Conservation Assessment

for

Hemphillia burringtoni, Burrington Jumping-slug

and

Hemphillia glandulosa, Warty Jumping-slug

Hemphillia burrington-glandulosa species complex. Photograph by Bill Leonard, used with permission

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By Thomas E. Burke

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By Mitch Wainwright & Nancy Duncan

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By: Sarah Foltz Jordan & Scott Hoffman Black (Xerces Society)
Reviewed By: Tom Burke

USDA Forest Service Region 6 and
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Interagency Special Status and Sensitive Species Program

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Preface

Summary of 2015 updates:
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 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.

EXECUTIVE SUMMARY

Species and Taxonomic group:

- *Hemphillia burringtoni* (Pilsbry 1948) Burrington Jumping-slug
- *Hemphillia glandulosa* (Binney & Binney 1872) Warty Jumping-slug

Taxonomic Group: Mollusks (Phylum Mollusca; Class Gastropoda, Family Arionidae)

Management Status & Occurrence on BLM/Forest Service Lands:

Hemphillia burringtoni:
Forest Service/BLM Status and Occurrence: This species is a Sensitive Species in Washington (ISSSSP 2015), where it is documented on the Olympic National Forest. The species is also a Category E Survey and Manage species throughout the range of the species, which also includes documented occurrences on the Siuslaw National Forest. In addition, this species is very likely documented on Salem BLM land in Oregon, although specimens are in need of examination (could also be *H. glandulosa*).

NatureServe status:
Global Status: G1G2
National Status: N1N2
State Status: Washington, S3; Oregon, not ranked
(NatureServe 2014a).
Note that this species is in need of new ranking by both Oregon and Washington Natural Heritage Programs, including evaluation of the information presented in Wilke and Ziegltrum (2004).

Hemphillia glandulosa:
Forest Service/BLM Status and Occurrence: This species is not listed as Sensitive in Oregon or Washington (ISSSSP 2015). This species is a Category E Survey and Manage species in the western Washington Cascades. Within this area, the species is documented on the Gifford Pinchot National Forest. Outside of this area, the species may occur on Salem BLM land and the

Siuslaw National Forest in Oregon, although further genetic study is needed to assess this. See discussion under *H. burringtoni* Forest Service/BLM Status and Occurrence, below.

NatureServe status:
Global Status: G3G4
National Status (US): N3N4; National Status (Canada): N2N3
State/Province Statuses: Washington: S3; Oregon: S3; British Columbia: S2S3 (NatureServe 2014b).
Note that this species may be in need of new ranking by both Oregon and Washington Natural Heritage Programs, in light of the information presented in Wilke and Ziegltrum (2004).

Range:
A recent study by Wilke and Ziegltrum (2004) investigated the anatomy and DNA of 199 specimens of *H. glandulosa* and *H. burringtoni* from 24 sites throughout their distribution areas. The study found that although there are two distinct clades within this species complex, there are no known morphological or anatomical characters that can be used to distinguish between the two clades, but rather, the two clades (species) are best separated on the basis of geographic information. The new ranges of these species as established by Wilke and Ziegltrum (2004) are very different than previously understood (see Figure 1, Range, Distribution, and Abundance section, below, for details). Based on Wilke and Ziegltrum (2004) the ranges of these species are understood to be as follows:

Hemphillia burringtoni – From Vancouver Island, south throughout the Olympic Peninsula and far western Washington to Siuslaw National Forest along the Oregon coast.

Hemphillia glandulosa -- From Olympia, Washington to the southwestern Washington Cascades and far northwestern Oregon.

For specimens occurring outside of either of these two regions or on the border of these regions, the designation *Hemphillia glandulosa/burringtoni* species complex is recommended. In addition, this designation is recommended for areas within these regions that have been poorly sampled; e.g., the Siuslaw National Forest where only two specimens/localities were analyzed.

Habitat:
Hemphillia burringtoni and *H. glandulosa* inhabit moist forests dominated by conifers, with an occasional hardwood component. Although often occurring within riparian areas, these species are not considered to be riparian obligates. Inhabited areas have forest floors which are moist, and sometimes wet or saturated, and large woody debris, both conifer and hardwood, is abundant. Logs of decomposition class 3-5 are most often used. Litter and duff layers may be deep and generally continuous. Understory and herbaceous vegetation is quite variable, from depauperate to patchy, often consisting of sword ferns (*Polystichum munitum*) and other plants of cool shaded forests. Some specific microsite habitat elements for both species include conifer logs and/or heavy ground cover of low vegetation, litter, and debris.

Threats:
Loss or degradation of habitat leading to loss or isolation of populations at occupied sites is considered to be the major threat to these species. Primary causes of habitat loss include forest

management, conversion for agricultural, urbanization and other uses, and fire. Natural threats may include vertebrate and invertebrate predators (i.e., predatory snails, and beetles), especially in locally restricted areas. Predation and competition from exotic and introduced mollusks are also a consideration.

Management Considerations:
Consider the following when managing a site for the two species listed in this Conservation Assessment:

- Maintain microsite characteristics, including areas large enough to moderate fluctuations in humidity, temperature, and other environmental characteristics.
- Provide cover by preserving and recruiting dead and downed woody debris. Within habitats for these species an abundance of large woody debris may be necessary; the quantity naturally available for a given site could be determined by use of the DecAID model or other predictor of down wood amounts for the plant community.
- Avoid disturbance to occupied rockslides and talus areas from road construction, quarrying, and other activities.
- Maintain adequate canopy closure of trees to moderate fluctuations of temperature and humidity on the site.
- Maintain the hardwood tree component (i.e., maples, cottonwood, red alder, aspen) and native plant diversity to provide a constant supply of logs, leaves, fungi and leaf mold.
- Manage riparian sites by increasing Riparian Reserve widths if necessary, to maintain microclimate.
- Manage fuels near sites to protect from adverse effects of fire.
- Avoid compaction of the soil or disturbance of the litter layer.

Research, Inventory, and Monitoring Opportunities:
It has been found that there are no known morphological or anatomical characters that can be used to distinguish between taxa from *H. burringtoni* and *H. glandulosa*, and that they are best separated on the basis of geographic information alone (i.e. taxa within the geographic range of clade I should be assigned to the *Hemphillia burringtoni* species-complex and taxa within the range of clade II to the *Hemphillia glandulosa* species-complex, Figure 1, below). However, given that there are many potential geographic contact points between clade I and II, Wilke & Ziegltrum (2004) suggest a follow-up study to determine a more precise geographic boundary between the two clades. In addition, molecular analysis of specimens collected from outside of the geographic regions represented by the two clades (e.g., Salem BLM land) is needed.

There are potentially several other undescribed species in both the *H. burringtoni* and the *H. glandulosa* major clades, the exact number of which remains unknown. Further molecular studies are needed to examine this potential (Wilke & Ziegltrum 2004).

In addition to range delineation, additional questions include:

What is the range of environmental conditions tolerated by these species?

What are the stand characteristics required to support the species?

- Plant associations;
- Specific plant species required/used;
- Specific foods;
- Amount of large woody debris desired;
- Optimum forest crown cover to maintain desired conditions;
- Other stand structure and components;
- Soil types, geology;
- Temperature, humidity.

How do the required stand characteristics vary under different circumstances (elevation, slope, aspect, etc.)?

What stand size is required to provide sufficient area of suitable habitat?

How long is required for recolonization of a site by individuals from adjacent populations?

Monitoring of known sites is needed to track trends in populations (numbers, density and distribution, reproduction) and compare to quantity and quality of habitats. Monitoring is also needed to determine impacts on habitats and populations from management activities, natural disturbances, and vegetative succession.

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 *Hemphillia burringtoni* and *H. glandulosa* in an effort to assist managers in the formulation of options for management activities. These species are of concern due to their limited mobility, narrow habitat requirements, restricted distributions, and sensitivity to anthropogenic disturbance. Federal management follows Region 6 Sensitive Species (SS) and/or OR/WA BLM Special Status Species (SSS) policies and the Survey and Manage standards and guidelines.

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. The Survey and Manage standards and guidelines are designed to provide a reasonable assurance of species persistence throughout the range of the northern spotted owl for rare and uncommon species associated with late-successional and old-growth forests.

B. Scope

The geographic scope of this assessment includes consideration of the known and suspected range of these 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 non-federal lands is included as it is relevant to the overall conservation of the species. This assessment summarizes existing knowledge of two relatively little known invertebrates. A great deal of new information has been generated regarding these species in the last decade, especially regarding genetic structure and distribution. Still, the current understanding of these species' distributions is incomplete, and information updates may be necessary to keep this assessment current with time. Also, the 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

1. *Hemphillia burringtoni*

A. Forest Service/BLM Status and Occurrence
Hemphillia burringtoni is a Sensitive Species in Washington (ISSSSP 2015), and a Survey and Manage species throughout the species range in Oregon and Washington.

This species is Documented on the Olympic National Forest in Washington and on the Siuslaw National Forest in Oregon. In addition, either *H. glandulosa* (less likely) or *H. burringtoni* (more likely) is Documented from Salem BLM land in Oregon. Wilke & Ziegltrum (2004) examined

only two specimens/localities in this region, and although both of these were determined to be *H. burringtoni*, it is uncertain if this is the *only* species in the area, or if *H. glandulosa* occurs in this region as well, given the occurrence of *H. glandulosa* farther north along the Oregon Coast. As such, we have elected to treat all records in this region as "*H. burringtoni-glandulosa* species complex" with the exception of the two Siuslaw National Forest specimens analyzed in Wilke and Ziegltrum (2004). Further genetic analysis is needed in this area.

B. NatureServe status
Global Status: G1G2
National Status: N1N2
State Status: Washington, S3; Oregon, not ranked.
(NatureServe 2014a).

Note that *Hemphillia burringtoni* is in need of new ranking by both Oregon and Washington Natural Heritage Programs, including evaluation of the information presented in Wilke and Ziegltrum (2004). In addition to missing Oregon, the state ranking for Washington is likely in error; there can't be a S3 state rank with a global rank of G1G2.

2. *Hemphillia glandulosa*

A. Forest Service/BLM Status and Occurrence
Hemphillia glandulosa is a Survey and Manage Category E species in the western Washington Cascades. The species is not Sensitive or Strategic for Oregon or Washington (ISSSSP 2015). This species is Documented on the Gifford Pinchot National Forest. In addition, this species may occur on Salem BLM land and/or Siuslaw National Forest in Oregon, although further genetic study is needed to assess this. See discussion under *H. burringtoni* Forest Service/BLM Status and Occurrence, above.

B. NatureServe status
Global Status: G3G4
National Status (US): N3N4; National Status (Canada): N2N3
State/Province Statuses: Washington, S3; Oregon, S3; British Columbia, S2S3
(NatureServe 2014b).
Note that *Hemphillia glandulosa* may be in need of new ranking by both Oregon and Washington Natural Heritage Programs, in light of the the information presented in Wilke and Ziegltrum (2004).

II. Classification and Description

A. Systematic and Synonymy
Family: Arionidae
Subfamily: Binneyinae
Species: *Hemphillia burringtoni* Pilsbry, 1948 and *H. glandulosa* Bland & Binney, 1872

B. Species Description
The genus *Hemphillia* is a unique group of slugs endemic to the Pacific Northwest, in the family Binneyidae. This family is distinguished from related families by having a shell that is not

completely covered by the mantle. Evolutionarily, the Binneyidae appear between snails and slugs, retaining the visceral mass in a raised hump under the mantle, and a shell plate that is not completely enclosed as it is in all other slug species of western North America. The visceral cavity does not extend into the tail behind the mantle as in other slugs (Burke 2013). There are three genera in this family: *Binneya* in coastal California and some offshore islands; *Staala* in the Queen Charlotte Islands, British Columbia, and *Hemphillia* in northern Oregon, Washington, northern Idaho, northwestern Montana, and southern British Columbia (Burke 2013).

There are seven described species of *Hemphillia*; divided into two groups: The *H. glandulosa* group, which includes *H. glandulosa*, *H. burringtoni,* and *H. pantherina*; and the *H. camelus* group, consisting of *H. camelus, H. malonei, H. dromedarius,* and *H. daniels*. The *H. glandulosa* group consists of small slugs, about 20 mm in length or less, with their bodies compressed under the visceral hump, and their tails behind the hump relatively short (about ½ the length of the mantle). The tail has a conspicuous dorsal keel, and is arched for all or part of its length. Members of the *H. camelus* group are larger slugs, 30 to 50 mm or longer, with relatively long tails (more or less the length of the mantle). The dorsal profile of the tail is straight, and the tail is laterally compressed but not raised into an arched keel. In cross section, the tail is somewhat triangular but with an indented dorsal line behind the mantle, separating a herringbone pattern of oblique lateral grooves.

Within the *H. glandulosa* group, *Hemphillia burringtoni* and *H. glandulosa* are distinguished from the closely related *H. pantherina* by the following traits: in *H. pantherina,* the head, tentacles, and tail have a white dorsal stripe, and the posterior one-third of the visceral pouch is not covered by the granulose-textured mantle. In contrast, in *H. burringtoni* and *H. glandulosa*, the white dorsal stripe is lacking, and the mantle completely covers the visceral pouch (except where the shell shows through the slit as in all *Hemphillia*), and the mantle is usually distinctly papillose, seldom otherwise.

Recent molecular analysis to determine if *Hemphillia burringtoni* and *H. glandulosa* are in fact separate species revealed that although these species do split into two distinct genetic clades, the morphological characters previously used to distinguish between the two species (notably the papillosity of the mantle and black spots above the pedal furrow; Pilsbry 1948, Branson 1972) do not allow for reasonable differentiation between the two species/clades (Wilke & Ziegltrum 2004). Moreover, this study concludes that there are no known morphological or anatomical characters that can be used to distinguish between the two species, and that geographic range is currently the best species indicator short of DNA analysis (see Figure 1).

III. Biology and Ecology

A. Life History and Reproduction

Nearly all of the terrestrial gastropods in the Pacific Northwest, including the genus *Hemphillia*, are hermaphroditic, having both male and female organs. Self-fertilization has been demonstrated in some species, although cross-fertilization is probably the norm. Bayne (1973) discusses problems encountered with self- and cross-fertilization in Pulmonates, and the dominance of mating systems using allosperms (sperm from another) over autosperms (sperm from oneself).

Hemphillia glandulosa/burringtoni slugs (unclear which species) have been observed in copulation (Ziegltrum 2000).

All *Hemphillia* are oviparous (egg layers); the clutches are generally small, consisting of only a few eggs. *Hemphillia malonei* have been reared in captivity and eggs hatched. Eggs were laid 1 to 6 days after copulation in clutches of 19 to 61 eggs, each individual producing up to 4 clutches. Development time at 14°C ranged from 47 to 63 days from oviposition to hatching (Leonard & Ovaska 2002).

B. Activity Pattern and Movements

The common name of *Hemphillia* (jumping slugs) is derived from their habit of flipping their tails and writhing when disturbed, causing them to flip off of objects such as shrubs to avoid predators.

Movements and home range of *H. glandulosa* and *H. burringtoni* are unstudied. These slugs are probably relatively sedentary and have poor dispersal abilities, as evidenced by the species' scattered distributions throughout their ranges. Small pockets of greater density and the presence of suitable but unoccupied habitat further suggest this possibility (COSEWIC 2003, NatureServe 2014).

C. Food Habits

Particular foods and cover types are not documented for these species, but, like others in the *Hemphillia* genus, they are usually found within or under rotting logs, or forest floor litter, apparently feeding on decaying wood, fungi, vegetation or micro-organisms associated with decaying matter.

D. Range, Distribution, and Abundance

The ranges of both of these species have been recently determined to be very different than previously understood (Wilke and Ziegltrum 2004). In the past, it was believed that the two species had overlapping distributions in the Pacific Northwest, and co-occurred at many sites, but could be separated by morphological/anatomical traits. *Hemphillia burringtoni* was understood to occur from Vancouver Island, throughout the Olympic Peninsula, the Willapa Hills area and into the Southwest Washington Cascades in Washington State. *Hemphillia glandulosa* was understood to occur from British Columbia, the Olympic Peninsula, the southwestern Washington Cascades and coastal Washington, south to the northern portions of the Oregon Coast Range. A recent study by Wilke and Ziegltrum (2004) investigated the anatomy and DNA of 199 specimens of *H. glandulosa* and *H.burringtoni* from 24 sites throughout their known distribution in British Columbia, Washington, and Oregon. This study found that while there are two distinct clades within this species complex, these clades (i.e., species) do not separate by morphological or anatomical characters, but rather, are best separated on the basis of geographic information (Figure 1).

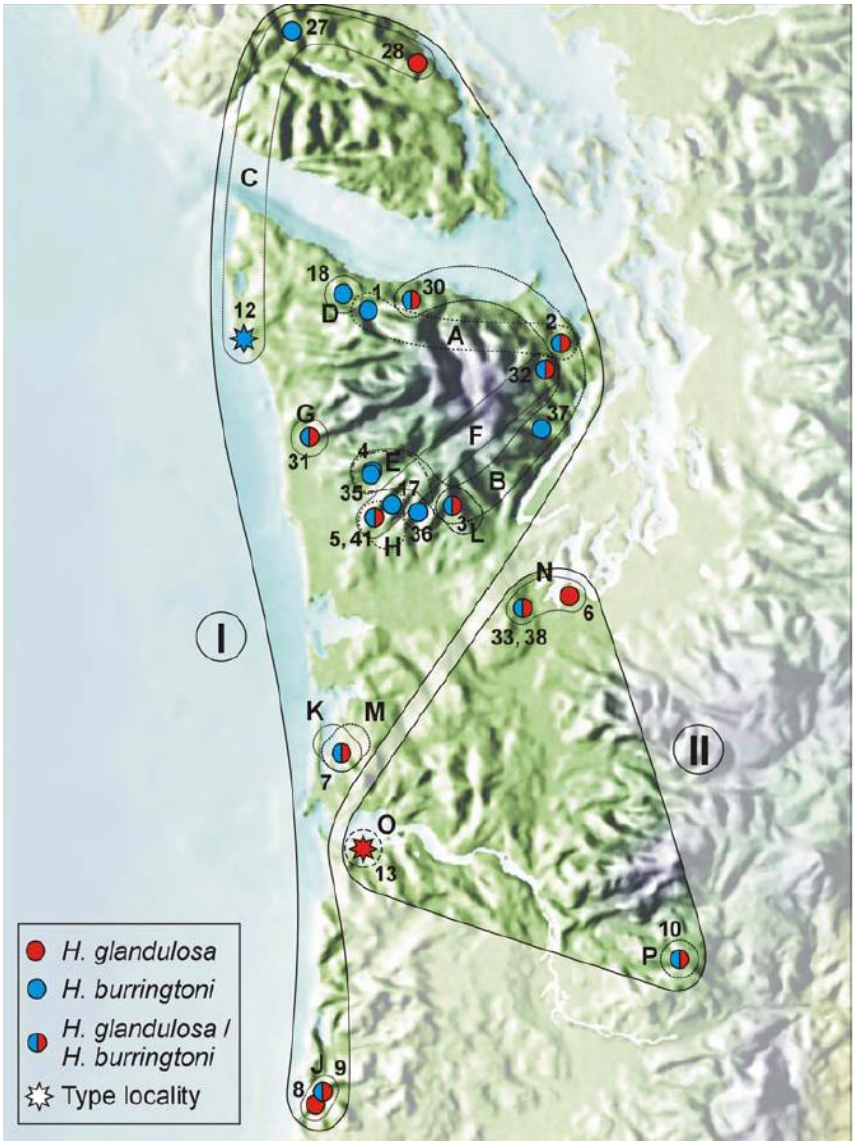

Figure 1. Map from Wilke and Ziegltrum (2004) showing the original identifications of specimens made from morphological characteristics and the geographic distribution of the major clades and sub-clades of *H. glandulosa* and *H. burringtoni* from their genetic work.

In Figure 1, the two major clades are indicated by Roman numerals I and II. Since the type locality for *H. burringtoni* falls within Clade I, and the type locality for *H. glandulosa* falls within Clade II, it is recommended that specimens occurring within the geographic region of Clade I be treated as *H. burringtoni*, and specimens occurring within the geographic region of Clade II be treated as *H. glandulosa*. Moreover, since there are potentially several other undescribed species within each of these major clades, the exact number of which remains unknown, Wilke and Ziegltrum (2004) recommend referring to taxa in clade I as the "*Hemphillia burringtoni* species-complex" and to taxa in clade II as the "*Hemphillia glandulosa* species-complex". Please note that for the purposes of simplification, these terms are *H. burringtoni* and *H. glandulosa* in this assessment. For a complete distribution map of these species, see the map at the end of this assessment.

The ranges of these species as currently understood are as follows (Wilke and Ziegltrum 2004):

Hemphillia burringtoni – From Vancouver Island, south throughout the Olympic Peninsula and far western Washington to Siuslaw National Forest along the Oregon coast. The type locality is Rialto Beach, Olympic National Park, just north of the Quillayute River mouth, Clallam County, Washington (H. B. Baker 1929; cited in Pilsbry 1948).

Hemphillia glandulosa – From Olympia, Washington to the southwestern Washington Cascades and far northwestern Oregon. The type locality is Astoria, Oregon (Pilsbry 1948).

The designation "*H. glandulosa/burringtoni* species complex" is recommended for specimens occurring outside of either of these two regions and on the border of these regions. It could also be argued that this designation should be used in localities where significant molecular work has not been done (even within the designated regions of Clades I and II, above).

Abundance:

Hemphillia burringtoni appears to be more common and well distributed in parts of its range (Olympic Peninsula), and less abundant within other parts. Pilsbry (1948) reported it only from the type locality. On Vancouver Island *H. burringtoni* appears to occur at low densities, but larger numbers of slugs are sometimes present in suitable moist habitats, if only in small pockets (COSEWIC, 2003, NatureServe 2014; note that these sources still treat the Vancouver Island occurrences as *H. glandulosa*). Branson (1977) found 9 specimens at 7 of 269 sites surveyed on the Olympic Peninsula, plus 1 specimen from near Willapa Bay. In their surveys of the Oregon Cascades and Coast Range, Branson and Branson (1984) found one specimen that may have been this species. Frest and Johannes (1993) said they had not found it at their Washington sites in 1986 through 1991. However, more recent, extensive surveys in the Olympic National Forest suggest that *H. burringtoni* species might be more widespread and abundant than previously thought, at least in the Olympic Mountains, where 541 new localities were found within this area from autumn 1998 to 2001 (J. Ziegltrum, pers. comm. in NatureServe 2014). In the Gifford Pinchot National Forest, where *H. glandulosa* occurs, recent surveys have revealed relatively few sites for *H. glandulosa*, and many more sites and records for the related *H. malonei*. This suggests that *H. malonei* may begin to replace the *H. glandulosa/burringtoni* complex in the Cascade Range. Burke *et al.* (1999, original version of this assessment) implied that *H. burringtoni* occurs at low densities, based on the capture of only up to 12 individuals per site.

Records for *H. glandulosa* were scarce prior to implementation of the Northwest Forest Plan in 1994. Branson did not record it in any of his surveys of the Washington Cascades (1980), the Olympic Peninsula (1977), or the Oregon Cascades and Coast Range (Branson and Branson 1984). Frest and Johannes (1993) said, "We have not seen this species at our sites." Pilsbry (1948) lists 8 locations from Washington and Oregon and 2 from British Columbia. In more recent years, it has been found to be "quite common in the northern part of its range in Oregon and Washington," however it is now known that many of the records attributed to *H. glandulosa* are actually *H. burringtoni*, which is has been documented from a greater number of sites and is often more abundant where it occurs. Most records of *H. glandulosa* are of just one or a few individuals at each site.

E. Population Trends
Although detection of this species has increased in the past 15 years (see above), population trends (changes in population number and size through time) are not known. It has been reported that many historic populations, e.g., in the Willapa Hills, have been extirpated due to land use changes (Frest & Johannes 1993).

F. Demography
Current knowledge of these species indicates that they have very spotty distributions across their range, probably due to fragmention of habitat and other factors. The small ranges of these species, combined with habitat restrictions within those ranges, make these slugs highly susceptible to problems associated with genetic isolation.

G. Habitat
Hemphillia burringtoni and *H. glandulosa* inhabit low to mid elevation rain forests dominated by conifers, with an occasional hardwood component. Although often occurring within riparian areas, these species are not considered to be riparian obligates. Inhabited areas have forest floors which are moist, and sometimes wet or saturated, and large woody debris, both conifer and hardwood, is abundant. Logs of decomposition class 3-5 are most often used. Litter and duff layers may be deep and generally continuous. Understory and herbaceous vegetation is quite variable, from depauperate to patchy, often consisting of sword ferns (*Polystichum munitum*) and other plants of cool shaded forests. Some specific microsite habitat elements for both species include conifer logs and/or heavy ground cover of low vegetation, litter, and debris.

The following species specific habitat details have been adapted from the 1999 version of this assessment, to align with our current knowledge of the distribution of these species:

Hemphillia burringtoni inhabits rainforests and other wet forest areas in western Washington to northwestern Oregon from sea level to at least 1050 meters (3445 feet) elevation, the point at which Branson (1977) called "transition zone." Habitat descriptions are not extensive, but they imply general rain forest, or other moist to wet forest conditions with heavy shading or vegetative cover, or (as with many gastropods) talus. Branson (1977 & 1984) found this species in dense rain forests including hemlock, spruce, western red cedar, pines, ferns and mosses, sometimes associated with fallen logs, talus, and/or shrubs. Branson (1972 & 1977) reported it from elevations ranging from 166 to 1050 meters (545 to 3435 feet), in rain forests, with heavy Pacific dogwood growth in one site, in talus at one site, and with ferns and fallen logs.
USDA, Forest Service, and USDI, Bureau of Land Management (1994: J2-347) says of *H. burringtoni*, "Species is a riparian associate." This may be true in the sense that moist riparian forests support many snails and slugs, but no references found indicate that *H. burringtoni* has any particular affinity to riparian habitat over other moist forest conditions. Frest and Johannes (1993) called it an "Old growth and riparian associate . . .", which better aligns with the meager descriptions of the locations by Branson (op cit).

The most recent survey efforts by the Forest Service (FS) and Bureau of Land Management (BLM) report this species complex (*H. burringtoni* and *H. glandulosa*, combined) from elevations ranging from 300 to 2700 feet. Slopes ranged from 0 to 75%, and aspect ranged from zero to 360 degrees. Canopy cover on the sites ranged between 2 - 100% and indicates that this species complex, as a whole, occurs in a wide range of forest conditions. These include several

old-growth sites and many in second growth conifer forests between 40 - 80 years old. Only a small number of old-growth sites have been located, but this is likely due to the focus on project surveys for commercial thinning timber sales (Ziegltrum 2000). It is important to note that most records are the results of surveys conducted for project clearances, which were mostly proposed commercial thinnings in young, second growth forests of Douglas-fir (*Pseudotsuga menziesii*), western hemlock (*Tsuga heterophylla*), western redcedar (*Thuja plicata*), Sitka spruce (*Picea sitchensis*) and occasionally Pacific silver fir (*Abies amabalis*). Therefore, only a small portion of potential *H. burringtoni* and *H. glandulosa* old growth habitat was inventoried, and the importance of this type of habitat for the species may be understated.

On the Olympic Peninsula, *H. burringtoni* slugs were found in elevations ranging from 300 to 2700 feet. Slopes ranged from 0 to 75%, and aspect ranged from zero to 360 degrees. The majority of the sites were in 40 - 60 year old second-growth forests. Canopy cover on the sites ranged between 2 - 100%. The overstory was western hemlock, Douglas-fir, Sitka spruce, western redcedar and occasionally Pacific silver fir. A number of the sites included red alder, bigleaf maple or vine maple microsites, however, hardwoods do not appear to be a limiting factor in *H. burringtoni* habitat. Plant associations and understory species were variable, with sites from both the west and east sides of the Olympic Mountains. Sites were in the Pacific silver fir vegetation zone, the Sitka spruce zone, and in the western hemlock zone. Plant associations in the western hemlock zone included drier sites with salal (*Gaultheria shallon*), and moister sites with sword fern or Devil's club (*Oplopanax horridus*), plus many other plant species, including Oregon grape (*Berberis nervosa*), salmonberry (*Rubus spectabilis*), Alaska huckleberry (*Vaccinium alaskaense*), and red huckleberry (*Vaccinium parvifolium*). Moss was a key habitat component at many sites, along with down wood in various sizes, generally in decay classes 3-5.

On the Gifford Pinchot National Forest where *H. glandulosa* occurs, locations in the Mt. St. Helens Ranger District are stands from 40 - 200 years old. Slopes ranged from 0 - 30%, aspect from 2 - 360 degrees and canopy cover from 40 - 100%. Fifty-three percent of the sites were in the Pacific silver fir zone, with an overstory of silver fir, western hemlock, western redcedar and occasionally Douglas-fir. The remaining sites were in the western hemlock zone and included 13 hardwood sites (vine maple, bigleaf maple and red alder). Two *H. glandulosa* slugs were found in a 12 year old plantation on the Gifford Pinchot National Forest. Surveys have been very limited in such young forests, and more work is needed in this area.

The sites in the Oregon Coast Range on the Hebo District of the Siuslaw National Forest were in relatively dense stands of 28 to 85 year old conifers, with a large component of Douglas-fir. Slope aspects were generally between 135 degrees (SSE) and 320 degrees (NNW). (Note that two of the sites on this Forest were determined to be *H. burringtoni;* the other sites are undetermined to species and treated as *H. burringtoni/glandulose* complex). Canopy cover on the majority of the sites was generally between 60 to 90%. The conifer overstory was primarily Douglas-fir. Western hemlock was mixed with Douglas-fir, and red alder occurred in some locations. Understory species included salmonberry, red huckleberry, fool's huckleberry (*Menziesia ferruginea*) and vine maple. Sword fern, moss and salal were common on many of the sites. Data from the BLM's Tillamook Resource Area were similar to the Siuslaw's. However, two of the BLM sites were in an 11 year old previously burned plantation; the former stand may have been mixed conifer and bigleaf maple.

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). The following list highlights some of the important ecosystem functions of terrestrial mollusks.

Decomposition and nutrient cycling: 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 for wildlife: Their unique "jumping" habit of the jumping-slugs (*Hemphilia* sp.) is assumed to be an adaptation for defense against predators. Specific predators of the jumping-slugs are not well-documented, but as with other mollusks, they are likely preyed upon by a variety of animals. 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. 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).

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 the Species

Loss or degradation of habitat leading to loss or isolation of populations at occupied sites is a major threat to *H. burringtoni* and *H. glandulosa*. Primary causes of habitat loss include timber harvest and associated activities, agriculture, and development of forested land for housing, recreation, and other uses. According to Frest and Johannes (1993), many of the historic sites were in the Willapa Hills and are probably extirpated, as this area has been almost completely logged. Most other localities were from areas that are now strongly urbanized (Frest and Johannes 1993).

As reviewed in Foltz Jordan & Black (2011), forestry and road-building activities frequently disturb the shady, moist forest floor conditions and coarse woody debris required by many native slugs, and may also restrict slug dispersal. In addition to anthropogenic threats, *H. burringtoni* and *H. glandulosa* are vulnerable to natural disturbances such as vertebrate and invertebrate predators (i.e., predatory snails, and beetles), especially in locally restricted areas (COSEWIC 2003, NatureServe 2014b). Predation and competition from exotic and introduced mollusks may also pose threats to these species.

B. Conservation Status

1. Overview

The majority of known records for *Hemphillia burringtoni* are in the Olympic Peninsula, Washington. This species is probably more vulnerable in Oregon, due to its limited distribution and low number of documented occurrences (although information is lacking in this regard, due to uncertainty about the species designation of a number of Oregon records). Range-wide, a number of threats are expected to impact the long-term survival of this species (see Threats section, above).

The majority of known records for *Hemphillia glandulosa* are in the Gifford Pinchot National Forest, Washington. Like *H. burringtoni,* this species is probably more vulnerable in Oregon, due its limited distribution and potentially very low number of documented occurrences (although information is lacking in this regard, due to uncertainty about the species designation of a number of Oregon records). Range-wide, a number of threats are expected to impact the long-term survival of this species (see Threats section, above).

Due to limited mobility and narrow habitat preferences, these species, like many other terrestrial snails and slugs, cannot easily escape unfavorable habitat changes, and are thus are highly impacted by environmental disturbance and (*reviewed in* Foltz Jordan & Black 2012). These life history factors suggest that known 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), *Hemphillia burringtoni* had a 33% chance of being well distributed across Federal lands, a 27% chance of being locally restricted (i.e., with significant gaps between

populations), a 20% chance of being restricted to refugia, and 20% of being extirpated. This ranking was based on the known sites and limited range known at that time. This ranking also did not take into account riparian reserve land-use allocations, added later in the selection of a preferred alternative for the Northwest Forest Plan. Current knowledge indicates there are significant gaps between populations. If additional surviving populations are discovered, as seems likely, the probability of a more favorable outcome might increase. "The rating for the species is based on the possible reduction from its historic distribution, the lack of knowledge of its current status, and the lack of specific protection in the Olympic AMA" (USDA, Forest Service, and USDI, Bureau of Land Management, 1994: J2-347). In 2001, it was categorized as a rare species, under Survey and Manage Category A, based on the low number of occurrences, its low detection rate in suitable habitat and its small range. After the Annual Species Review in 2002 this species was placed in Category E, due to difficulties in taxonomy and identification, and uncertainty about association with mature and old growth forests.

Hemphillia glandulosa was listed under Table C-3, Survey Strategies 1 and 2 of the Survey and Manage Standard and Guidelines (USDA, Forest Service, and USDI, Bureau of Land Management, 1994: Standards and Guidelines C-6 and C-59). "The rating for the species is based on the possible reduction from its historic distribution, the lack of knowledge of its current status, and the lack of specific protection in the Olympic AMA" (USDA, Forest Service, and USDI, Bureau of Land Management, 1994: J2-347). It was originally considered to be a rare species throughout its range, under Survey and Manage Category A, based on the low number of occurrences, its low detection rate in suitable habitat and its small range. After the Annual Species Review in 2002 the populations in the Oregon Coast Range and the Olympic Penninsula were considered to be stable and were removed from the Survey and Manage Standards and Guides, while the western Washington Cascades populations were designated Category E. .

3. Major Habitat and Viability Considerations

Although significant progress has been made by Wilke & Ziegltrum (2004), the occurrence and distribution of *H. burringtoni* and *H. glandulosa* are in need of better clarification. There may be confusion over distribution, biology, ecology, and habitats due to reports in the literature, and numerous incorrect species or subspecies determinations. As the knowledge about the species' distributions continue to improve, it will be necessary to use this information to better understand the differences and similarities between habitats, ecology, and biology, as well as population trends, and statuses.

The number 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, increasing opportunities for interaction between populations. Genetic diversity in small or low density populations should be of concern.

4. Distribution Relative to Land Allocations

AMA/LSR Background: Adaptive Management Areas (AMAs) are landscape units comprised of lands administered by both the Bureau of Land Management and National Forests as part of the Northwest Forest Plan. Under this Plan, ten AMAs ranging from about 92,000 to nearly 500,000 acres of federal lands have been identified in California, Oregon, and Washington. In each AMA, a certain percentage of the land is further classified by the Northwest Forest Plan as Late-Successional Reserve (LSR). This designation has some important implications regarding AMA

management. While the primary management goal for AMAs is essentially the same goal as for LSRs (to maintain and develop late-successional forest habitat), some significant differences exist between the two allocations. The objective of AMAs is to encourage the development and testing of technical and social approaches to achieving desired ecological, economic, and other social objectives. The objective of LSRs is to protect and enhance conditions of late successional and old-growth forest ecosystems, which serve as habitat for late-successional and old-growth forest related species including the northern spotted owl. Limited stand management is permitted in LSRs, and is subject to review by the Regional Ecosystem Office. The standards and guidelines for LSR are more specific than those for AMA: No programmed timber harvest is allowed inside the reserves. However, thinning or other silvicultural treatments inside these reserves may occur in stands up to 80 years of age [110 years in the Northern Coast Range AMA] if the treatments are beneficial to the creation and maintenance of late-successional forest conditions (PLAN, page 8). On the other hand, programmed timber harvest is not only permitted, but expected in those portions of the AMA that are not LSR. "One reason for locating Adaptive Management Areas adjacent to communities experiencing adverse economic impacts is to provide opportunity for social and economic benefits to these areas. Adaptive Management Areas are expected to produce timber as part of their program of activities..." (ROD 1994, page D-8). In the portions of the AMA not designated as LSR, there is no upper age limit specified for timber stand management--so a great deal of room exists for innovation. Under the Plan's guidelines, stands of any age could be treated to enhance multistoried structure, increase species diversity, or encourage development of large, limby trees. The design of stand treatments may reflect a greater emphasis on providing economic benefits for local communities, while continuing to work towards the goal of increasing the amount of older-forest structure. Also, research projects planned for the AMA may incorporate a wider range of treatment types than would be considered appropriate in an LSR.

The largest number of *Hemphillia burringtoni* locations are in the Olympics and Oregon Coast Range. The majority of the Olympic Peninsula sites are in Adaptive Management Areas (AMAs), as are the sites in the Oregon Coast Range. The Olympic Peninsula sites are on the Olympic National Forest, Olympic National Park, the Quinault Indian Reservation, and one is in a State Park. Within the Olympic National Forest, 81% of the *H. burringtoni* locations are in AMA outside of Late Successional Reserves, and 19% are in AMA-Late Successional Reserves (LSR). The population segments in the National Park may be secure, but without additional surveys, little is known about the percentage of the historic range that occurs there. Based on the much broader range of the species, it is speculated that the populations within the Park are a relatively small portion of the total populations, at least historically. The primary habitat of *Hemphillia burringtoni* is in rainforests and riparian habitats, which have been heavily logged on the Olympic Peninsula. Other habitat may be managed as Late-Successional Reserve (LSR) or Adaptive Management Area (AMA) on the Olympic National Forest. Since AMAs are to be managed experimentally, habitat may be adversely modified or lost as projects are implemented. Occupied habitat in LSRs is more likely to remain suitable, as thinning projects in mid- successional stands (40-80 years of age) are designed to accelerate the development of late-successional conditions. Thinning operations are the predominant type of forest disturbance on the Forests (both within and outside of LSRs).

In addition to sites on the Olympic Peninsula, a number of *Hemphillia burringtoni* locations are in the Oregon Coast Range. On the Siuslaw National Forest, 84% of the sites are in AMA-LSR,

and 16% in AMA outside of LSR. The Tillamook Resource Area of the BLM also has most of its sites in Late Successional Reserves (85%).

The largest number of sites for *H. glandulosa* is on the Gifford Pinchot National Forest, Washington. The majority of sites on the Gifford Pinchot NF are in the Matrix land allocation, with some in Late Successional Reserves. This distribution of sites is reflective of where pre-disturbance survey efforts have occurred on the forest; most projects requiring surveys have been in the Matrix land allocation. There is no reason to believe that the density of sites in the Late Successional Reserves is any less than in Matrix. Habitat in Late Successional Reserves is likely to remain suitable, as the main activity in that allocation is thinning projects in mid- successional stands (40-80 years of aged), designed to accelerate the development of late-successional conditions.

C. Known Management Approaches and Considerations

1. Management Goals for the Taxon

Management for these 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. Management also follows the Survey and Manage Standards and Guidelines, to provide a reasonable assurance of species persistence throughout the range of the northern spotted owl in Oregon and Washington. Project surveys for this species should follow the terrestrial mollusk survey protocol (Duncan et al. 2003) available from the Survey and Manage website: http://www.blm.gov/or/plans/surveyandmanage/.

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 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. Based on the small size and limited dispersal ability of these species, the size required to sustain a population of interacting individuals may range in size, depending on the extent of contiguous habitat and the condition of surrounding habitat needed to maintain suitable moisture conditions. Consideration should be given to daily and yearly activity cycles of the slugs as this data is collected. At the smallest scale, within each habitat area, habitat elements such as large down wood and rock features, 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 during the active seasons.

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.

In general, *Hemphillia* are quite vulnerable to heat and desiccation and use 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 could focus on maintaining the temperature and moisture regime of these microsites. Consider retaining sufficient overstory crown cover and understory vegetation to shade the ground, provide humidity through evapotranspiration, condense fog and dew, intercept underground water and hold it on the site, and impede air movement that would tend to displace the cool moist air. Available crown cover information for these habitats is meager, but observations recorded in some western hemlock/Douglas-fir stands indicated summer crown cover of 70-90% plus.

Consider maintaining or enhancing the naturally occurring diversity of plant species in Species Habitat Areas. 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 assurance that specific plant species, if found to be critical in the life cycle of these mollusk species, are not inadvertently lost. As yet we know too little about the needs of these species to identify an optimum mix of tree species, but it appears that mixed stands of conifer and hardwoods provide the best habitat. Maintaining a mix of hardwood and conifer species would provide a more diverse and complete set of conditions for multiple species and a more fully functioning ecosystem.

Maintenance and future recruitment of large and small woody debris is important, as is a thick layer of litter and duff on the forest floor. These components provide cool moist places in which these animals spend the days, hide from predators, deposit their eggs, and find food. These animals use a wide variety of sizes of large woody debris. Logs appear to provide dispersal corridors as well as the above mentioned essential habitat elements. Habitat quality probably improves in direct proportion to the amount of large woody debris to a point where the debris interferes with the shade and humidity regulating function of the forest canopy cover. Specific types of cover, debris, litter, etc. will be determined by the species for which management is to be emphasized.

As possible, protect Species Habitat Areas from fire events that cause direct mortality and loss of habitat. Prescribed fire treatments could be used to reduce fuel loading outside of Habitat Areas to protect those areas from catastrophic wildfire events.

Activities that cause soil compaction or disturbance to forest floor litter should be avoided within Species Habitat Areas.

Manage occupied rockslides and talus areas 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. These sites should be considered potential habitat when they lie within or near to suitable moist forest habitat areas, or at the edges of moist or wet mountain meadows.

Consider increasing the width of occupied Riparian Reserves as needed, as part of management for these mollusk species.

Mollusk species are known to have limited dispersal abilities and the current species diversity is the result of generations of isolated populations developing unique characteristics. Care should be taken not to further isolate individual populations. Therefore, in addition to managing this species group within Species Habitat Areas, attempts should be made to connect these habitat areas to each other or to other reserves, such as Riparian Reserves and LSRs. This could be done 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.

4. Lessons from History: Effects of Fire

Once extirpated from a site, populations of most gastropods are slow to recover. Fire is a natural disturbance factor, which has occurred over many centuries. Even as a natural process, its effects can be harmful to existing populations. The effects of fire depend on several variables, including intensity, season and relationship to the life cycle of the species. Fire can be very destructive to snails and slugs, not only killing them outright, but in its destruction of logs and other woody debris that hold moisture and create microsites necessary for survival of these animals (Applegarth 1995). Sites that appear to be suitable habitat for many gastropods, but which have been burned in the past, support few if any species or individuals even after 50 years and longer. Some of the more abundant, larger species begin repopulating these sites from adjacent stands after suitable habitat for them is restored, which may take many years. The first species to reappear in western Washington stands are usually the *Haplotrema* and *Vepericola*. These species are the most abundant of the large snails in a variety of forest habitats. The time required for the abundance and diversity of the molluscan fauna to be restored to these sites is indicated by the much greater numbers of species and individuals found in old growth than in stands in which signs of fire (and other management in some cases) are still evident but not necessarily obvious. In these burned stands, we have an ecosystem that is lacking the components and functions provided by the mollusk fauna.

In contrast to severely burned areas, stands in which numerous large logs were left and which were not severely charred during the fire have been found to retain a portion of their mollusk fauna after an undetermined number of years but within a time that evidence of the burn was still apparent upon examination of the site (Burke, unpublished report). Logs were not measured, but are estimated to be well over 1000 linear feet per acre, and greater than 20 inches average diameter. Whether these gastropods remained through the burn, protected by the abundant logs, or they were able to more rapidly disperse back into the stand because of the cover provided by the logs has not been determined. What is apparent is that an abundance of large logs is important to many forest snails and slugs. Zero to two or rarely three species may be expected in burned stands without abundant logs remaining; five to seven species may be expected to be found in stands similarly treated but with the logs remaining; and in unburned stands 13 to 20 or more species may be found (Burke, unpublished report). Therefore, it is apparent that an intense burn leaves the biotic community under moist conifer stands with only a small fraction of its molluscan fauna for many years (possibly a century or more). Fire is generally not acceptable management for the habitat of these species.

While other methods of fuel reduction are preferred, prescribed fire may be considered as a tool to be used to reduce the risk of catastrophic natural fire. Prescribed burning or other treatments should be designed to avoid significant impacts to the habitat conditions within species habitat areas as outlined in Section IV-C, while reducing the risk of wildfire in surrounding areas. If burning is conducted during seasons when animals area active, care should be taken to ensure that a mosaic of unburned patches is retained. This may provide a measure of confidence that some individuals survive the treatment.

5. Other Management Issues and Considerations

Implementation of the Aquatic Conservation Strategy in Riparian Reserves requires an analysis of habitat conditions and occurrences to determine if actions within riparian reserves are consistent with the Aquatic Conservation Strategy objectives and should document the effectiveness of these riparian land allocations for conservation of these species habitat.

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. The content of this section has not been prioritized or reviewed as to how important the particular items are for species management. While the research, inventory, and monitoring information is not required, these recommendations should be addressed by a coordinating body at the regional level.

A. Data Gaps and Information Needs

Additional genetic analysis to further decipher the range of these two species is needed. This work should model that of Wilke & Ziegltrum (2004), with attention to areas where genetic investigations have not yet been completed (e.g., Salem District BLM land), or where analysis has been minimal (e.g., Siuslaw National Forest). Additional data gaps are listed in the following sections.

B. Research Questions

What is the specific geographic range of each of these species?

What is the range of habitat conditions tolerated by each species? What is the range of conditions required for populations to remain secure and viable?

Biological attributes:

- Plant associations;
- Specific plant species required/used;
- Specific foods;
- Amount of large woody debris desired;
- Optimum forest crown cover to maintain desired conditions;

Physical attributes:

- Elevation;
- Soil types, geology, trace elements;

- Temperature, humidity.

What are the stand characteristics (canopy cover, age, large woody debris, litter and duff, etc.) required to support the conditions required?

How do the required stand characteristics vary under different circumstances (elevation, slope, aspect, etc.)?

What stand size is required to provide sufficient area of suitable habitat?

How much time is required for recolonization of a site by species from adjacent populations?

What are the effects on mollusk populations of herbicides and other chemicals used in forest management?

What are the life history characteristics of these species, including breeding season, egg depositories, life span, seasonal habits (e.g., aestivation, hibernation), food preferences, predators, diseases, and ecosystem functions?

C. Monitoring Opportunities

Monitoring of known sites is recommended to track trends in populations (numbers, size, and density), reproduction, quantity and quality of habitats.

Monitoring is also recommended to determine impacts on habitats and populations from management activities, natural disturbances, and vegetative succession.

- 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 known populations following land management activities to determine whether or not recommendations applied for this species protection are effective and sufficient.

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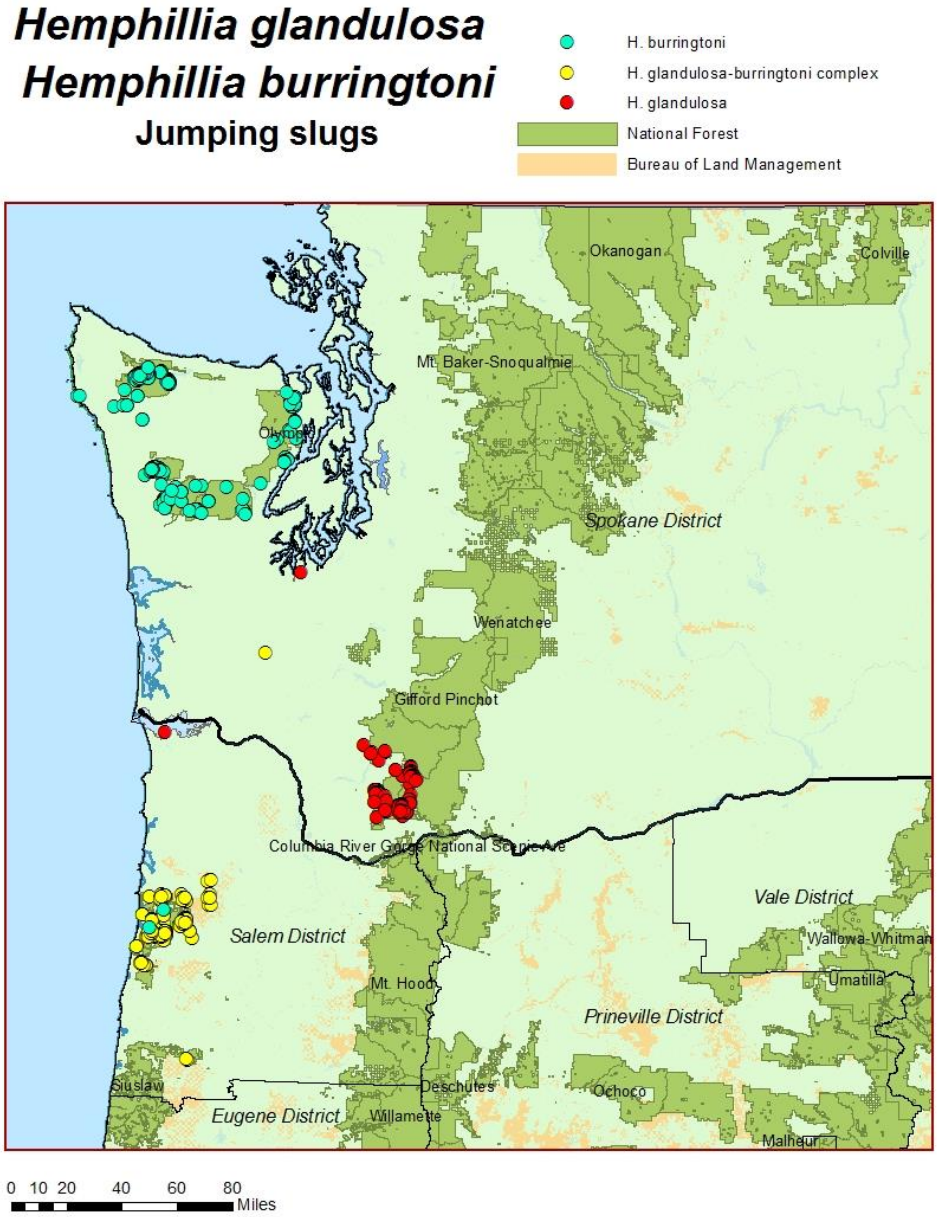
Ziegltrum, Joan. 2002. Draft Management recommendations for two species of the genus *Hemphillia*. Olympic National Forest. December 5, 2000

VII. Photographs

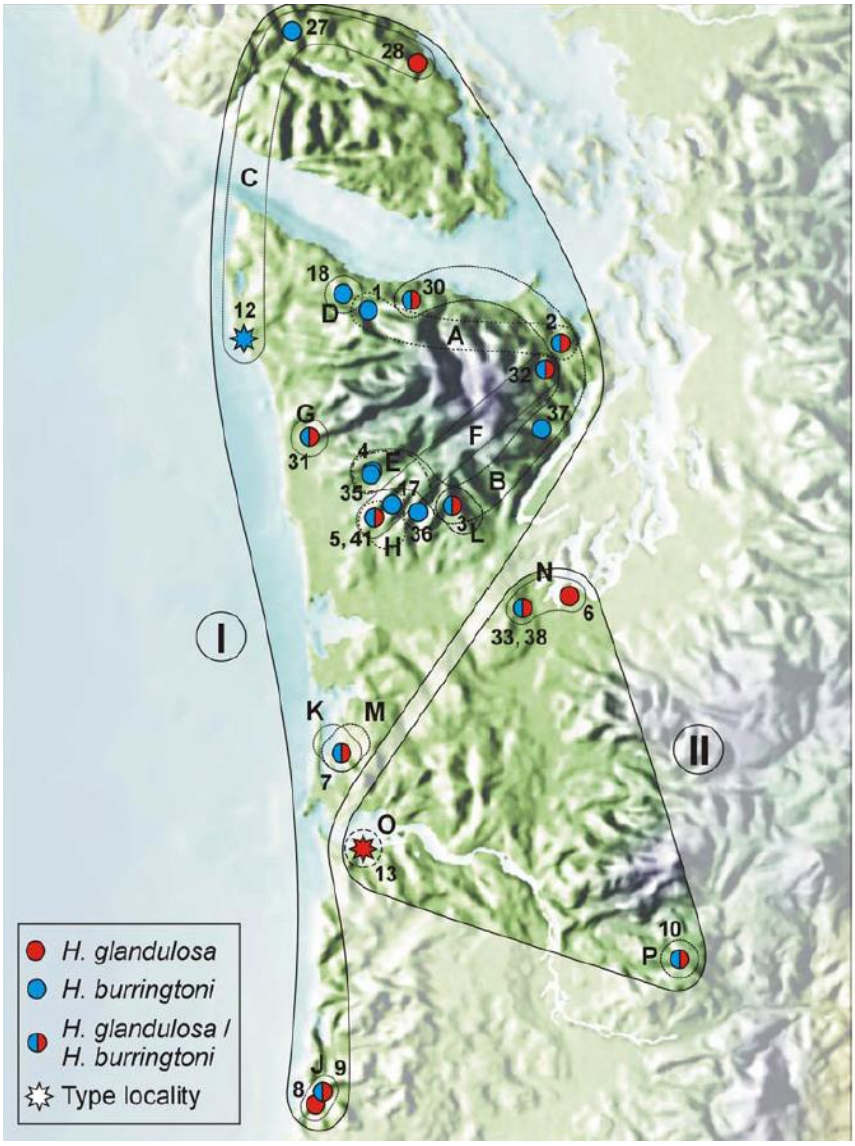
Hemphillia burrington-glandulosa species complex. Photograph by Bill Leonard, used with permission

Hemphillia burrington-glandulosa species complex. Photograph by Bill Leonard, used with permission

VIII. Distribution Maps



Known records of *Hemphillia burringtoni, H. glandulosa, and H. burringtoni-glandulosa* species complex, relative to BLM and Forest Service lands. Assignment of species designation follows that presented in Wilke and Ziegltrum (2004) (see map, below). For example, since this study sampled a large number of localities in the Olympic National Forest, all of which were determined to be *H. burringtoni,* we have reclassified all records in this region as this species. In contrast, only two specimens/localities were examined in Siuslaw National Forest, and although both of these were determined to be *H. burringtoni*, it is uncertain if this is the *only* species in the area, or if *H. glandulosa* occurs in this region as well, given the occurrence of *H. glandulosa* farther north along the Oregon Coast. As such, we have elected to treat all records in this region as "*H. burringtoni-glandulosa* species complex" (with the exception of the two specimens analyzed in Wilke and Ziegltrum (2004)). Further genetic analysis is needed in this area, as well as in Western Washington between the Cascade Range where *H. glandulosa* occurs, and Olympic Mountains, where *H. burringtoni* occurs.



Map from Wilke and Ziegltrum (2004) showing the original identifications of specimens made from morphological characteristics and the geographic distribution of the major clades and sub-clades of *H. glandulosa* and *H. burringtoni* from their genetic work. The two major clades are indicated by Roman numerals I and II.