Conservation Assessment

for

Cryptomastix hendersoni,
Columbia Oregonian

Cryptomastix hendersoni, photograph by Bill Leonard, used with permission.

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USDA Forest Service Region 6 and
USDI Bureau of Land Management, Oregon and Washington
Interagency Special Status and Sensitive Species Program

Preface

Summary of 2015 update: The framework of the original document was reformatted to more closely conform to the standards for the Forest Service and BLM for Conservation Assessment development in Oregon and Washington. Additions to this version of the Assessment include NatureServe ranks, photographs of the species, and Oregon/Washington distribution maps based on the record database that was compiled/updated in 2014. Distribution, habitat, life history, taxonomic information, and other sections in the Assessment have been updated to reflect new data and information that has become available since earlier versions of this document were produced. A textual summary of records that have been gathered between 2005 and 2014 is provided, including number and location of new records, any noteworthy range extensions, and any new documentations on FS/BLM land units. A complete assessment of the species' occurrence on Forest Service and BLM lands in Oregon and Washington is also provided, including relative abundance on each unit.

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Executive Summary

Species: *Cryptomastix hendersoni* (Pilsbry, 1928), Columbia Oregonian

Taxonomic Group: Mollusks (Phylum Mollusca: Class Gastropoda)

Management Status: *Cryptomastix hendersoni* is a Forest Service Sensitive Species in both Oregon and Washington, and a BLM Sensitive species in Oregon. The NatureServe Status for this species is as follows:

Global Status: G1G2 (2005)
National Status (United States): N1N2 (2005)
State/Province Statuses: Oregon (S1S2), Washington (S1), Idaho (SNR)
(NatureServe 2014).

Range: The range (and species concept) of *Cryptomastix hendersoni* has been interpreted differently by various authors (see Range, Distribution, and Abundance section of this Assessment for details). Here, we follow the distribution as presented in Burke (2013). *Cryptomastix hendersoni* is known from springs and spring-fed streams along both sides of the Columbia River in Oregon and Washington, from the Columbia River Gorge east through the Blue Mountains and Hells Canyon region to west-central Idaho (Burke 2013). This species also occurs north along the Yakima River in Washington, and north along the Columbia River as far as Chelan County (Burke 2013, Jepsen *et al.* 2012). The type locality for *Cryptomastix hendersoni* is The Dalles, Wasco County, Oregon.

Habitat: *Cryptomastix hendersoni* is a low-elevation, riparian-associate species, known primarily from the margins of seeps and spring-fed streams. It typically occurs along sun-lit margins of streams in open rocky prairies with few or no trees. The microhabitat for this species is under rocks and herbaceous vegetation.

Threats: Primary threats to this species are the loss and fragmentation of habitat due to roads, railroads, recreation, urbanization, grazing, dewatering, and conversion of land for agricultural purposes (Frest & Johannes 1995, Burke 2008, *pers. comm.*).

Management Considerations: Along the Columbia River, it is recommended that habitat be managed through exclusion of livestock and removal of exotic vegetation from inhabited riparian zones, and by conserving perennial hydrologic flow at occupied sites.

Research, Inventory, and Monitoring Opportunities: Both this species and its genus need to be better defined anatomically. According to Tom Burke (2014, *pers. comm.*), *C. hendersoni* is a confusing species and very much in need of a thorough reevaluation. Pilsbry (1928, 1940) defined *Cryptomastix hendersoni* only on the characteristics of shell morphology, and there are no published descriptions or illustrations of the internal anatomy of this species. Anatomical, morphological, and/or molecular clarification of the species concept for this taxon, as well as other *Cryptomastix* species, is needed. In particular, taxonomic investigations should examine specimens from the type locality (The Dalles, Oregon) for comparison with specimens collected in eastern Oregon and Washington (Blue Mountains region), Chelan County, Washington, and Mount Hood National Forest, Oregon, for reasons discussed in the report below. Further analyses of these populations are needed to verify whether they represent the same species, distinct races of this species, or separate species. In addition, the ecology, distribution, and abundance of these species should be examined.

I. Introduction

A. Goal

The goal of this Conservation Assessment is to summarize existing information regarding the biology, ecology, known threats, and management considerations for *Cryptomastix hendersoni* (the Columbia Oregonian), in order to assist managers in the formulation of options for management activities. This species is of concern due to its highly restricted distribution, limited mobility, narrow habitat requirements, and sensitivity to anthropogenic disturbance. Federal management for this species follows Region 6 Sensitive Species (SS) and/or OR/WA BLM Special Status Species (SSS) policies.

For OR/WA BLM administered lands, SSS policy details the need to manage for species conservation. For Region 6 SS policy requires the agency to maintain viable populations of all native and desired non-native wildlife, fish, and plant species in habitats distributed throughout their geographic range on National Forest System lands. Management "must not result in a loss of species viability or create significant trends toward federal listing" (FSM 2670.32) for any identified SS.

B. Scope

The geographic scope of this assessment includes consideration of the known and suspected range of the species, in the planning area of the Forest Service Region 6 and/or Oregon and Washington BLM. An emphasis of species-considerations is provided for federal lands; however, species-knowledge compiled from federal lands outside the planning area and non-federal lands is included as it is relevant to the overall conservation of the species. This assessment summarizes existing knowledge of a relatively little known invertebrate. A great deal of new information has been generated regarding this species in the last decade, and is incorporated here, but information updates may be necessary to keep this assessment current with time. Also, threats named here summarize known or suspected existing threats, which also may change with time. Management considerations typically apply to site-specific locations; however some larger scale issues such as population connectivity and range-wide concerns are listed. Uncertainty and inference are acknowledged where appropriate.

C. Management Status

Region 6 of the Forest Service classifies *Cryptomastix hendersoni* as a Sensitive Species in both Oregon and Washington. This species is also classified as a Sensitive Species by Oregon BLM. The NatureServe Status for this species is as follows:

Global Status: G1G2 (2005)
National Status (United States): N1N2 (2005)
State/Province Statuses: Oregon (S1S2), Washington (S1), Idaho (SNR)
(NatureServe 2014).

In the Northwest Forest Plan area of Oregon and Washington, *Cryptomastix hendersoni* is also considered to be a Category A species under the Survey and Manage Standards and Guideliens, based on the low number of occurrences, its low detection rate in suitable habitat and its small range.

II. Classification and Description

A. Systematic/Taxonomic History and Synonymy
Family: Polygyridae
Subfamily: Triodopsinae
Species: *Cryptomastix hendersoni* (Pilsbry, 1928), Columbia Oregonian

Pilsbry (1939, 1940) and most subsequent authors (Turgeon *et al.*, 1998) have placed *Cryptomastix* in the pulmonate snail family Polygyridae, which was originally proposed as a subfamily by Pilsbry (1895). A recent exception is Burch and Pearce (1990) who used Mesodontidae for this family and treated Polygyridae as a junior synonym. Bouchet and Rocroi (2005) retained Polygyridae as the family and listed two subfamilies: Polygyrinae and Triodopsinae with four tribes and three subtribes under Polygyrinae. In their listing, Mesodontina Tryon, 1866, is one of the subtribes under the tribe Polygyrini Pilsbry, 1895, which doesn't appear pertinent to *C. hendersoni*. Pilsbry (1940) listed *Triodopsis* with the subgenus *Cryptomastix* under the subfamily Triodopsinae (all under the family Polygyridae). It therefore appears that the taxonomy as it stands today should be Family Polygyridae; Subfamily Triodopsinae; and Genus *Cryptomastix* (Burke 2014, *pers. comm.*).

The genus *Cryptomastix* was originally proposed as a subgenus of *Triodopsis* by Pilsbry (1939, page xvii). Vagvolgyi (1968) noted that *Cryptomastix* might be considered a genus on the basis of anatomy and distribution, but chose to follow the existing subgeneric status because his work was focused at the species level. However, *Cryptomastix* has been treated as a full genus by Webb (1970) and subsequent authors. Webb (1970, 1990) made *Cryptomastix hendersoni* the type species of a new subgenus, *Bupiogona*, based on his observations of their reproduction. Frest and Johannes (1995, 1996) view the subgenus as biologically valid but recognized the snails studied by Webb as *Cryptomastix populi*, not *Cryptomastix hendersoni*, so they treated this species as *Cryptomastix* (*Cryptomastix*) *hendersoni* (Pilsbry 1928). A type species based on a misidentification is a problem that should be resolved by the International Commission on Zoological Nomenclature under Article 70(b) of the Code (ICZN, 1985).

Cryptomastix hendersoni was originally proposed as a subspecies of *Polygyra mullani* by Pilsbry (1928), who stated the type specimen had been collected by Henry Hemphill "near the Dalles" but provided an incorrect Academy of Natural Sciences catalogue number. Later, Pilsbry (1940) classified this snail as *Triodopsis mullani hendersoni* and cited the correct catalog number for the type specimen (ANSP 145479). Pilsbry (1940) changed the description of the type locality (the source of the type specimen) from "near the Dalles" to "The Dalles." Henry Hemphill, who lived from 1830 to 1914, apparently collected the type specimen and over 80 other specimens of this snail from this location, possibly over several dates or years. At the turn of the century the name of the nearest town was often considered quite adequate for a locality description, so this series could have come from either in or near The Dalles.

Vagvolgyi (1968) treated *Polygyra mullani hendersoni* Pilsbry, together with five other subspecies that were recognized by Pilsbry in 1940 plus *Triodopsis populi*, as synonyms of *Triodopsis mullani mullani* (Bland and Cooper 1862). Vagvolgyi based this taxonomic action on the shell morphology of only 11 samples of what he considered *Triodopsis mullani mullani*, with 1-11 specimens of each and only 37 specimens altogether. Since that taxonomic "lumping" action, the "splitters" have prevailed. Webb (1970) recognized *Cryptomastix hendersoni* as a full species, and that status has been followed by subsequent authors (e.g., Turgeon *et al.* 1998, Burke 2013).

B. Species Description

This taxon belongs to a genus in the land snail family Polygyridae. This family is composed of small- to large-sized snails with distinctly reflected lip margins and aperatural teeth varying in size and number from zero to three (Burke 2013). The shells in this family range from various shades of yellow, tan, or brown, without markings. Periostracal hairs/bristles adorn the shells of many polygyrid species in the immature stages. Although a few species retain periostracal setae at maturity, these hairs are generally lost in the adult stage, or are evident only as hair-scars or scales (Burke 2013).

The *Cryptomastix* genus is distinguished from other members of the Polygyridae family as follows (Burke 2013): medium to moderately large snails (10 to 25 mm in diameter), with sub-globose to low-conic, narrowly umbilicate to imperforate shells. The peristome (rim or lip around aperature) is distinctly reflected and often recurved or revolute. Dentition consists of a parietal tooth, a basal cusp, usually at the outer end of a basal ridge or fold on the inside of the basal lip margin, and one inside the palatal or the outer lip margin. The teeth, however, may be reduced to a mere callus or lamina, or may be absent, so any combination from zero to three may occur. The young of many *Cryptomastix* are hirsute, but few species retain the hairs in adulthood. Hair-scars or associated papillae can sometimes be found on the periphery or on the penultimate whorl in front of the aperture. The shells may be sculptured with spiral striae, although these are often faint or indistinct (Burke 2013).

Cryptomastix hendersoni is a medium-sized snail with $5^{1}/_{3}$ to $5^{1}/_{2}$ whorls measuring 14.5 to 16.2 mm wide by 8.2 to 9 mm high (Burke 2013). The spire is low to moderately elevated. The umbilicus is narrow, contained $9^{1}/_{2}$ to 10 times in the shell width, with the reflected peristome covering about one-fourth of it. The periphery is rounded. The aperture is widely lunate and generally lacks dentition, although some specimens, especially from the eastern part of their range, have a small parietal tooth. The last whorl descends only little before the aperture. It has a rather strong constriction before the white, reflected, and narrowly recurved peristome. Shells are sculptured with weak or very faint spiral striae (Burke 2013). There are typically no apparent traces of hairs, although periostracal hairs have been found on *C. hendersoni* in eastern Oregon (Jepsen *et al.* 2012; Burke 2014, *pers. comm.* See photo in Appendix). The shell color of a live *C. hendersoni* snail is brown, which is the color of the periostracum (the protective proteinaceous outer coating), except where it is damaged to reveal the gray mineral part of the shell. Empty shells exposed to sunlight and moisture will become bleached and chalky white. The soft parts of the living snail are a pale grayish tan, with darker pigment in the ocular tentacles and their retractor muscles.

According to Tom Burke (*in* Jepsen *et al.* 2012), the lack of or reduced size of lip dentition in the aperture has been found to be the most useful character in distinguishing this taxon. *Cryptomastix populi* is the only other *Cryptomastix* that typically lacks dentition; however, the shape of its shell is dissimilar to that of *C. hendersoni. Cryptomastix populi* has a very low spire and relatively large elliptical aperture without a constriction of the last whorl (Burke 2013).

It should be noted that while Burke (2013) describes this species as being either toothless or having a small parietal tooth (see above), previous authors have treated this species as strictly toothless. For example, in the original description, Pilsbry (1928) described this snail as being toothless, which is true of his photos of the type and paratype from The Dalles. Similarly, Terry Frest considered *C. hendersoni* to be toothless, and treated those with a parietal tooth as a different taxon (Burke 2014, *pers. comm.*). However, this character seems to vary, as noted by Pilsbry (1940) and Frest and Johannes (1996). With regard to differences in dentition across the range, Burke (2014, *pers. comm.*) reports that the specimens he has checked from the Deixis Rowland Spring site (considered to be *C. hendersoni* by Frest) all have a small parietal "tooth" or lamella (similar to the dentition seen in the Snake River area), which raises questions as to Frest's treatment of Snake River specimens as "undescribed species" separate from *C. hendersoni* in the Gorge, based on dentition. In fact, it appears that the Columbia River Gorge *C. hendersoni* exhibit a range of dentition from present (e.g., at some Washington sites) to lacking (e.g., at The Dalles type locality). In addition, Burke has found specimens that lack dentition from Stevens and Chelan Counties, and from the Blue Mountains (Burke 2014, *pers. comm.*). It has been questioned whether denticulate specimens from the far eastern part of the species range might be a separate, undescribed species. E.g., Frest & Johannes (1996) consider "*Cryptomastix hendersoni*" from Idaho and eastern Oregon as representing other species that have similar shells but anatomically represent distinct biological entities. However, these anatomical differences and the taxa that they define have not been reported, nor have new species names been proposed (Burke 2013). Since these eastern specimens are highly similar to *C. hendersoni* as described by Pilsbry, and are found with the typical variation exhibited at the west end of their range, Burke (2013) has elected to treat them as the same species, while also recognizing the need for further study (Jepsen *et al.* 2011, 2012; Burke 2013).

See Appendix for photographs of this species, including the unusual specimen with periostracal hairs. Black-and-white photos of the holotype and a paratype shell can be found in Pilsbry (1928, 1940).

III. Biology and Ecology

A. Life History

Like most terrestrial gastropods, *Cryptomastix* are hermaphroditic, having both male and female organs. Although not confirmed specifically for *C. hendersoni*, self-fertilization has been demonstrated in some species of gastropods, but cross-fertilization is the norm. Bayne (1973) discussed the complexities of the Pulmonate reproductive system, and studied mechanisms by which allosperms (sperm from another) exert dominance over autosperms (sperm from oneself) during fertilization. Thus, ". . . self-fertilization is normally avoided, but remains a possible alternative to cross-fertilization." The advantage is in normally avoiding potentially deleterious inbreeding, yet retaining the option to reproduce if a mate is not available.

Cryptomastix hendersoni hatch from eggs and live for more than one year. However, little is known regarding the oviposition behavior, number/appearance of eggs, development, generation time, or potential longevity of this species, or of other members of the *Cryptomastix* genus (Applegarth & Duncan 2005). Other members of the Polygyridae family have been found to live for 8 or more years in captivity after reaching maturity. Applegarth & Duncan (2005) note that if *Cryptomastix* species have a potential life span of several years after reaching maturity, then individuals should have multiple opportunities to reproduce.

B. Activity Pattern and Movement
Little is known about the movement patterns of this species. According to Pilsbry (1940), "the young [Polygyridae] snails wander abroad more freely than adults, and are often found on plants where the adults are under cover."

Like most terrestrial mollusks, these snails are probably relatively sedentary and have poor dispersal abilities, as evidenced by the species' scattered distribution throughout its range. Small pockets of greater density and the presence of suitable but unoccupied habitat further suggest this possibility.

C. Food Habits
Other than limited habitat observations, almost nothing is known about the ecology or diet of *Cryptomastix hendersoni*. This species is known to consume herbaceous plants in captivity, and in the wild may also consume the decaying remains of herbaceous plants as well as algae from wet surfaces at the edge of streams and seeps. It is possible that this species may be partially herbivorous on green plants during certain seasons, while also feeding on microorganisms associated with decaying leaf litter, such as molds, yeasts and bacteria. Pilsbry (1940) states of the family Polygyridae, "their food is chiefly the mycelia of fungi," although this statement has not been well-verified.

D. Range, Distribution, and Abundance
Cryptomastix hendersoni is known from springs and spring-fed streams along both sides of the Columbia River in Oregon and Washington, from the Columbia River Gorge east through the Blue Mountains and Hells Canyon region to west-central Idaho. This species also occurs north along the Yakima River in Washington as far as 3 miles N of Yakima (Burke 2013, Jepsen *et al.* 2012). Specimens that appear to be this species (but are in need of further verification) have been found north along the Columbia River as far as Chelan County) (Burke 2014, *pers. comm.*). The type locality for *Cryptomastix hendersoni* is The Dalles, Wasco County, Oregon.

<u>Summary of historic and recent records</u>:
The range of *C. hendersoni* has been interpreted differently by various authors. Pilsbry (1940) gave the range of this species as from The Dalles east through southeastern Washington and northeastern Oregon to Adams County, Idaho, and one site 3 miles north of Yakima. However, Frest and Johannes (1995) believed that its range included only the middle and eastern Columbia Gorge including Hood River, Wasco and Sherman counties, Oregon and Skamania and Klickitat counties, Washington, and that the reports from farther east (e.g., the Blue Mountains and the Hells Canyon area) were a different taxon (Jepsen *et al.* 2012). In contrast, Burke (2013) and Jepsen *et al.* (2011, 2012) treat the eastern Oregon specimens as *C. hendersoni,* based on similarity to the original Pilsbry description. Several detections of this species from the Blue Mountains area (including Vale-OR BLM land and Umatilla National Forest in both Oregon and

Washington) have been documented in recent years (Jepsen *et al.* 2011, 2012). Recent detections of this species have also been made west of The Dalles type locality in the Columbia River Gorge.

According to Tom Burke, specimens that appear to fit Pilsbry's description also occur farther up the Columbia at least as far as Chelan County, Washington (Jepsen *et al.* 2012, Burke 2014, *pers. comm.*). These are likely to be the true *C. hendersoni,* but are in need of further examination (Burke 2014, *pers. comm.*), and are therefore not included in the current database or distribution map of this species.

Earlier versions of this Conservation Assessment, as well as the Forest Service NRIS database, indicate the occurrence of this species in Mt. Hood National Forest. However, Burke (2013) does not treat locations in the Mount Hood National Forest to be within range of this species. Tom Burke (2014, *pers. comm.*) reports having found only one specimen from Mt. Hood that is similar to this species (Burke #98-200); this shell will key out to *C. hendersoni* but in Burke's original examination he noted that this was an "unusual specimen most closely resembling *hendersoni* but with the peristome and periphery unusual for the species. The apertural lip (peristome) is widely flaired without recurve; smooth, rounded and creamy-white inside; buff colored on the outside. The periphery is rather strongly shouldered or angled to the last half whorl" (Burke 2014, *pers. comm.*). Tom Burke notes, however, that he has only examined one of specimen from Mount Hood National Forest (from the Hood River Ranger District, sent by Phil Rickus), and doesn't know if the 6 or 7 other specimens collected from this area and identified as *C. hendersoni* are similar to the one he examined, or if they are more typical of *C. hendersoni*. Applegarth (1999, version 1 of this Assessment) noted that although the Mt. Hood shells fit Pilsbry's description of this species, no specimens have been dissected to see if they are anatomically the same as *Cryptomastix hendersoni* from the type locality. Applegarth further noted that anatomical and biochemical analyses may eventually show these new snails to be a distinct race within this species, which could be named as a subspecies. Until further analysis, we have elected to follow Burke (2013) and treat the Mt. Hood specimens as an unknown taxon, not included in the current database or distribution map of this species.

Similar to the Mt. Hood situation, Burke (2014, *pers. comm.*) reports several specimens from northeastern Washington that will key out to *C. hendersoni*, but on reexamining them he believes that there might be a new species among them. They are generally smaller than the ones from the Columbia Gorge, have a somewhat higher spire (although not higher than illustrated in Pilsbry, 1940), a rounder aperture, a more revolute lip, and a darker colored shell. These records are not included in the current database or distribution map of this species.

<u>Distribution on FS/BLM lands</u>: In Washington, this species is Documented on Umatilla National Forest. It is Suspected on Columbia River Gorge NSA-WA based on close proximity to a few known records. It is also Suspected on Gifford Pinchot National Forest in Washington. In Oregon, this species is Documented on Columbia River Gorge NSA-OR; Umatilla National Forest; and Vale District BLM land. It is suspected on the Wallowa-Whitman National Forest.

<u>Further details regarding FS/BLM distribution:</u> Most sites for this species are on the Oregon side of the Columbia River Gorge, in the Columbia River Gorge National Scenic Area, Oregon state parks, and private land. A rare species, *C. hendersoni* is known from less than five records on

each of the National Forests, National Scenic Areas, and BLM Districts where it has been documented.

Summary of Recent Data: Less than 10 new records of this species have been found since the Conservation Assessment was last updated in 2005, none of which represent significant range extensions for this species (although new documentations on agency land were found) (Jepsen *et al.* 2011, 2012). Another change since the last update is that the Mt. Hood National Forest (where approximately half of the known sites were located) is no longer understood to be within the range of this species (Burke 2014, *pers. comm.*, Burke 2013), resulting in a significant contraction of the known range.

Species Abundance:
The small range of this species, combined with habitat restrictions within that range, make this a rare species that can be locally abundant. Few to many individuals are typically found at the sites where this snail still occurs. Relatively dense populations (over 10 snails per square meter) have been noted at some sites, and many of the museum collections are lots of 10 or more specimens. However, the relative abundance of this species across the landscape is low. According to Burke (2014, *pers. comm.*), the species composition from throughout the occupied area contains relatively few *C. hendersoni*.

E. Population Trends
According to Frest & Johannes (1995), population trends (number of sites, number of individuals) were downward at the time. Some populations have been extirpated and others have exhibited decline in recent years (Frest & Johannes 1995). For example, this species was historically very common/abundant near The Dalles, as evidenced by over 80 specimens of this snail from this location collected before 1914 (possibly over several dates or years). In more recent years, the snail has been extirpated from several localities in this area that have succumbed to urbanization and highway development (Frest & Johannes 1995).

F. Demography
Current knowledge of this species indicates that it has a very spotty distribution across its range, probably due to fragmentation of habitat by historic changes in climate and restriction to spring-runs. In addition, populations of this species appear to have been further reduced and fragmented by recent habitat loss (Frest & Johannes 1995; Burke 2014, *pers. comm.*). The small range of this species, combined with habitat restrictions within that range, make this species highly susceptible to problems associated with genetic isolation.

G. Habitat
This riparian-associate land snail is known from low to middle elevations, generally near seeps and springs, where it occurs in leaf litter along streams, under logs, among brush, and in basalt talus. Frest & Johannes (1995) classify it as a somewhat mesophile-weakly-xerophile taxon, noting that it is sometimes seen at the base of taluses, slopes or valleys with persistent moisture in otherwise quite dry terrain.

Along the Columbia River *Cryptomastix hendersoni* inhabits the margins of spring-fed streams and associated rock talus, in situations where there is perennial moisture under the surface of rock talus. This species survives the semiarid climatic conditions of the western part of the Columbia Basin by inhabiting these microhabitats where cool, moist refugia are available. These locations are at low elevation in the generally treeless landscape of the eastern part of the Columbia River Gorge. Elevation at these known sites ranges from 52 to 134 meters (170 to 440 feet) with an average of 78 meters (253 feet). Vegetation is either an open grassland, or there is an open canopy of riparian trees and bushes, but no conifers are reported as being either at the sites or immediately upslope. Herbaceous plants that have been noted include *Clematus*, *Mimulu*s, *Rorippa*, and *Urtica*. Woody species include *Ailanthus* (an exotic tree), *Celtis*, *Cornus*, *Populus*, *Rhus*, and *Rosa*.

Surveys by Jepsen *et al.* (2011, 2012) detected *C. hendersoni* shells and live individuals at eight sites in eastern Oregon and Washington with the following features:

- A very dry bunchgrass opening on a ridgetop
- A rock outcrop with talus, a small seep, blackberry, horsetail, maple, and pacific ninebark present
- A seep on the side of a trail
- A rock outcrop with a spring upwelling at the base of the site, a small stream, mossy rocks, dry talus, fern, and snowberry
- A seep on the side of the road with rushes, horsetail, teasel, and a rock face with water trickling over it in many places and a pile of talus
- Seeps on a rock face on the side of the road with some talus at the base
- A south facing grassy hillside with the dry bed of an ephemeral creek and a few scattered ponderosa pines
- An upwelling spring on the side of a trail, with wet ground, poison ivy, and other vegetation

H. Ecological Considerations

Terrestrial gastropods make a significant contribution to the biomass and energy in boreal forests, where they comprise at least 2.5% of the animal biomass and 6% of the animal energy (highly conservative estimates based only on active gastropods on the forest floor) (reviewed in Foltz Jordan & Black 2012).

<u>Decomposition and nutrient cycling</u>: As primary consumers of plant, animal, and fungal matter, gastropods aid in forest decomposition processes and contribute to nutrient cycling, soil formation, and soil productivity (reviewed in Foltz Jordan & Black 2012). For example, the slug *Ariolimax columbianus* speeds up nutrient cycling by ingesting large amounts of living and senescing plants, and subsequently excreting the partially digested plant tissue. Snails and slugs further contribute to the breakdown of forest floor litter by aiding in the dispersal of some fungi, and by physically and chemically altering plant material in ways that appear to promote fungal and bacterial growth. *Cryptomastix* species probably have a digestive efficiency rate in the high forties for assimilation of food materials, a low rate that allows viable spores and fragments of fungal hyphae to be excreted with the feces (Applegarth 1999, Version 1 of this Assessment). Thus, they represent an important dispersal mechanism for fungal species throughout the year when this mollusk is active.

Food and calcium for wildlife: Terrestrial gastropods are an important food source to a vast number of species, including salamanders, frogs, toads, turtles, snakes, lizards, birds, shrews, voles, moles, rats, mice, chipmunks, and squirrels (reviewed in Foltz Jordan & Black 2012). Invertebrate predators of terrestrial mollusks include sciomyzid fly larvae, firefly larvae, parasitic wasp larvae, carabid and staphylinid beetles, ants, spiders, and harvestmen. Terrestrial snails can also serve as important food sources to other gastropods such as predatory snails, and slugs that become cannibalistic when no other food is available (Burke 2014 *pers. comm.*). Additionally, the reproductive cycles of some nematodes and trematodes (flatworms) are dependent on snails and slugs as intermediate hosts for their parasitic eggs and larvae (reviewed in Foltz Jordan & Black 2012).

Since snail shells are very high in calcium, terrestrial snails have an important role in storing, releasing, and cycling calcium in the ecosystems they inhabit (reviewed in Foltz Jordan & Black 2012). Snail shells are the primary calcium source for the eggs of some bird species, and declines in mollusk abundance in forest ecosystems have been significantly linked to eggshell defects, reduced reproductive success, and population declines in the song bird, *Parus major* (reviewed in Foltz Jordan & Black 2012). Empty snail shells are used as shelters and egg laying sites by insects and other arthropods, and broken down shells return calcium to the soil (reviewed in Foltz Jordan & Black 2012).

Plant pollination and seed dispersal: Although pollination by snails (malacophily) is a rare and obscure phenomenon, at least one study clearly demonstrates the significant role of a snail (*Lamellaxis gracile*) in the pollination of a flowering plant (Convolvulaceae: *Volvulopsis nummularium),* especially on rainy days when the activity of bees is completely lacking (reviewed in Foltz Jordan & Black 2012). Since some slugs consume fruit and excrete seeds, these animals can play a significant role in seed dispersal (albeit over short distances) and also appear to increase seed germination rates of some flowering plants (reviewed in Foltz Jordan & Black 2012).

Indicators of environmental health: Due to limited mobility, small home ranges, defined habitat preferences, and acute sensitivity to environmental conditions, snails and slugs are excellent and unique indicators of ecosystem health (reviewed in Foltz Jordan & Black 2012). Since terrestrial gastropods cannot easily escape areas that are subjected to disturbance, changes in gastropod abundance and diversity reflect the immediate impact of natural or experimental disturbance in their habitat. As such, gastropods provide managers with a valuable tool for site-specific assessment of environmental and community change (reviewed in Foltz Jordan & Black 2012).

IV. Conservation

A. Threats to Species

Primary threats to this species are the loss and fragmentation of habitat due to roads, railroads, recreation, urbanization, and grazing practices (Frest & Johannes 1995, Burke 2008, *pers. comm.*).

Road construction and maintenance: Construction of new roads and maintenance of existing roads is a threat across the species' range. Much of the known habitat for this species along the Columbia River is traversed by I-84/US 30 or WA 14, as well as by Burlington Northern and Union Pacific Railroad tracks, all of which have disturbed and impacted preferred habitat (Frest & Johannes 1995). Roadways eliminate and degrade snail habitat, cause direct mortality in snails, and hinder snails' ability to disperse (reviewed in Foltz Jordan & Black 2012). Mollusk populations are not only extirpated in the roadway proper, but impacts can extend into adjacent habitat as well, due to site preparation, road construction, vehicle use, and maintenance activities. Where roads and railroads cross rivers and streams, there is the risk of petrochemicals, herbicides and silt entering the waterways. Roadside spraying has been identified as a problem for some colonies of *C. hendersoni,* and additional threats may come from quarrying operations and road construction (Frest & Johannes 1995). For a complete review of ecological impacts of roadways on snails including environmental contaminants, traffic and desiccation-related mortality, roads as distribution barriers, and road-related changes in the direction and intensity of gene flow, see Foltz Jordan & Black (2012).

Impoundment and stream diversion for grazing: At many sites along the Columbia River, this species' habitat is threatened by the impoundment or diversion of spring-fed streams, and the resulting loss of perennial flow. Habitat degradation by domestic livestock allowed to graze within these spring-runs is also a serious threat. Sites in the eastern Columbia River Gorge are often overgrazed, and the impact of trampling, water pollution from feces, and vegetation changes could contribute to extirpation of snail populations (Frest & Johannes 1995).

Urbanization and recreation: Urban expansion from The Dalles and Hood River also threatens known sites of this species. Localities in The Dalles, for example, have recently succumbed to urbanization and highway development (Frest & Johannes 1995). In addition, many of the regions occupied by this species are heavily utilized for recreation, and are likely to be more so in the future due to both local population growth and national recreation trends (Cordell *et al.*, 1996). In addition, as the human population grows in this area, an increase in the number of water wells may decrease the output of springs.

Invasive vegetation: At low elevations sites near the Columbia River this snail may be negatively impacted by nonnative trees and berry vines, i.e., Himalayan blackberry, because those plants can heavily shade sites and greatly reduce the native herbaceous vegetation on which populations of this snail may depend for food and shelter.

High intensity fire - Although natural and anthropogenic fire have played major roles in shaping forest ecosystems in the Pacific Northwest, the impacts of fire management on invertebrate communities are often highly variable. Fire has the potential to negatively influence gastropods in several ways: directly, by fire-related mortality, and indirectly, by altering microclimate conditions, and by reducing, eliminating, or otherwise altering resources, including vegetation, fungi, leaf-litter, duff, woody debris, and other habitat elements pertaining to shelter or food (*reviewed in* Foltz Jordan & Black 2012). The degree of fire-related impact and the potential for animals to rebound post-impact are related to a number of factors, namely, the degree of exposure to lethal temperature, the stress experienced in the post-fire environment, the suitability of post-treatment vegetation as habitat, and the ability to rebuild numbers in the site (from survivors and/or colonizers). Direct mortality due to fire exposure can be avoided by animals either in space (i.e., by escaping/retreating into shelter from fire) or in time (i.e., by being in a physiologically least susceptible stage at the time of burn). In general, less decline has been recorded for species below ground, within or beneath unburned wood, or above flames in treetops, and greater decline for species in the herb (fuel) layer or near the soil surface, particularly for individuals with low mobility. Mobility is important in both fire avoidance (e.g., the ability to escape approaching flames and reach suitable unburned habitat) and in post-fire recolonization (e.g., the ability to reach burned sites from unburned sites) (*reviewed in* Foltz Jordan & Black 2012).

Since *C. hendersoni* lives for the most part on vegetation and in litter, has limited mobility and poor active dispersal aptitudes, and is sensitive to desiccation, this species is considered highly vulnerable to fire itself and to subsequent habitat destruction. According to Frest & Johannes (1995), major brush fires in 1994 impacted known sites of *C. hendersoni*, and high intensity fire is a serious threat to this species. Burke (2013) notes that fires, especially controlled burns, can kill thousands of snails, sometimes in a single burn. Slash disposal burns may be particularly devastating to gastropods since the accumulated woody debris provides excellent habitat and can have especially high snail densities. Moreover, prescribed burns are usually done during wet periods when the snails are active on or near the surface of the ground and most vulnerable to fire. In contrast, natural wildfires typically occur in dry weather, and it appears that at least some of the snails survive, possibly because they are aestivating underground at the time of the burn (Burke 2013).

Note, however, that controlled burns can be beneficial to mollusk habitat, e.g., by reducing the threat of invasive plant species such as Himalayan blackberry.

Predation: Several species of *Haplotrema* and *Ancotrema* (predatory snails that feed on snails, slugs, and other invertebrates) and *Scaphinotus* sp. (ground beetles specifically adapted for preying on snails) are common throughout the Pacific Northwest (White 1983; Kozloff 1976), and other insects as well as reptiles, amphibians, birds, and mammals also prey on snails and slugs. In particular, Burke (2013) discusses the threat of introduced wild turkeys that are known to scratch up large patches of forest floor litter inhabited by snails. Hiding and escape cover is often provided by forest floor litter, including deep leaf packs and fine and large woody debris. Concern about predators increases as habitat quality or quantity decreases. When habitat patches are limited in size and number, predators can easily focus hunting efforts and severely reduce rare snail populations. However, at sites with extensive habitat, predators are a lesser threat to a population.

Climate Change: Continued global climate change raises further issues for this riparian-associated species: projected changes from this phenomenon include increased frequency and severity of seasonal droughts and flooding, reduced snowpack to feed river flow, increased siltation, and increased air and water temperatures (Field *et al.* 2007), all of which could unfavorably impact this species' habitat and long-term survival.

B. Conservation Status

1. Overview

Cryptomastix hendersoni is considered vulnerable to extinction or extirpation in both Oregon and Washington due to limited distribution, low number of occurrences, extirpation of many historic sites, narrow habitat requirements, and a number of threats that are expected to impact the long-term survival of this species across its range (see Threats section, above). The vast majority of recent detections are from a small area of the Columbia River Gorge, where population trends are not known, and habitat has been impacted by roads, railroads, recreation, urbanization, and grazing practices (Frest & Johannes 1995, Burke 2008, *pers. comm.*).

Due to limited mobility and narrow habitat preferences, this species, like many other terrestrial snails and slugs, cannot easily escape unfavorable habitat changes, and is thus highly impacted by environmental disturbance (*reviewed in* Foltz Jordan & Black 2012). These life history factors suggest that populations are especially vulnerable to habitat change or other changes in the environment.

2. Status History

Findings under the FEMAT assessment conducted in 1993 implied that, under the preferred alternative (Option 9) for the Northwest Forest Planning Area, *Cryptomastix hendersoni* had a 27% chance of being well distributed across Federal lands, a 22% chance of being locally restricted (i.e., with significant gaps between populations), a 25% chance of being restricted to refugia, and 27% of being extirpated within the range of the northern spotted owl. Currently, only one site of *Cryptomastix hendersoni* is known on Federal lands within the Northwest Forest Plan area, on the Columbia River Gorge National Scenic Area. The remaining sites and the large portion of the suspected range of the species are from outside the range of the spotted owl. These outcome percentages were derived before riparian reserves and Survey and Manage Standards and Guidelines were added to the preferred plan option; with the addition of those protective measures to the selected Plan alternative, it is expected that the probability of a more favorable outcome might increase (USDA, 1994). Appendix J2 of the Northwest Forest Plan EIS "Summary" states, "The rating reflects uncertainty about the number of species locations that would be protected by riparian reserves or LSRs under the proposed action or any other alternative. Given this uncertainty, there is some likelihood that the species may be extirpated from some parts of its range." (USDA 1994). This statement reflects an analysis of the population within the Northwest Forest Plan area only; at the time, the range of the species outside the Plan area was relatively unknown. Tom Burke (2014, *pers. comm.*) affirms this statement, adding that this species seems to be found mostly in arid lands outside of the Northwest Forest Plan area, concentrated around small springs, streams and wet areas.

This species was considered to be a rare species and was placed in Survey and Manage Standards and Guidelines Category A for the Northwest Forest Plan area, based on the low number of occurrences, its low detection rate in suitable habitat and its small range.

3. Major Habitat and Viability Considerations

At the east end of the Columbia River Gorge most of the landscape is uninhabitable for *Cryptomastix hendersoni* because of aridity, so any dispersal would need to be along stream margins. However, most of the inhabited streams in the area do not have perennial surface connections with other streams, so most of the known populations are presently isolated from one another and, therefore, more vulnerable to extirpation. However, land mollusks have low mobility and are relatively sedentary through geologic time. What is most urgent is the identification and conservation of inhabited locations, in order to maintain the current distribution of the species (Burke 2014, *pers. comm.*).

The number and distribution of population sites required to maintain species viability is unknown, however, it can be assumed that the likelihood of species viability increases with the number of populations, and with increasing opportunities for interaction between populations. The historic distribution pattern for this species is thought to be related in the eastern part of its range to the occurrence of seeps, springs and other moist habitats, especially in the Columbia Gorge. While the current distribution of these features is probably not very different from the historic pattern, management on private land may have limited the quality of some of those habitats by changing the amount and type of canopy cover, or by allowing grazing impacts or altering the hydrologic flow within sites. Landscape management which maintains a distribution of populations and habitat in a pattern similar to or stable but altered from the historical distribution pattern is thought to be necessary for species persistence by providing habitat of sufficient quality, distribution, and abundance to allow the species populations to stabilize on federal lands. Small gaps in distribution may continue to limit population interaction somewhat, but without causing any of the following: isolation or extinction of local populations, loss of genetic or ecological diversity, or loss of ecological function.

4. Distribution Relative to Land Allocations:

Almost all of the know locations are in the low elevation, semi-arid eastern part of the Columbia River Gorge, either on private land or road right-of-ways outside of lands managed by either Federal or State agencies. The previous version of this assessment (2005) noted that half of the known sites are on Mt. Hood National Forest in matrix land use allocations in the Cascades province. However it has since been suggested that the snail present at these sites is most likely a species other than *C. hendersoni* (Burke 2014, *pers. comm.*). (See discussion in Summary of historic and recent records, above).

C. Known Management Approaches and Considerations

1. Management Goals for the Taxon

Management for this species follows Forest Service Region 6 Sensitive Species (SS) policy, and/or Oregon and Washington BLM Special Status Species (SSS) policy. For Oregon and Washington Bureau of Land Management administered lands, SSS policy details the need to manage for species conservation. For Region 6 of the Forest Service, Sensitive Species policy requires the agency to maintain viable populations of all native and desired non-native wildlife, fish, and plant species in habitats distributed throughout their geographic range on National Forest System lands. Management should also not create significant trends towards federal listing, for any identified Sensitive species.

2. Identification of Species Habitat Areas

All known sites on federal lands administered by the Forest Service and/or BLM in Oregon and

Washington are identified as areas where the information presented in this Conservation Assessment could be applied. A species habitat area is defined as the suitable habitat occupied by a known population plus the surrounding habitat needed to support the species at the site.

This document addresses management at two spatial scales. At the local population scale, a species habitat area is designed to support a functional population of interacting individuals. The size of such areas is based on estimates of dispersal distances in similar-sized terrestrial mollusks and estimates of genetic neighborhood, or deme, size and the environmental tolerances of the species. Based on the small size and limited dispersal ability of this species, the amount of area required to sustain a population of interacting individuals may range in size, depending on amount of contiguous moist habitat and the environmental modification effect of the surrounding habitat.

In addition to managing this species within species habitat areas, attempts should be made to connect habitat areas to each other or to other reserves, either directly, by locating them adjacent to occupied habitat within reserves, or indirectly, by retaining suitable quantities of key habitat elements in harvest or project areas to provide a potential bridge or temporary "bank account" to accelerate future habitat development.

At the smallest scale, within each habitat area, habitat elements such as rock talus and woody debris should be protected from disturbance, to provide for the critical periods in the animals' life history (aestivation, hibernation, reproduction). The remainder of the species habitat area may be managed to provide foraging and dispersal habitat for the active seasons. In all cases where springs or seeps provide the only available moisture, the water source, its average flow rate and associated aquifer, should be identified and managed.

3. Management Within Species Habitat Areas

The objective of species habitat areas is to maintain habitat conditions such that species viability will be maintained at an appropriate scale, in accordance with agency policies.

At low elevation sites near the Columbia River, conserve the perennial nature of the surface dampness. This species is quite vulnerable to heat and desiccation and uses logs and other large woody debris, forest floor litter and spaces under or between rocks as refugia - areas that maintain low temperature and moderate to high humidity. Management considerations should focus on maintaining the temperature and moisture regime of these microsites. Activities that lower the water table or otherwise alter the available moisture at these sites should be avoided.

Management considerations should also focus on maintenance or restoration of the native local herbaceous vegetation community. This will increase the range of hosts for a variety of species of fungi and make other food substrates available throughout the season. It will also provide insurance that specific plant species, if found to be critical in the life cycle of these mollusk species, are not inadvertently lost.

As possible, protect species habitat areas from fire events which cause direct mortality and loss of habitat. Prescribed fire treatments could be used to maintain the herbaceous vegetation and to reduce fuel loading outside of species habitat areas to protect those areas from catastrophic wildfire events (Burke 2014, *pers. comm.*).

Limit activities which cause soil compaction or disturbance to forest floor litter, rock or woody debris or which release silt or toxic chemicals into the water within species habitat areas. In heavily grazed areas, exclude livestock from concentrated sites for this species; develop watering sites away from springs and streams where these snails occur (Burke 2014, *pers. comm.*).

Occupied rockslides and talus areas could be managed to prevent adverse effects from road construction, quarrying, and other major site disturbing activities that may cause temperature and/or humidity changes within the interspaces.

Protect inhabited areas from introductions of non-native species. This includes restricting use of un-washed vehicles that could carry weed seeds or other exotics, and use of hay bales or other nonnative mulching materials and planting mixes used for erosion control.

4. Other Management Issues and Considerations

Management of springs and small wetlands involves a combination of knowledge in hydrology, geology and biology. The habitats that support this species are often centered around small hydrologic features which are relatively rare on the landscape, many of which are not mapped. Such features in dry landscapes will naturally attract heavy use by native wildlife and domestic cattle. Compaction of soil and litter as well as direct mortality to mollusks may result. Damage to unprotected spring and wetland habitats by overgrazing and water diversions has been documented extensively across the western U.S.

Exotic species of both plants and animals are entering habitats occupied by this species. If exotic species are found, measures to control them should be implemented if feasible. Measures to control exotic species should not be adverse to *Cryptomastix hendersoni* and other native species.

In general, fire can be directly harmful to terrestrial mollusk populations and habitat (reviewed in Foltz Jordan & Black 2011). Fire may negatively impact identified habitat areas by degrading woody debris and reducing vegetative cover, thereby reducing the moisture retention capacity of the site. For the isolated populations of *Cryptomastix hendersoni* along streams at low elevations near the Columbia River, negative effects of fire, in addition to direct mortality from the heat, are likely to include the temporary loss of native herbaceous plants that this species seems to need for food, cover, and microclimate. Frest and Johannes (1995) noted that major brush fires in 1994 had impacted some sites inhabited by this species. Fire may also have some positive benefits. If these snails survive the fire itself, then they may be favored by a reduction of blackberry vines and other exotic vegetation that can heavily shade sites and reduce the supply of native herbaceous vegetation. Reduction of hazardous fuels in adjacent areas that are not inhabited by this species ought to reduce the danger of a wildfire burning through an identified habitat area and, thereby, possibly causing a local extirpation. Prescribed fire is likely to have a less damaging effect if conducted while mollusks are dormant during the summer or winter and are insulated from surface heat (Burke 2014, *pers. comm.*).

V. Research, Inventory, and Monitoring Opportunities

The objective of this section is to identify opportunities for additional information that could contribute to more effective species management.

A. Data Gaps and Information Needs

According to Tom Burke (2014, *pers. comm.*), *C. hendersoni* is a confusing species and very much in need of a thorough re-evaluation. Pilsbry (1928, 1940) defined *Cryptomastix hendersoni* only on the characteristics of shell morphology, and there are no published descriptions or illustrations of the internal anatomy of this species. Anatomical, morphological, and/or molecular clarification of the species concept for this taxon, as well as other *Cryptomastix* species, is needed.

Specimens fitting the key characteristics of *C. hendersoni* span the full range between *C. hendersoni* and the *C. mullani* subspecies. Although there do seem to be some distinctions in size, color, smoothness or roughness of the shell, no consistency has been found in the dentition, either in *C. hendersoni* or *C. mullani* (Burke 2014, *pers. comm.*). Recent Xerces Society collections from the Blue Mountains contained specimens of what appeared to be both *C. hendersoni* and *C. mullani*, as well as various intergrades between those two species (Jepsen *et al.* 2011, 2012; Burke 2014, *pers. comm.*). Specimens from this region were considered by Frest & Johannes 1995, 1996 to be a different taxon. In addition, Tom Burke has specimens that appear to be *C. hendersoni* from farther up the Columbia in Chelan County, well outside of the previously known range. Snails collected from mid-elevations in the Mount Hood National Forest also need to have their taxonomy examined; these specimens key out to *C. hendersoni* but appear to be a different species or even genus (Burke 2014, *pers. comm.*).

In light of the above, anatomical/molecular investigations should examine specimens from the type locality (The Dalles, Oregon) for comparison with specimens collected in eastern Oregon and Washington (Blue Mountains region), Chelan County, Washington, and Mount Hood National Forest, Oregon. Further analyses of these populations are needed to verify whether they represent the same species, distinct races of this species, or closely related species. For further details, see summary by Tom Burke in Jepsen *et al.* (2012).

In addition, the ecology, distribution, and abundance of and threats to these species should be examined.

B. Research Questions

- What anatomical and/or genetic differences distinguish this species from other *Cryptomastix*? Are these consistent with the external features used to identify this species in the field? Does genetic and/or anatomical evidence support the most recent concept of this species, e.g., as presented in Burke (2013)?
- What are the biological attributes required by this species?
    - Plant community associations, and specific plant species required/used
    - Amount of large woody debris/rock desired
    - Optimum forest crown cover to maintain desired conditions

- What is the life history of this species, including longevity, reproductive ecology, and diet?
- What are the daily and annual movements, and seasonally used refugia structures?
- How does this snail respond to prescribed fire and other vegetation management?
- What are the threats to this snail from increasing recreational activities?
- Does the air pollution in the Columbia River Gorge have any effect on this snail?

C. Monitoring Opportunities

Since the security of this species is questionable, monitoring existing populations is considered a critical conservation measure for this species (Burke 2008, *pers. comm.*). Monitoring known sites is recommended to track trends in populations (numbers, size and density), reproduction, and quantity/quality of habitats. Monitoring is also recommended to determine impacts on habitats and populations from management activities, natural disturbances, and vegetative succession.

Monitoring recommendations include:

- Conduct surveys in spring and fall after the first heavy rainfall or frost.
- Record all environmental conditions where these species are found to better understand their habitats and management needs.
- Through surveys and studies, determine the extent of the species range, and the habitats and ecology of the species.
- Monitor sites for conditions and trends of populations.

VI. References

Bland, T., and J. G. Cooper. 1862. Notice of land and freshwater shells collected by Dr. J. G. Cooper in the Rocky Mountains, etc., in 1860. Lyceum of Natural History of New York (published in New York, but printed in London), Annals, volume 7 (for 1861, volume title page dated 1862), pages 362-370 [part of signatures 24 and 25, both dated June 1861, but all parts were printed in England, so signature dates only refer to meeting dates] and plate 4. [*Cryptomastix mullani*, as *Helix mullani*, was named on page 363 and illustrated in figures 16-17 on plate 4.]

Bouchet, P. and J. P. Rocroi. 2005. Classification and nomenclature of gastropod families. Malacologia: International Journal of Malacology 47(1-2):1-397.

Burch, J. B. and T. A. Pearce. 1990. Terrestrial Gastropoda. Chapter 9 (pages 201-309) *in* Daniel L. Dindal (editor). Soil biology guide. John Wiley and Sons (New York, NY), xviii+1349 pages.

Burke, Tom. 2008. Regional mollusk expert. Personal communication with Sarah Foltz Jordan, Xerces Society.

Burke, Tom. 2014. Regional mollusk expert. Personal communication with Sarah Foltz Jordan, Xerces Society.

Burke, T. 2013. Land snails and slugs of the Pacific Northwest. Oregon State University Press, Corvallis, Oregon. 344 pp.

Cordell, H.K., McDonald, B.L., Teasley, R.J., Bergstrom, J.C., Martin, J., Bason, J., and Leeworthy, V.R. 1996. Outdoor recreation participation trends. *In*: Outdoor recreation in American life: a national assessment of demand and supply trends (Cordell, H.K., Betz, C.J., Bowker, C.J., eds.). Sagamore Publishing, Champaign, IL. 449 pp. Available at: http://www.srs.fs.usda.gov/pubs/ja/ja_cordell010.pdf.

Field, C.B., Mortsch, L.D., Brklacich, M., Forbes, D.L., Kovacs, P., Patz, J.A., Running, S.W. and M.J. Scott. 2007. Chapter 14: North America. *In:* Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J. and Hanson, C.E., eds.). Cambridge University Press, Cambridge, UK. Available at: www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4-wg2-chapter14.pdf

Foltz Jordan, S. and S. H. Black. 2012. Effects of forest land management on terrestrial mollusks: A literature review. Prepared for Interagency Special Status and Sensitive Species Program, USDA Forest Service, Region 6 and USDI Oregon/Washington Bureau of Land Management. 87 pp. Available online at: http://www.xerces.org/wp-content/uploads/2012/04/forest-land-management-and-mollusks.pdf

Frest, T., and E. Johannes. 1995. Interior Columbia Basin mollusk species of special concern. Report by Deixis Consultants (Seattle, WA) to Interior Columbia Basin Ecosystem Management Project, xi+274 pages, plus 54 pages of tables and 34 pages of figures, January 15.

Frest, T., and E. Johannes. 1996. Taxonomic report for ROD mollusk species. Report by Deixis Consultants (Seattle, WA) to USDI Bureau of Land Management [Oregon State Office and Salem District Office], contract order number 1422H952-P5-4298, 55 pages, March.

GeoBOB 2014. GeoBOB Database: Fauna observations. GIS export provided to Sarah Foltz Jordan, Xerces Society, by Diane Stutzman, January 2014.

Hohler, D.B., and other members of the Riparian Reserve Technical Team. 1997. Riparian Reserve evaluation techniques and synthesis. Supplement to Section II of Ecosystem analysis at the watershed scale: Federal guide for watershed analysis (version 2.2). Regional Ecosystem Office (Portland, OR), iv+42 pages and Species information addendum to Appendix B (x+342 pages), February.

ICZN (International Commission on Zoological Nomenclature). 1985. International Code of zoological nomenclature. Third edition. International Trust for Zoological Nomenclature (British Museum, London), xx+338 pages.

Jepsen, S., Burke, T., and S. Foltz Jordan. 2011. Final Report to the Interagency Special Status / Sensitive Species Program regarding Surveys for four terrestrial mollusk species on the Umatilla National Forest and Vale District BLM lands. Report submitted by The Xerces Society for Invertebrate Conservation.

Jepsen, S., Carleton, A., and S. Foltz Jordan. 2012. Spring 2012 Blue Mountains terrestrial mollusk surveys. Final Report to the Interagency Special Status / Sensitive Species Program (ISSSSP) from The Xerces Society for Invertebrate Conservation. Assistance agreement L08AC13768, Modification 7.

NatureServe. 2014. *Cryptomastix hendersoni*. NatureServe Explorer: An online encyclopedia of life [web application]. Feb. 2009. Version 7.1. NatureServe, Arlington, Virginia. Available at: http://www.natureserve.org/explorer/ (Accessed 11 Sep. 2013).

NRIS 2014. Forest Service NRIS Database: Wildlife observations. GIS export provided to Sarah Foltz Jordan, Xerces Society, by Diane Stutzman, January 2014.

Pilsbry, H.A. 1895. Index to the Helices. Volume 9 *in* George W(ashington) Tryon. 1885-1935. Manual of conchology, structural and systematic, with illustrations of the species. Second series, Pulmonata. 28 volumes in 30 parts (author and publisher varies).

Pilsbry, H.A. 1928. Species of *Polygyra* from Montana, Idaho, and the Pacific Coast states. Academy of Natural Sciences (Philadelphia, PA), Proceedings, volume 80, pages 177-186, August 6.

Pilsbry, H.A. 1939. Land Mollusca of North America (north of Mexico). Academy of Natural Sciences (Philadelphia, PA), Monograph 3, volume 1, part 1, pages i-xvii, 1-573, and i-ix (volume index), December 6.

Pilsbry, H.A. 1940. Land Mollusca of North America (north of Mexico). Academy of Natural Sciences (Philadelphia, PA), Monograph 3, volume 1, part 2, pages i-viii, 575-994, and i-ix (volume index), August 1.

Turgeon, *et al.* 1998. Common and scientific names of aquatic invertebrates from the United States and Canada: Mollusks. Second edition. American Fisheries Society, Special Publication 26, x+526 pages.

USDA Forest Service and USDI Bureau of Land Management. 1994. Final Supplemental Environmental Impact Statement on management of habitat for Late-Successional and Old-Growth forest related species within the range of the Northern Spotted Owl. Appendix J2. Results of additional species analysis. and Record of Decision. USDA Forest Service and USDI Bureau of Land Management (Washington, DC), vi+476 pages, February.

USDI and USDA Forest Service. 2004. Final Supplemental Impact Statement to Remove or Modify the Survey and Manage Mitigation Standards and Guidelines.

Vagvolgyi, J. 1968. Systematics and evolution of the genus Triodopsis (Mollusca: Pulmonata: Polygyridae). Harvard University, Museum of Comparative Zoology, Bulletin, volume 136, number 7, pages 145-254, February 12.

Walton, M.L. 1963. Length of life in west American land snails. Nautilus, volume 76, number 4, pages 127-131, (April 19).

Walton, M.L. 1970. Longevity in *Ashmunella*, *Monadenia* and *Sonorella*. Nautilus, volume 83, number 3, pages 109-112, (January 23).

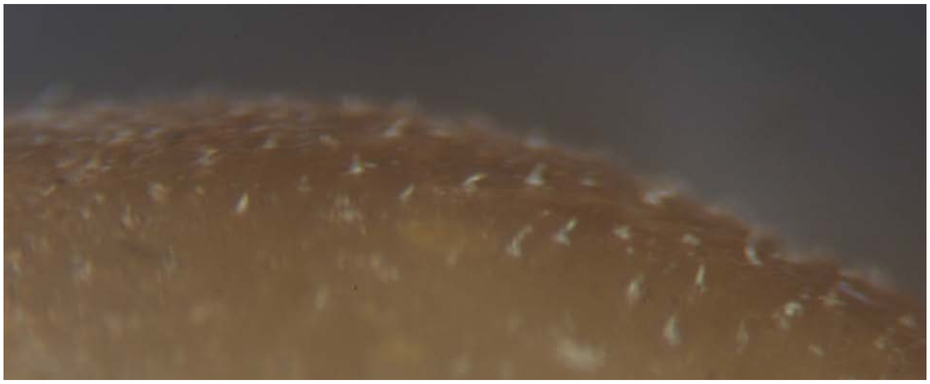
Webb, G.R. 1970. Fragmentary observations on sexology of *Cryptomastix hendersoni* Pilsbry and *C. magnidentata* Pilsbry and a new subgenus (Pulmonata, Polygyridae, Ashmunellinae). Gastropoda, volume 1, number 8, pages 77-78.

Webb, G.R. 1990. Photographs of the copulation of *Cryptomastix* (*Bupiogona*) *hendersoni*. Gastropodia, volume 2, number 3, page 22.

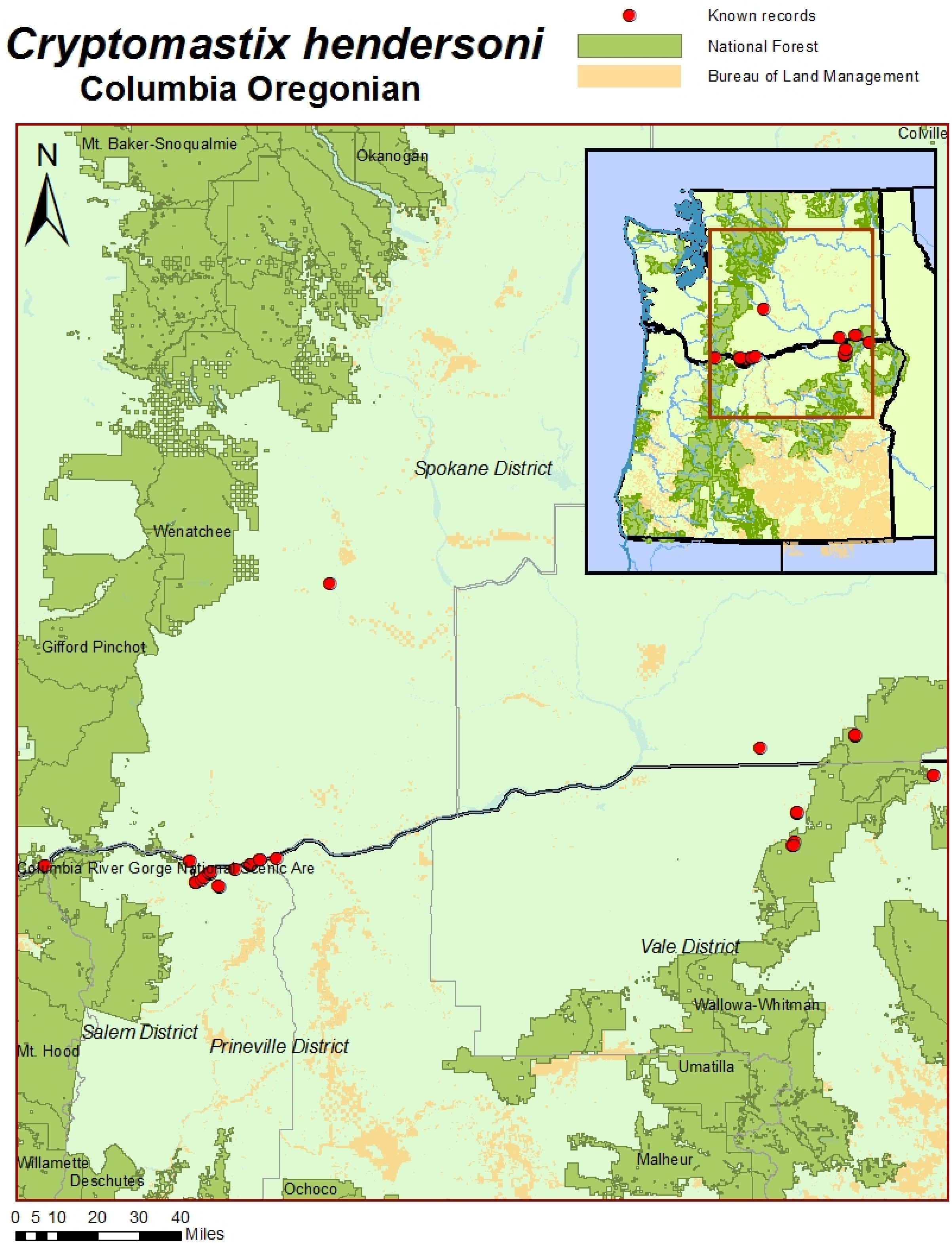
VII. PHOTOGRAPHS

Cryptomastix hendersoni shell from the Blue Mountains, shown from dorsal, lateral, and ventral views. Note the lack of apertural dentition. Photographs by Tom Burke in Jepsen *et al.* 2012, used with permission.

Cryptomastix hendersoni shell from Klickitat County, Washington, shown from dorsal, lateral, and ventral views. Note the small parietal tooth. Photographs by Bill Leonard, used with permission.


Cryptomastix hendersoni specimen with periostracal hairs, an unusual trait for this species. Photograph by Tom Burke in Jepsen *et al.* 2012, used with permission.

VIII. DISTRIBUTION MAP



Map showing known *Cryptomastix hendersoni* distribution relative to Forest Service and BLM lands.