AN ABSTRACT OF THE THESIS OF

Margaret McAndrews Cowden for the degree of Master of Science in Forest Resources presented on September 13, 2002.
Title: A Study of the Current Range and Habitat of Fuzzy Sandozi Conks (*Bridgeoporus nobilissimus*) Throughout Pacific Northwest Forests

Abstract approved _______________________________________
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*Bridgeoporus nobilissimus* (W.B. Cooke) Volk, Burdsall, & Ammirati (BRNO) is a Survey and Manage fungi species listed under the Northwest Forest Plan. Perennial sporocarps (conks) fruit on large, dying and dead conifers in late-successional old-growth forests and on remnant stumps and snags in young and mature second-growth forests of the Pacific Northwest (PNW). The research objective is to describe the relationship between BRNO and the environment at the individual conk-, host- and stand-level. Only twelve known sites occur in Oregon and Washington with one to several hosts (and/or plots) per site. Twenty-one Known Site Survey plots (KSS plots) were sampled for this study. Additionally, six BRNO hosts were sampled outside KSS plots. Known Site Survey data was measured previously and used for multivariate analysis of the conk variables, plant community, and environmental data. At each sampled host location, morphology, and aspect of conk were determined. Wood samples were collected from all well-decayed hosts to determine species. Sixty BRNO hosts were sampled, 9 in Washington and 51 in Oregon. Eighty-one conks occurred on 60 hosts; 15 hosts had multiple fruiting bodies present. Conks were observed fruiting on old, large live trees and on well-decayed snags and stumps, but not on downed logs. Hosts most often have northern or western aspects, while dominant conks frequently face south. Conk position varied with host type – conks observed on live trees and snags fruit solely at the base of the host or below 1.5 meters in height; conks on stumps fruit at various locations. All wood sampled from hosts was identified as *Abies spp*. Analysis on plant community data indicated the presence of elevation and canopy cover gradients on KSS plot data. Analysis on conk variables data revealed patterns in conk-host relations relative to region, elevation, and host type. Current observations of BRNO indicate a range of occurrence by elevation, forest cover type, successional stage and plant communities throughout its geographical range. Conservation efforts of BRNO must focus on the management of existing stands that have at least a minor component of true fir (*Abies spp*.) present. Management should also focus on all aspects of true fir – recruitment and retention of large live trees, recently dead, and well-decayed substrate as potential hosts. The conservation of potential habitat will be the most critical measure toward species conservation of *Bridgeoporus nobilissimus*.

# A Study of the Current Range and Habitat of Fuzzy Sandozi Conks (*Bridgeoporus nobilissimus*) Throughout Pacific Northwest Forests

By
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# INTRODUCTION

Forest fungi have recently been recognized as an important component of biodiversity in the Pacific Northwest (PNW) (USDA and USDI 1994a). Yet, understanding the life cycle, dynamics, and abundance of these organisms is a continuing challenge. *Bridgeoporus nobilissimus* (W.B. Cooke) Volk, Burdsall, & Ammirati (BRNO) is a sensitive fungus fruiting in Pacific Northwest forests (Coombs 1991, USDA and USDI 1994a, Castellano, et al. 1999). This fungus is associated with late-successional forests but is also known to fruit on large stumps, snags, and trees in second-growth stands throughout its range (Hibler and O'Dell 1998). Federal agencies are mandated to provide survey and management guidelines for this species throughout its range (USDA and USDI 2001). A better understanding of BRNO habitat and variability in fruiting bodies is needed to enable federal agencies to better manage the species.

*Bridgeoporus nobilissimus* is a Category A species under the Survey and Management guidelines for fungi under the Northwest Forest Plan (USDA and USDI 1994a, USDA and USDI 2001). Category A species have 3 criteria: 1) manage all known sites, 2) conduct pre-disturbance surveys in proposed project areas with potential BRNO habitat, and 3) conduct strategic surveys to detect presence of species. On federal land at each known BRNO site 600 acres surrounding the organism is initially removed from ground-disturbing activities in order to protect the habitat until all potential habitat has been surveyed for additional BRNO conks (Hibler and O'Dell 1998, Castellano, et al. 1999).

In the early to mid 1940s, unusual and unknown fungal sporocarps (conks) were collected in Oregon and Washington by loggers and mycologists. In Clackamas County, Oregon Ali and Fred Sandoz presented the first specimens of BRNO, then coined “Fomes fuzzii sandozii”. William Bridge Cooke (1949) declared this unusual specimen *Oxyporus nobilissimus*, a white rot fungus closely related to *Oxyporus populinus*. More recently, Burdsall, Volk and Ammirati (1996) reclassified this organism as *Bridgeoporus nobilissimus*, a brown rot, not white. A microscopic characteristic of this reclassification included bearing true cystidia rather than pseudocystidia.

Since its discovery over 50 years ago, there have been very few new BRNO sightings in the Pacific Northwest despite its massive size and unique morphology. *Bridgeoporus nobilissimus* is a parasite and saprophyte (Burdsall, et al. 1996) feeding on living trees and dead wood (Hibler and O'Dell 1998). *Bridgeoporus nobilissimus* is described in the literature as having three main morphologies: shelved, hoof-like and substipitate (conical) (Burdsall, et al.

1996). Perennial sporocarps (conks) can attain a weight of 130 kg (Burdsall, et al. 1996), with the largest recorded conk 75 cm x 101 cm x 51 cm in height. This massive polypore often hosts epiphytic associations with algae, lichens, and mosses (Burdsall, et al. 1996, Hibler and O'Dell 1998). Due to its large size, fuzzy, pileal surface, and perennial persistence, BRNO is easily detected in the field (Hibler and O'Dell 1998).

*Bridgeoporus nobilissimus* occurs in conifer-dominated forests in western Oregon and Washington. The region is characterized by relatively warm, wet winters and hot, dry summers (Franklin and Waring 1979 , Waring and Franklin 1979 ). Many different forest vegetation zones occur in this region ranging from low elevation western hemlock (*Tsuga* heterophylla) to high elevation subapline fir zones (*Abies lasiocarpa*) (Franklin and Dyrness 1973). The current geographic range of *Bridgeoporus nobilissimus* is from King County, Washington south to Linn County, Oregon, within the western hemlock and Pacific silver fir (*Abies amabilis*) zones. The elevation range is from 300 to 1200 meters, subjecting conks to harsh winter climates at higher elevations. Previous monitoring suggested that BRNO is more often detected at the lower end of its elevation range (Hibler and O'Dell 1998). Within the Pacific silver fir zone the majority of precipitation falls predominantly in the form of snow, with snowpack accumulation providing summer moisture on many sites (Franklin and Dyrness

1973). Precipitation in the western hemlock zones falls as both rain and snow (Franklin and Dyrness 1973).

Current literature characterizes BRNO as inhabiting old, large trees and dead wood in the Pacific silver fir and western hemlock zones, most likely true fir (*Abies spp.*) wood (e.g. Hibler and O'Dell 1998, Volk, et al 1996, Stamets, 2001). Within the Pacific silver fir zone BRNO is found in such places as Mary's Peak in the Oregon Coast Range and Mount Rainier National Park in Washington. Understory plants commonly found in the Pacific silver fir zone include *Gaultheria shallon, Vaccinium alaskaense, Menziesia ferruginea*, and *Rhododendron macrophyllum* (Franklin and Dyrness 1973). Within the western hemlock zone, BRNO occurs on the Mount Hood National Forest in Oregon and in the Gifford Pinchot National Forest in Washington, among other locations. Understory plants commonly associated with moist or mesic western hemlock associations include *Oxalis oregana*, *Rhododendron macrophyllum*, *Polystichum munitum*, and *Berberis nervosa* (Franklin and Dyrness 1973).

From existing data, BRNO conks fruiting in second growth stands reside on large old snags and stumps, hereafter referred to as "legacy wood". In intact stands, conks have been observed fruiting on large old live trees and snags. In

Washington BRNO has most frequently been detected in old-growth stands (Hibler and O'Dell 1998).

The lack of knowledge about this organism has led federal managers to institute field surveys to better understand BRNO ecology. At one site in Oregon, it was noted that several BRNO conks were on what appeared to be Douglas-fir (*Pseudeotsuga* menziesii) stumps (USFS 1999). Other sites have live tree hosts that are known to be noble fir (*Abies procera*). Questions exist whether or not BRNO is host specific, and if so, on what species it fruits.

Despite two taxonomic publications (Cooke 1949, Burdsall, et al. 1996) and intensive surveying on federal lands, many uncertainties exist regarding BRNO ecology. It is unclear what drives BRNO to establish and produce sporocarps. Several papers describe the ecological niche of BRNO as old growth noble fir trees within intact stands (Trappe 1990, Coombs 1991, Stamets 2001). Yet, many conks have been observed recently in second-growth stands. Research is needed to provide insight into the range and ecology of BRNO to improve detection and conservation of this organism. It is the only fungus categorized as Strategy A in the Northwest Forest Plan (USDA and USDI 2001) and is listed as endangered under the Oregon Natural Heritage Program (2001).

## Role of Legacy Wood

Large old and/or dying trees, legacy stumps and snags (large old remnants from a former stand) are quintessential factors for BRNO fruiting (e.g. Bursdall, et al 1996; Hibler 1998). Coarse woody debris is usually formed resulting from abiotic and biotic factors such as wind, fire, insects, pathogens, or inter/intra-species competition (Harmon 1986). The presence of legacy wood is highly variable spatially and temporally in forest ecosystems due to disturbance patterns and stand history (Graham and Kermit Cromack 1982, Harmon 1986). Legacy wood is generally more often concentrated in old-growth or young stands than in mature stands (Spies, et al. 1987). The vast diversity of mycoflora is found in the large dead wood in forests rather than on small remnant twigs or stumps (Renvall 1995). At the BRNO sites, large wood has been generated through a combination of biotic, abiotic, and human disturbance (timber harvest) factors.

An understanding of the relationship between dead wood, decay dynamics, and BRNO fruiting is critical to the understanding of BRNO ecology. The ability to classify dead wood may be very important to understanding the dynamics of BRNO fruiting. Sollins (1982) and Graham and Cromack (1982) utilized a five-class system for classifying dead wood in the Pacific Northwest. This methodology has been widely accepted and implemented throughout the

Northwest (Triska and Cromack 1980, Graham and Kermit Cromack 1982, Sollins 1982, Sollins, et al. 1987, Brown, et al. 1998).

The five wood decay classes are from I (recently dead) to V (almost completely decomposed). Class I is characterized by the presence of small twigs, bark, and sound wood. Class II includes sound bark and heartwood, with no or few small twigs and some sapwood decay. Class III is characterized by some bark sloughing, more sapwood decay while remaining structurally sound. Class IV cannot support its own weight and its shape reflects this (more elliptical than round). Class IV also has little bark or sapwood present, and large branch stubs come loose when pulled. Class V has severely fragmented heartwood, and its shape is often irregular and mounded (Sollins 1982). This classification system is routinely applied to coniferous forests in Oregon and Washington.

Conk substrate is constantly decaying, and current BRNO hosts will someday be incapable of providing adequate nutrition for the fruiting bodies. Harmon et al (1987) found that white fir (*Abies concolor*) almost completely decomposed in 60 years. In another study, true fir (*Abies spp.*) decayed the fastest and supported a larger number of sporocarps than other conifer species, with sapwood decay occurring within the first 7 years of decay (Harmon 1994). True fir stands occur at mid- to higher elevations in Oregon and Washington, thus decomposition rates probably differ from well-studied lower elevation areas of the PNW. Ambient temperatures are critical for wood-decaying fungi to respire (Harmon 1986). Snow pack covers most BRNO sites during the winter months thus reducing the ability of decomposers (including BRNO) to function.

## Ecology of True Fir

Since most studies to date have proposed true fir and western hemlock as the potential hosts of BRNO (Burdsall, et al. 1996, Hibler and O'Dell 1998), it is important to understand the dynamics of these ecosystems. More specifically, BRNO has been observed on live noble fir trees and on a single Pacific silver fir snag. These true firs are found mainly in the central Cascades of Oregon north through the state of Washington. Some islands of noble and Pacific silver fir are located in the Coast Range of Oregon and Washington. Climate within these true fir forests are characterized as maritime, with year-round moisture availability (Franklin 1983, Crawford and Oliver 1990). Elevation ranges for true fir forest types range from sea level to over 1,800 meters. Associated vegetation of true fir forests is typically ericaceous shrubs including several *Vaccinium spp*., rustyleaf menziesia (*Menziesia ferrugiana*), and Cascades azalea (*Rhododendron albiflorum*) (Franklin 1983, Crawford and Oliver 1990).

The specific ecology of noble fir differs from that of Pacific silver fir. Noble fir is the most shade intolerant species among North American true firs. Franklin (1983) described noble fir as requiring large disturbances, and sufficient light, to establish and regenerate. Wildfires appear to be the most common natural disturbance agent associated with noble fir establishment, with fires occurring on a very infrequent but large spatial scale. Noble fir is found from 1070 to 1700 meters in elevation, mostly in the Cascade Ranges of Oregon and Washington. Precipitation in this elevational range falls in the form of snow and rain, with snowpack accumulation supplying the majority of the moisture during the dry summer months. There are no major pests or pathogens that limit noble fir persistence in forests, although some fungi are known to rot the species. Noble fir was found to be susceptible to Annosus root rot (*Heterobasidion annosum*) in managed forests of the Oregon Cascades (Sullivan, et al. 2001). Butt and root rots such as *Phaeolus schweinitzii*, *Inonotus tomentosus*, and *Poria subacida* are known to rot noble fir; stem decay can be caused by *Echinodontium tinctorium*, *Phellinus pini*, and *Fomitopsis pinicola*. Noble fir is considered a short-lived, seral species, reaching senescence by 400 years (Franklin 1983). Human-caused disturbances that affect BRNO habitat are removal of host trees and harvesting large areas of noble fir, road and trail building, and other recreational construction such as campsites (Hibler and O'Dell 1998).

Pacific silver fir has a much broader range than that of noble fir. Crawford and Oliver (1990) described the ecology of silver fir as follows. It is a distinctly maritime species, ranging from coastal sites at sea level in its northern range to montane sites over 1,800 meters in elevation. Mean annual precipitation for silver fir in the Cascades is 1500 mm, falling in the form of snow and rain. As in noble fir, silver fir requires ambient moisture levels throughout the growing season provided from snowmelt. Pacific silver fir has much higher tolerance to shade than noble fir. It can regenerate in partial shade, as advanced regeneration, in open stands, or in burned areas. However, when growing in open conditions, it is often overtopped by other tree species due to its slow height growth early on. Pests of this species include many insects as well as fungi. Seed predators, defoliators, and bark beetles are all known to infect silver fir. At maturity to senescence, silver firs are prone to Indian paint fungus (*Echinodontium tinctorium*) and bleeding conk fungus (*Heamatostereum sanguinolentum*). Decay fungi observed include *Ganoderma applanatum*, *Fomitopsis pinicola*, and *Poria subacida*.

There is a large gap in information pertaining to BRNO ecology, yet this organism is found over a large geographical range. This study focused on exploring BRNO habitat and variability through observational data.

# OBJECTIVES

The research objective for this study was to describe the relationship between BRNO and the environment at three different scales: the individual conk-, host-, and the plot-level. This study also was designed to provide pertinent and useful information to managers and surveyors regarding BRNO habitat preference since agencies with suitable habitat are required to survey and manage current and potential BRNO habitat. Specific objectives of this study were to:

1. Synthesize existing data pertaining to the environmental range of BRNO known sites.
2. Identify relationships between BRNO conk presence and vegetation patterns.
3. Develop an understanding of the relationship between site disturbance and conk fruiting.
4. Identify host genera and decay class of BRNO hosts.
5. Classify conk morphology among host types, identify conk position occurrences on host, and analyze aspect of occurrence of both conk and host.

# METHODS

This study combined the use of existing BRNO monitoring data with field data collection of conk-level and microsite attributes to better understand conk habitat and variability across the known range of BRNO occurrence. Known Site

Survey Plots (KSS plots) provided all vegetation and environmental data at the plot-level used to describe patterns among sites. Conk morphology, location, and aspect data were collected during the 2001 field season.

## Study Area

Ecologists working with various federal agencies have identified 11 sites of BRNO occurrence in western Oregon and Washington (Figure 1). One known site has been located but no permanent plot established (Mount Rainier National Park site). Of the 12 total known sites, one was located on Mary's Peak on the Siuslaw National Forest in Oregon, and one on the Olympic National Forest in Washington; the remaining 10 sites were located on the western slopes of the Cascade Ranges of Oregon and Washington in the western hemlock and Pacific silver fir zones. Cascade KSS plots ranged from the Sweet Home District, Willamette National Forest in Oregon to the North Bend District, Mt. Baker-Snoqualmie National Forest in Washington. All KSS plots had at least one BRNO conk occurring on a stump, snag or live tree host. Most sites contained one plot and one fruiting body on a tree, snag or stump. On each host, there were one to four fruiting bodies detected. In certain areas one to several fruiting bodies and/or BRNO hosts were represented by a single KSS plot. Five BRNO hosts included in this study were not located near an established KSS plot because they were detected after the establishment of the KSS Plots. Stand conditions ranged from intact old growth to young second-growth plantation forests.

## Known Site Survey Plots

Known Site Survey (KSS) plots were established in 2000 by the PNW Research Station Survey and Manage Team. Circular plots, 1/10-ac in area, were established at 11 sites. Sites were established by presence of at least one fruiting body on a host when KSS Plots were installed in 2000. There were one to six plots per site depending on habitat heterogeneity, 21 plots in total. When multiple hosts were located in homogenous habitat only a single vegetation plot was established as multiple plots would not yield any new information relating to conk habitat. If multiple hosts were present at a site with varying stand conditions or vegetation, plots were established around each host. Information collected on permanent plots included diameter and height of all trees and an inventory of shrub and herbaceous cover. Environmental plot data also included slope, aspect, elevation, latitude, longitude, plant association, microconfiguration, macroposition, topographic position, canopy cover, moss cover, and successional stage.

**Figure 1**. **Map of BRNO known range.** The known range of BRNO in the Pacific Northwest extends from Linn County, Oregon to Kings County, Washington. Sites are depicted at the state level with the map on the far right. A sample of KSS plots are shown at the county level (Linn County, Oregon) and a sample population of individual hosts is shown in the topographic inset within Linn County, Oregon.

Because of multiple hosts and BRNO conks at Salem BLM, four plots were established at this site in the central Oregon Cascades. This relatively small geographic region contains the majority of all known conks in Oregon. All known hosts throughout the known range of BRNO were sampled except on Salem BLM plots. Subsampling occurred at two of the Salem BLM KSS Plots due to accessibility. Three hosts (between 2 plots) were not found and therefore not sampled. Due to the unique population size at this site, Salem BLM data will be addressed separately throughout the document.

## Field Methods

All sites and plots were sampled during the 2001 field season. All hosts were sampled for conk-level data with the exception of Salem BLM where a sub-sample of hosts was studied. Five sampled hosts (at 3 separate sites) were not associated with KSS plots because they had been discovered recently. At each sampled host all conk(s) were photographed, their approximate size, shape, location, and aspect relative to the site were recorded. Conks were categorized according to the shape. When multiple conks were present, the dominant conk was also determined. A dominant conk is defined in this study as an individual conk present on a host or, among multiple fruiting bodies on a host, the most active and healthy conk (determined by looking at the hymenium) and generally the largest in size. Host disturbance was categorized relative to nature of disturbance. Living trees were classified as having no disturbance, snags were naturally disturbed, and stumps were disturbed by humans. Decay classes of all hosts were classified according to the Douglas-fir five-class system (Sollins 1982), which has been widely applied in the Pacific Northwest (e.g. Triska and Cromack 1980, Graham and Kermit Cromack 1982, Brown, et al. 1998).

Conk aspect was recorded as the direction the conk faced from its location on its host. Site aspect and conk aspect were measured in degrees; slope was recorded in percent. Geographical position (UTM coordinates) and elevation of each site were recorded using a Garmon 300, hand-held GPS unit. Overstory canopy cover was recorded to the nearest 10 percent by ocular estimation. The topographic moisture index was calculated using site slope, position, and configuration. The topographic moisture index combines a site's slope with its position on the landscape (draw, ridgetop, midslope, etc) and the configuration of the land being surveyed (concave, convex or straight). The value reflects the site's potential moisture index derived from these three measurements. Drier sites have lower TMI values while wetter sites have higher TMI values.

## Host Identification

Wood samples were collected from all stump and most snag hosts by removing a piece (<8 $in^3$) from the stump surface or near the base of the host. Wood samples for all well-decayed stump and snag hosts were used to determine host genera. Live tree and sound snag hosts were identified in the field. Wood samples from each sampled substrate (well-decayed snag or stump) were used for host identification. Because the Snow Peak area of Salem BLM contains a very dense population of BRNO, 20 randomly selected hosts at this site were used for wood analysis from the 36 sampled hosts.

In the lab, specimens were analyzed to identify host species. Potential BRNO hosts were Douglas-fir (*Pseudotsuga menziesii*), western hemlock (*Tsuga heterophylla*), Pacific silver fir (*Abies amabilis*) and noble fir (*Abies procera*) as indicated from previous field investigations and records. Slices of the tangential, transverse, and radial planes were cut by hand using a razorblade (Figure 2). The transverse plane was often very difficult to cut due to deterioration.

Cross sections were prepared on a slide and the following microscopic characteristics determined (Table 1 and Figure 2). In the tangential plane, the presence or absence of spiral thickenings was determined; if no spiral thickenings were present, then the host was not Douglas-fir, but rather western hemlock or true fir. In the transverse plane, resin canals were sought on undeteriorated cross-sections; no resin canals suggested the samples were true fir or hemlock, thus eliminating Douglas-fir as a potential host genera. The radial plane was used to distinguish hemlock from true fir. The types of pits and presence or absence of ray tracheids were the primary characteristics used to decide if the sample was hemlock or true fir (Figure 3). The presence of crystalliferous structures in the latewood parenchyma cells was an indication that the sample was noble fir; the absence of crystals indicated the sample was Pacific silver fir (Table 1).

## Data Analysis

This study was observational and included the known population of BRNO. The inferences drawn from this population are representative of the current known variability of this organism. However, this study will not draw causal inferences from the data, rather identify significant trends and recommend future studies for further investigation.

Nonmetric multidimensional scaling was implemented as the most robust tool to describe the variability among all sites and habitats. This ordination method was robust to nonparametric data, data on multiple scales, or discontinuous scales. This technique iteratively searched for the minimal stress configuration

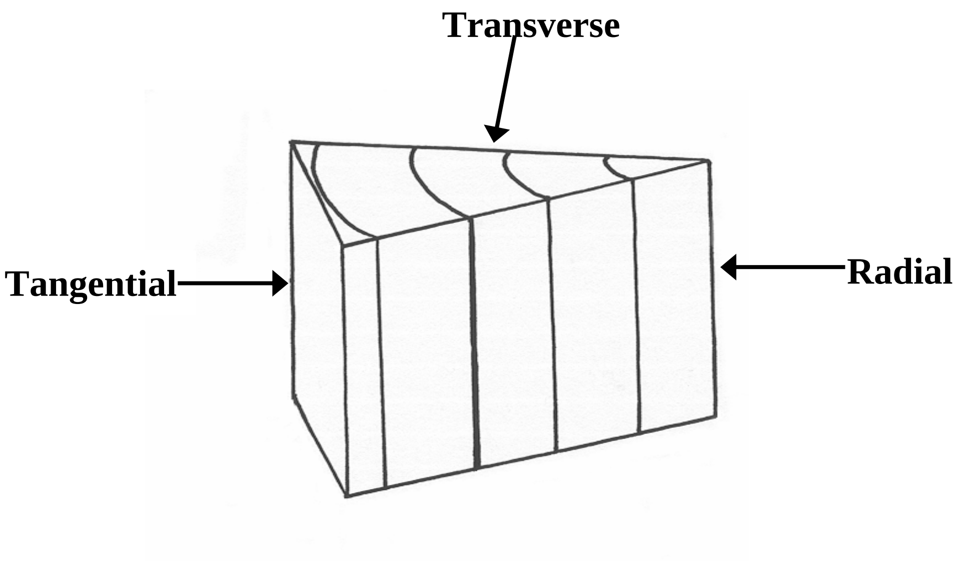
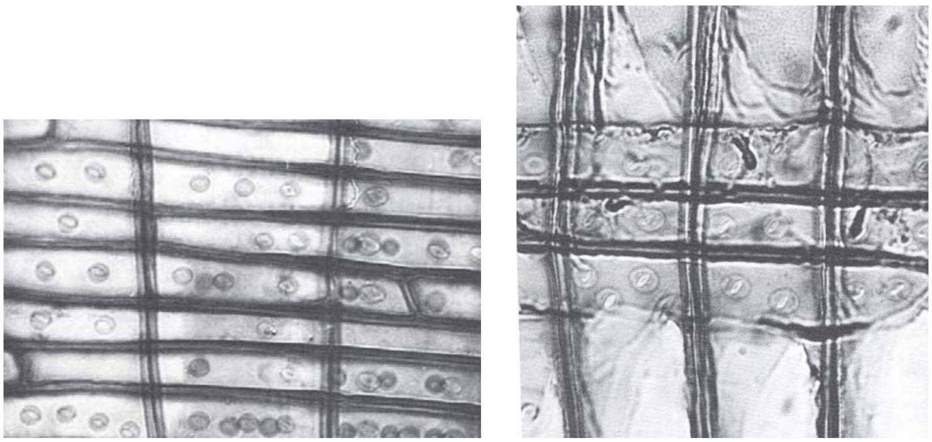



**Figure 2**. **The three planes of wood.** A diagram of the 3 planes of wood used for host identification. The transverse plane contains information about resin canals, the radial plane reveals pit types and latewood parenchyma and the tangential plane exposes spiral thickenings.

**Table 1. Wood identification of several conifer genera.** Microscopic characteristics of true fir, hemlock and Douglas-fir genera used to key out wood samples for analysis. Also, the species characteristics distinguishing noble from Pacific silver fir are presented at the bottom of the table.

| | True fir Characteristics | Hemlock Characteristics | Douglas-fir Characteristics |
|---|---|---|---|
| **Transverse Plane** | No resin canals | No resin canals | Resin Canals |
| **Radial Plane** | No ray tracheids; nodular endwalls, conspicuous pitting; Taxoidiod pits | Ray tracheids; Piceoid to cuppressoid pitting | -- |
| **Tangential Plane** | Few longitundinal parenchyma | Few longitundinal parenchyma | Spiral Thickenings |
| ***Key Characteristics for true fir species identification*** | | | |
| | **Noble fir** | **Pacific silver fir** | |
| **Radial Plane** | Crystalliferous structures in latewood parenchyma | Lack of crystals in parenchyma | |

Adapted from Panshin (1980)



**a. Taxoidiod Pitting** **b. Cuppressoid Pitting**

**Figure 3a and b. Distinguished pitting**. Pictures of pits characteristic of *Abies spp*. (3a) and *Tsuga spp*. (3b). Taxoidiod pitting can be found in the radial plane of *Abies spp*. and cuppressoid pitting is often a distinguishing characteristic for *Tsuga spp*. (Photos from NCARS Bulletin 474) of n items in k dimensions within the data set from a calculated distance matrix. Stress was described as the departure from monotonicity between the distance measures in original space versus ordination space (McCune and Grace 2002). Solutions with low stress are associated with low to no monotonicity – solutions yielding very similar solutions during NMS iterations. With ecological data sets, stress levels at or below 21 are acceptable; stress lower than 10 are rare with ecological data (McCune and Grace 2002). The program repeatedly searched for the solution with the least amount of stress, and repeated the search n number of times. Each run of NMS could be different, however, if a stable solution was achieved the individual NMS solutions should be quite similar across runs.

Three scales of data were examined during analysis: conk-level (conk position, aspect, and morphology), host-level (host type and decay class), and stand-level (vegetation and environmental patterns). Ordination by NMS provided graphical outputs of the relationship among many categorical and quantitative variables. The data were compiled into 3 matrices (vegetation, environmental, and conk variables) (Appendix A) and NMS run using PC ORD version 4.0 (McCune and Mefford 1999). Known Site Survey vegetation data from all 21 plots were used in conjunction with KSS environmental data for plant community analysis. Data collected for this study and KSS environmental data were used to describe conk variability.

An environmental matrix was used for both conk variables and plant community ordinations. The selected environmental variables came from data collected by the USFS Mycological Team during the KSS plot inventories in 2000. The variables listed in Table 2 were selectively chosen from the KSS database for exploratory correlation with the conk and plant community analyses. Environmental parameters were overlayed onto the 2-dimensional graph with a minimum $r^2$ value determined by the strength of the relationships. Some data will have many correlations at an $r^2$ of 0.20, while others require an $r^2$ of 0.10 to observe environmental overlays on their community data. Biplots were generated from the ordination by overlaying environmental variables (one at a time) onto the community ordination.

Ordination of conk variables was used to explore the relationship between host type and conk variables such as morphology and location. Conk attributes used for this ordination were conk morphology (shelved, conical, vertical, round), conk location (basal, on bole, on top of stump, inside stump center), conk aspect, host aspect, host diameter, host height, and host type (tree, snag, stump). Ordination techniques described conk habitat variability across the known range

**Table 2. Environmental variables.** A list of all environmental variables selected from KSS plots for NMS overlays on conk and plant association bipplots.

| Environmental Variable | Description |
|---|---|
| Decay Class | Derived from the Douglas-fir decay class system (Sollins 1982), varying from 1 (recently dead) to 5 (well-decayed wood) |
| Elevation | Site elevation measured in meters |
| Aspect | Average aspect of plot measured in degrees |
| Slope | Average slope of plot measured in percent |
| Overstory Canopy Cover | Average percent cover of overstory trees in plot |
| Understory Canopy Cover | Average percent cover of understory canopy in plot |
| Macroposition | Average position of plot on hillside (top, mid, bottom) |
| Microposition | Average position of plot locally |
| Successional Stage | Developmental stage of stand based on timber objectives (clearcut, pole/sapling, mature, old-growth) |
| Stand Structure | Described the homo- or heterogeneity of the overstory |
| Moss Cover | Average percent moss cover in plot |
| Topographic Moisture Index | Measurement of how water moves through system derived from slope, position, and configuration (convex, concave or straight ground) |

of BRNO for these variables. Conk variables were categorical; each category was given its own column for analysis so that correlations among variables could be calculated. This ordination procedure yielded a 2-dimensional graph describing conk variability, again overlaying environmental factors onto the ordination graph with a minimum $r^2$ value determined by the strength of the relationship between the selected environmental variables and the community data.

# RESULTS

*Bridgeoporus nobilissimus* conks have been located in 12 sites throughout western Oregon and Washington (Table 3). Eleven of the 12 sites have been surveyed using Known Site Survey protocol (Hibler and O'Dell 1998); the Mount Rainier National Park site is the only site that has not been surveyed using this protocol. *Bridgeoporus nobilissimus* conks fruited over a wide range of elevation, forest cover types, topographic positions, and geography on many host types with variable morphologies and locations. *Bridgeoporus nobilissimus* conks occurred from the Olympic and Mount Baker-Snoqualmie National Forests in Washington to the Siuslaw and Willamette National Forests in Oregon. Conks in Washington occurred on 3 National Forests (one on a National Monument) and one National Park. In Oregon, conks occurred on 4 National Forests and on USDI Bureau of Land Management (BLM) land.

## Forest Cover Types

*Bridgeoporus nobilissimus* conks have been detected across a wide range of forest conditions (Table 3). Sites ranged in age from a 25 year-old second growth stand to an over 400-year-old intact stands. Sites were located exclusively in the western hemlock and Pacific silver fir plant association zones exclusively.

**Table 3. Site descriptions.** A list of all 12 BRNO sites in the Pacific Northwest, with their overstory composition and stand age estimates. Data taken from KSS plots except for the Mount Rainier site.

| Site | Overstory composition |
|---|---|
| Asahel Curtis, WA | Older, intact forest dominated by western hemlock (+375) with western redcedar and Pacific silver fir components (+190 yrs) |
| Humptulips, WA | Intact, old-growth forest dominated by western hemlock (200+ yrs) |
| Mount Rainier NP, WA* | Older, intact forest (+250 yrs) dominated by noble fir, western redcedar, and Pacific silver fir |
| Goat Marsh, WA | Open, intact older forest dominated by western hemlock (+120 yrs) and noble fir (300 yrs) with minor Douglas-fir component |
| Larch Mountain, OR | Younger, second-growth forest dominated by western hemlock (30-50 yrs) with remnant old hemlocks (+200 yrs); Pacific silver fir component present (<100 yrs) |
| Wildcat Mountain, OR | Second-growth Douglas-fir-western hemlock dominated overstory (60 – 90+ yrs) with a western redcedar and minor pacific silver fir component |
| Snow Peak, OR | Young second-growth forest dominated by Douglas-fir (30 yrs) and western hemlock (50 yrs); some second-growth plots dominated by Pacific silver fir, and/or have Pacific silver fir as a minor component |
| Monument Peak, OR | Open, young stand dominated by noble fir and western hemlock (22 yrs) |
| Mt. Horeb, OR | Older, mostly intact forest dominated by 300-year old Douglas-fir and western hemlock, with a minor Pacific silver fir component |
| Harter Mountain, OR | Young, second-growth stand dominated by noble fir (30+ yrs) &/or Douglas-fir (20-30 yrs) with a western hemlock component |
| Sweet Home RD, OR | Young, second-growth Douglas-fir (40 yrs) dominated forest with western hemlock, western redcedar and Pacific silver fir components |
| Mary’s Peak, OR | Mature, open noble fir stand (+95 yrs) |

* Mount Rainier National Park site has no associated KSS plot.

Sites were dominated by Douglas-fir (*Pseudotsuga menziesii*), western hemlock (*Tsuga heterophylla*), Pacific silver fir (*Abies amabilis*), noble fir (*Abies procera*), and western redcedar (*Thuja plicata*). Six sites were located in second-growth stands, two of which were dominated by true fir. The remaining second-growth sites were dominated by Douglas-fir. Six sites were located in intact stands, three of which had a dominant true fir component.

*Bridgeoporus nobilissimus* conks observed in this study occurred at varying elevations and forest site conditions (Table 4). *Bridgeoporus nobilissimus* occurred between 1000 and 4380 feet. Within the range, the lowest elevation BRNO occurrences were in Washington on the Olympic and Mt. Baker-Snoqualmie National Forests. In Oregon, the lowest elevation host was at 2,800 feet. In Washington conks generally fruited at lower elevations and in lower topographic positions; Oregon conks fruited at higher elevations and at higher topographic positions. The slope of the sites was moderate, averaging around 20% ranging from flat benches to steep mid and upper slopes. Aspect ranged from south-southeast to north-facing. However, the majority of sites were located on western or northwestern-facing slopes. *Bridgeoporus nobilissimus* also was found fruiting in a wide range of canopy densities, from open, young second-growth to closed canopy, even-aged mature forest and multiple-story old growth forest.

**Table 4. Summary of environmental variables.** The range of measured environmental variables related to BRNO habitat. The ranges are summarized for all 21 plots in Oregon and Washington where KKS plots were established.

| | Mean (st. dev) | Range |
|---|---|---|
| **Slope (%)** | 21.7 (12.7) | 5 - 55 |
| **Topographic Moisture Index** | 4 (1) | 2 – 6 |
| **Successional Stage (1-5)** | 3 (1) | 2 - 5 |
| **Macroposition** | 2.73 (0.77) | 1 – 4 |
| **Microposition** | 2.64 (1.05) | 1 – 5 |
| **Overstory Canopy Cover (%)** | 81 (14) | 44 - 95 |
| **Understory Canopy Cover (%)** | 67 (27) | 2 - 95 |
| **Host Diameter (ft)** | 4.26 (0.84) | 2.8 – 6.2 |
| **Host Height (ft)** | 25 (56) | 2.5 – 246 |
| **Host Decay Class (0-5)** | 4 (1) | 0 – 5 |

Conks fruited on large live trees, snags, and stumps, exhibiting regional variation between Oregon and Washington sites. In general, most conks fruited on stump hosts. In Oregon, the majority of hosts were stumps whereas in Washington only one host was a stump. Snag hosts, however, were distributed quite equally throughout the region, four snag hosts in Washington, five in Oregon. Four tree hosts occurred in Washington, while only one was detected in Oregon. Conk hosts averaged 1.3 meters in diameter at breast height (dbh), and ranged from 86 – 190 cm in diameter.

Eleven sites were sampled during this study, 4 in Washington and 7 in Oregon, with a total of 60 conk hosts sampled. Each conk host had at least one fruiting body associated with it. Fifteen conk hosts had multiple fruiting bodies present, yielding a total of 81 fruiting bodies (Table 5).

## Topographic Position of Sites

Topographic position varied widely among all sites and all BRNO host types. Across the region, conks were found fruiting in draws, benches, lower-, mid-and upper slopes, and at ridgetop positions. Washington BRNO sites were more frequently observed in lower slopes and draws, compared with Oregon sites dominated by mid- and upper slope locations. Three conk hosts were located in a

**Table 5. Site to site variability.** List of all known BRNO sites in Oregon and Washington, demonstratiting the variability among known sites. The number in parentheses indicate the number sampled.

| Site | Number of KSS Plots | Number of Conk Hosts | Number of hosts with multiple fruiting bodies | Number of fruiting bodies |
|---|---|---|---|---|
| Asahel Curtis, Mount Baker-Snoqualamie National Forest, WA | 1 (1) | 1 (1) | 1 | 3 |
| Mount Rainier National Park, WA | 0 (1) | 2 (2) | 0 | 2 |
| Humptulips, Olympic National Forest, WA | 1 (2) | 1 (1) | 0 | 1 |
| Goat Marsh, Gifford Pinchot National Forest, WA | 2 (2) | >5 (5) | 1 | 6 |
| Larch Mountain, Mount Hood National Forest, OR | 2 (2) | 2 (2) | 1 | 3 |
| Wildcat Mountain, Mount Hood National Forest, OR | 3 (3) | 5 (5) | 0 | 4 |
| Cascade Resource Area, BLM, OR | 4 (4) | >36 (36) | 9 | 50 |
| Mount Horeb, BLM, OR | 1 (1) | 1 (1) | 1 | 2 |
| Monument Peak, BLM, OR | 1 (1) | 1 (3) | 1 | 2 |
| Harter Mountain, Willamette National Forest, OR | 3 (3) | 3 (3) | 1 | 4 |
| Sweet Home, Willamette National Forest, OR | 2 (2) | 2 (2) | 1 | 3 |
| Mary's Peak, Siuslaw National Forest, OR | 1 (1) | 1 (1) | 0 | 1 |
| *Total* | *21* | *60* | *16* | *81* |

bench, one in a draw, and six at lower slope position. Thirty-six conk hosts fruited at the mid-slope position, 11 at upper slope, and 3 conk hosts were located on ridge tops. Among host types, tree hosts occurred in lower slopes and draws, snag hosts occurred from lower to upper slopes, and stump hosts were detected from draws and bench positions to ridgetops (Figure 4).

Oregon distribution patterns were strongly influenced by Salem BLM sites (Figure 5), with the vast majority of known hosts at mid-slope or higher on stumps and snags. The single live tree host observed was the only host occurring at a lower slope position. Snags occurred on upper slopes only. One stump host occurred on a bench and the remainder occurred mid-slope or higher.

In this study, *Bridgeoporus nobilissimus* was observed to have as many as four fruiting bodies present on a single host. Conks were observed at the base or on the bole (up to 1.5 meters) on tree, snag or stumps, and inside rotten centers or on the top of stump hosts. Conks were observed fruiting downslope, to either side, as well as up slope of their host. Multiple conks were observed on some stump or snag hosts, likely the same individual. Multiple fruiting bodies on a single host often had distinct morphologies, and different fruiting locations, on the same host.

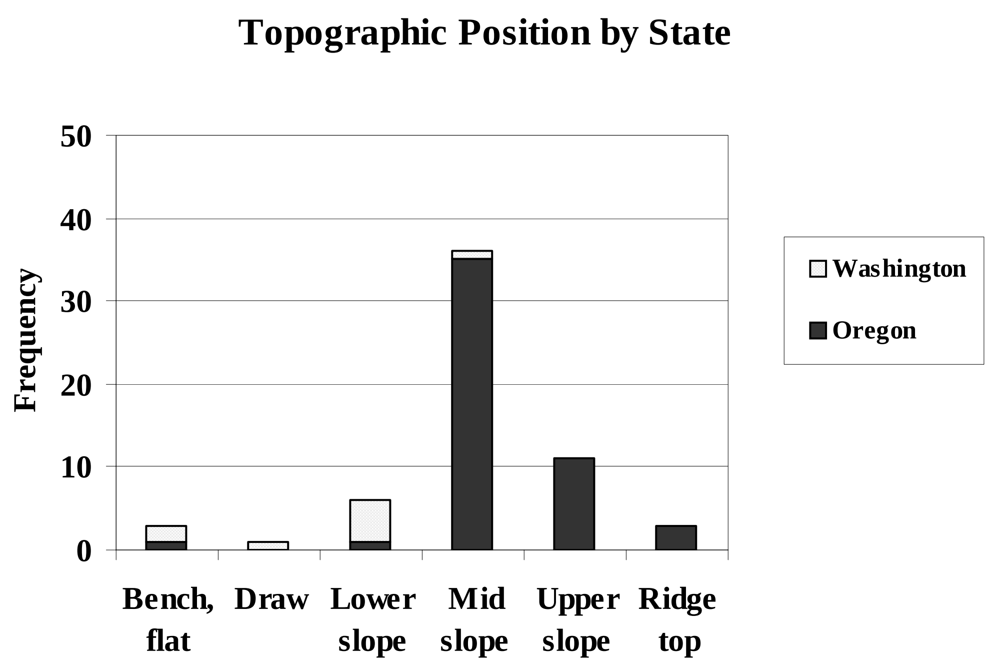



**Figure 4. Topographic position by state.** Topographic position graphs by state demonstrate the variation in topographic positions across the region.

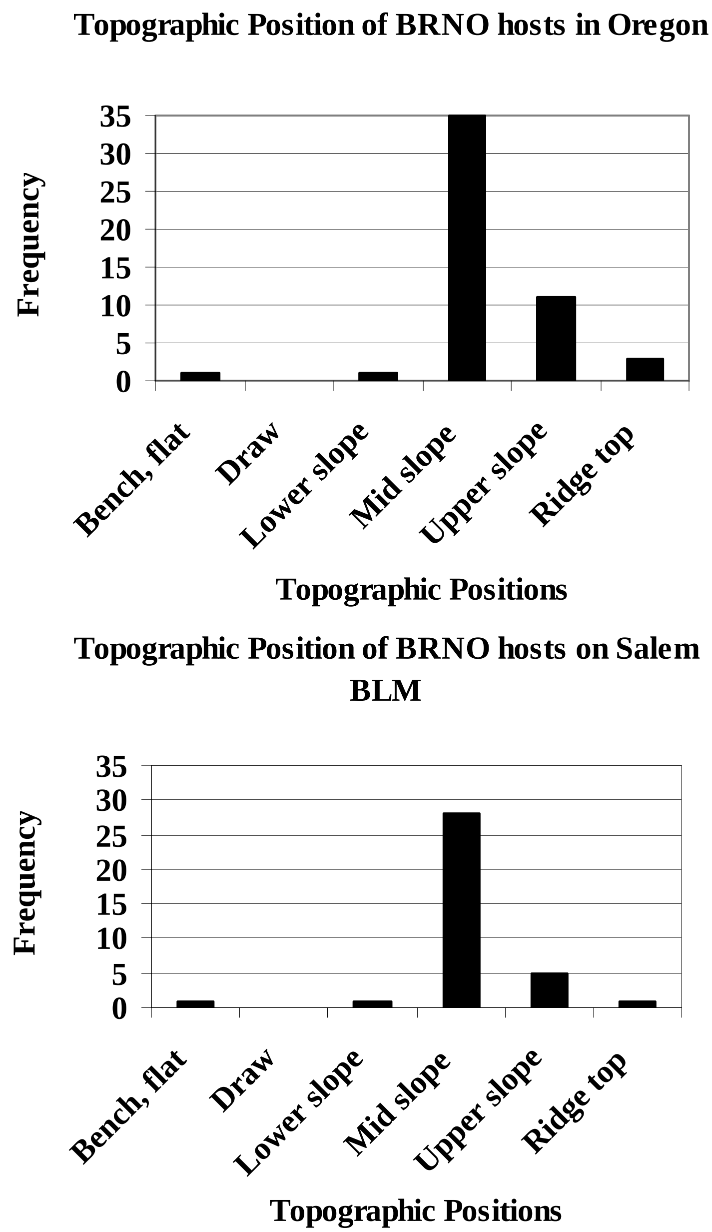



**Figure 5. Topographic position in Oregon & Salem BLM land.** Topographic position of BRNO hosts in Oregon (5a) and those in Oregon on Salem BLM lands (5b). Notice the trend in Oregon is driven by the large population residing on BLM land.

## Conk Morphology

Four unique conk morphologies were identified during this study. These morphologies were shelved, conical, “button”/round, and vertical (Figure 6). Seventy-seven percent (n=62) of the 81 individual conks were shelved, 10% (n=8) conical, 11% (n=9) round, and 2% (n=2) vertical. Forty-five of the 60 dominant conks were shelved. Shelved conks were usually large and had algal growth and litterfall accumulation on the upper, pileal surface of the sporocarp, and were found on trees, snags, and stumps. Seven dominant conks were conical. These conks only fruited on top of stumps and had algal growth and litterfall on the upper, pileal surface of the sporocarp. Conical conks were characterized by a long stem, observed protruding from deep within the stump center. Six dominant rounded conks were observed, characterized as small, conks, with an active pileal surface but were not a secondary host to algae or mosses. These conks did not appear to have an active hymenium. Vertical conks were very rare, observed fruiting on only two stump hosts in Oregon. Characterized by a vertical growth pattern from the stump top downward, vertical conks were creamy beige in color and had no algal growth or litter present. Of the multiple fruiting bodies, dominant conks were 80% shelved, 6% conical, 6% vertical, and 6% rounded.

a. Conical

b. Shelved

c. Vertical

d. Round

**Figure 6. Conk morphologies.** Morphology types on stump and snag hosts. Conical (a) and vertical (c) morphologies were detected only on stumps. Shelved (b) and rounded (d) morphologies were detected on trees, snags, or stumps.

## Variability among Host Type, Disturbance Type, & Decay Class

*Bridgeoporus nobilissimus* conks fruited across a suite of host types and stand conditions. Snag and live tree hosts occurred in both intact and second-growth stands across the region. From the 12 sites, 3 sites had a live tree host, 7 sites had snags present, and 7 sites had stumps present. Predominant hosts were 8% live trees, 15% snags, and 79% stumps. Two of three live tree hosts occurred in intact stands. Snags were detected in both second-growth (in Oregon only) and old-growth stands throughout its known range. Stump hosts occurred in second-growth or partially-cut stands in Oregon and Washington. Fifty-seven percent of hosts were stumps located on Salem BLM land. For Salem BLM conks, 95% of the 38 hosts sampled were stumps, one was a live tree and one a snag; all were in stands that have been partially or clearcut harvested.

The distribution of hosts within each state was less variable than between states. Nine hosts were located in Washington and 51 in Oregon. In Washington, four hosts were live trees, four were snags, and one was a stump. All Washington hosts except for one stump host were located in intact, older forests. Conversely in Oregon, one host was a live tree, four were snags, and 45 were stumps (Figure 7). In Oregon, all hosts except for 3 were located in second-growth stands. Of the 51 hosts in Oregon, 38 hosts were located on Salem BLM land.

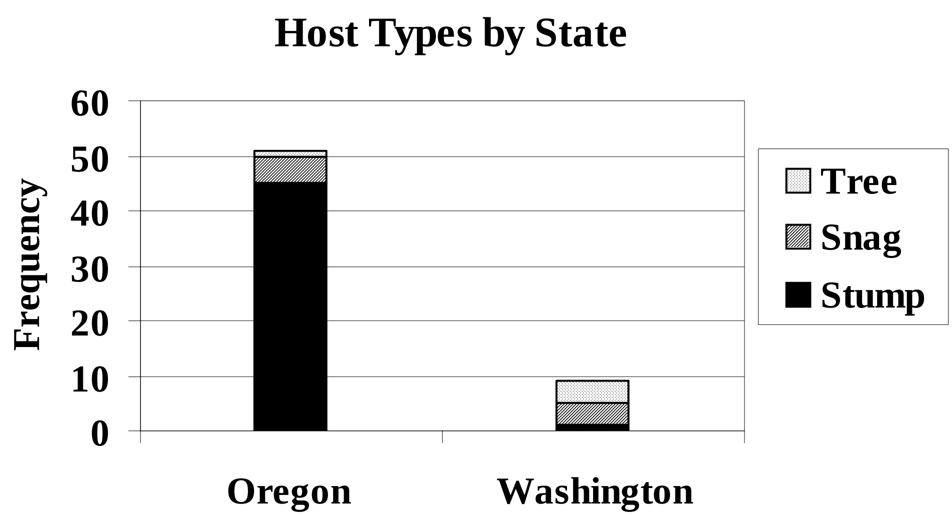



**Figure 7. Host types by state.** The distribution of tree, snag and stump hosts by state for BRNO hosts.

Well-decayed wood was a predominant characteristic of BRNO hosts. Of all 60 hosts sampled, 8% were live trees, 5 % decay class 2 or 3, 59% decay class 4, and 29% decay class 5 (Figure 8). Decay class 2 had one snag host and decay class 3 had one stump and one snag host. Decay class 4 were predominantly stumps (n=31), with four snag hosts. Within decay class 5, 11 % were snags and the remainder stumps.

Thirty-eight hosts were sampled from the Salem BLM population. One was a live tree, 66% were decay class 4 and 32% decay class 5. No conks were detected fruiting on decay class 2 or 3. Within decay class 4 one host was a snag and the remainder were stumps. All hosts in decay class 5 were stumps. Assessing the known range of BRNO occurrences without the Salem BLM data, the largest proportion of conk hosts remained in decay classes 4 and 5, similar to the trends reflected in Figure 8.

## Host Specificity

Wood identification was performed on all stump hosts (n=29) and well-decayed snag hosts (n=7) that could not be identified in the field. All live trees (n=5) were field identified as *Abies procera*. All sampled wood specimens keyed to *Abies spp* lacking spiral thickenings, ray tracheids, and possessing taxoidiod

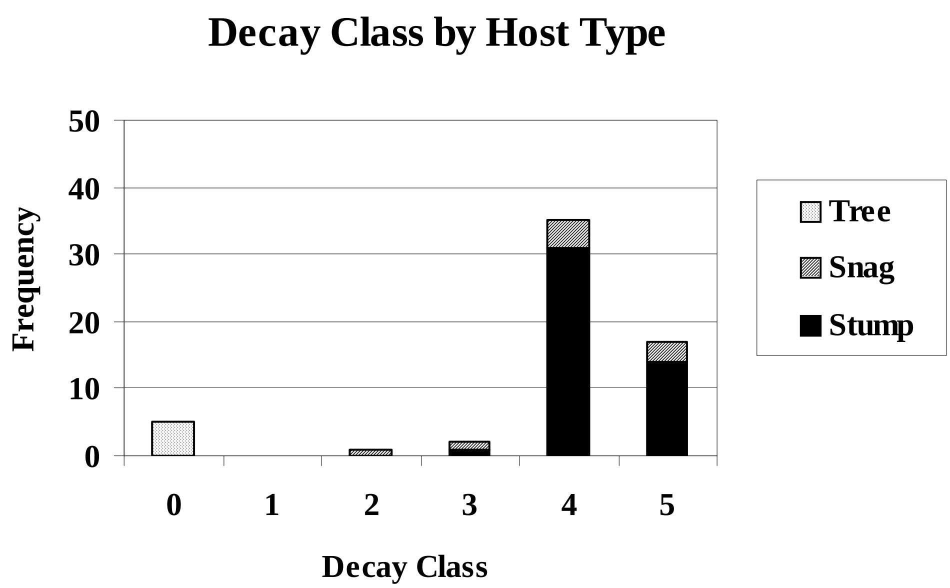



**Figure 8. Decay classes by host type.** Graph of decay class by host type for all 60 sampled BRNO hosts. Decay class 0 signifies a live tree, decay class 4 and 5 are well-decayed hosts that lack bark and sound wood (adapted from Sollins 1982).

cross-field pitting. The three specimens that were keyed to species were determined to be *Abies procera* since crystalliferous structures were located in the latewood parenchyma of the radial section.

## Fruiting Location

Conks were located at three areas on a host: at the base of a tree, snag, or stump, on the bole (<1.5 m in height) of trees, snags and stumps, and on top or inside a stump (Figure 9). The majority of conks were observed fruiting at the base of a stump, snag, or tree host. Basal fruiting occurred most frequently (for dominant conks) across all three host types: 55% of the time on stumps, 100% on trees, and 88% on snags. The other sampled conks were located on the top or inside the center of stump or on the bole of a host (Table 6).

On Salem BLM lands, over half of the sampled dominant conks were located at the base of a stump, snag, or tree. Conks fruited at the base of all live trees, all snags, and half of all stump hosts on Salem lands. The other fruiting bodies on stump hosts were located on the top, inside the center, or on the bole of a stump.

The majority of all dominant conks observed were in the shelved category, regardless of host type. Seventy-five percent of hosts had a shelved conk, 12%

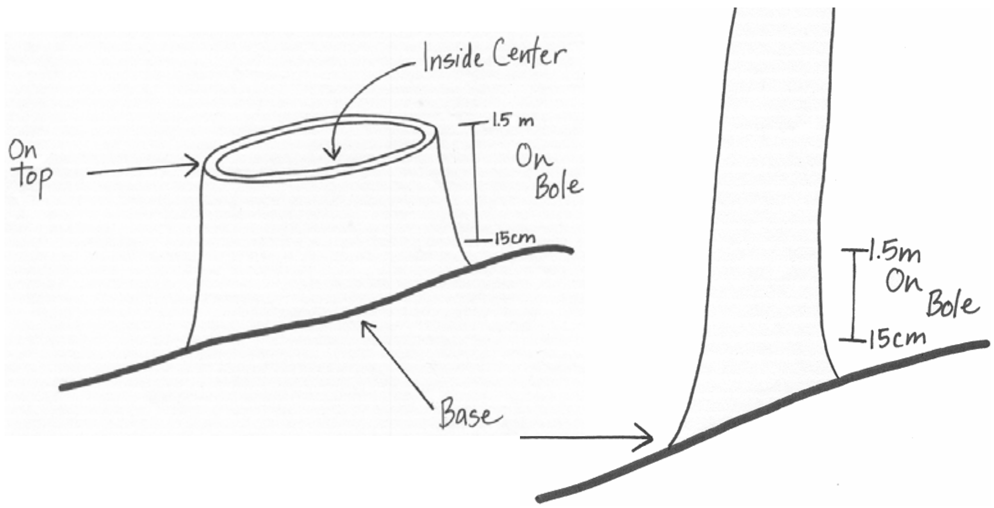



**Figure 9. Conk location on host.** Conk location on stump or snag/tree hosts. The stump figure on the left illustrates the four possible conk fruiting locations on a stump host: on top of the stump, inside a rotten center, on the side/bole of a stump or at the base. The snag/tree figure on the right illustrates the 2 locations of conks: at the base or on the bole less than 1.5 meters high.

**Table 6a and b. Conk location.** Table 6a contains dominant conk location by host type for all 60 sampled hosts. Table 6b contains conk location data for all 81 individual conks across the 60 sampled hosts. Each column is the total number of hosts found at each location; their percent for that location type is in parentheses below the value. The total column contains the percent across all host types for the respective conk location.

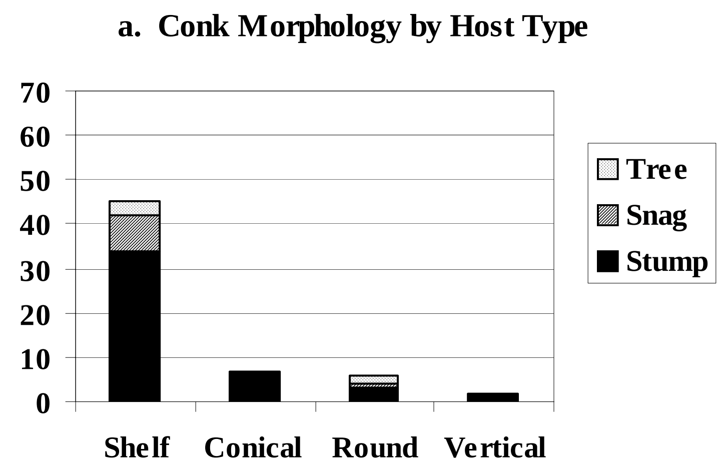
| **a. Dominant Conk Location by Host (n=60)** | **Tree** | **Snag** | **Stump** | **Total** |
|---|---|---|---|---|
| **Base/Root Collar** | 5<br>(100%) | 7<br>(88%) | 26<br>(55%) | *38*<br>*(63%)* |
| **Top of Stump** | 0 | 0 | 10<br>(21%) | *10*<br>*(26%)* |
| **Inside Stump Center** | 0 | 0 | 6<br>(13%) | *6*<br>*(16%)* |
| **On Bole** | 0 | 1<br>(12%) | 5<br>(11%) | *6*<br>*(13%)* |
| *Total* | *5* | *8* | *47* | *60* |

| **b. Conk Location for all Individual Conks (n=81)** | **Tree** | **Snag** | **Stump** | **Total** |
|---|---|---|---|---|
| **Base/Root Collar** | 5<br>(100%) | 10<br>(83%) | 42<br>(66%) | *38*<br>*(70%)* |
| **Top of Stump** | 0 | 0 | 10<br>(16%) | *10*<br>*(12%)* |
| **Inside Stump Center** | 0 | 0 | 7<br>(11%) | *6*<br>*(9%)* |
| **On Bole** | 0 | 2<br>(17%) | 5<br>(8%) | *6*<br>*(9%)* |

hosted a conical conk, 10% a round conk, and 3% demonstrated a vertical growth pattern (Figure 10a). Taking into account multiple fruiting bodies among all sampled trees, snags, and stumps revealed similar trends as above. For all 81 individual conks, 77% were shelved, 10% conical, 10% round, 4% exhibited vertical growth pattern (Figure 10b). Shelved conks fruited on all host types while conical and vertical conks fruited only on stump hosts. The pattern observed on Salem BLM lands reflect the same trends found from the dominant conk per host and all 81 individual conks.

## Conk Aspect relative to Site Aspect

In general, conks were observed fruiting downslope of their host, regardless of host type. For all 60 sampled hosts throughout the Pacific Northwest, dominant conks were found fruiting downslope of their host 43% of the time on stump hosts, 63% on snag hosts, and 80% on live tree hosts. Only snag and stump hosts had conks fruiting upslope of their host (Figure 11a). Fruiting bodies detected on trees always fruited down- or side-slope. The same trends were observed on Salem BLM lands (Figure 11b).



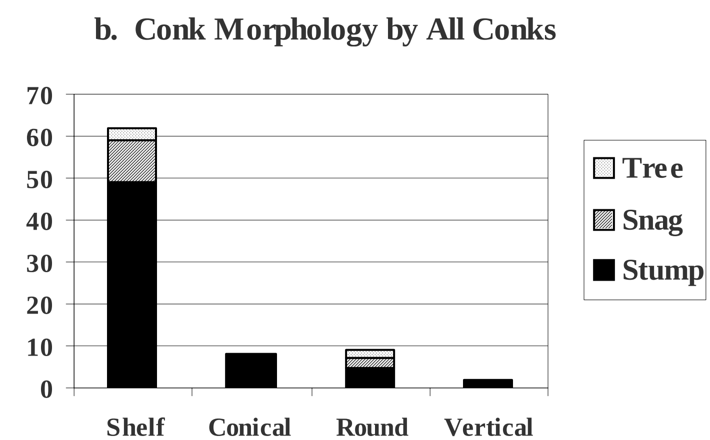




**Figure 10a and b. Conk morphology.** Figure 10a shows the distributions of dominant conk morphology by host type for all 60 hosts. Figure 10b shows the distribution of conk morphology by host type for all 81 individual conks on the 60 sampled hosts. The general pattern at the host level was also found at the individual conk level with the majority of conks being shelved regardless of host type.

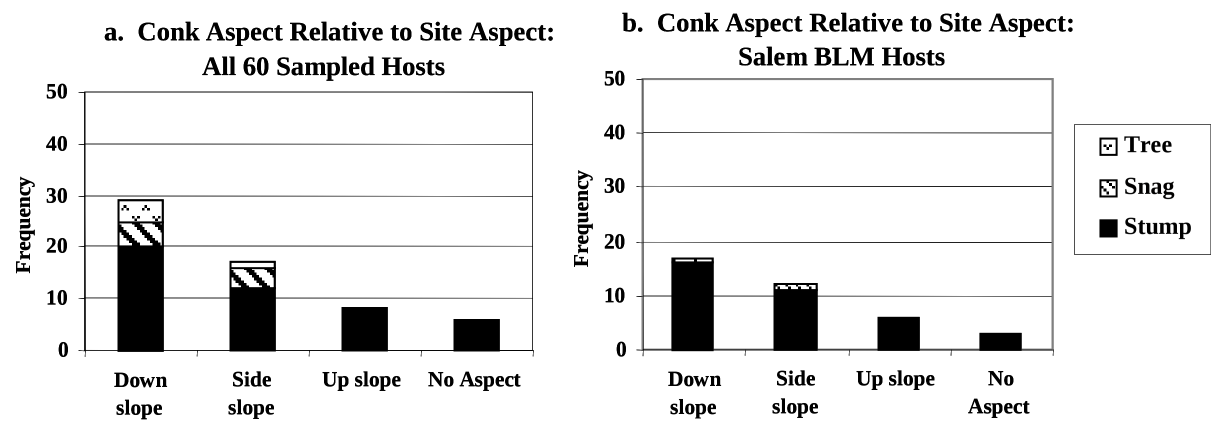



**Figure 11a and b. Conk aspect.** Two graphs illustrating the aspect of the fruiting bodies in comparison to the aspect of the site. The graph on the left represents the variation among all 60 sampled hosts in Oregon and Washington. The graph on the right represents the variations on Salem BLM lands of all 38 sampled conks.

## Conk Variability and Plant Community Description Through NMS Ordination

Results of NMS ordination revealed data patterns relative to conk morphology, host characteristics, vegetation, and regional location. A single NMS ordination was run on both the conk variability and plant community data, yielding two 2-dimensional solutions.

Conk variability ordination indicated that conk characteristics have regional variation. Conk variability (fruiting location, host type, conk morphology) was related to elevation, successional stage, and overstory canopy cover. The total variation explained by this ordination was 84.3%, with Axis 1 contributing 54% of the total variation explained. Final stress was 14. Correlations with the environmental matrix were set at an r-squared value of 0.15.

Trends among host type (tree, snag, or stump) were strong for the conk variability ordination. Along Axis 1 (Figure 12), the strongest trend was the separation among all three hosts types. Stump hosts were located on the left side of the ordination, while snag and tree hosts were located to the right and on the bottom of the graph, respectively. Another obvious trend along the first axis was the separation of sites in Oregon from sites in Washington (Figure 13). Oregon

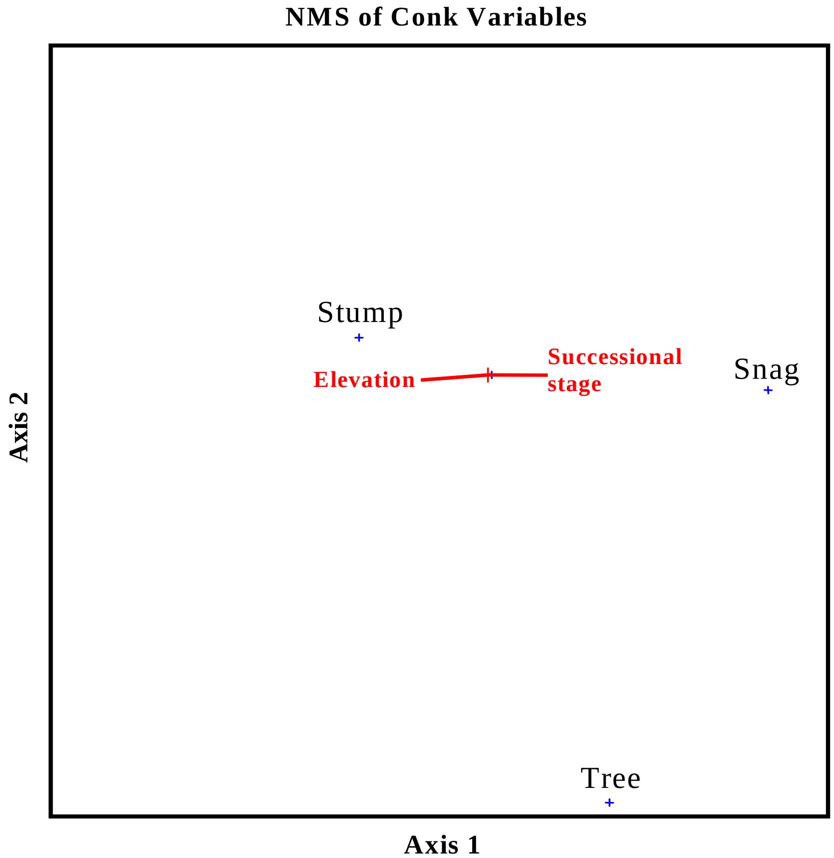



**Figure 12. NMS of conk variables by host.** Biplot of ordination on conk attributes with host type and environmental variables plotted. Notice the distinct separation among host types. Axis 1 explained 54% of the variation, axis 2 30.4%.

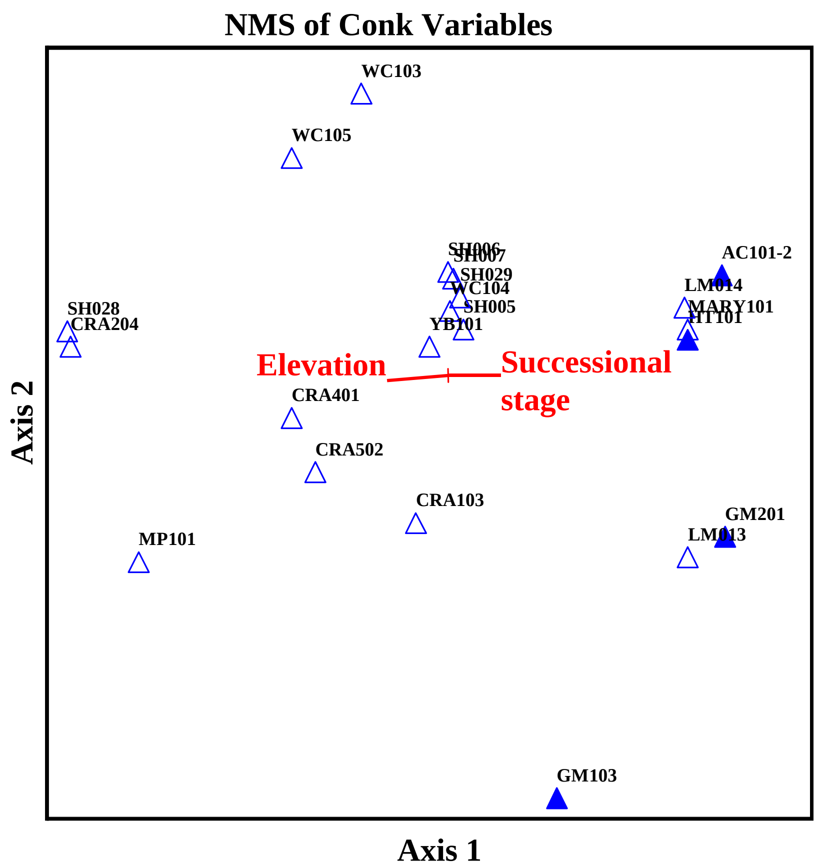



**Figure 13. NMS of conk variables by plot.** Biplot of ordination on conk attributes with plots and environmental variables plotted. Solid triangles are Washington plots, open triangles represent Oregon plots. Axis 1 explained 54% of the variation, Axis 2 30.4%.

sites were concentrated on the left half of the graph while Washington sites comprised the right side of the graph. Conk attributes associated with Axis 1 included snag host, shelf morphology, and base location. Stump host, top of stump location, and conical morphology were negatively associated with Axis 1 (Table 7 and Figure 14). The first axis explained 54% of the variation.

Conk attributes were categorized from stump hosts to tree/snag hosts and from more unique morphology to more common morphology along Axis 1. Conical and vertical morphologies and top fruiting were placed in the far left region, separating these characteristics from the more common base fruiting shelved conks. Shelved morphology and base location occurred in a more central location, reflecting their ubiquity among all host types.

The second axis of conk variability ordination did not have as many strong patterns as the first axis, nor as much variation explained. The variation explained by Axis 2 was 34.3%. The main pattern was the gradient from well-decayed host types (usually stumps) to hosts with little or no decay (live trees). This trend overlapped with fruiting location of conks on hosts (Figure 14). Another trend was the transition among host types, paralleling the decay class trend from well-decayed stumps and snags to live tree hosts (with presumably sound wood). For example, Goat Marsh (GM 103) was the only site with live

**Table 7. Correlation coefficients of conk variable NMS.** Correlation coefficients for the main variables in the conk habitat ordination of conk variables. Positive scores indicate a strong position on the right side of axis 1, or on the top of the graph for axis 2. High negative scores indicate the variable is located on the left side or the bottom of the ordination. The correlation coefficients and their r-squared values are listed below for both axes of the ordination.

| | **Axis 1** | **Axis 1** | **Axis 2** | **Axis 2** |
|---|---|---|---|---|
| **Conk Variable** | **Pearson's r** | **r-squared** | **Pearson's r** | **r-squared** |
| Decay Class | -0.273 | 0.074 | 0.330 | 0.109 |
| Diameter | 0.106 | 0.011 | 0.007 | 0.000 |
| Host height | 0.321 | 0.103 | -0.514 | 0.264 |
| Host Aspect | -0.131 | 0.017 | -0.425 | 0.181 |
| Conk Aspect | -0.117 | 0.014 | -0.159 | 0.025 |
| Snag | 0.789 | 0.622 | -0.066 | 0.004 |
| Stump | -0.811 | 0.657 | 0.343 | 0.118 |
| Tree | 0.121 | 0.015 | -0.621 | 0.386 |
| Base location | 0.364 | 0.133 | 0.737 | 0.544 |
| Top of stump | -0.631 | 0.398 | -0.052 | 0.003 |
| In Stump | -0.344 | 0.118 | -0.276 | 0.076 |
| On bole | 0.328 | 0.107 | -0.438 | 0.192 |
| Shelf morphology | 0.728 | 0.530 | -0.283 | 0.080 |
| Conical | -0.611 | 0.373 | 0.078 | 0.006 |
| Button | -0.096 | 0.009 | 0.414 | 0.172 |
| Vertical | -0.376 | 0.141 | 0.032 | 0.001 |

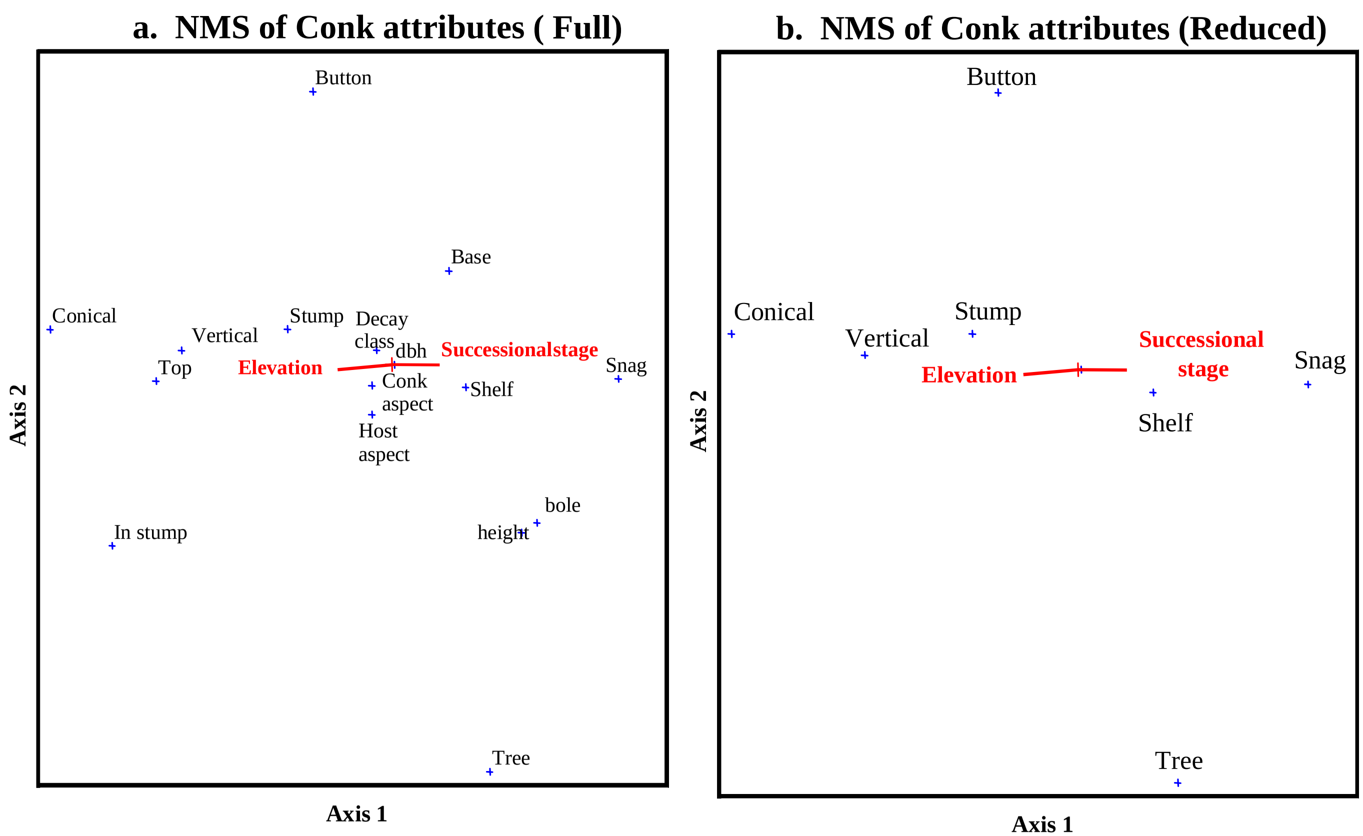



**Figure 14. NMS of conk variables by attributes.** Biplots of conk attribute ordinations with the full set of variables (Figure 14a) and a reduced set of variables (Figure 14b). Figure 14b shows only the conk morphology and conk location variables used in ordination. Both figures have the two strongest environmental variables overlayed onto the bilplot: elevation and successional stage.

tree hosts, and had the lowest value of all decay classes. This site occupied the lower half of Axis 2 (Figure 13). Conk attributes positively associated with Axis 2 included decay class, stump host, base location and button morphology (Table 7).

Negatively associated conk attributes included host height, tree host, and location on bole.

The environmental overlay onto the conk ordination related environmental factors to the patterns of BRNO conk characteristics. For the conk variables ordination, elevation and forest structure were the strongest conk-level variables (Table 8). Successional stage ($r = 0.355$) and overstory canopy cover ($r = 0.328$) were positively correlated with Axis 1; elevation was negatively correlated with Axis 1 ($r = -0.378$). Stump hosts generally occurred in second-growth at high elevations while tree and snag hosts were found in older forests at lower elevations. The difference between Oregon and Washington also plays a role in this description since all of the stump hosts used for analysis were in Oregon and most of the snag hosts were from Washington.

Plant community data was used in the conk habitat ordination to describe patterns among sites. This 2-dimensional ordination indicated that BRNO sites

**Table 8. Correlation coefficients of environmental variables.** Correlation coefficients (Pearson's r) of all the environmental variables overlayed the conk and plant association (PA) ordinations. Negative values indicate a relationship with the left side of axis 1 or the bottom half of axis 2, while positive scores indicate a strong correlation with the right side of axis one and the top half of axis two.

| | **Conk ordination** | **Conk ordination** | **PA ordination** | **PA ordination** |
|---|---|---|---|---|
| | **Axis 1** | **Axis 2** | **Axis 1** | **Axis 2** |
| **Variable** | **Pearson's r** | **Pearson's r** | **Pearson's r** | **Pearson's r** |
| Decay Class | N/A | N/A | 0.099 | 0.027 |
| Elevation | -0.378 | -0.115 | 0.429 | -0.000 |
| Aspect | -0.077 | 0.119 | -0.295 | -0.131 |
| Slope | -0.053 | 0.233 | 0.327 | 0.185 |
| Overstory Canopy Cover | 0.328 | 0.170 | -0.404 | 0.168 |
| Understory Canopy Cover | 0.003 | 0.044 | -0.213 | -0.177 |
| Macroposition | -0.023 | -0.054 | 0.135 | 0.044 |
| Microposition | 0.054 | 0.034 | 0.260 | 0.095 |
| Successional Stage | 0.355 | -0.007 | -0.038 | -0.089 |
| Stand Structure | -0.107 | -0.090 | -0.131 | 0.276 |
| Moss Cover | -0.114 | -0.010 | -0.126 | 0.057 |
| TMI | 0.058 | -0.129 | -0.239 | -0.089 |

occupy a wide array of habitat types. Environmental overlays revealed patterns among elevation, overstory canopy cover, and site moisture index. The total amount of variation explained through this ordination was 65%, 22% by Axis 1, and 43% on Axis 2. The final stress was 22. Correlations with the environmental matrix were set at a minimum r-squared value of 0.11.

Ordination of conk habitat variables with vegetation data from KSS plots revealed a relationship between canopy cover and elevation among sites. A weak moisture gradient is implied by results of plant species ordination. After ordination was complete, plot labels were replaced with plant association names from KSS data. Major environmental variables associated with Axis 1 were elevation and canopy cover. Elevation had a correlation coefficient of 0.429 and canopy cover –0.404 (Table 8). Species positively correlated with Axis 1 were *Rosa gymnocarpa*, *Holodiscus discolor*, and *Asarum caudatum*. Species negatively correlated with Axis 1 included *Oxalis oregona*, *Clintonia uniflora*, and *Rubus pedatus* (Table 9).

The majority of variation in this ordination was explained by Axis 2 and represents a site moisture gradient based on autecological species characteristics. There were no strong correlations with any environmental variables from KSS

**Table 9. Plant community correlation coefficients.** A list of the strongest correlated variables on conk habitat ordination by plant community data.

| Species | Axis 1 | Species | Axis 2 |
|---|---|---|---|
| *Rosa gymnocarpa* | 0.490 | *Athyrium filix-femina* | 0.396 |
| *Holodiscus discolor* | 0.462 | *Oplopanax horridus* | 0.310 |
| *Asarum caudatum* | 0.434 | *Xerophyllum tenax* | -0.340 |
| *Oxalis oregona* | -0.620 | *Fragaria virginiana* | -0.318 |
| *Clintonia uniflora* | -0.498 | *Epilobium angustifolium* | -0.533 |
| *Rubus pedatus* | -0.340 | | |

sampling. High positive scores on Axis 2 were generally associated with plant species requiring abundant year-round moisture including *Athyrium filix-femina*, and *Oplopanax horridus*. Species occurring in drier and disturbed environments were generally positioned in the lower half of Axis 2 and included species such as *Xerophyllum tenax*, *Epilobium angustifolium*, and *Fragaria virginiana* (Table 10).

In plant community ordination space, plots that were located on the upper half of the graph were generally Pacific silver fir zone sites and plots in the lower half of the graph were predominantly western hemlock sites (Figure 15). Many sites located in the middle of the graph were typed as transitional plant associations between western hemlock and Pacific silver fir zones. Plant associations further described patterns among the vegetation across all known sites. Along Axis 1, the two extremes were described primarily by western hemlock plant associations. The *Tsuga heterophylla-Vaccinium alaskaense-Oxalis oregana* and *Tsuga heterophylla-Oxalis oregana* plant associations were located on the left side of ordination space, associated with closed canopies and lower elevations. The right side of the graph was described by *Tsuga heterophylla-Vaccinium alaskaense –Cornus canadensis*, *Tsuga heterophylla-Achlys Triphylla*, and *Tsuga heterophylla-Oplopanax horridus* (Figure 15).

**Table 10. Plant species by sites.** A list of the sites associated with various regions of the plant community ordination, followed by a list of the most abundant species present within this region of the ordination.

| Left Side | Right Side | Top | Bottom | Center |
|---|---|---|---|---|
| Wildcat Mountain | Mount Horeb | Larch Mountain | Snow Peak | Asahel Curtis |
| Mary's Peak | Monument Peak | | Wildcat Mountain | Snow Peak |
| Humptulips | Harter Mountain | | Larch Mountain | Goat March |
| Sweet Home | | | Monument Peak | Humptulips |
| | | | | Wildcat Mtn. & Sweet Home |
| *Berberis nervosa* | *Achlys triphylla* | *Oxalis oregana* | *Berberis nervosa* | *Acer circinatum* |
| *Blechnum spicant* | *Aster campestris* | *Rubus ursinus* | *Cornus canadensis* | *Achlys triphylla* |
| *Clintonia uniflora* | *Cornus canadensis* | *Streptopus streptopoides* | *Epilobium angustifolium* | *Cornus canadensis* |
| *Gaultheria shallon* | *Coptis laciniata* | *Tiarella trifoliata* | *Fragaria virginiana* | *Coptis laciniata* |
| *Hypopitys spp.* | *Holodiscus discolor* | *Trillium ovatum* | *Polystichum munitum* | *Clintonia uniflora* |
| *Madia dissitiflora* | *Rosa gymocarpa* | *Vaccinium membranaceum* | *Rhododendron macrophyllum* | *Oxalis oregana* |
| *Oxalis oregana* | *Rubus laciniata* | | *Trillium ovatum* | *Polystichum munitum* |
| *Polystichum munidum* | *Rubus parviflorus* | | *Vaccinium alaskaense* | *Rubus spectabilis* |
| *Rhododendron macrophyllum* | *Rubus ursinus* | | *Vaccinium parvifolium* | *Tiarella uniflora* |
| *Rubus pedatus* | *Ryla* | | *Xerophyllum tenax* | *Trillium ovatum* |
| *Smilacina stellata* | *Vancouveria hexandra* | | | *Vaccinium alaskaense* |
| *Trillium ovatum* | *Vaccinium ovatum* | | | *Vaccinium membranaceum* |
| *Vaccinium alaskaense* | | | | |
| *Viola sp.* | | | | |

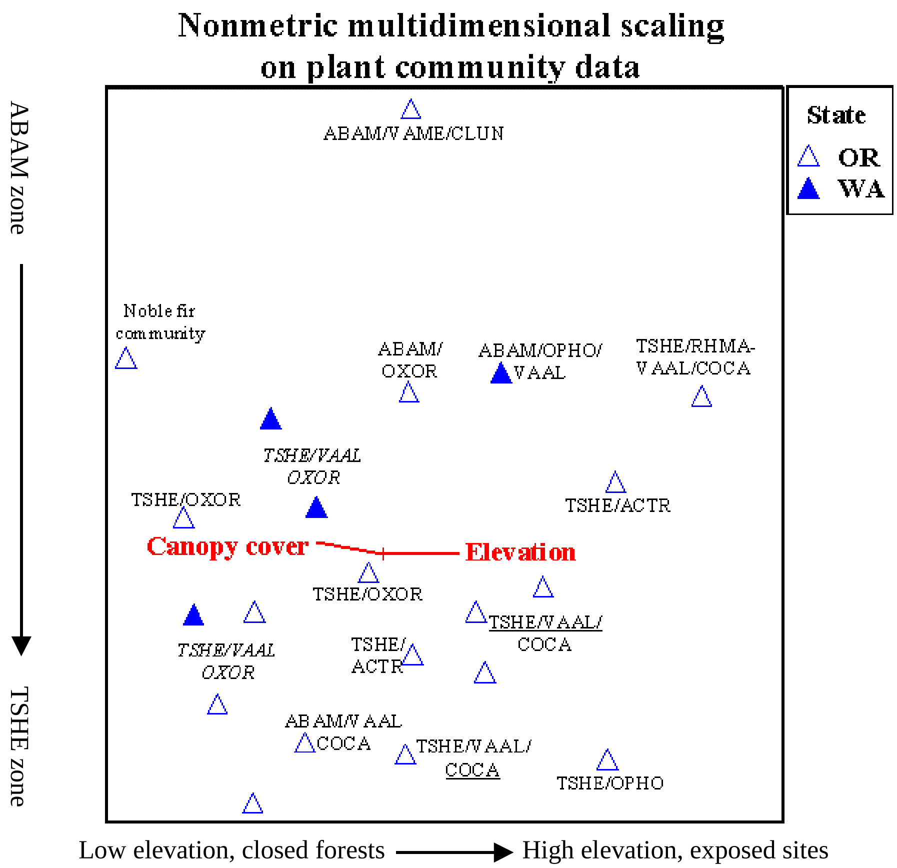



**Figure 15. NMS of plant community data.** Plant community ordination biplot. This graph illustrates the placement of all 21 KSS plots in terms of their respective plant associations. Solid triangles are Washington plots, open triangles are Oregon plots.

A handful of plants dominated species composition across all sites. The most common plant species (0.01- 80%) present at over half the plots were *Clintonia uniflora*, *Cornus canadensis, Oxalis oregana, Polystichum munitum, Smilacina stellata*, *Vaccinium alaskaense, and Trillium ovatum* (Table 11). At least one of these species was present (0.01% or greater) at all plots. The least common species were disturbance and xeric species *Epilobium angustifolum* and *Xerophyllum tenax*, respectively. These two species were present in only a handful of sites, concentrated in the ordination at the bottom of the biplot.

**Table 11. Plant species by abundance.** Plant species that were associated varying number of plots on the ordination graph (reference Table 5 for a list of sites). The rare species (species found in less than 5% of the 21 plots) were associated with the bottom of the graph. The most common species, *Trillium ovatum*, was found in many locations of the ordination space because it is so common. Common species (in 50-75% of all plots) were associated with the left half of the graph.

| Less than 5% | 5-30% | 30-50% | 50-75% | 90% |
|---|---|---|---|---|
| *Epiloboium angustifolium* | *Blechnum spicant* | *Acer circinatum* | *Clintonia uniflora* | *Trillium ovatum* |
| *Xerophyllum tenax* | *Fragaria virginiana* | *Achlys triphylla* | *Cornus canadensis* | |
| | *Galtheria shallon* | *Aster campestris* | *Oxallis oregana* | |
| | *Holodiscus discolor* | *Berberis nervosa* | *Polystichum munitum* | |
| | *Madia dissitiflora* | *Coptis laciniata* | *Smilacina stellata* | |
| | *Rosa gymnocarpa* | *Rhododendron macrophyllum* | *Vaccinium alaskaense* | |
| | *Rubus laciniatus* | *Rubus spectabilis* | | |
| | *Rubus parviflorus* | *Rubus ursinus* | | |
| | *Rubus pedatus* | *Tiarella unifoliata* | | |
| | *Xerophyllum tenax* | *Vancouveria hexandra* | | |
| | | *Vaccinium membranaceum* | | |

# DISCUSSION

*Bridgeoporus nobilissimus* is a dramatic perennial polypore fungus associated with woody hosts, endemic to the Pacific Northwestern United States. This organism is a species of concern and was listed as a Survey and Manage Fungi under the Northwest Forest Plan in 1994 (USDA and USDI 1994a) and was placed on the Oregon Natural Heritage Program's endangered list in 1995 (Lizon 1995). Also, it has been frequently documented as being a sensitive or endangered species (e.g. Christy 1991, Coombs 1991, Trappe 1990, Stamets 2001). *Bridgeoporus nobilissimus* is a species whose lack of habitat will most likely limit conservation efforts (Oregon National Heritage Program 2001).

*Bridgeoporus nobilissimus* is found within the western hemlock and Pacific silver fir plant association zones of the Pacific Northwest, primarily on the western slopes of the Cascade Range (2,200 to 4,300 feet in elevation). *Bridgeoporus nobilissimus* spans a large geographic region, including one site on the Olympic Peninsula and one in the Coast Range of Oregon. This variability in sites lends evidence that this species is not limited by dispersal, but rather is limited by the presence or absence of its habitat requirements.

Habitat fragmentation for BRNO is a potential concern in managing this species. The range of true fir throughout the Pacific Northwest is inherently fragmented because management practices of clearcutting and planting Douglas-fir monocultures on federal and private lands have further isolated true fir stands on the landscape. Since we have only detected 12 known sites of BRNO occurrence across the Pacific Northwest region, we have an overall small population. Furthermore, at least 2 of the sites contain fruiting bodies that are currently in decline with no obvious replacement conks. These sites are at the current geographic extremes with one site in the Coast Range of Oregon and one on the Olympic Peninsula of Washington. This is cause for concern as these isolated populations may face local extinction in the next few decades. Fragmentation increases the risk of local extinction through deterioration of habitat, environmental or demographic stochasticity, or loss of genetic variation (Davies, et al. 2001). Conservation of this species is imperative because BRNO occurs at so few sites, many having single fruiting bodies associated with them, or conks on very well-decayed substrate. Maintaining and improving current BRNO habitat is key to conservation efforts.

Although this species range is known to extend beyond federal jurisdiction, with conks identified on private lands, known sites of BRNO occurrences are currently only managed on USFS or USDI BLM lands, those agencies who adhere to the Northwest Forest Plan's Survey and Manage Criteria for Fungi (USDA and USDI 2001). Clearly BRNO habitat –and most likely the conks themselves – extend beyond these political boundaries. However, only federal agencies are actively managing this organism at this time. Conservation efforts need to extend across these political boundaries and multiple ownerships to be successful.

## Ecophysiology of *Bridgeoporus nobilissimus*

*Bridgeoporus nobilissimus* conks were detected only on old, large live trees, snags, and stumps, never on downed logs or any form of dead wood that lacked roots or some connection to a root system. On the Mount Hood National Forest, a once vital conk died within several years after its host was uprooted by a fallen tree (USFS 1999). The fact that BRNO is only known to fruit on hosts connected to a root system is evidence that roots system are a quintessential part of BRNO persistence. This ecological implication is similar to butt rots such as Annosus root rot (*Heterobasidion annosum*) and *Phaeolus schweinitzii* (Burdsall 2001, Dreisbach 2002). Butt rots have been considered pathogenic for years, as they degrade wood quality and in some cases kill their hosts (Boyce 1961).

*Bridgeoporus nobilissimus* was rarely detected on live trees in this study, but more commonly was detected after the host has been damaged or died. Conks were predominantly located at the base of their host. All trees and snags had conks fruiting at the base or on the bole (<1.5 m in height). Fruiting location, combined with the suggested requirement of a root system provides evidence that BRNO should be considered a root or butt rot (Burdsall 2001, Dreisbach 2002).

Butt rots are sometimes characterized by fruiting bodies at the base of their hosts or fruiting terrestrially (appearing from the roots), and often not detected until after a stand has been harvested (Arora 1986). Most brown rotting decay fungi decompose wood such that the wood becomes sectioned into cubes, known as cubical butt rot in some species (Alexopoulos, et al 1996). These characteristics have been observed on most dead wood specimens of BRNO, suggesting that BRNO is a butt rot and a brown rot.

Investigating the natural history of BRNO may provide more insight into what type of a rot BRNO is and what type of relationship it has with its host. *Bridgeoporus nobilissimus* may infect its host prior to harvest or death, persisting in the roots or bole of the tree for years before showing signs of a fruiting body (Dreisbach 2002, Volk 2002). Research is needed to clarify when BRNO infects its host. Molecular techniques have been used recently to amplify BRNO mitochondrial and ribosomal DNA from spores (Redberg 2002). This preliminary work will be followed up by testing the primer on soil and wood samples at one of the known sites to see if BRNO DNA can be amplified from these samples.  The goal is to determine how sensitive the developed DNA primer is in detecting BRNO in the environment (when it is known to be in the stand).  In the long term, there is hope that these DNA methodologies will be used to detect the presence of BRNO in trees of all ages, and at specific heights on the bole so that this organism can be better understood and managed.

The amount of litterfall deposition and moss and algal colonization on the upper surface of the fruiting bodies may provide an insight into time since conk fruiting with the establishment of long-term observational monitoring.  Conks that had extensive litterfall and epiphytic associations appeared to have established for several years prior to conks lacking epiphytic associations.  Many shelved and conical conks were characterized by a large amount of algal growth.  Rounded and vertical morphologies in general lacked epiphytic associations, thereby appearing to be younger than shelved or conical varieties.  It became apparent that some conks have persisted for more time than others.

Determining the age of BRNO conks has been and continues to be the goal of many researchers.  Scientists have attempted to age BRNO specimens by counting the tube layers within the fruiting body. William Bridge Cooke counted the tube layers of one conk to be 35 years (Cooke 1949).  Other scientists have been surveying some known sites for more than 10 years, the conks presumably established some time prior to that. Volunteers at Mount Hood National Forest have been photo-documenting conks over several growing seasons and it appears that a fruiting body with vertical morphology is showing signs of multiple shelves (Roger 2002). Long-term observational data such as this will provide information regarding how morphology changes with conk age.

## Decay Class Trends and Survey Strategies

There was a large gap in host presence among decay classes. Conks were found on old, decadent noble fir trees, as well as moderately decayed snags, and well-decayed stumps and snags. There was a gap in detection between living trees and decay class 2. Decay classes 2 and 3 have been detected on only a small number of hosts, while hosts of decay classes 4 and 5 were the most abundant. In this study, conks were observed fruiting only on old (>200 years old), large (>1m dbh) live trees or well-decayed snags or stumps.

The true range of BRNO hosts may be quite different from what we have been able to detect thus far with surveys for fruiting bodies. Since detection has been so sporadic across the region, the distribution of host decay classes could be an inaccurate representation of potential BRNO hosts. Detection capabilities may be reflecting weakness in surveying methodology rather than the real range of

BRNO habitat. Current surveys are designed based on previous BRNO observations, including targeting well-decayed stumps in second-growth stands. Intact old, mature and young forests with a true fir component (snags or stumps of all decay classes) needs to be added (even experimentally) to survey sites. Expanding the surveys across a wider range of stand types and stand ages throughout the upper western hemlock and Pacific silver fir zones of Oregon, and the upper western hemlock and Pacific silver fir, and lower mountain hemlock zones of Washington will likely help define the range of BRNO decay classes and host types more accurately.

Results of this study indicate that BRNO is host specific, fruiting only on true fir (*Abies spp.*). *Bridgeoporus nobilissimus* appears to require large, true fir substrate in order to fruit and persist. This criteria provides a narrow range for managing potential BRNO habitat, and maintaining and creating suitable structural habitat for long-term BRNO conservation.

## Population on Salem BLM lands

Even though there are a large number of conks from one specific area (Salem BLM), it reflected general population trends among conk morphology, location, or host type. The Salem BLM population reflects trends observed across the entire known range. This is true both when Salem data is present or absent from the entire data set. However, the data does amplify some trends significantly such as topographic position and host type. It lacks the variability in topographic positions observed across the region, especially those that were unique to Washington. This population could be used for a study of BRNO as it appears to contain the range of host types, morphologies, and fruiting body locations.

## Identifying and Locating Conks and Potential Habitat

Known habitat of BRNO conks include large, old true fir trees, snags, and stumps occurring in young second-growth stands and intact old-growth forests throughout western Oregon and Washington. Decomposition rates of BRNO hosts indicate that 40 year old true fir stumps (age of stump estimated from harvesting records) range from decay class 3 to 5 in Oregon. Thus, it is feasible that this conk substrate will be completely decomposed (uninhabitable) within 50 to 75 years. Well-decayed substrates should not be the focus of future BRNO habitat as it has less nutrition available than more sound dead wood.

There appeared to be an elevational-latitudinal gradient in BRNO occurrence from Washington to Oregon sites. Sites in Washington generally occurred in older forests and at lower elevations (300 to 1200 meters). Sites in Oregon generally occurred in young to mature forests at mid to high elevations (950 to 1300 meters). Conks fruited on many different locations on their host and possessed a wide array of morphological variability in Oregon. There was less variability in Washington conks than Oregon. This may be partly an artifact of the NW Forest Plan since surveys for fungi were driven by imminent forest operations (i.e. thinning dense second-growth Douglas-fir plantations). However, both states have potential and current habitat for BRNO in both intact and second-growth forests.

Topographic position exhibited region-specific trends. Conks in Oregon fruited generally at higher topographic positions than conks in Washington. *Bridgeoporus nobilissimus* sites in Washington were generally located in more mesic areas than BRNO sites in Oregon. In general, BRNO populations in Washington were observed at lower topographic positions, lower elevation, and in older forests. This could be reflective of sampling techniques or an ecological gradient within the range of BRNO. Regional differences should be accounted for when planning and conducting surveys for BRNO. An increase in detections within the variability of BRNO habitat will allow better prediction relative to latitude, elevation and topography.

## Plant communities among BRNO sites

*Bridgeoporus nobilissimus* does not seem to be restricted within an area by vegetative patterns. Plant community ordination indirectly tested and confirmed field typing of plant associations. The ordination technique arranged plots according to vegetation composition, with similar plant associations being very close to one another in the output. Pacific silver fir plant associations occupied similar space (Figure 15) and were separate from the aggregated western hemlock plant associations. The ordination of vegetation data supported the field typed plant associations from the 21 KSS plots. This was a unique way to investigate the accuracy of the plant association types for these plots and provided some insightful information about plots, sites, and their similarity or dissimilarity to other sites.

The most common western hemlock plant associations were the *Tsuga heterophylla*, *Oxalis oregana*, and *Vaccinium alaskaense* association and the *Tsuga heterophylla* and *Oxalis oregana* association. These plant associations are described as sites in the mid to upper western hemlock zone, characterized as cool, moist sites (Halverson, et al. 1986). From the sampled BRNO sites, Douglas-fir, noble fir, and western hemlock were the dominant tree species within these common plant associations. Pacific silver fir plant associations from this study occupied wetter, cooler sites than the western hemlock sites

(Hemstrom, et al. 1982, Henderson 1989). The Pacific silver fir, *Opoplanax horridus*, and *Vaccinium alaskaense* plant association was characterized by wet, cool conditions on lower slopes (Henderson, et al. 1992).

Environmental parameters associated with vegetation patterns among BRNO sites were canopy cover and elevation. The general trend was from closed forests, lower elevation sites to open forest BRNO sites at higher elevations. Bridgeoporus nobilissimus sites such as Humptulips (HT) on the Olympic Peninsula reflected these trends. Humptulips is a low elevation site with high levels of overstory canopy cover, with understory vegetation mainly comprised of *Vaccinium alaskaense* and *Rubus spectabilis*. The other extreme of site conditions can be characterized by Yellowbottom (YB101), a mid-elevation site located on Salem BLM land in Oregon in an older stand that has been selectively harvested. This site was located at 3400 feet elevation with 13% canopy cover. Plant species strongly associated with this site included *Rubus parviflorus, Oplopanax horridus* (OPHO), and *Vaccinium ovatum*. *Vaccinum sp*. and *Rubus sp*. and are associated with many forest types; OPHO is an indicator of a site with abundant year-round moisture.

Plant associations were usually similar within sites containing multiple fruiting bodies or plots. For example, Wildcat Mountain is a site with 3 plots, 5 BRNO hosts all with one single fruiting body each. All four BRNO hosts here occurred in the same plant association and also occupied one portion of the ordination. Other Mount Hood NF sites, however, had different plant associations despite their close proximity. These two plots varied from virtually no understory to a more open stand with a well-developed understory composition.

## Conk characteristics: Observation versus Ordination

Trends in conk variables observed in the field were subsequently reflected in the ordination results. For example, a large number of stump hosts were observed, as well as shelved morphologies among fruiting bodies. These characteristics overlapped at many sites, and were reflected in analysis by being the central core of the ordination space. The single, live tree host used in ordination was placed the farthest away from all other variables considered, distinguishing it as a unique variable.

Regional differences among sites were confirmed with the conk characteristics ordination graphs. Washington sites aggregated together because of their narrower range of conk characteristics. Oregon sites represented all types of conk characteristics (host types, morphology, and location), and thus represented a larger proportion of the total variation among sites. This suggested a regional difference in conk characteristics. Host type, conk morphology and conk location appeared much more variable within Oregon than Washington. Sample size may obviously be impacting these observations as fewer conks were sampled in Washington. However, distribution of Washington conks was much more narrow with respect to conk characteristics than those of Oregon.

Both plant community and conk variable ordinations aggregated plots from the same geographic region. For example, Salem BLM and Willamette National Forest sites had multiple plots; their plots occupied very similar ordination space. This suggests that conk characteristics and species composition among plots from the similar geographic regions have more in common that plots from more distant sites.

When comparing overall trends between plant communities and conk characteristics, both analyses demonstrated a narrow range of variability overall. Conk characteristics revealed some simple patterns. Conks occurred only at the base or on the bole of trees and snags. Conical morphology was strongly correlated with top fruiting on stumps; stumps and snag host were associated with shelved morphology. Plant associations were quite similar to one another within each zone. From this study, BRNO thrives in moist sites within the

Pacific silver fir plant associations and moist site conditions within the upper western hemlock plant associations.

## Survey and Manage Implications

To improve detection success, site selection for surveys should include both young and older stands, as well as all possible decay classes of true fir. In expanding the criteria, surveys may indicate that the range of BRNO hosts is much wider than current data suggests. It is possible that BRNO establishes in younger trees where it resides for decades (to perhaps centuries) without producing a fruiting body. Thus, being able to determine the presence of this organism from molecular techniques applied to soil and wood samples will greatly improve our understanding of this fungus.

Surveyors must be well trained in recognizing the variety in BRNO conks (Appendix B) and the various fruiting positions on hosts. When surveying, it is imperative that the surveyors encircle all potential hosts. Conks have been detected fruiting in any direction on their host, and basal conks may be easily overlooked. Furthermore, conks are often overgrown with mosses and algae and are extremely camouflaged in their environment; they may be easily overlooked at the base of hosts. On stump hosts, it is important to look inside rotten centers for fruiting bodies. All federal forest lands within the western hemlock and

Pacific silver fir zones that have a history of large *Abies spp*. or some true fir in their stands are potential candidates for BRNO populations.

Federal managers with known BRNO sites are required to actively manage the immediate area around any conk. Up to 50 acres should be considered for management since we are still unsure of the size of the fungal mat or the individuality among neighboring conks. Within the management area, recruitment and retainment of true firs, especially noble and Pacific silver fir should be a driving factor for any silvicultural operation. To provide future habitat, large diameter *Abies* trees should be promoted in young developing stands.

Ideally, BRNO habitat would be managed with biodiversity goals. In areas where BRNO habitat occurs but conks have not been detected, the true fir component should be retained, and diversity of overstory species favored over a single dominant overstory. Multi-aged stands with 2 or 3 age classes of trees may also provide a greater likelihood of BRNO habitat in the long-term, producing large diameter trees over the long-term.

Results from this study indicate that there is still much information to be gathered to adequately describe the habitat requirements and range of BRNO populations in the PNW. Surveying within the elevational bands specific to Oregon (2800 to 4300 feet) and Washington (2200 to 3600 feet in the Cascades) within the western hemlock, Pacific silver fir, and mountain hemlock zones with a true fir component would be an effective place to continue surveys for BRNO habitat and fruiting bodies. Surveys should be conducted during months when sites are snow-free and accessible, namely from June through October. A potentially useful survey methodology might include expanding surveys from KSS sites in a concentric fashion within similar habitat since there is currently more similarity within sites than regionally. Additionally, each year a subset of surveys might be randomly located in potential habitat (intact forest with old-growth Abies or within western hemlock, mountain hemlock, or Pacific silver fir zones) to increase coverage of potential habitats. Currently, a lack of survey data for potential BRNO habitat comparing presence and absence of fruiting bodies is limiting the development of predictive models, necessary for planning conservation efforts. The coupling of field sampling and lab work using the developed DNA methodologies will hopefully expand our knowledge of the life cycle, geographical range, as well as provide insight as to timing of BRNO fruiting patterns.

# CONCLUSIONS

*Bridgeoporus nobilissimus* has been detected over a large geographical range in the Pacific Northwest. Habitat fragmentation across the range of BRNO occurrences appears to be quite extreme, based on the current site conditions. However, historical ranges of noble fir – favored BRNO habitat – occur in small patches scattered throughout the Cascades and Coast Ranges of the PNW. Two sites (Mary's Peak and Humptulips) have substantially declined in health; these sites are isolated geographically, fragmented from similar habitat by agricultural land and water, respectively. It is still quite unclear how much fragmentation BRNO can tolerate, what its natural range is, and what the natural history of this organism is. Since all federal agencies in the Pacific Northwest are required to conduct pre-disturbance surveys, manage known sites, and conduct strategic surveys, it is important to gain a better understanding of the dynamics of this organism to ensure conservation efforts are successful.

Conservation of BRNO appears to be tightly linked with the conservation of true fir, noble fir in particular. Many sites containing well-decayed hosts most likely will not be hosts for the next century, as they will have completely decayed. Recruitment of new hosts is critical to maintaining local BRNO populations. When managing for species conservation, dispersal rate across the landscape has a profound impact on species persistence (Davies, et al. 2001). For BRNO, the reduction of true fir across the landscape will be more limiting to species persistence than dispersal rates since without the substrate the species will not establish. Some questions to consider with respect to dispersal rates and habitat fragmentation of BRNO are:

- When does BRNO establish within its substrate? At what tree age? What decay class of snags and stumps?
- How far can spores travel from a fruiting body to another potential host and successfully establish?
- Does the organism propagate vegetatively? What are inoculation levels of fungal hyphae in soil? In potential hosts?
- How will fragmentation affect reproduction?

Because *Bridgeoporus nobilissimus* has only been observed on large true fir hosts, it is likely to remain habitat limited, as the occurrence of these hosts is very limited on the PNW landscape. Unfortunately, historical records providing information about stand conditions prior to harvest (old-growth conditions) have not been maintained in many cases (Fennell 2001). This lack of information makes targeting potential second-growth BRNO habitat (plantations containing large Abies stumps) challenging.

It is difficult to adequately characterize and quantify BRNO habitat, since observations have been limited to scattered sites across the PNW. Detection of fruiting bodies has occurred both by serendipitous encounters and systematic surveying by mycologists. Current survey criteria for potential host stands include either the presence or history (<50 years) of large true fir; an elevational band from roughly 2,000 to 5,000 feet in elevation in the Cascade Range within the western hemlock and Pacific silver fir plant associations. By focusing solely on these criteria additional stands and hosts may be overlooked. Therefore, the current geographical range of BRNO may be an inaccurate description in some aspects. Substrate requirements appear to be decadent noble fir trees and true fir snags and stumps (> 1m dbh). However, we do not know when BRNO establishes itself in its host.

Successful conservation of rare species requires extensive planning, commitment, and long-term goals. One certainty in managing threatened species on federal lands is the uncertainty of forest regulations from year to year. If we can work on committing to the recruitment and management of BRNO habitat – regardless of short-term changes in policy – we will likely be recruiting habitat for other species as well. If we begin to truly manage for long-term goals, BRNO and other threatened species in the Pacific Northwest will have a better chance of survival.

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# APPENDICES

# APPENDIX A. Data Matrices

## Environmental Matrix

| 21 | plots | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 14 | attributes | | | | | | | | | | | |
| | q | q | q | q | q | q | q | q | q | q | q | q |
| | Decay class | Elev. | Aspect | Slope | CC over | CC under | macroposition | microposition | Succ stage | Structure | moss cover | TMI |
| AC101-1 | 3 | 2250 | 162 | 33 | 90 | 40 | 4 | 4 | 5 | 2 | 30 | 6 |
| CRA103-2 | 4 | 3550 | 272 | 20 | 85 | 70 | 2 | 3 | 4 | 2 | 6 | 4 |
| CRA204 | 4 | 3850 | 224 | 23 | 95 | 30 | 3 | 2 | 2 | 6 | 45 | 5 |
| CRA401-1 | 4 | 3830 | 354 | 30 | 80 | 88 | 3 | 2 | 2 | 6 | 8 | 4 |
| CRA502 | 5 | 3870 | 170 | 12 | 44 | 8 | 3 | 2 | 2 | 6 | 9 | 2 |
| GM103 | 0.1 | 3600 | 183 | 15 | 80 | 93 | 3 | 2 | 3 | 6 | 8 | 5 |
| GM201 | 5 | 3100 | 260 | 7 | 95 | 95 | 3 | 2 | 3 | 6 | 10 | 5 |
| HT101 | 5 | 1000 | 270 | 5 | 95 | 85 | 3 | 2 | 3 | 6 | 6 | 6 |
| LM013 | 5 | 3660 | 334 | 15 | 90 | 2 | 2 | 2 | 3 | 6 | 11 | 4 |
| LM014 | 4 | 3560 | 330 | 15 | 90 | 50 | 2 | 2 | 5 | 2 | 11 | 4 |
| Mary101 | 3 | 3860 | 302 | 37 | 75 | 85 | 3 | 5 | 5 | 3 | 95 | 3 |
| MP101-2 | 4 | 3931 | 324 | 15 | 58 | 80 | 4 | 5 | 5 | 2 | 70 | 6 |
| SH005-1 | 4 | 4130 | 140 | 55 | 75 | 70 | 4 | 4 | 5 | 2 | 15 | 2 |
| SH006 | 4 | 4340 | 336 | 48 | 70 | 75 | 2 | 3 | 2 | 6 | 7.5 | 2 |
| SH007 | 4 | 4380 | 350 | 20 | 90 | 92 | 1 | 1 | 2 | 6 | 8 | 4 |
| SH028 | 5 | 3490 | 290 | 25 | 85 | 80 | 2 | 2 | 2 | 6 | 25 | 4 |
| SH029-1 | 4 | 3930 | 20 | 14 | 75 | 80 | 3 | 3 | 2 | 6 | 3 | 4 |
| WC103 | 4 | 3130 | 338 | 15 | 95 | 85 | 3 | 3 | 3 | 6 | 17 | 5 |
| WC104 | 4 | 3240 | 268 | 16 | 93 | 50 | 3 | 2 | 3 | 6 | 40 | 5 |
| WC105 | 4 | 3170 | 314 | 15 | 70 | 65 | 3 | 2 | 4 | 2 | 4 | 4 |
| YB101 | 5 | 3990 | 190 | 20 | 70 | 86 | 2 | 3 | 2 | 6 | 2 | 3 |

**Conk Variable Matrix**

21plots
18attributes

| | Q | Q | Q | Q | Q | C | C | C | C | C | C | C |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | decay | dbh | height | Host Aspect | Conk Aspect | Snag | Stump | Tree | Base | Top | in stump | bole |
| AC101-2 | 3 | 6.2 | 100 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| CRA103 | 4 | 4.6 | 4.9 | 90 | 180 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| CRA204 | 4 | 5.4 | 3.8 | 180 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 |
| CRA401 | 4 | 4.8 | 3.4 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 |
| CRA502 | 5 | 4 | 3 | 135 | 135 | 0 | 1 | 0 | 0 | 1 | 0 | 0 |
| GM103 | 0.1 | 3.5 | 246 | 180 | 180 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| GM201 | 4 | 3.8 | 3 | 90 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| HT101 | 4 | 3.6 | 18 | 135 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| LM013 | 5 | 5 | 10 | 45 | 90 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| LM014 | 4 | 3.75 | 21 | 45 | 45 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| MARY101 | 2 | 5.2 | 50.5 | 90 | 90 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| MP101 | 4 | 4 | 2.5 | 45 | 135 | 0 | 1 | 0 | 0 | 0 | 1 | 0 |
| SH005 | 4 | 5.3 | 4 | 90 | 90 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| SH006 | 4 | 4 | 3.7 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| SH007 | 5 | 5 | 3 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| SH028 | 5 | 3.9 | 3.3 | 90 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 |
| SH029 | 4 | 3.6 | 3.6 | 0 | 135 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| WC103 | 4 | 3.5 | 3.3 | 0 | 180 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| WC104 | 5 | 2.8 | 20.6 | 90 | 45 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| WC105 | 3 | 3.5 | 2.5 | 90 | 180 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| YB101 | 5 | 4 | 4 | 135 | 180 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |

## Plant Community Matrix

| 21 Plot<br>108 Species | Q<br>ACCI | Q<br>RUSP | Q<br>VAME | Q<br>SARA | Q<br>VAPA | Q<br>ATFE | Q<br>BLSP | Q<br>OPHO | Q<br>POMU | Q<br>LYAM |
|---|---|---|---|---|---|---|---|---|---|---|
| AC101 | 15 | 3 | 3 | 2 | 0.1 | 8 | 7 | 6 | 4.25 | 3 |
| CRA103 | 2 | 0.5 | 0 | 0 | 0.5 | 0 | 0.1 | 0 | 0.1 | 0 |
| CRA204 | 0 | 5 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| CRA401 | 11 | 15 | 0 | 0 | 0 | 0.4 | 0 | 0 | 1 | 0 |
| CRA502 | 52 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| GM103 | 1 | 0 | 0 | 0 | 0.5 | 0 | 0 | 0 | 1 | 0 |
| GM201 | 20 | 0 | 45 | 0 | 1 | 2 | 1 | 0 | 0 | 0 |
| HT101 | 0 | 25 | 0 | 0 | 6 | 0 | 4 | 0 | 8 | 0 |
| LM013 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| LM014 | 0 | 1 | 0.01 | 0.25 | 0.5 | 0.3 | 0 | 0 | 0 | 0 |
| MARY101 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| MP101 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SH005 | 10 | 0 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SH006 | 2 | 1.3 | 0.01 | 0 | 0 | 0.01 | 0 | 0 | 1 | 0 |
| SH007 | 20 | 1 | 0.5 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| SH028 | 0.5 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 9 | 0 |
| SH029 | 56 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| WC103 | 0 | 0 | 0 | 0.1 | 1 | 0 | 4.5 | 0 | 3 | 0 |
| WC104 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0.1 | 0 |
| WC105 | 0 | 0 | 0 | 0 | 4 | 0.01 | 2.5 | 0 | 0.1 | 0 |
| YB101 | 0 | 1 | 1 | 0 | 0 | 0.2 | 0 | 1 | 0 | 0 |