		*Picea* spp.

(continued)

Table A3.3 (continued)

		Occurrence			Origin	Introduction		Plant or animal host
Scientific name	Common name	ID	OR	WA		Accidental	Intentional	
Adelges nüsslini (=nordmaneanae)		x	x	x	Europe	•		*Picea* spp., *Abies* spp.
Adelges piceae	Balsam woolly adelgid	x	x	x	Europe	•		*Abies* spp.
Adelges strobilobius (=laricis)	Larch woolly aphid	x	x	x	Europe	•		*Picea* spp., *Larix* spp.
Arocatus melanocephalus	Elm seed bug	x	x	x	Europe	•		*Ulmus* spp.
Asterolecanium minus	Oak pit scale			x	Europe	•		*Quercus* spp.
Cinara tujafilina		x	x	x	Europe	•		Cupressini
Carulaspis juniperi	Juniper scale	x	x	x		•		
Dialeurodes chittendeni	Rhododendron whitefly				Asia	•		*Rhododendron* spp.
Elatobium abietinum	Spruce aphid		x	x	Europe	•		*Picea* spp.
Eriosoma ulmi	European elm leafcurl aphid				Europe	•		*Ulmus* spp.
Eucallipterus tiliae	Linden aphid	x	x	x		•		*Tilia* spp.
Euceraphis punctipennis	European birch aphid				Europe	•		*Betula* spp.
Eulecanium cerasorum	Calico scale	x	x	x		•		
Gossyparia spuria	European elm scale				Europe	•		*Ulmus* spp.
Halyomorpha halys	Brown marmorated stink bug	x	x	x	Asia	•		Fruit/vegetable crops
Icerya purchasi	Cottony cushion scale	x				•		
Lecanium corni	European fruit lecanium				Europe	•		Broad-leaved trees
Lepidosaphes ulmi	Oystershell scale	x	x	x	Europe	•		Broad-leaved trees
Metopoplax ditomoides			x	x	Europe	•		
Nezara viridula				x		•		
Periphyllus californiensis					Asia	•		*Acer* spp.
Periphyllus lyropictus	Norway maple aphid	x	x	x	Europe	•		*Acer platanoides* and other *Acer* spp.
Periphyllus testudinacea					Europe	•		*Acer* spp.
Physokermes piceae	Spruce bud scale	x	x	x	Europe	•		*Picea* spp.
Pineus strobi	Pine bark aphid				Europe	•		*Pinus* spp.
Quadraspidiotus perniciosus	San Jose scale	x	x	x	Asia	•		Broad-leaved trees
Raglius alboacuminatus			x	x	Europe and the Mediterranean Basin	•		Mint (Lamiaceae) seeds
Rhyparochromus vulgaris	Dirt-colored seed bug			x	Europe	•		
Schizolachnus pineti					Europe	•		*Pinus* spp.
Stephanitis pyrioides	Azalea lace bug		x	x	Japan	•		*Azalea* spp., *Rhododendron* spp.
Thysanoptera								
Taeniothrips inconsequens	Pear thrips		x	x				
Hymenoptera								
Agathis pumila		x	x	x	Europe		•	*Coleophora laricella*
Apanteles solitarius					Europe		•	*Stilpnotia salicis*
Caliroa cerasi	Pear sawfly	x	x	x		•		

(continued)

Table A3.3 (continued)

		Occurrence			Origin	Introduction		Plant or animal host
Scientific name	Common name	ID	OR	WA		Accidental	Intentional	
Chrysocharis laricinellae		x	x	x	Europe		•	*Coleophora laricella*
Cladius grandis				x	Eurasia	•		*Alnus* spp., *Populus* spp., *Salix* spp.
Cladius gregarius				x	Eastern North America	•		*Populus* spp.
Craesus alniastri				x	Europe	•		*Alnus* spp.
Diprion similis	Introduced pine sawfly			x	Europe	•		*Pinus* spp.
Eupareophora parca				x	Eastern North America	•		*Carya* spp., *Fraxinus* spp.
Eriocampa ovata	Alder woolly sawfly				Europe	•		*Alnus* spp.
Fenusella nana				x	Europe	•		*Betula* spp.
Fenusa pusilla	Birch leafminer	x	x	x	Europe	•		*Betula* spp.
Fenusa ulmi				x	Europe	•		*Ulmus* spp.
Gilpinia hercyniae	European spruce sawfly			x	Eurasia	•		*Picea* spp.
Halidamia affinis				x	Europe	•		*Gallium* spp.
Heterarthrus nemoratus				x	Eurasia	•		*Betula* spp.
Heterarthrus vagans				x	Eurasia	•		*Alnus* spp.
Kaliofenusa ulmi	Elm leafminer		x	x	Europe	•		*Ulmus* spp.
Macrophya punctumalbum				x	Europe	•		*Ligustrum* spp., *Syringa* spp., *Fraxinus* spp.
Mesoleius tenthredinis					Europe		•	*Pristiphora erichsonii*
Metallus lanceolatus				x	Europe	•		*Geum macrophyllum*
Meteorus versicolor					Europe		•	*Stilpnotia salicis*
Monophadnus pallescens				x	Europe	•		*Ranunculus* spp.
Monostegia abdominalis				x	Europe	•		*Glaux* spp., *Lysimachia* spp., *Anagallis* spp.
Monsoma pulveratum	Green alder sawfly	x	x	x	Europe, Asia Minor and North Africa	•		*Alnus* spp.
Nematus lipovskyi				x	Eastern North America	•		*Rhododendron* spp.
Neodiprion sertifer	European pine sawfly			x	Europe	•		*Pinus* spp.
Polistes dominulus	European paper wasp			x	Europe	•		Omnivore
Pristiphora erichsonii	Larch sawfly	x	x	x	Europe	•		*Larix* spp.
Pristiphora geniculata	Mountain ash sawfly			x	Europe	•		*Crataegus* spp., *Sorbus* spp.
Pristiphora rufipes				x	Central Europe	•		*Aquilegia* spp.
Profenusa thomsoni	Amber-marked birch leafminer			x	Eurasia	•		*Betula* spp.
Trichiocampus viminalis	Poplar sawfly	x	x	x	Europe	•		*Populus* spp., *Salix* spp.
Vespula germanica	German yellowjacket	x			Europe	•		Omnivore
Xiphydria prolongata	Willow wood wasp		x	x	Europe	•		Broad-leaved trees
Lepidoptera								
Aethes rutilana	Pale juniper webworm				Europe	•		*Juniperus* spp.
Anarsia lineatella	Peach twig borer	x	x	x		•		*Prunus* spp.
Archips rosanus					Europe	•		Broad-leaved trees

(continued)

Table A3.3 (continued)

		Occurrence			Origin	Introduction		Plant or animal host
Scientific name	Common name	ID	OR	WA		Accidental	Intentional	
Calophasia lunula	Toadflax defoliating moth	x	x	x	Eurasia		•	Dalmatian and yellow toadflax, *Linaria* spp.
Caloptilia negundella	Boxelder leafroller				Europe	•		*Acer* spp.
Caloptilia syringella	Lilac leafminer				Europe	•		Lilac and *Fraxinus* spp.
Cnephasia longana	Omnivorous leaftier				Europe	•		*Pseudotsuga* spp. and broad-leaved trees
Coleophora laricella	Larch casebearer	x	x	x	Europe	•		*Larix* spp.
Coleophora serratella	Birch casebearer		x	x	Europe	•		*Betula* spp.
Dichomeris marginella	Juniper webworm	x	x		Europe	•		*Juniperus* spp.
Enarmonia formosana	Cherry bark tortrix		x	x	Eurasia	•		*Crataegus* spp., *Malus* spp., *Prunus* spp., *Pyrus* spp., *Sorbus* spp.
Epinotia nanana	European spruce needleminer		x	x	Europe	•		*Picea* spp.
Homadaula anisocentra	Mimosa webworm				Unknown	•		*Albizia* spp., *Gleditsia* spp.
Leucoma salicis	Satin moth	x	x	x	Europe	•		*Populus* spp., *Salix* spp.
Leucoptera spartifoliella					Europe		•	Scotch broom, *Cytisus scoparius*
Lymantria dispar dispar[a]	North American gypsy moth				Europe	•		Broad-leaved trees
Lymantria dispar asiatica/japonica[a]	Asian gypsy moth				Asia	•		Broad-leaved trees and conifers
Ocnerostoma piniariellum					Europe	•		*Pinus* spp.
Operophtera brumata	Winter moth		x	x	Europe	•		Broad-leaved trees and agricultural crops
Pandemis cerasana					Europe	•		Broad-leaved trees
Rhyacionia buoliana	European pine shoot moth	x	x	x	Europe	•		*Pinus* spp.
Spilonota ocellana	Eyespotted bud moth		x		Europe	•		*Quercus* spp. and other broad-leaved trees
Synanthedon myopaeformis	Apple clearwing moth			x	Europe, Mediterranean Basin	•		*Crataegus* spp., *Malus* spp., *Prunus* spp., *Pyrus* spp.
Synanthedon scitula	Eastern dogwood borer			x	Eastern North America	•		Broad-leaved trees esp. *Cornus* spp., *Carya* spp., *Malus* spp.
Tyria jacobaeae	Cinnabar moth		x	x	Europe		•	Tansy ragwort, *Senecio jacobaea*

[a]Detected repeatedly in the Northwest region, but eradicated. [O] Native range within the region

This list was compiled primarily from Furniss and Carolin (1977) with additions from Acheampong et al. (2016), Bai et al. (2002), Bellows et al. (1998), Childs and Swanson (2003), Doerr et al. (2008), Foote et al. (1993), Gerberg (1957), Hatch (1953, 1962), Hayes and Ragenovich (2001), Hitchcock et al. (2002), Idaho State Department of Agriculture (2013), Ivie (2002), Johnson (1998), Kruse et al. (2010), LaBonte et al. (2005), LaGasa (2006), LaGasa and Murray (2007), Lee et al. (2009, 2011), Looney et al. (2012, 2016a,2016b), Mudge et al. (2001), Murray et al. (2012, 2013), Nugent (2005), Phillips (2002), Rabaglia et al. (2006, 2019), Rosetta (2013), Sabrosky and Reardon (1976), Seybold and Downing (2009), Sing et al. (2016), Vernon et al. (2001), USDA (1986, 2019), Washington Invasive Species Council (2012), White (1982), and Winston et al. (2014a, b)

US Department of Agriculture 2009. National Agriculture Library. Species Profiles. Accessed online at http://www.invasivespeciesinfo.gov/plants/main.shtml

Other terrestrial invertebrates found in Oregon and Washington include *Amynthas agrestis* (Crazy snake/Asian jumping earthworm), giant African snail (*Achatina fulica*), vineyard snail (*Cernuella virgata*), white garden snail (*Theba pisana*), heath snail (*Xerolenta obvia*)

Table A3.4 Priority non-native invasive aquatic invertebrates (noninsect) of the Northwest region

Scientific name	Common name	ID	OR	WA	R6[a]
Potamocorbula amurensis	Asian clam	x	x		x
Radix auricularia	Big-eared radix				x
Eriocheir sinensis	Chinese mitten crab		x	x	
Cipangopaludina chinensis, C. japonica	Chinese mystery snail, Japanese mystery snail	x			x
Orconectes spp., *O. virilis; Procambarus* spp.	Crayfish (red swamp, rusty, ringed, virile, marbled, signal, red claw, yabby, marron)	x		x	x
Carcinus maenas	European green crab			x	
Potamopyrgus antipodarum	New Zealand mud snail	x		x	x
Philine auriformis	New Zealand sea slug		x		
Bythotrephes longimanus [*cederstroemi*], *Cercopagis pengoi*	Water fleas	x	x		
Dreissena polymorpha, D. rostriformis bugensis	Zebra/quagga mussels	x	x	x	x

[a]R6 = USDA Forest Service Region 6 (OR, WA) priority invasive species

Table A3.5 Priority non-native invasive vertebrates of the Northwest region

Scientific name	Common name	ID	OR	WA	R6[a]
Aquatic vertebrates					
Lithobates catesbeianus (*Rana catesbeiana*)	American bullfrog	x		x	x
Amia calva	Bowfin	x			
Hypophthalmichthys spp., *Mylopharyngodon piceus*	Carp (Asian, black, big head, diploid grass, silver)	x	x	x	
Salmo salar	Atlantic salmon		x	x	
Didemnum vexillum	Didemnum tunicate			x	
Chelydra serpentina serpentina	Eastern snapping turtle	x	x		
Lepisosteidae spp.	Gar	x			
Neogobius melanostomus, Rhinogobius brunneus, Tridentiger bifasciatus	Goby	x	x		
Notemigonus crysoleucas	Golden shiner		x		
Acipenser medirostris	Green sturgeon	x			
Leuciscus idus	Ide	x			
Esox spp.	Muskellunge/northern pike		x		
Serrasalmus spp., *Rosseveltiella* spp., *Pygocentrus* spp.	Piranhas	x			
Trachemys scripta elegans	Red-eared slider	x			
Taricha granulosa	Rough-skinned newt	x			
Scardinius erythrophthalmus	Rudd	x			
Gymnocephalus cernuus	Ruffe	x	x		
Channa spp.	Snakehead	x	x	x	
Dorosoma petenense	Threadfin shad (yellowtails)		x		
Clarias spp.	Walking catfish	x			
Terrestrial vertebrates					
Sus scrofa	Feral swine		x	x	x
Cygnus olor	Mute swan		x		
Myocastor coypus	Nutria	x	x	x	x

[a]R6 = USDA Forest Service Region 6 (OR, WA) priority invasive species

wildlife (Edwards 1999). Toxic algal blooms are enhanced by high water temperatures and fertilizer runoff. The diatom rock snot (didymo) is actually native to the Pacific Northwest, but in the mid-1980s, it became more prolific in its distribution and began to impact recreational activity.

Three invasive terrestrial plants—Himalayan blackberry (*Rubus armeniacus*), Japanese knotweed (*Fallopia japonica*), and giant hogweed (*Heracleum mantegazzianum*)—are problematic in both upland and riparian environments in the Marine West Coast Forest ecoregion (Fig. A3.3a). These very abundant species were introduced intentionally as ornamentals or crops. They tend to shade out smaller native plants, reducing plant diversity and limiting habitat and food sources for both birds and native wildlife. Native to Western Europe, Himalayan blackberry is an evergreen woody vine whose canes have large stiff prickles and form dense thickets. Its growth form approximates a shrub in terms of how animals use it and its height in the environment. The plant is very common in the Northwest region, providing prolific berries that are collected recreationally

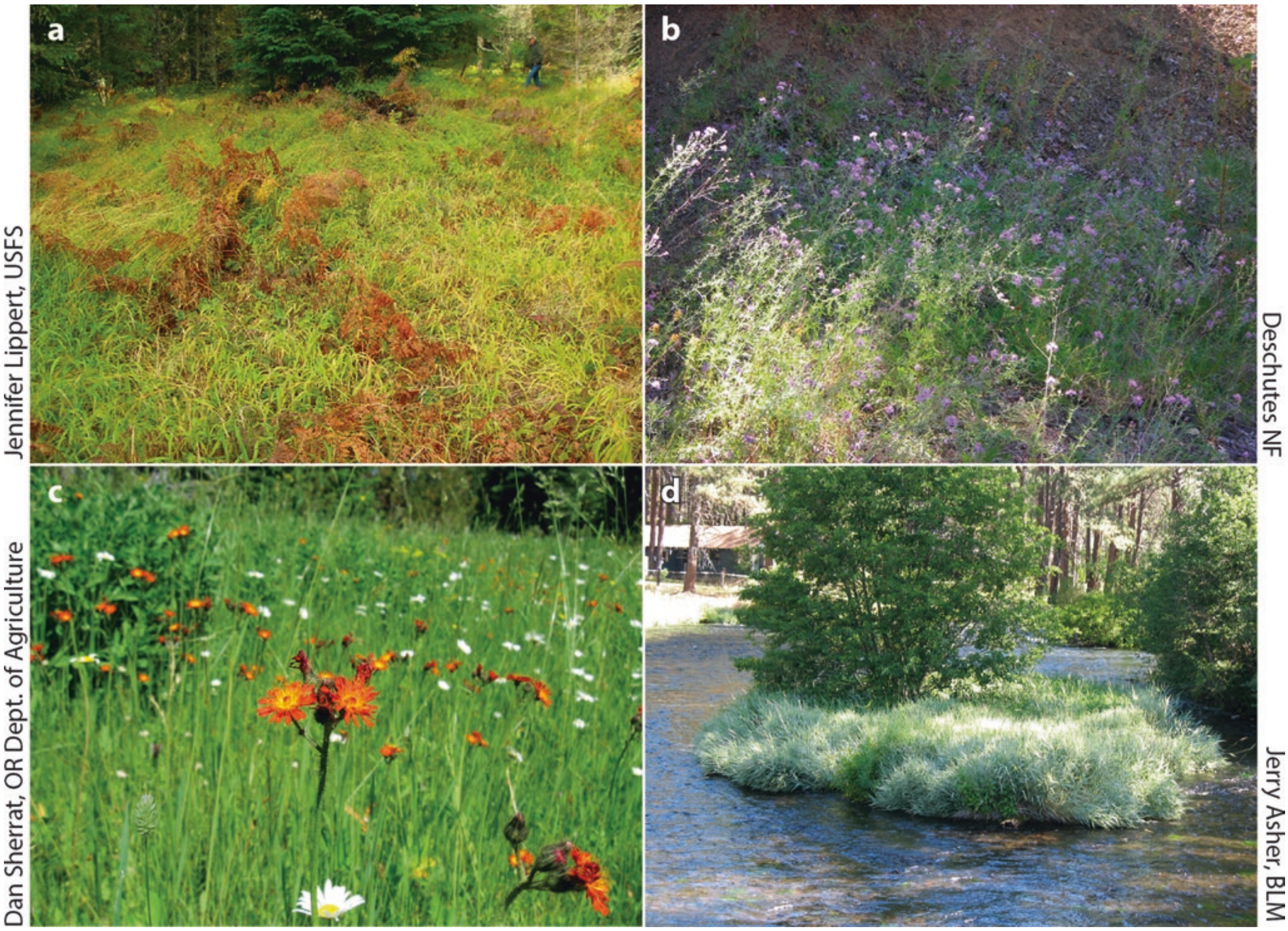

Fig. A3.3 Invasive plants in the Northwest region include (**a**) false brome (*Brachypodium* spp.), on the Willamette National Forest, OR; (**b**) roadside infestation of spotted knapweed (*Centaurea stoebe*) on the Deschutes National Forest, OR; (**c**) orange hawkweed (*Hieracium aurantiacum*) on the Wallowa-Whitman National Forest, OR; (**d**) ribbon grass, a striped horticultural variety of reed canary grass (*Phalaris arundinacea*), on an islet in the Metolius River, Deschutes National Forest, OR

and commercially (Stannard 2014). The thickets, mounds, or banks can completely and permanently exclude other plant species and pose a potential fire hazard. Japanese knotweed, native originally to Asia, but introduced to the Netherlands in 1829 (The Knotweed Company Ltd. 2018), and giant hogweed, native to the Caucasus region of Eurasia, can grow as tall as 15–20 ft. and spread rapidly. Japanese knotweed is known globally as one of the world's most destructive invasive species because its large underground root system can damage structures, walls, and architectural sites, as well as reduce channel capacity. Giant hogweed is considered a public health hazard because it causes a phototoxic reaction when animal skin is exposed to sap and ultraviolet radiation.

Many of the invasive plants in the Northwest region were imported initially as ornamentals to either the area, or, more generally, North America. Some examples are English ivy (native to the United Kingdom), old man's beard (native to the United Kingdom), orange hawkweed (native to Europe), yellow archangel (native to Europe/Western Asia), garlic mustard (native to Europe and Asia), Scotch broom (native to Europe and North Africa), purple loosestrife (native to Europe and Asia), and saltcedar (*Tamarix* spp., native to Europe and Asia) (Table A3.1). Saltcedars (see Southwest region summary) are riparian shrubs or small trees that are aggressively invasive. Populations of these plants are prevalent in the warm and dry riparian corridors of the Blue Mountains and Cold Basins Ecoregions of eastern Oregon and Washington along the Owyhee, Snake, and John Day Rivers, and in the Columbia Plateau Ecoregion (Fig. A3.2) (Thorson et al. 2003). These riparian trees are known to decrease stream flows, lower biodiversity, and create salinization issues. Purple loosestrife is a wetland forb that can rapidly establish and replace native vegetation with a dense, homogeneous stand that reduces local biodiversity, endangers rare species, and provides little value to wildlife. English ivy and old man's beard are both vigorous creepers that not only cover terrestrial surfaces but will climb high into trees and smother competing vegetation. Garlic mustard was initially introduced to the East Coast of North America as a medicinal herb, but it has spread through forest understories and competes with native species. Orange hawkweed and yellow archangel are also understory shade plants that spread vigorously and smother competing native plants.

Many of the remaining invasive upland plants (Table A3.1) are weed species that can become dominant in meadow, range, or forest habitats, often creating monocultures. Most of these species were introduced accidentally, although some were introduced as ornamentals (i.e., Dalmatian toadflax). They can severely degrade the quality of range habitats for cattle and other domestic and native ungulates (i.e., cheatgrass, knapweeds). Although they are not toxic specifically to livestock as are some other species (i.e., some knapweeds, tansy ragwort), they can cause mechanical damage to the animals. In addition, invasive annual grasses like cheatgrass, medusahead, and ventenata are considered highly detrimental in the interior Western United States because they have the potential to alter wildfire regimes in some areas (see Chap. 2, Box 2.1; and the Southwest region summary for additional discussion of these issues). These species are problematic largely in the Blue Mountains and Cold Basins Ecoregions of the Northwest region (Fig. A3.2). Western juniper (*Juniperus occidentalis*) is an example of a native species that is often managed as an invasive species due to emergent concerns of its ecological and economic impact in the interior ecoregions, including degrading habitat for the threatened greater sage-grouse (*Centrocercus urophasianus*). Juniper management may be problematic, however, because removal can encourage exotic weedy grasses like cheatgrass to invade cut areas.

Plant Pathogens

In the Pacific Northwest, invasive pathogens (fungi, water molds, bacteria, nematodes, and viruses) are a significant forestry problem for wood production as well as for urban and rural landscaping (Table A3.2). Two of the most damaging invasive species are in the genus *Phytophthora*, "water molds" in the kingdom Straminipila (formerly Chromista), which includes aquatic organisms such as diatoms and kelp (Dick 2001). These fungi-like microbes thrive in wet conditions, so hydric or mesic native ecosystems west of the Cascade Mountains and well-irrigated nurseries of the Northwest region are conducive for their growth and reproduction. Notably, all three of the destructive pathogens described below were introduced on imported nursery stock, illustrating the significance of the nursery pathway (Liebhold et al. 2012) in the Northwest region.

Sudden Oak Death (*Phytophthora ramorum*) First discovered in this region in coastal forests of southwest Oregon in 2001, *Phytophthora ramorum* causes sudden oak death and other diseases. It is lethal to tanoak (*Notholithocarpus densiflorus*) and threatens this species throughout its range in Oregon (Kanaskie et al. 2017) (see Chap. 2, Box 2.5; Chap. 6, Sect. 6.4.2; Chap. 7, Sect. 7.4.2; and the Southwest regional summary for additional discussion of this pathogen). The pathogen also infects *Rhododendron*, *Viburnum*, and other important plant species in Pacific Northwest horticultural nurseries so the Federal and State quarantines affect the nursery industry throughout Oregon and Washington as well as forestry interests in part of Oregon's Curry County. The pathogen was inadvertently introduced to Oregon forests via infested nursery stock that originated in either California or Oregon (Kamvar et al. 2015).

From 2001 to 2012, a Federal and State interagency team attempted to eradicate the pathogen from Oregon, supported by the Oregon quarantine that required destruction of infected and nearby uninfested host plants. Although eradication treatments eliminated this disease from many infested sites, the pathogen continued to spread slowly. The wildland quarantine area has expanded from 22 km^2 (9 mi^2) in 2001 to 1333 km^2 (515 mi^2) in 2017, affecting over 30% of Curry County. Hundreds of thousands of tanoaks have died from *P. ramorum* in southwest Oregon (Kanaskie et al. 2013).

In 2015, a second significant introduction of the pathogen was detected in this region—the first find of the *P. ramorum* EU1 lineage (European Union Lineage One) in a US forest. The detection (on a tanoak tree) was approximately 1.6 km (1 mi) north of a small private nursery (now closed) near the Pistol River which, once again, underscores the importance of the nursery pathway for long-distance invasive pathogen movement (Grünwald et al. 2016). In Europe, the EU1 lineage of *P. ramorum* damages and kills several conifer species of significance to the Northwest region, including larch (*Larix* spp.), Douglas fir (*Pseudotsuga menziesii*), western hemlock (*Tsuga heterophylla*), and grand fir (*Abies grandis*) (Webber et al. 2010). In 2016, the EU1 strain was detected in an Oregon rural forest for a second time, less than 1.6 km (1 mi) south of the original 2015 detection (California Oak Mortality Task Force 2016).

Current management of *P. ramorum* focuses on early detection and rapid response. To support the overall goal of containment, new infections outside of the generally infested area are eradicated. With detection of new infections on the rise, management strategies will need to include a general, integrated pest management approach to minimize the impact to urban and rural forests susceptible to *P. ramorum* in the Northwest region.

Port-Orford-Cedar Root Disease (*Phytophthora lateralis*) Port-Orford-cedar or Lawson's cypress

(*Chamaecyparis lawsoniana*) is a large, beautiful conifer, endemic to southwestern Oregon and northwestern California (Zobel 1990). It is planted frequently in urban areas of the Pacific Northwest. However, the introduction and spread of the exotic fungus-like pathogen *Phytophthora lateralis* has caused high mortality levels on high-risk sites in old-growth Port-Orford-cedar forests (Fig. A3.4) and in ornamental landscapes (Hansen 2011) (see the Southwest regional summary for additional discussion of this pathogen).

The pathogen was introduced on infected nursery stock near Seattle, WA, in the 1920s and moved southward on horticultural plantings until it reached native southwest Oregon forest stands in 1952 (Hansen 2011). Port-Orford-cedar and Pacific yew (*Taxus brevifolia*) are the only native North American tree species known to be susceptible to *P. lateralis* (DeNitto and Kliejunas 1991), but the pathogen can persist in soil for more than 5 years (Hansen and Hamm 1996). The pathogen moves via transport of infected nursery plants, infested soil, and contaminated runoff water, and disease spread is correlated with proximity to roads and rivers (Hansen et al. 2000).

Several management practices are recommended to minimize the impact of Port-Orford-cedar root disease. The best management strategy involves a combination of appropriate techniques tailored for use in a specific site or landscape. These include planting resistant trees, closing forest roads during the wet season, limiting activities involving heavy equipment (e.g., timber harvesting, road maintenance) to the summer dry season, washing vehicles before they enter uninfested areas, paving road surfaces, and using only pathogen-free water for dust abatement and firefighting (Betlejewski et al. 2011; Hansen et al. 2000).

White Pine Blister Rust (*Cronartium ribicola*) In the Northwest region, white pine blister rust (*Cronartium ribicola*) threatens, damages, or kills western white pine (*Pinus monticola*), sugar pine (*P. lambertiana*), and other high-elevation white (five-needle) pines, i.e., whitebark (*P. albicaulis*) and limber (*P. flexilis*). The future of whitebark pine in the Pacific Northwest is a serious concern due to *C. ribicola* infection and the effects of colonization by mountain pine beetle (*Dendroctonus ponderosae*), wildfire, climate change, and other factors (Aubry et al. 2008).

Cronartium ribicola is one of the most damaging invasive pathogens in US forests and parks (Benedict 1981; Boyce 1938; Vitousek et al. 1996) (see also Chap. 7, Sect. 7.3.2; and the Southwest regional summary for additional discussion of this pathogen). The rust, which is native to Asia, was introduced to Western North America around 1910, on nursery stock from France imported into Vancouver, British Columbia, Canada (Liebhold et al. 2012). The 1912 Plant Quarantine Act was prompted by its introduction, with US Quarantine No. 1 prohibiting import of five-needle pines (Maloy 1997).

In the Northwest region, surveys for *C. ribicola* began around Puget Sound, WA, in 1917, with the first detection in Washington reported on black currant (*Ribes* spp.) and western white pine in 1921 (Detwiler 1922, as cited by Geils et al. 2010). Over the next several decades, the pathogen had spread on that host throughout much of Washington and

Fig. A3.4 Port-Orford-cedar killed by *Phytophthora lateralis* on the Gold Beach Ranger District, Rogue River-Siskiyou National Forest. (Figure courtesy of Ellen Goheen, USDA Forest Service Northwestern Region, Forest Health Protection)

Oregon, but was also detected on whitebark pine (Geils et al. 2010).

This rust fungus is an obligate, biotrophic (requires a live host) pathogen with a complex life cycle that requires an alternate host, primarily currants, along with the white pine host for the disease to occur (Geils et al. 2010). The Civilian Conservation Corps undertook extensive efforts to control the disease by removing *Ribes* species in the 1930s (Benedict 1981), but contemporary management favors resistance breeding programs (Kegley et al. 2012; Schoettle et al. 2012), as well as pruning young stands to minimize infections in the lower crowns and protecting larger trees from other mortality agents, such as fire and mountain pine beetle (Goheen and Goheen 2014) (see also Chap. 7, Table 7.2).

Insects

A late twentieth-century summary of extra-continental forest insects known to have been established in Western North America suggested that 75 species had been introduced and that 17 of these were purposeful introductions—releases as biological agents for the control of insects or noxious plants (Furniss and Carolin 1977). Many of these historical introduced species, as well as some new species, have established populations in the Northwest region (Table A3.3) (Furniss and Carolin 1977; Hayes and Ragenovich 2001; LaBonte et al. 2005; Mudge et al. 2001; Rabaglia et al. 2019; Seybold and Downing 2009). A large number of additional purposeful introductions have been made in the Northwest region for the biological control of urban and wildland forest pests (Bellows et al. 1998) or invasive plants (Sing et al. 2016; Winston et al. 2014a, b). Though not invasive species in the strict sense, we include these purposefully introduced taxa (Table A3.3) to maintain continuity with the original summary by Furniss and Carolin (1977). The European (North American) gypsy moth (*Lymantria dispar dispar*) was included in the historical summary (Furniss and Carolin 1977), but the Asian gypsy moth (*Lymantria dispar asiatica/japonica*) has been detected recently in the vicinity of the coastal ports of the Northwest region (see below). Furthermore, this region has sustained new invasions by pest insects that threaten valuable horticultural crops. Several insect species that already damage or threaten to damage forest trees and horticultural crops in the Northwest region are highlighted below.

Balsam Woolly Adelgid (*Adelges piceae*) A tiny (about 1-mm-long) sap-sucking insect, the balsam woolly adelgid (*Adelges piceae*) (Fig. A3.5), is probably the most prominent invasive pest of forest trees in the Northwest region (Ragenovich and Mitchell 2006) (see Southeast and Caribbean regional summary for further discussion of this species). It first appeared on the West Coast in the late 1920s (Annand 1928; Keen 1952). In this region, it infests primarily subalpine fir, Pacific silver fir (*Abies amabilis*), and grand fir (*A. grandis*) (Ragenovich and Mitchell 2006). Other susceptible hosts include noble fir (*A. procera*), Shasta fir (*A. magnifica*), and white fir (*A. concolor*). Subalpine fir and Pacific silver fir are impacted to a greater degree in

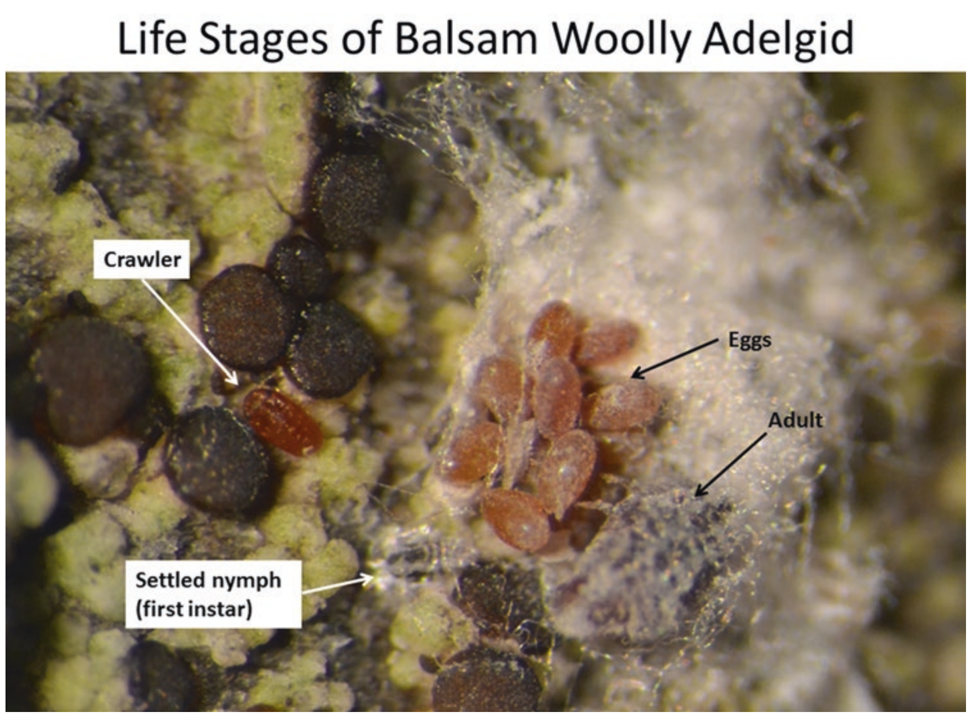

Fig. A3.5 Life stages of the balsam woolly adelgid (*Adelges piceae*). (Figure courtesy of USDA Forest Service Northwestern Region, Forest Health Protection) mountainous areas, whereas grand fir is impacted to a greater degree in lowland valleys. The symptoms of attack by balsam woolly adelgid, especially on young fir trees, include buds failing to open and twigs becoming enlarged at the nodes and around the buds. Feeding by the insect results in stem and twig injury whereby the adelgid injects a substance into the inner bark, resulting in abnormal cell division and differentiation in the inner bark and newly formed wood. In the 1950s, a major balsam woolly adelgid outbreak killed or "seriously weakened" over 3,539,606 m^3 (1.5 billion board feet) of mature Pacific silver fir trees across 161,874 ha (400,000 ac) in southwestern Washington (Johnson et al. 1963). The life cycle of this species (and related adelgids) is unusual (Havill and Foottit 2007; Havill et al. 2011). North American populations are composed entirely of females; thus reproduction is parthenogenetic (i.e., without mating and fertilization). Adults are dark purple to black, nearly spherical, and wingless (Fig. A3.5). They produce a thick mass of a white waxy wool-like material that covers the body and protects the adult and her eggs (Fig. A3.5).

The range of balsam woolly adelgid has been expanding in the eastern portion of the Northwest region (Fig. A3.6) (Gast et al. 1990; Hrinkevich et al. 2016; Lowrey and Davis 2017). In apparent synergy with climate change effects, the invasive threat here is to high-elevation stands of subalpine fir, which play an important ecological function in regulation of snow melt and wildlife habitat and have a modest, yet measureable, timber value (Alexander 1987; Steele et al. 1981). Although 20 predaceous insects were introduced to the West for the biological control of balsam woolly adelgid (Table A3.3) (Bellows et al. 1998; Mitchell and Wright 1967), only 5 species were considered established in 1998 (*Aphidoletes thompsoni*, *Pullus impexus*, *Laricobius erichsonii*, *Cremifania nigrocellulata*, and *Leucopis obscura*), and Bellows et al. (1998) characterized the

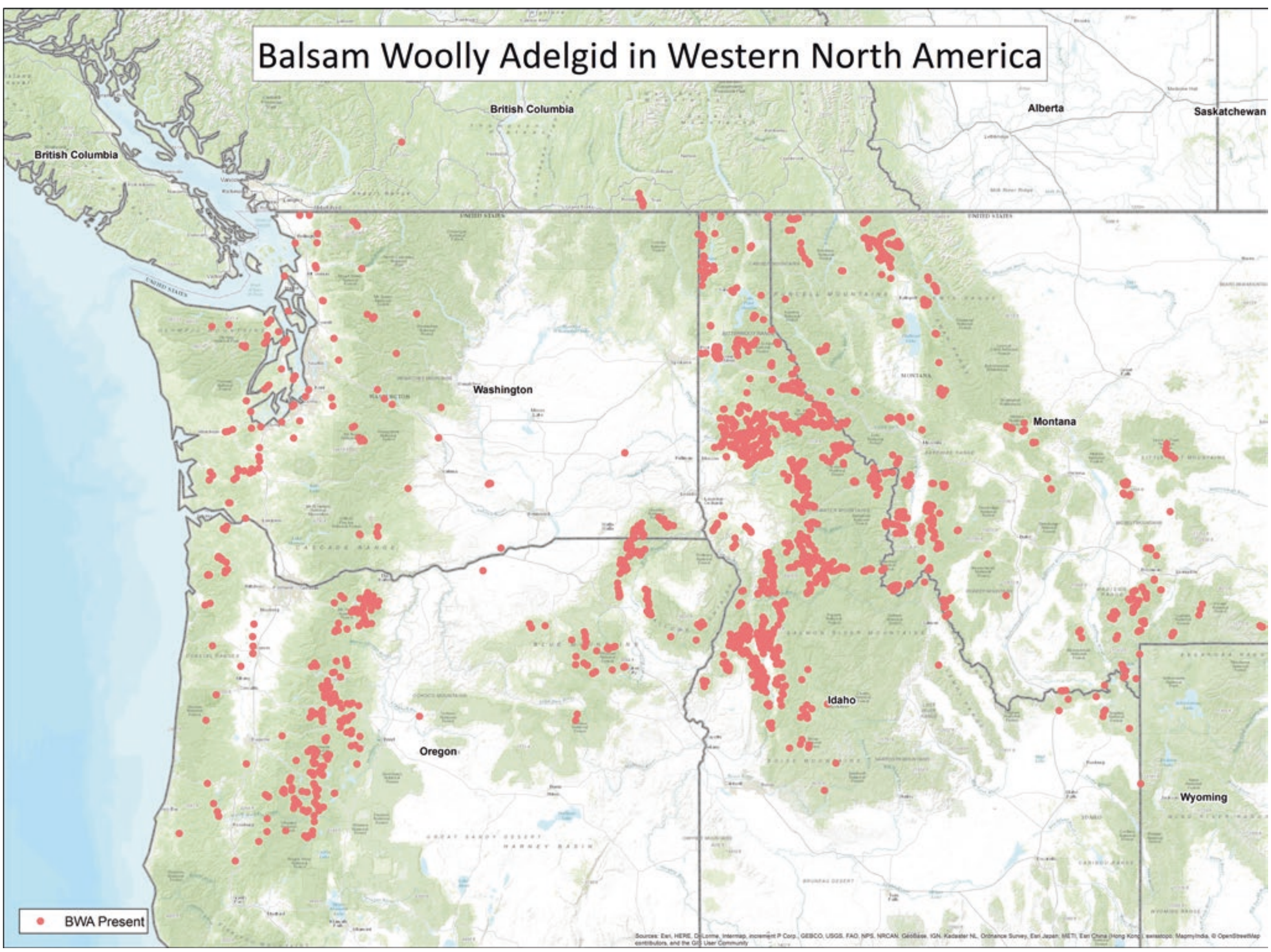

Fig. A3.6 Distribution of the balsam woolly adelgid (*Adelges piceae*) in the Northwest region of the United States and Canada as of spring 2016 based on georeferenced collection records and positive identification of specimens. (Figure courtesy of Amy Gannon, Montana Department of Natural Resources and Conservation, Missoula, MT) effectiveness of the biological control as "variable and somewhat limited." It is unknown whether any of these species (released in Oregon, Washington, and British Columbia) may have spread into the expanding range of balsam woolly adelgid in the eastern portion of the Northwest region (Lowrey and Davis 2017).

Hemlock Woolly Adelgid (*Adelges tsugae*) Hemlock woolly adelgid (*Adelges tsugae*) is an economically and ecologically important invasive pest of hemlock trees (*Tsuga* spp.) in eastern North America (McClure et al. 1996) that has only had minor impacts to ornamentals and other plantings in the Northwest region (Furniss and Carolin 1977) (see the Southeast and Caribbean regional summary for further discussion of this species). Western hosts include western hemlock, *T. heterophylla*, and mountain hemlock (*T. mertensiana*), though the latter has only been colonized in adventive plantings (Havill et al. 2016). Recent molecular analyses (microsatellite and mitochondrial DNA sequences) have revealed that populations of hemlock woolly adelgid in the Northwest region are a consequence of an ancient colonization event from an ancestor whose host was an Asian hemlock (*T. sieboldii*) (Havill et al. 2016). Colonization of Western North America was estimated to have occurred prior to the last glacial period by adelgids directly ancestral to those in southern Japan, perhaps carried by birds. Havill et al. (2011) report that the earliest North American specimens were collected in 1907 from South Bend, WA (US National Collection of Insects, Beltsville, MD). Other early records from the West include a report of damage to western hemlocks in Vancouver, British Columbia (Chrystal 1916), and specimens collected in Oregon and California that were used to formally describe hemlock woolly adelgid as a new species (Annand 1924). Populations of adelgids in the Northwest Region have served as important sources of natural enemies for the biological control program for hemlock woolly adelgid in the Eastern United States (McClure 2001; Reardon et al. 2004). Two non-native species in this program, a beetle, *Laricobius erichsonii*, and a fly, *Leucopis obscura*, were introduced originally into the Northwest region to control hemlock woolly adelgid (Furniss and Carolin 1977). However, a native species of beetle, *Laricobius nigrinus*, and two native species of flies, *Leucopis argenticollis* and *Leucopis piniperda*, have been recognized as predators of hemlock woolly adelgid in Idaho (*L. nigrinus* only), Oregon, and Washington and were moved subsequently by specialists to the Eastern United States for biological control (Kohler et al. 2008, 2016; Mausel et al. 2011).

An ensemble of other sapsucking insects has invaded the Northwest region and has, at times, threatened the health of native trees (Table A3.3). These include larch woolly aphid, eastern spruce gall aphid, spruce aphid, European elm scale, European birch aphid, and pine bark aphid.

Larch Casebearer (*Coleophora laricella*) Larch casebearer (*Coleophora laricella*) is a small moth whose larvae feed in the needles of western larch (*Larix occidentalis*), in the Northwest region. The species was introduced from Europe first to the Eastern United States in 1886 (Bellows et al. 1998) and detected in western larch near St. Maries, ID, in 1957 (Tunnock and Ryan 1985). In the 1970s, it caused significant damage to western larch in the Blue Mountains (OR and WA). Its invaded range in this region is now coincident with that of western larch, which is present in all three States of the Northwest region, as well as in Montana and southern Canada (Tunnock and Ryan 1985). Beginning in the 1960s, ten parasitoid wasps were introduced into the region from eastern North America, Europe, and Japan (Bellows et al. 1998); two of the parasitoids, *Agathis pumila* and *Chrysocharis laricinellae*, established populations in the Blue Mountains and appeared to significantly lower the population density of larch casebearer to the point that "the species is no longer considered a pest in the West" (Bellows et al. 1998; Ryan 1997). However, Hayes and Ragenovich (2001) suggested that the level of control of larch casebearer in eastern Oregon relaxed in the late 1990s such that insect population densities and western larch defoliation increased. A subsequent survey in this area for both larch casebearer and the two principal parasitoids revealed that both the defoliator and the introduced natural enemies were widespread, that parasitism rates ranged from 1.8% to 53.4%, and that moth population density was negatively correlated with percentage parasitism by *A. pumila* (Shaw and Oester 2010).

Gypsy Moths (*Lymantria* spp.) Larvae of two non-native invasive moths are a constant and recurring threat for introduction and establishment in the Northwest region. These defoliators are the European (North American) gypsy moth (*Lymantria dispar dispar*) and the Asian gypsy moth (*Lymantria asiatica/japonica*) (see Chap. 2, Sect. 2.3; Chap. 7, Sect. 7.4.1; and the Southwest and Southeast and Caribbean regional summaries for additional discussion of this insect complex). Potential sources of European gypsy moth include populations from northeastern and North central North America (introduced and established first in Medford, MA, in 1869) and ancestral locations in Europe; sources of Asian gypsy moth include Siberia, the Russian Far East, Korea, China, and Japan. The Canadian province of British Columbia has also experienced frequent introductions and attempted eradications of these moths (Myers et al. 2000). These ecologically and behaviorally distinct subspecies were distinguished initially by mitochondrial and nuclear DNA sequencing techniques, including microsatellite DNA analysis (Bogdanowicz et al. 1993, 1997, 2000). Other workers have used more sophisticated approaches and methodology, including real-time multiplex PCR (Djoumad et al. 2017; Islam et al. 2015; Stewart et al. 2016). With its broader host range (that includes conifers) and the flight capacity of females, Asian gypsy moth is considered a greater threat to the forests of the Western United States. Other potentially invasive moth defoliators that threaten forest trees in the Northwest region are the nun moth (*L. monacha*), the pink gypsy moth (*L. mathura*), and the Siberian moth (*Dendrolimus superans sibiricus*) (Hayes and Ragenovich 2001). Three other *Lymantria* species in Japan are also recognized as threats to Northwest region forests, *L. albescens*, *L. umbrosa*, and *L. postalba*, which are all listed as quarantine pests by the North Atlantic Plant Protection Organization (NAPPO).

Increased trade with the Russian Far East and other parts of Asia has greatly increased the frequency of encounters that regulatory entomologists face with Asian gypsy moth and other lymantriid moths. In 1990 and 1991, an introduced population of Asian gypsy moth was detected in pheromone-baited traps primarily around Tacoma, WA (Bogdanowicz et al. 1993), which resulted in a 47,146-ha (116,500-ac) eradication program. In a similar scenario in 2015, trap captures of ten Asian gypsy moth males in Washington (primarily in the southern half of the Puget Sound area) and two Asian gypsy moth males near Portland, OR, revealed that an incipient population of Asian gypsy moth with gravid adult females may have occurred on the U.S. mainland. Potential pathways included egg masses or pupae attached to ship cargo from Asia and then moved inland as the cargo was offloaded or dispersal of young larvae or adults from cargo on board or from the ship superstructure to sites on shore. These pathways are likely as Asian gypsy moth egg masses are intercepted annually on ships and cargo in Washington and Oregon ports. One male Asian gypsy moth has been trapped as far inland as northern Idaho (Kootenai County), with speculation that the insect was transported on a shipping container along a nearby rail line (Lech and Livingston 2004; Pederson et al. 2004). To mitigate introductions, USDA entomologists have long pursued a cooperative assistance program with their foreign counterparts in and around ports in the Russian Far East, Japan, Korea, and China to detect and manage these potential invaders (Freyman 2015; Humble et al. 2013; USDA 1993, 2016). To further reduce interceptions of Asian gypsy moth and other lymantriids in North America, NAPPO developed Regional Standards for Phytosanitary Measures (RSPM 33: Guidelines for Regulating the Movement of Vessels from Areas Infested with the Asian Gypsy Moth).

In response to the 2015 detection of Asian gypsy moth, a technical working group proposed a combination of insecticide treatment and delimitation trapping in the areas where moths were detected. Three- and six-mile (4.8- and 9.7-km) radius zones were established around each of six locations. A microbially based material, *Bacillus thuringiensis* var. *kurstaki* (Btk), was applied aerially three times within the designated treatment areas of more than 4047 ha (10,000 acres) in Washington and 2833 ha (7000 ac) in Oregon. Approximately 11,000 delimitation traps were placed in Washington, and approximately 3100 traps were placed in Oregon. The estimated cost for the 2016 Asian gypsy moth eradication program was $5 million. Detections of Asian gypsy moth in the Northwest region are continually being made against a backdrop of detections of European gypsy moth, presumably from introductions from eastern North America. In 2015, a population of European gypsy moth found in the Seattle area raised the concern that this population might mix with the contemporaneously detected Asian gypsy moth populations.

Sawfly Defoliators (Hymenoptera, Symphyta) A major survey for native and non-native invasive sawflies has revealed a large number of new defoliators in Washington and Oregon (Table A3.3) (Looney et al. 2012, 2016a, b). At least 20 species were found when field trap catches or museum collections were evaluated, and these were primarily free feeding or leaf-mining forms on hardwoods (alder, birch, elm, etc.), shrubs, and herbaceous vegetation. Many of the species were originally from Europe, but had first invaded eastern North America before they were introduced into the Northwest region (Looney et al. 2016b). Some key forest pests of note are the green alder sawfly (*Monsoma pulveratum*), which has also been damaging alder in Alaska (Kruse et al. 2010), the introduced and European pine sawflies (*Diprion similis* and *Neodiprion sertifer*, respectively), the European spruce sawfly (*Gilpinia hercyniae*), and various leafminers on birch (*Fenusa pusilla*, *Fenusella nana*, and *Profenusa thomsoni*). The ultimate impact of these new species to the region—mostly collected since the mid-2000s—is unknown, but the local biology, feeding behavior, and interactions within this assemblage of invading defoliators bear future scrutiny.

Spotted Wing Drosophila (*Drosophila suzukii*) The spotted wing drosophila (SWD) (*Drosophila suzukii*) was first found in August 2008 in the US mainland in California (Hauser 2011). Infestations were reported soon thereafter in 2009 in Oregon and Washington (Lee et al. 2011) and in 2012 in Idaho. While SWD is a primary economic concern in blackberry, blueberry, cherry, and raspberry crops, this insect species has a wide host range that includes many wild and ornamental hosts, which enables it to persist in woodland areas (Kenis et al. 2016; Lee et al. 2015). In a 2-year study at 35 farms, SWD were captured earlier in farms that had more woodland area surrounding the farm (Pelton et al. 2016).

These woodland habitats often contained wild blackberry and wild cherry in mid-summer and other fall-bearing fruit that may provide SWD with a late-season host after the crop has been harvested. A study that marked wild blackberry borders revealed that SWD moved from there and into the raspberry crop in the summer (Klick et al. 2015). Within agricultural areas, SWD is primarily managed with insecticides (Bruck et al. 2011). Classical biological control agents for SWD from Asia are being evaluated and are still under quarantine. Endemic parasitoids, such as the pupal parasitoid *Pachycrepoideus vindemiae* and the larval parasitoid *Leptopilina heterotoma*, have been found to attack sentinel SWD in mixed farm, raspberry, blueberry, and riparian habitats of Oregon (Miller et al. 2015). Although parasitism counts were low, conserving or augmenting these biological control agents may lead to greater pest suppression in unmanaged areas.

Brown Marmorated Stink Bug (*Halyomorpha halys*) The brown marmorated stink bug (BMSB) (*Halyomorpha halys*) was first found in Portland, OR, in 2004 and in Vancouver, WA, in 2010 (ODA 2010; Wiman and Lowenstein 2017). As with the invasion process in the East Coast, BMSB was first a nuisance pest reported by homeowners and then appeared in agricultural crops and spread to every county in the Willamette Valley of Oregon, Hood River, and southern Oregon. By 2013, economic losses from BMSB were reported in the northern Willamette Valley (Wiman and Lowenstein 2017). Although BMSB is a primary economic concern to stone fruit, vegetables, and field crop and nut tree growers (Rice et al. 2014), it also has a wide host range that includes many trees: elm, hawthorn, holly, linden, maples, and tree of heaven (Bergman et al. 2014; Leskey and Nielsen 2018). Many ornamental hosts are partial hosts meaning that one or more of BMSB's life stages can develop on the host but not all stages (Bergman et al. 2014, 2016), and these partial hosts may facilitate the movement of BMSB across a landscape. In agricultural areas, BMSB are often treated with insecticides although some may have limited efficacy (Leskey et al. 2012; Leskey and Nielsen 2018). The classical biological control agent, *Trissolcus japonicus*, is being studied for potential release. Genetic analyses of the *T. japonicus* found in the field in Maryland and Oregon-Washington revealed that these populations were not related to the populations in quarantine (stopBMSB.org; Mortenson 2016). In Oregon, the Oregon Department of Agriculture has approved releases of the *T. japonicus* reared from field sources, and efforts are underway in Washington to make similar releases.

Noninsect Invertebrates

Aquatic invasive invertebrates (Table A3.4) include several mollusks (Asian clam, big-eared radix, Chinese mystery snail, New Zealand mud snails, New Zealand sea slug, and zebra/quagga mussels) and crustaceans (crayfish, crabs, and water fleas). Many of the invasive mollusks of concern in the Northwest spread rapidly and can attain large population sizes that displace native species. These taxa can accrue prey resources rapidly, affecting foundation levels of food webs (algae, phytoplankton) in aquatic systems. Along with abundant populations come abundant waste products that can affect environmental systems. In some systems, for example, the tissues or waste products of zebra mussels may accumulate contaminants to 300,000 times the level available in the environment, with subsequent effects on their environment, including contaminating their predators (Snyder et al. 1997) (see Chap. 2, Sect. 2.6, and Box 2.6 for additional discussion of the impacts of zebra mussels). Another concern is that large numbers of mollusks can foul human structures. Introductions of some species are likely tied to inadvertent human transmission, such as in ship ballast water or in boats or fishing gear (i.e., zebra/quagga mussels, spiny water flea (*Bythotrephes longimanus*), and green crabs). The deliberate introduction and consequent escape of some species are also associated with food and medical markets (i.e., Chinese mystery snails, crayfish, and mitten crabs). Nearly all terrestrial invertebrates are insects (see above and Table A3.3).

Vertebrates

Two frogs (American bullfrog, red-legged frog (Ranidae)), a tunicate (*Didemnum vexillum*), a turtle, and 11 fishes (Table A3.5) have established populations in the Northwest region as a consequence of human activities. For example, American bullfrogs are native to the Eastern United States, but were brought to the West to establish food farms and out of nostalgia for their calls. Bullfrogs are carriers of the amphibian chytrid fungus, *Batrachochytrium dendrobatidis* (Bd) (Table A3.2), but do not always exhibit disease symptoms and hence may serve as a reservoir species of the pathogen. Invasive fishes include a mix of species introduced for human food, as bait for recreational fisheries, or from the aquarium or ornamental industry (Table A3.5). They are of concern primarily because of their ecological effects on native ecosystems. Atlantic salmon are native to the North Atlantic Ocean, where they are anadromous, occurring in the ocean and returning to spawn in rivers. Farms in Washington and British Columbia are thought to be the origin of the species found elsewhere in the Northwest, as these fish stray from "natal" streams—even as far as Alaska. Competition with native salmonids, pollution from the farms, and the potential for farm-raised animals to carry pathogens to native stocks are all ecological impacts of these invaders. Certain species of gobies (Table A3.5) are of Asian origin and occur in fresh and brackish water. They are thought to have been introduced to the Northwest region by ballast water and may compete with or prey upon native species. Golden shiners are from the Eastern United States and are pond-cultured fishes that are also used as bait. Golden shiners may displace native species. The carpet sea squirt or ascidian (*Didemnum vexillum*) is a colonial tunicate in the phylum Chordata (hence its inclusion under vertebrates). It seems to be native to Japan, but it has been detected along the Washington coast since 2009 and in two Oregon bays since 2010. It is a fouling organism in marine and estuarine systems, growing rapidly and covering vast surfaces as mats, displacing native biota and encrusting dock pilings and aquatic equipment. It can be introduced in ballast water, or it may hitchhike on the hulls of boats, or with commercial shellfish stock or equipment.

The category of terrestrial invasive vertebrates in the Northwest region contains only six species (Table A3.5), but they can have extensive effects, ecologically and socioeconomically. Three species are strongly associated with wetland and riparian environments (feral swine, mute swan, nutria). Feral swine are escaped domestic pigs whose rooting behavior can have several effects: waterway habitat degradation, provision of an invasion pathway for non-native plants, and damage to agricultural crops and lands. The mute swan was introduced from New York for scenic enjoyment. These aggressive, large (11.3–13.6 kg, 25–30 lb) birds may consume significant quantities of aquatic plants, competing with native birds for food and habitat supplies. Nutria were initially brought to the Pacific Northwest as part of fur farming in the 1920s. Escaped and released animals (after the collapse of this element of the fur industry) subsequently spread throughout the region. They burrow into the banks of streams and agricultural canals, destabilizing natural stream systems and human agricultural infrastructure. See the Pacific Southwest regional summary for additional discussion of nutria. In addition to these three species, European starling and rock doves are strong competitors for nest space and food sources with native birds. The Norway rat is common in urban settings in the Northwest region and is closely affiliated with human structures. These animals may cause extensive damage to human structures and are known carriers of pathogens that may affect human health.

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Southwest Region

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Introduction

The Southwest region (Arizona, California, Colorado, Nevada, New Mexico, and Utah) (Figs. A4.1 and A4.2) is marked by Mediterranean, montane, and desert climates/ecosystems that provide unique and amenable conditions and habitats for invading plants, pathogens, insects, and vertebrates. Aridity is perhaps the dominant climatic feature framing the forest ecosystems of the Southwest (Peterson 2012). Extreme elevational gradients and the intervening desert landscapes in this region (Fig. A4.2) create pronounced biogeographical boundaries and refugia for endemic species of plants and animals. The southern edge of this region has an extensive, but ecologically contiguous, border with Mexico that facilitates biological invasions. Future climate conditions projected for the southern portion of this region predict a trend of increasing temperature and decreasing precipitation (Cayan et al. 2010; Peterson 2012; Williams et al. 2010). Changing climate will likely place water stress on native trees and other plants, perhaps accelerating the establishment of invasive species (Peterson 2012) and amplifying outbreaks of native pest species (Breshears et al. 2005). These changes may also facilitate the spread of invasive species northward across this international border (e.g., Billings et al. 2014; Moser et al. 2005). The rate of spread of invasive species across this border may be increased by instances of unregulated movement of humans and cargo.

This region also features a wide range of non-native ornamental plants in urban and rural areas, enormously productive and diverse agroecosystems, and huge tracts of public lands with grazing impacts that favor the establishment and spread of invasive plants and pathogens by wild and domestic ungulates and other animals. High property values and residences in and near this region's forests make the impacts of invasive species particularly expensive and difficult to manage, as they often range across varied and numerous land ownerships. From a sociological perspective, the diverse human population of the region provides linkages to many overseas source populations of invasive species, whereas numerous maritime and overland ports-of-entry as well as U.S. and international tourism in response to the attractive natural features and mild winter climate may also enhance the introduction, establishment, and spread of invading organisms.

Plants

Terrestrial invasive plants in the Southwest region include annual, biennial, and perennial species of grasses, forbs,