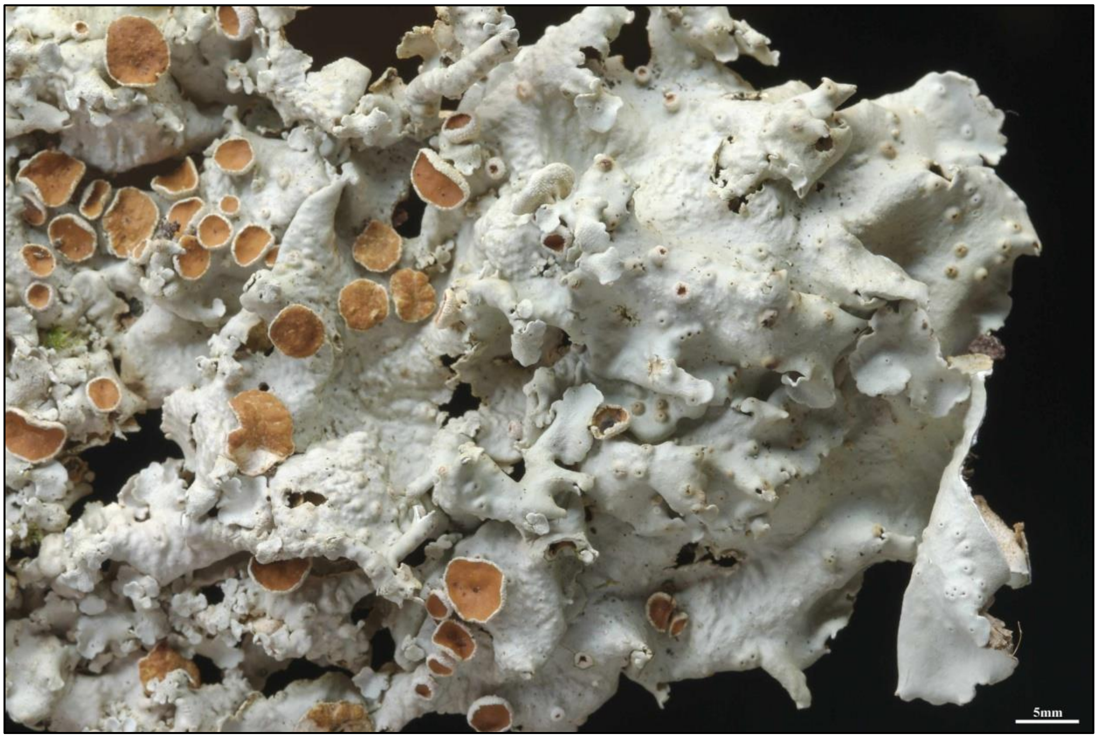
Ricasolia amplissima (Scop.) De Not. subspecies *sheiyi* Derr & Dillman: Species Assessment on the Tongass National Forest, Alaska Region



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Cover Photo:
Ricasolia amplissima subsp. *sheiyi*, with reproductive apothecia from Warren Island. Photo by T. Wheeler

EXECUTIVE SUMMARY

Ricasolia amplissima subsp. *sheiyi* (formerly treated in the literature as *Lobaria amplissima*) has a global range restricted to southeastern Alaska. This lichen was recently confirmed to differ genetically, biochemically, and morphologically from related lichens in the eastern hemisphere. A total of 31 populations have been identified south of Peril Strait and Fredrick Sound, with one disjunct population near Yakutat. All extant populations occur on Tongass National Forest lands. *Ricasolia amplissima* subsp. *sheiyi* is not listed as threatened or endangered or as a species proposed for listing by the US Fish and Wildlife Service. It was designated by the Regional Forester in the Alaska Region as a Sensitive Species for USDA Forest Service and is listed by the Alaska Natural Heritage Program as S1 (critically imperiled in the state). The lichen is an epiphyte on tree trunks and branches of the forest-beach ecotone, often on small marine islands and exposed peninsulas. This lichen is restricted to unshaded portions of branches and trunks of *Picea sitchensis* and *Tsuga heterophylla*. The largest population is found on about 20 mature *Picea sitchensis* trunks. One population is presumed extirpated since its discovery as a single host tree fell into the inter-tidal zone due to beach erosion.

The microclimate specificity and narrow substrate preferences of *Ricasolia amplissima* subsp. *sheiyi* is a factor to its inherent vulnerability; these factors appear to be responsible for the restricted distribution and chronically low population sizes. Additionally, various aspects of this lichen's biology, including its limited sexual reproduction, sensitivity to pollutants, and slow growth rate, contribute to its vulnerability. In Alaska, less than 20% of the known *R. amplissima* subsp. *sheiyi* populations bear the reproductive spore-producing structures of the fungal symbiont (apothecia). Air pollution is also a concern: cyanolichens such as *R. amplissima* subsp. *sheiyi* are considered highly susceptible to air pollution damage. Air quality biomonitoring in certain locations in the Tongass National Forest has revealed levels of nitrogen and sulfur that are above cyanolichen thresholds. Additionally, this lichen and other long-lived *Ricasolia* and related *Lobaria* species have relatively slow annual growth and need long term continuity of habitat to become established. Climate projections for southeastern Alaska predict the frequency of storms to increase. Because this lichen exclusively occupies forest-beach ecotones along exposed shorelines, *Ricasolia amplissima* subsp. *sheiyi* may be vulnerable to windthrow as observed at one population.

Though the beach fringe is protected from large scale timber harvest on the Tongass National Forest, this lichen still faces a number of management-related threats, including the following: recreation (trails and cabins, firewood collecting in camp sites, etc.); small scale individual tree removal (unscheduled salvage harvests, construction of LTF's, and free-use cutting); and air pollution, such as contaminants from diesel engine exhaust in popular marine anchorages. The paucity of information on the lichen's basic biology, distribution, and ecology poses some limitations on our understanding of potential impacts from management-related activities, climate change-related threats, and the natural vulnerability of *Ricasolia amplissima* subsp. *sheiyi*.

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INTRODUCTION

This assessment is one of many being produced to support current and future forest planning efforts on the Tongass National Forest. *Ricasolia amplissima* subsp. *sheiyi* (synonym = *Lobaria amplissima* in part) is the focus of an assessment because it is both a 'Sensitive Species' in the Alaska Region and it is a rare taxon in Alaska and globally. Within the National Forest System, 'Sensitive Species' are plants and animals whose population viability is identified as a concern by a Regional Forester because of significant current or predicted downward trends in abundance or significant current or predicted downward trends in habitat capability that would reduce a species distribution (FSM 2670.5). Sensitive Species require a detailed effects analysis be conducted during project planning that identifies any special management that may be needed for a particular population. Knowledge of the biology and ecology of Sensitive Species is critical for a science-based, informed analysis and decision-making that is clear and transparent among resource managers. The condition and trends of Sensitive Species also serve as a barometer for viability of the species at the State level.

This assessment addresses the biology and conservation considerations of *Ricasolia amplissima* subsp. *sheiyi* in the Alaska Region, and more specifically within the Tongass National Forest, as the "planning area". The broad nature of the assessment leads to some constraints on the specificity of information for particular locales. Furthermore, completing the assessments promptly requires establishment of some limits concerning the geographic scope of particular aspects of the assessment and further analysis of existing (but unanalyzed) field data. This introduction outlines the scope of the assessment and describes the process used in producing the assessments.

Goal

Species assessments are designed to provide forest managers, research biologists, and the public with a thorough discussion of the biology, ecology, and conservation status of certain species based on the most current body of scientific knowledge for the species. The assessment goals limit the scope of the work to critical summaries of scientific knowledge, discussion of broad implications of that knowledge, and outlines of information needs. The assessment does not seek to develop specific management recommendations, but provides the ecological background upon which management can be based. It focuses on the consequences of changes in the environment that result from management (i.e. management implications).

Scope

The *Ricasolia amplissima* subsp. *sheiyi* assessment examines the biology, ecology, and management of this species with specific reference to the geographic and ecological characteristics of the Tongass National Forest and the Alaska Region. A majority of the literature on the lichen originates from field investigations within the region, as the taxon is restricted to southeastern Alaska. We also draw on some of the literature for the closely related subspecies that occurs in Eurasia. This assessment is concerned with reproductive behavior, population dynamics, and other characteristics of *Ricasolia amplissima* subsp. *sheiyi* in the context of the current environment rather than under historical conditions.

In producing the assessment, Alaska Natural Heritage Program (AKNHP) at the Alaska Center for Conservation Science reviewed refereed literature, non-refereed publications, research reports, and data accumulated by resource management agencies. Not all publications on *Ricasolia amplissima* subsp. *sheiyi* are referenced in the assessment, nor were all published material considered equally reliable. The assessment emphasizes refereed literature because this is the accepted standard in science. However, there is a paucity of peer-reviewed literature relating to this taxon within Alaska. Therefore, reports and other publications that were not peer-reviewed were selected where available.

Especially important sources of information for *Ricasolia amplissima* subsp. *sheiyi* within the Tongass National Forest, Alaska, and adjacent British Columbia were the U.S. Forest Service National Resource Information System (NRIS) Threatened, Endangered, and Sensitive Plants (TESP) database and collections from multiple herbaria. These data sources provided information for global range and Alaska occurrences, habitat, and ecology. While data collected during TESP surveys and botanical forays are useful to discern patterns relating to the biology and ecology of the species, any analysis is limited by the disparity of data collectors, methods, and study goals.

Motivation to produce species assessments rapidly, in order to make information available for a Forest Plan amendment lead to tight timelines. The goal to produce assessments rapidly limited the analysis of existing, unpublished data, or attempts to conduct meta-analysis to synthesize information from published literature.

Treatment of Uncertainty

Science represents a rigorous and systematic approach to obtaining knowledge, in which ideas regarding how the world works are measured against observations. Because our descriptions of the world are incomplete and our observations limited, however, some level of uncertainty is implicit in the scientific method. Science includes approaches for dealing with this uncertainty. A commonly accepted approach in science, which results in reductions of uncertainty and development of stronger inference, is based on a progression of critical experiments (Platt 1964). However, conducting meaningful and crucial experiments in the ecological sciences is often difficult, time consuming, and expensive. Often, a systems approach is applied to an ecological question, in which existing data and observations from multiple sources (including those derived from inventories, categories, and counting [Allen and Hoekstra 1992]) are used to construct a predictive framework where ideas can be tested. Reduced uncertainty follows when there is high consistency among the diverse sources of information.

The spatial accuracy of occurrence points varies widely. Data from the NRIS TESP database were received as polygons and converted to centroid points retained inside the polygons. Conversion of polygon data to points allowed comparison of NRIS data with herbarium records and was cartographically beneficial by making all NRIS occurrences visible at the mapping scales selected for this project. When more than one occurrence point or specimen collection were located within 1 km of one another, the collections were aggregated under a single "population" or "element occurrence", in part to address the spatial uncertainty (see NatureServe 2002).

Additionally, there is some uncertainty in the identification of specimens. The identifications of voucher specimens were not checked for this project and occurrences from the NRIS TESP database are not always associated with a voucher. *Ricasolia amplissima* is morphologically similar to an eastern North American species *Ricasolia quercizans*. However, all collections in Alaska have been reviewed by qualified lichenologists (K. Dillman and C. Derr) and material from five populations in Alaska has been confirmed to be genetically and biochemically uniform and distinct from other species and subspecies (Cornejo and Scheidegger, 2015). AKNHP therefore assumed that all determinations are correct for both NRIS TESP records and herbarium records.

This assessment necessitates an evaluation of potential direct and indirect threats due to climate change. The modeled climate data used in this analysis was obtained from Scenarios Network for Alaska and Arctic Planning (SNAP) at University of Alaska Fairbanks. Climate models are downscaled from the five best performing General Circulation Models for Alaska under the A2 emissions scenario. Data modeled into the future is predictive and therefore inherently uncertain. While this represents the best knowledge available at this time, the data should be interpreted at a broad scale representing regional patterns rather than at a pixel by pixel level. Further, for this species no studies have been conduction to determine limitations to growth, reproduction, and establishment associated with climate and environmental conditions.

Publication of Assessment on the World Wide Web

To facilitate use of species assessments in this project, assessments may be published on the Tongass National Forest and the Alaska Region World Wide Web sites. Placing the documents on the web makes them available to agency biologists and the public more rapidly than publication as a book or report. More importantly, revision of the assessments will be facilitated by providing them in a widely accessible digital format. Revision will be accomplished based on guidelines established by the USFS in the Alaska Region.

Peer Review

Assessments developed for the Species Conservation Process have been peer reviewed prior to release on the web. This report was reviewed through a process administered by an independent scientific organization that choses two recognized experts to provide critical input on the manuscript. Peer review was designed to improve the quality of communication and increase the rigor of the assessment.

MANAGEMENT STATUS AND NATURAL HISTORY

This section describes the special management classifications assigned by government and non-government organizations in the U.S. and Canada. Existing regulatory mechanisms, management plans, and conservation strategies specific to *Ricasolia amplissima* subsp. *sheiyi* are discussed. Management actions and recommendations are reviewed. The information provided in this section is meant to be a historic and current overview of species management. More detailed information on potential future management options tailored to the Alaska Region and Tongass National Forest are provided in the "Conservation: Potential Management of the Species" section.

Management Status

Ricasolia amplissima subsp. *sheiyi* is not designated as an endangered species or candidate species by the US Fish and Wildlife Service. In 2009, *Ricasolia amplissima* subsp. *sheiyi* (under the synonym *Lobaria amplissima*) was designated as a Sensitive Species in the Alaska Region of the Forest Service. It was designated as a Sensitive Species at that time due to its rarity, narrow habitat requirements, and possible threats to the viability of the species in the Region, the State, and in North America. It is currently known only from the Tongass National Forest in the Alaska Region, as the population at the Craig Cemetery is presumed extirpated. The global status of this lichen has not been determined by NatureServe or IUCN (see NatureServe, 2009). Its state ranking is currently S1S3 (Critically Imperiled to Rare within the state) (AKNHP, 2016). With the current knowledge of the distribution of other rare lichens known in Alaska, it is conservative to state that the global ranking of *R. amplissima* would likely be ranked at G3 (Rare globally). However, using the updated rank calculator (NatureServe 2015) and the information included within this assessment, the lichen's ranking has recently been estimated at S1 (Appendix B).

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

Sensitive Species management follows Forest Service Manual direction (FSM 2670), as well as standards and guidelines outlined in the Tongass National Forest Plan Revision for Plants, which recommends providing protection around plant populations that meet the habitat needs of the species (USDA, 2008). Forest Service Manual direction requires the agency to "maintain viable populations of all native and desired non-native wildlife, fish, and plant species in habitats distributed throughout their geographic range on National Forest System lands" (FSM 2670.22). Management practices must insure that species do not become threatened or endangered because of Forest Service actions (FSM 2670.22). Though no management plans specific to *Ricasolia amplissima* subsp. *sheiyi* exist for Tongass National Forest, the Tongass Forest Plan Revision protects beach fringe areas, the lichen's preferred habitat, from large scale commercial timber harvesting (USDA, 2008).

Other management activities occur on the beach fringe that may impact this species, however; these include unscheduled tree cutting for free-use and recreation. In a Forest Plan Amendment planned for completion in 2016 the Tongass proposes to open beach and estuary fringe to timber harvest in certain early seral stands (young growth) (USDA 2015). Recreational harvesting may also present a threat to *Ricasolia amplissima* populations as many of the recreation sites on Tongass National Forest are located on or near beaches, and many are accessible only by boat.

Restricting firewood or free-use cutting in beach fringe areas in areas with known populations, coupled with limited timber harvest in the beach fringe could mitigate this threat.

The National Forest System Land Management Planning Rule was revised in 2012 and under the new regulations discontinues the concept of "Sensitive Species" and adopts a revised approach to "At risk species" by evaluating potential "Species of Conservation Concern (SCC)". Similar to the Sensitive Species process of listing, formal SCC lists are designated by the Regional Forester in consultation with Forest managers who prepare recommendations based on a species ability to persist over the long term in the plan area (36 CFR 219.9). The Forest Service through direction from the National Forest Management Act requires that plans provide for diversity of plant and animal communities (16 USC 1604 (g)(3)(B)). The new planning rule requires that all plans identify and assess at-risk species (36 CFR 219.6(b)). In addition, new direction requires plans to assess the status of the ecosystems for ecosystem integrity for the purpose of determining whether ecosystems are functioning normally and are uncompromised. The plan shall identify and assess available information relevant to the plan area for threatened, endangered, proposed and candidate species and potential species of conservation concern present in the plan area by assessing the ecological conditions for these species in the assessment.

Adopting the revised National Forest System regulations provided in the 2012 Planning Rule and new directive system (FSH 1909.12) that defines "at-risk species" is currently in transition. The departure of the "Sensitive Species" designation and subsequent adoption of "Species of Conservation Concern" will likely take the Tongass National Forest several years. In the meanwhile, it is important to note that to date, this species (and others on the Tongass) remain under the "Sensitive Species" policy (FSM 2670.22 and 2670.32). Whether designated as "Sensitive" or as "SCC", the core concept of "at-risk species" remains consistent in both definitions.

Ricasolia amplissima subsp. *shéiya* was recently under review to be designated as a Species of Conservation Concern by the Alaska Region, but was not recommended for this status due an increase in the number of populations that have been discovered and because the habitat is protected at this time from large scale timber harvest. Approximately a third of the populations are in legislatively protected areas and considered protected from direct and indirect effects associated with timber harvest, road construction, and other larger-scale activities on the Tongass National Forest. Wilderness areas with populations of *R. amplissima* subsp. *shéiya* include South Baranof, Tebenkof Bay, Kuiu, Coronation Island and Warren Island. Three populations of the lichen are known from Misty Fiords National Monument, and one population is found on Land Use Designation II lands (USDA 2008, 2015). The lichen currently remains on the Regional Forester's Sensitive Species List.

Inventory and monitoring of lichens primarily occurs with the Air Resource Management (ARM) program on the Tongass National Forest. Air quality biomonitoring with lichens began in the late 1980's, resulting in several publications documenting the lichen flora of southeastern Alaska (Geiser et al., 1994a, 1994b, 1998; Derr, 2004). During the early years of biomonitoring with lichens, *R. amplissima* subsp. *shéiya* was not found in air monitoring plots, probably because few plots or lichen surveys were conducted in the beach fringe. Since 2001, most of the *R. amplissima* subsp. *shéiya* populations on the Tongass were identified during research on the epiphytic lichens of the forest-marine ecotone (Dillman, 2004) and recent establishment of air biomonitoring plots in wilderness (Dillman et al. 2007). Since the inclusion of *R. amplissima* subsp. *shéiya* on the Alaska Region Sensitive Species list, surveys for this lichen occur simultaneously with vascular plant surveys. Systematic monitoring of population size has occurred in two populations.

Biology and Ecology

Classification and Description

Ricasolia amplissima subsp. *sheiyi* was first discovered in North America in 1992 by USFS botanist Chiska Derr on the Sukoi Islets on Frederick Sound near Petersburg. This specimen was initially identified as "*Lobaria japonica*", a synonym of *Ricasolia japonica*, by Irwin Brodo of Ottawa, Canada. *Ricasolia japonica* occurs primarily in cool-temperate deciduous forests in mountainous Japan (Yoshimura 1971). A duplicate sample was sent to Japan for verification by Yoshimura, the *Lobaria/Ricasolia* authority for Asia. He verified the specimen as "*Lobaria japonica*", but that specimen was evidently lost in Japan (Derr pers. comm., 1992) and the record never published. Other specimens collected since then from the Sukoi Islets have been identified as "*Lobaria amplissima*" by the Norwegian lichenologist Tor Tønsberg.

In 1999, Tor Tønsberg, collected a *Ricasolia* from the windward side of a Sitka spruce in the Yamani Islets off of Baranof Island. This was identified as "*Lobaria amplissima*" (a synonym of *Ricasolia amplissima*) and was published as new to North America from Alaska (along with one sample on an oak from Northern California found earlier by another lichenologist and was sent to Tor Tønsberg for identification) (Tønsberg & Goward, 2001). The collection from northern California, however, is of poor quality and its identity remains as *Ricasolia amplissima* (Cornejo et al. 2017).

The North American and European *Ricasolia amplissima* lichens differ in a number of chemical and morphological characters, as well as genetically. A single lichen species may contain two or more "chemical races" that differ in their main chemical make-up (Orange et al., 2001). The chemistries of several Alaskan samples of *R. amplissima* were analyzed with Thin Layer Chromatography (TLC) at Oregon State University and Arizona State University lichen laboratories. Though European *R. amplissima* specimens often contain a number of secondary compounds (including m-scrobiculin, p-scrobiculin, pseudocyphellarian A and an unknown scrobiculin derivative), TLC analysis of Alaskan samples did not detect these secondary substances (Elix and Tønsberg 2006, Cornejo et al. 2017).

Recent genetic analysis has confirmed that *Ricasolia amplissima* from southeastern Alaska is genetically distinct from populations in Europe (Cornejo and Scheidegger, 2015, Cornejo et al. 2017). Molecular phylogenies based on nuclear ITS and RPB2 and mitochondrial SSU, consistently showed the populations of the Alaskan lichen to be monophyletic and sister to populations in Europe.

The American and European *Ricasolia amplissima* also differ in the morphology of their cephalodia. The cephalodia of the European *R. amplissima* are up to 2 cm in diameter, branched, shrubby, and dark green-brown or black on the upper surface of the thallus (Purvis et al., 1992;

Tønsberg & Goward, 2001) (Figure 1). The cephalodia found on the Alaskan populations appear as tiny warts on the upper surface of the lichen, which represent the initial branches of the protruding cephalodia. Branched cephalodia may exist in Alaska populations, but is presumed very rare. Grazing by gastropods has been documented on *R. amplissima* in Norway, and it is possible that the lack of branched cephalodia on the Alaskan specimens is due in part to selective grazing by invertebrates (Asplun et al., 2009). Many of the Alaska populations contain tiny, carved-out holes in the upper cortex of the lichens, presumably where the cyanobacteria-filled cephalodia have been grazed. Factors other than herbivory, such as climate and microhabitat, may also cause the apparent lack of branched cephalodia in the Alaskan populations.

Furthermore, *Ricasolia amplissima* is hypothesized to form its own dendriscocauloid lichen. These lichens, placed in the genus *Dendriscocaulon*, are thought to be "escaped" cephalodia, which are small, gall-like, cyanobacteria-containing growths on the lichen thallus. Unlike traditional cephalodia, *Dendriscocaulon* species grow unattached from the lichen thallus and instead grow freely on other surfaces. These diminutive lichens are uncommon and cryptic. In most cases, the relationship between the *Dendriscocaulon* species and the lichen from which it "escaped" is poorly understood. (Brodo et al., 2001; Tønsberg & Goward, 2001). Recent phylogenetic research on the Lobariaceae has placed the "*Lobaria. amplissima* group" into the genus *Ricasolia*, and deemed *Dendriscocaulon* a synonym (Moncada et al., 2013).

Figure 1. *Ricasolia amplissima* subsp. *amplissima* with branched cephalodia (small black structures containing *Nostoc* in lower part of the photo) from Fairy Isles, UK. Photo from britishlichens.co.uk.

Species Description

The lichen species *Ricasolia amplissima* (Scop.) De Not. was originally described from Europe by Scopali (1772) with De Notaris (1846) later moving the taxon from the genus *Lichen* to the genus *Ricasolia*. Forssell (1883) then placed the taxon in the genus *Lobaria*. Moncada et al. (2013) and Cornejo and Scheidegger (2015) have strong evidence that *Ricasolia amplissima* is part of a clade that is distinct from *Lobaria* and related lichens and therefore warrants recognition at the generic level. Cornejo and Scheidegger (2015) also distinguish the Eurasian and North American lichens as distinct entities. Cornejo et al. (2017) specifically describe *Ricasolia amplissima* ssp. *sheiyi* as an Evolutionarily Significant Unit. They describe *Ricasolia amplissima* subsp. *sheiyi* from Alaska as follows:

> Foliose cyanolichen, forming patches as large as 50 cm wide. Older rosettes in the center often erode and become blackened. The lobes have wavy edges with rounded apices, and on older thalli are up to 2.5 to 3 cm in width. The upper surface is grayish-white when dry and sage green when wet. Young thalli have a smooth surface and older tissue has an uneven and wrinkly appearance. Conical-shaped warts are scattered on the upper surface, with some reaching 1 mm in diameter. The lower surface is light brown and tomentose, becoming lighter and less hairy at the lobe margins. Cyphellae or pseudocyphellae are not present on the thallus. Apothecia are rarely observed; when present they are up to 4 mm in diameter, red-brown to dark pink. Asci are empty, lacking spores. (See 'Definitions' section for terminology; Purvis et al, 1992).

Ricasolia amplissima subsp. *sheiyi* is distinguished from co-occurring *Lobaria* lichens by drying to a pale green/grey to white (Figure 2), while *Lobaria* lichens dry to green or brownish-green when dry (Figure 3).

Figure 2. Left: Dry *Ricasolia amplissima* subsp. *sheiyi* on DeLong Island, Misty Fjords. Right: *Ricasolia amplissima subsp. sheiyi* from Misty Fjords, wet in the center and drying out on the margins. Photos by K. Dillman.

Similar Species

Three epiphytic species related to *Ricasolia amplissima* subsp. *sheiyi* of occur in southeastern Alaska: *Lobaria oregana, L. pulmonaria,* and *L. linita*. *Ricasolia amplissima* subsp. *sheiyi* is the only one of these species that is closely attached to the tree bark and the only species that dries to light gray (Figure 3). *Lobaria oregana*, is a sage green to grass green when wet and dries to a lighter sage green. *Lobaria oregana* has frilly, deeply dissected margins with upturned edges that expose the white underside. It occurs in the upper canopy of old growth forests throughout the Alaska region (both Tongass and Chugach National Forests) and is most often seen scattered on the forest floor after a wind storm. It inhabits forested edges along beaches, muskegs, and lakes. *Lobaria pulmonaria* has isidia or soredia on the margins or on the ridges of the upper thallus. In general, *L. pulmonaria* is often more brown than green, but this may be due to the amount of exposure to the sun. When wet, it is a dull green, to somewhat bright, but not as "grass" green as *L. linita*. This lichen occurs on the beach and mainland riparian areas across the Tongass National Forest. *Lobaria linita*, when wet, has the brightest green color among *Lobaria* members. When dry, it can be a brownish green to pale green. *Lobaria linita* often has apothecia on its surface that are obvious little brown dots. It tends to grow in shady places, such as the lower trunks of trees in sheltered areas of the forest.

Figure 3. The three epiphytic *Lobaria* species that occur in southeastern Alaska. Left: *Lobaria oregana* shown with edges of the thallus drying out and becoming lighter green than the center of the lichen. Center: Brown, sun-exposed *Lobaria pulmonaria*. Right: bright green, wet *Lobaria linita*. Photos by K. Dillman.

The full technical species description, based on the European *Ricasolia amplissima*, is provided in "The Lichen Flora of Great Britain and Ireland" (Purvis et al., 1992). For a description of the North American cyanotype, consult Tønsberg and Goward (2001).

Distribution

Due to the relatively recent discovery of *Ricosolia amplissima* subsp. *sheiyi* in North America, the full extent of its range is unknown. The subspecies is known primarily from Tongass National Forest and has not been found northwest of Yakutat or southeast of Misty Fjords (Figure 4). One population in northern California was originally identified as "*Lobaria amplissima*," but the material is not of high quality and the identification is tentative. It is doubtful that this northern California specimen is in fact *Ricosolia amplissima* subsp. *sheiyi* and we therefore omit discussion of it here.

There are 44 unique records of *Ricosolia amplissima* subsp. *sheiyi* on the Tongass National Forest (NRIS database 2015, AKNHP 2016, UAM Herbarium 2015). However, these unique records do not necessarily represent meaningful populations or occurrences since the data are often collected at a very fine spatial scale (< 100 m apart), are revisits to known sites, or there is uncertainty regarding the actual location for records collected without GPS. The Alaska Natural Heritage Program follows NatureServe guidelines for determining and identifying rare plant populations (Element Occurrences), where populations are defined as occurring ≥ 1 km apart (NatureServe 2002). Applying these standards results in 31 populations of *Ricosolia amplissima* subsp. *sheiyi* in Alaska (Appendix A. Table 1, Figures 6 and 7). Earlier reports on this lichen may indicate a different number of sites or populations (e.g., Tongass Species Assessments 2014), based on the number of collections known at the time and whether proximal sites were combined or not. The most northwestern location in North America is near Yakutat on Canon Beach (59° N, 139° W) (Appendix A. Table 1, Figure 5). Many populations are found on relatively small islands, such as Coronation Island and Warren Island; or islets often less than 1 km wide, such as Sukoi Islets, McDonald, Kadin, Rookery, Delong, and Shakes islands. On the larger islands, two populations are found on Kruzof, four on Baranof, five on Kuiu, one on Mitkof, one on Etolin, three on Kosciusko, and two on Prince of Wales islands. Two populations are found on the mainland (Yakutat and Boca de Quadra). Of the 31 populations, one is now presumed extinct (at the Craig Cemetery on Prince of Wales Island), after the tree the lichens were growing on fell into the sea. Thus 30 populations in Alaska are currently presumed to be extant.

Figure 4. Range of *Ricasolia amplissima* subsp. *sheiyi* extending from Misty Fjords north to Yakutat in southeastern Alaska. A potential population in the redwood forests of northwestern California is shown, however the identity of this collection is dubious.

Ricasolia amplissima subsp. *sheiyi* populations have not been located north of Fredrick Sound and Peril Strait except the single disjunct population in Yakutat. Most of the currently known populations, however, were located during or after 2001, when comprehensive lichen surveys on the beach fringe first occurred, and surveys including this lichen did not begin until its inclusion on the Sensitive Species list in 2008 (Dillman 2004; USDA Forest Service, 2008). USFS survey intensity north of Fredrick Sound from 2008 on is notably less than the southern portion of southeastern Alaska (NRIS 2015, figure not shown); however dozens of surveys have occurred during this time on Admiralty and Chichagof islands and lands adjacent to Stephens Passage and Lynn Canal, including along beach fringes, and *Ricasolia amplissima* subsp. *sheiyi* has not been observed.

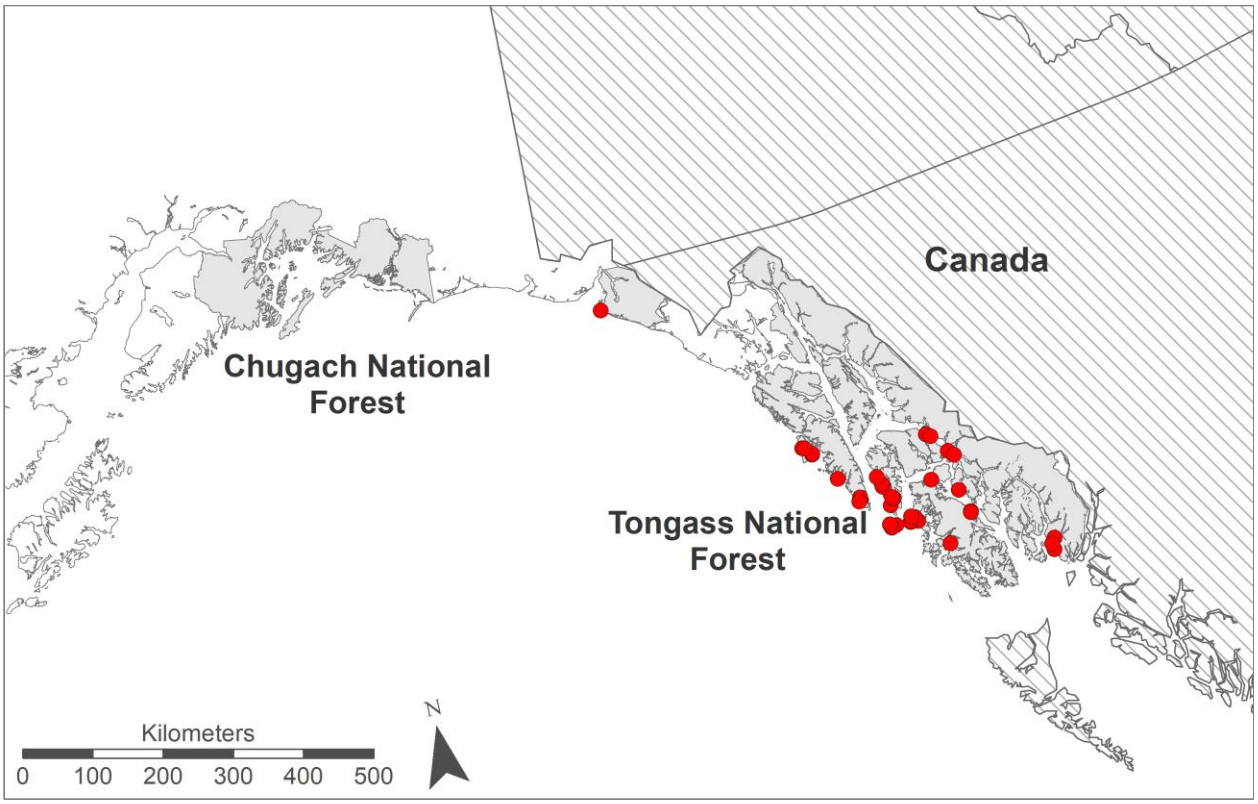

Figure 5. Known occurrences of *Ricasolia amplissima* on the Tongass National Forest, Alaska Region and surrounding area from the NRIS TESP database, ALA Herbarium, UAAH Herbarium, and AKNHP rare plant database.

Of the total area occupied by the 30 known populations, approximately 75% are located within Wildernesss Areas (Non-development Land Use Designations (LUDs) and 25% are located within Development LUDs (USDA 2015). Non-development LUDs represent landscapes that are not currently open to resource development, such as timber harvest, road construction or renewable energy and mineral development.

In Alaska, the lichen is only known as an epiphyte on tree trunks and branches of the forest-beach ecotone. Often the sites are small marine islands and exposed peninsulas. The sites are exposed to the open Pacific Ocean or large bodies of marine water, such as ocean entrances to large bays and inlets. The beach fringes adjacent to large bodies of marine waters are often shrouded in fog and receive copious salt spray, even during periods without precipitation. These sites are presumably snow-free most of the winter (Dillman, 2004).

In general, this lichen is characterized by very small and isolated populations. Populations are typically restricted to just one or a few trees (Appendix A. Table 1). Only one population (Warren Cove EO #7) is relatively large; here patches of *R. amplissima* subsp. *sheiyi* occupy 21 to 25 Sitka spruce trees, nearly every large Sitka spruce within a 200 meter stretch along the cove.

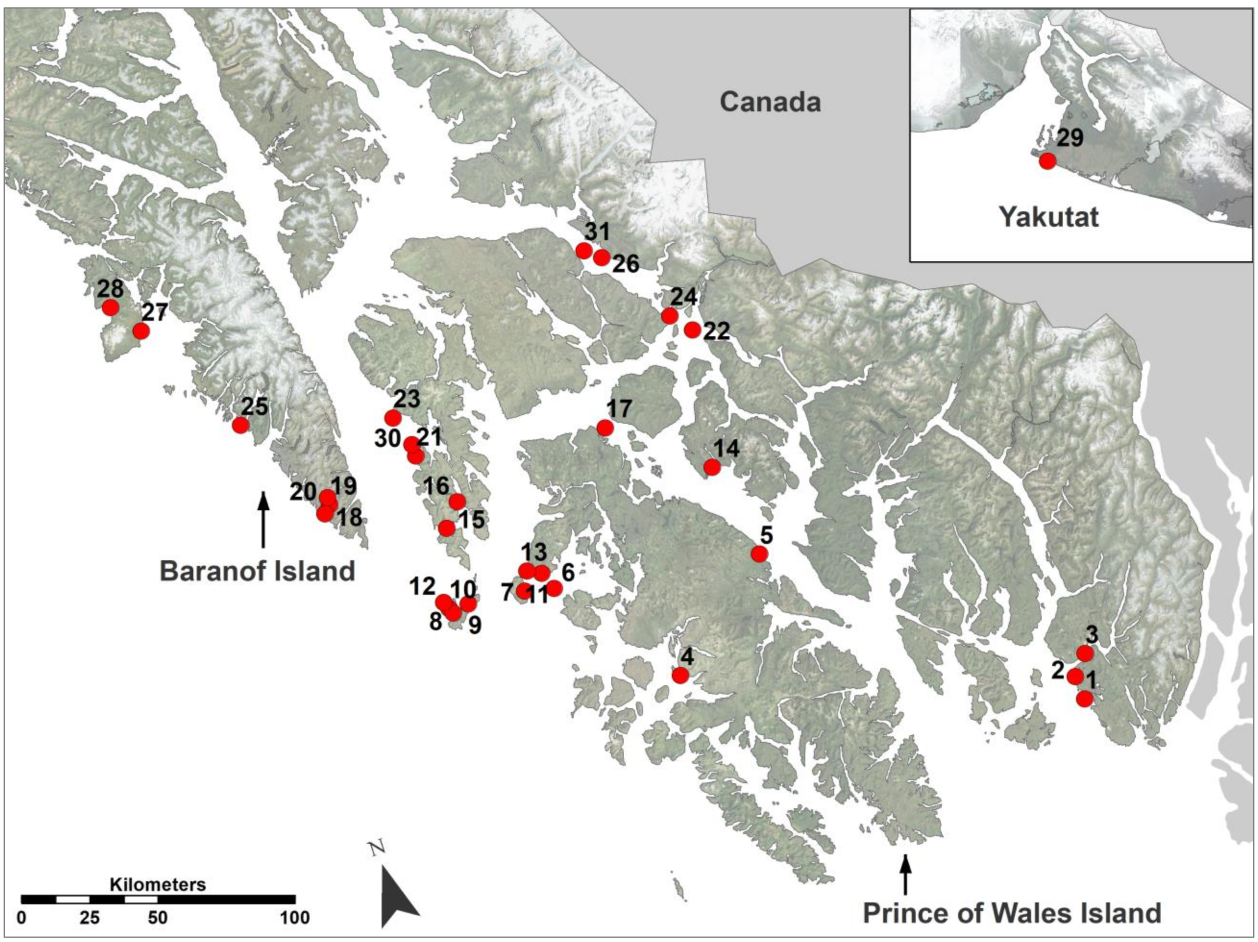

Figure 6. *Ricasolia amplissima* subsp. *sheiyi* occurrences on the Tongass National Forest with EO numbers labelled.

Historic Range and Influence of Human Activity since European Settlement

No records prior to the 1990s exist for *Ricasolia amplissima* subsp. *sheiyi* in North America and therefore evaluation of historic range and influence of land-use practices on populations is not possible. Past harvesting practices on Tongass National Forest did target the beach fringe forests

(26,167 acres logged, USDA 2014) to which *R. amplissima* is apparently restricted. Thus, it is possible that some *R. amplissima* populations were impacted by past timber harvest. Additional targeted surveys of similar beach fringe sites that had timber harvest and those that did not would help elucidate the long-term sensitivity of *R. amplissima* to timber harvest.

Globally, cyanolichens (such as *R. amplissima*) are on the decline or have disappeared due to habitat fragmentation and destruction, loss of ecological continuity, and increasing air pollution (see Wirth 1988, Hallingbäck 1989, Richardson 1992, Gries 1996, Krivorotov 1998, Maass and Yetman 2002, Richardson and Cameron 2004, Cameron and Richardson 2006). Since the mid-19th century increasing air pollution and consequent bark acidification have contributed to the decline of *Ricasolia amplissima* subsp. *amplissima* in Britain (BLS, 1998). In Germany, where that subspecies was widespread throughout the 19th century, the lichen is now known only from the southernmost regions of Baden-Württemberg (Aptroot & Zielman, 2004). The European subspecies is considered one of the most threatened lichens in central Europe and is cited in most Red Lists as being either Critically Endangered or Extinct (Türk & Hafellner, 1999; Wirth et al., 1996). Changes in forest management practices also provide an explanation to its decline: this lichen and other long-lived related species have relatively slow annual growth and need long term continuity of habitat to become established.

No data is available to assess current trends throughout the range of *Ricasolia amplissima* subsp. *sheiyi*. There is no evidence to suggest that the overall range of *Ricasolia amplissima* subsp. *sheiyi* is either expanding or retracting. All occurrences of the lichen have been found within the past two decades, with most of these only in the last ten years during the research of the epiphytic lichens from the forest-marine ecotone (Dillman, 2004) and recent establishment of air biomonitoring plots in wilderness (Dillman et al 2007).

Population Trend and Abundance

Information on population sizes through time for this lichen is not comprehensive enough to warrant a characterization of trends across Tongass National Forest lands. Furthermore, the minimum number of individuals or populations of this lichen that is necessary to be considered a viable population is unknown. Six populations (EO #4, 7, 8, 12, 28, and 30) have been revisited since their initial collection, however population estimates were often not made and data collection methods were not consistent, making inference of changes through time difficult. Two populations Warren Cove (EO #7) and Head of Egg Harbor (EO #10) are monitored approximately every five years.

In 2005, Dillman estimated the Warren Cove population to have an abundance of between 10-40 individuals or colonies ("abundance code 3" see Geiser 2004 for protocols). In 2009 the lichen's presence was noted, but the population size was not estimated. The population was estimated to have an abundance of 10-40 individuals in 2016. The Head of Egg Harbor population was initially estimated to have less than three individuals or colonies in 2005 and again in 2009 ("abundance code 1" see Geiser 2004 for protocols) by Dillman.

The Nation Point (EO #12) population, which was initially reported to consist of a single tree, was revisited in 2012 by Lease and the sole *Ricasolia amplissima* subsp. *sheiyi* specimen was "found on a branch that had broken out of the tree." Though this anecdote does not definitively indicate the elimination of this population, it illustrates the threat posed to this species by windthrow and other storm-related events.

The Craig Cemetery Island population (EO #4) was initially observed in 2009 by Dillman and numerous thalli were restricted to the bole of a single dead Sitka spruce tree at the beach fringe. This tree as subsequently fell into the sea (2012) and no *Ricasolia amplissima* subsp. *sheiyi* has since been observed at this location (Lease pers. comm. to Dillman). This population is believed to be extirpated.

Collectively, these observations suggest that the generally small populations of *Ricasolia amplissima* subsp. *sheiyi* can be subject to local extirpation. Some of the other populations, however, appear to be relatively stable over a few years at least. Because of the lack of consistent monitoring of more populations, it is difficult to infer whether population numbers (or number of trees colonized by *Ricasolia amplissima* thalli) are changing and whether the range of *Ricasolia amplissima* subsp. *sheiyi* has expanded or contracted over time.

Habitat

Ricasolia amplissima subsp. *sheiyi* is only known as an epiphyte on tree trunks and branches of the forest-beach ecotone. Often the sites are small marine islands and exposed peninsulas (Figure 7). The sites are exposed to the open Pacific Ocean or large bodies of marine water, such as ocean entrances to bays and inlets. The beach fringes exposed to large bodies of marine waters are often shrouded in fog and receive copious salt spray throughout the year. These sites are presumably snow-free most of the winter. The beaches where this lichen grows are often flat but are uplifted a few meters, or are large coastal cliffs rising 1 to 3 meters from mean high tide. Aspect of the shoreline does not seem to be a factor in the presence or abundance of this lichen (Dillman 2004, and see Turner 2012).

The preferred microhabitats of the *Ricasolia amplissima* subsp. *sheiyi* are unshaded portions on trunks and branches of *Picea sitchensis, Tsuga heterophylla, Malus fusca*, and *Alnus rubra*. One population is growing on *Thuja plicata*. Though Alaskan populations exhibit a strong substrate preference for *Picea sitchensis* and *Tsuga heterophylla,* no research has been conducted to investigate whether this preference is associated with bark pH or some other distinguishing factor. The absence of this lichen in forested habitats with low-light environments may be a function of the intense bryophyte competition often found on trees in shady forests. Interior and more upland forests may also be unsuitable microclimates (e.g. too consistently wet or too cold) that limit the distribution of some lichens to beach fringe forests (Dillman 2004, Sillett & Goward 1998). Forests edges are warmer, brighter, windier, and often less humid than interior portions of forests (Chen et al. 1995). However, the presence of fog in these habitats indicates that the combination of the humidity from fog and high light intensity may play a role in the presence of *R. amplissima* and other beach-only lichens.

The forested habitat tends to be well drained, with old growth *Picea sitchensis* and *Tsuga heterophylla*. Understory often consists of *Calamagrostis* spp., *Maianthemum dilatatum*, and *Oplopanax horridum*. Generally, large crab apple (*Malus fusca*) and red alder (*Alnus rubra*) are present in the beach fringes. The lichen generally occurs about one meter above the ground and higher along the trunk and into the tree canopy. It has not yet been found on trees away from the immediate coast, nor at lake margins or along riparian forest edges. At some sites, the trees where this lichen is found are out in the open, away from the rest of the forest edge, thus receiving the maximum light and moisture in a predominantly cloudy environment.

Figure 7. Preferred habitat of *Ricasolia amplissima* subsp. *sheiyi* from Warren Cove adjacent to the beach on Warren Island (left). Thalli are present on the bole of the large spruce tree in the foreground. The understory is open with *Oplopanax horridum*, *Maianthemum dilatatum*, and other small forbs. Right photo shows an old, solitary Sitka spruce trees on a prominent point and exposed shoreline, which is candidate habitat for *Ricasolia amplissima* subsp. *sheiyi*. Photos by K. Dillman.

This lichen is notably absent from lower trunks of Sitka alder (*Alnus viridis*), a species common to the region that often forms a dense, uninterrupted band of vegetation paralleling the shoreline. Additionally, *Ricasolia amplissima* subsp. *sheiyi* has not been found on yellow-cedar (*Callitropsis nootkatensis*), snags, bare wood, or on thick bryophyte mats on branches or trunks.

Ricasolia amplissima subsp. *amplissima* is known to have broader habitat requirements than subsp. *sheiyi*. In the United Kingdom, subspecies *amplissima* grows as an epiphyte in high light environments such as edges of forests, roadsides and open woodlands. It occupies long-established woodland sites where the bark pH is 5.5 to 6.0. *Ricasolia amplissima* subsp. *amplissima* is considered to be an "ancient woodland" indicator (British Lichen Society 1998). In one particular location in Germany, this lichen grows on calcareous rock outcrops with other rare lichens (Aproot & Zielman 2004). This is the only known rock dwelling record for this otherwise epiphytic lichen.

Ricasolia amplissima is described as needing long term continuity of habitat to become established. For example, subsp. *amplissima* in the United Kingdom is considered to be an "ancient woodland" indicator. However, both subspecies in European and North American also tend to occur in high light environments. In Europe, the lichen is most often occupies forest edges, roadsides and open woodlands (British Lichen Society, 1998). In Alaska, populations are often exposed to the large bodies of marine water, such as ocean entrances to bays and inlets (Dillman, 2004). At some sites, the trees where *Ricasolia amplissima* subsp. *sheiyi* is found are out in the open, away from the rest of the forest edge, thereby receiving the maximum light and moisture in a predominantly cloudy environment. The lichen is absent from early seral habitats and responds poorly to large-scale disturbance, but it appears to benefit from disturbances that decrease non-substrate density.

Other lichens growing with *Ricasolia amplissima* subsp. *sheiyi* in Alaska are*: Lobaria oregana, L. pulmonaria, Fuscopannaria laceratula, Parmotrema arnoldi, Pseudocyphellaria crocata, P. anolmala, and P. rainierensis*, *Ramalina farinacea, R. menzesii, R. roesleri, Sticta limbata*, and *Usnea longissima*. These are all macrolichens and are also found primarily on the beach fringe or other natural forest edges (i.e. lakes or riparian margins).

One of the lichens found at nearly all locations with *Ricasolia amplissima* subsp. *sheiyi* is *Pseudocyphellaria rainierensis* (Figure 8), a rare Pacific Northwest endemic found in humid, old growth forests from southeastern Alaska to Oregon (Sillett & Goward, 1998, McCune & Geiser, 2009). In Alaska, *P. rainierensis* is primarily restricted to the beach fringe near Petersburg, south to Misty Fjords, and west to Baranof and Coronation Islands. Other than the marine beach fringe, *P. rainierensis* has been found on *Malus fusca* at Ohmer Creek riparian edge near Blind Slough on Mitkof Island and on one *Alnus rubra* on the Stikine River near Flemer Cabin. This lichen is found in the vicinity of nearly all known *R. amplissima* populations in Alaska (except in Yakutat).

Figure 8. Lichen *Pseudocyphellaria rainierensis* found with *Ricasolia amplissima* subsp. *sheiyi* in most locations. This is a rare PNW endemic, found on beach fringes and a few riparian areas of the Tongass. Photo by K.Dillman.

Reproductive Biology and Autecology

Among lichens, reproduction and dispersal are complicated phenomena: sexual reproduction of the fungal symbiont may occur via the production of ascospores, which must successfully germinate both on the appropriate substrate and near the appropriate photobiont(s) for a new lichen to form. Similarly, the asexually produced spores called conidiophores, produced in pycnidia, must also find suitable substrates and photobionts. Bypassing this complicated sequence requires vegetative reproduction: this can occur via fragmentation, or via production of soredia or isidia, which are tiny vegetative propagules that contain both photobiont cells and fungal hyphae.

Reproduction seems particularly challenging for *Ricasolia amplissima* subsp. *sheiyi*. Isidia or soredia appear to be absent from the lichen (Tønsberg & Goward, 2001). However, apothecia (ascospore producing reproductive structures) have been identified more recently in a small fraction (less than 20%) of *Ricasolia amplissima* subsp. *sheiyi* populations. Most populations (except Warren Cove and Windfall Island populations) are without individuals with apothecia. Of the few populations that produce apothecia, all that have been dissected appear to be sterile (i.e., no spores were visible). The European *R. amplissima* subsp. *amplissima* contains spores 40-60 × 6-7 µm and 1-3 septate (Purvis et al., 1992).

Demography

No information is available on growth rates, survivorship, asexual or sexual reproduction and subsequent establishment for this taxon. Taking a monitoring and analytical approach such as Shriver et al. (2012) would facilitate estimation of population vital rates. For example Shriver et al. (2012) show for *Vulpicida pinastri* in south-central Alaska that growth rates of thalli are rapid and variable, survivorship for small individuals is low and variable, but longevity averages more than 50 years for intermediate sized individuals.

Community Ecology

Very little information on the community ecology of *Ricasolia amplissima* subsp. *sheiyi* is available. Grazing by gastropods has been documented in Norwegian populations of *Ricasolia amplissima* subsp. *amplissima*, and morphological anomalies in some Alaskan populations have been interpreted as indication of grazing, but this hypothesis has not been confirmed. Specifically, the lack of branched cephalodia on the Alaskan specimens may be due in part to selective grazing by invertebrates (see Asplun et al., 2009). Many of the Alaskan populations contain tiny, carved-out holes in the upper cortex of the lichens, where the cyanobacteria-filled cephalodia may have been grazed. In Norway, grazing has been found to play a role in the distribution and spatial patterns of epiphytic lichens in gastropod-rich environments. However, factors other than herbivory, such as climate and microhabitat, may cause the apparent lack of branched cephalodia.

Though there is limited literature on the ecology of *Ricasolia amplissima* subsp. *sheiyi*, it is thought that its absence from forested habitats with low-light environments may be a function of the intense bryophyte competition often found on trees in shady forests (Dillman, 2004).

Animals can act as important dispersal vectors for lichens; thalli can be moved by birds and flying squirrels, which use foliose lichens in their nests, and by blacktail deer, mountain goats, and invertebrates that consume lichens. But, because *Ricasolia amplissima* subsp. *sheiyi* effectively restricted to the Alexander Archipelago, dispersal among islands by animal vectors is expected to be a very uncommon occurrence.

CONSERVATION

This section describes the threats, conservation status, and potential management of *Ricasolia amplissima* subsp. *sheiyi* specifically within USDA Forest Service Alaska Region with focus on the Tongass National Forest. Threats include both risks to the habitat and direct threats to individuals and populations. Within the threats section, we have provided a climate sensitivity analysis including a comparison of climatic conditions in southeastern Alaska between the 2010s decade and the 2060s decade. The Conservation Status and Potential Management sections integrate habitat, current management, and potential management into the discussion of threats. The Conservation Status section details the distribution and population trends, inherent vulnerability of the species with regards to habitats available in Alaska and management risk in Alaska. The Potential Management section is a synthesis of management implications and potential tools and practices that may benefit species conservation in the Tongass National Forest.

The final section, Information Needs, details the current data gaps that may prevent the most effective and efficient conservation of *Ricasolia amplissima* subsp. *sheiyi* on the Tongass National Forest. These data gaps are discussed in terms of their direct relevance to management. Data gaps that are especially important for effective management are selected as research priorities.

Threats

The primary threats to *Ricasolia amplissima* subsp. *sheiyi* is the loss of sites and preferred habitat resulting from unscheduled tree cutting in beach fringe for free-use and recreation, air pollution impacts in popular marine anchorages, changes in shoreline structure due to natural wind events, and changes in sea level due to isostatic rebound or tectonic events. The minimum number of individuals or populations of this lichen that is necessary to be considered a viable population within a designated management area such as a National Forest is not known.

Logging

In the past, beach fringe forests were heavily harvested on the Tongass National Forest, but the Tongass National Forest Plan now protects beach fringe areas from large scale commercial timber harvesting (USDA 2008). However, in a Forest Plan Amendment planned for completion in 2016 the Tongass proposes to open beach and estuary fringe to timber harvest in certain early seral stands (young growth) (USDA 2015). The impacts of these activities are expected to be minimal to *Ricasolia amplissima* subsp. *sheiyi*, considering the closed canopy stand conditions and younger trees are not preferred habitat for this lichen. The interior forests of many islands, however, may still be targeted for timber harvesting; therefore, construction of log transfer facilities (LTFs) (as is the case for the Etolin Island [EO #14] population) or access roads bisecting the beach fringe still pose potential threats, especially to populations that inhabit the coasts of natural harbors or major marine passageways.

A number of other populations occur in close proximity to previously logged areas, including the Narrow Point (EO #5), Survey Cove (EO # 11), Southwest Kosciusko Island (EO #13), and Kruzof Island (EO #28) populations. If these timber stands are harvested again in the future, the nearby *Ricasolia amplissima* subsp. *sheiyi* populations may also face secondary threats posed by logging operations, including LTF construction or road maintenance.

Road construction and Maintenance
Though most known populations of *Ricasolia amplissima* subsp. *sheiyi* are not accessible by road, a few do occur near towns, and others remain at risk of logging road-related disturbance. The population on southern Mitkof Island (EO #24) is accessible by road and may face threats from future road maintenance. Populations mentioned in the 'Logging' section above (EOs #5, 11, 13, and 28) may also face similar threats from future road maintenance. Proposed state road building on Forest Service lands along shorelines are also a threat (e.g., Kupreanof Island road to Kake, though no *R. amplissima* populations are known in this area).

Pollution
Air pollution in several wilderness sites is also a concern to this species, where levels of nitrogen and sulfur are above thresholds established for lichens on the Tongass National Forest (Dillman et al., 2007). The nitrogen and sulfur concentrations are possibly due to the emissions from marine vessels in the area. Several locations are traditionally used as anchorages for fishing vessels and other private boats. It is unknown how much nitrogen or sulfur deposition is acceptable before detrimental effects occur in lichen communities on the Tongass National Forest (referred to as critical loads; see Nilsson and Grennfelt, 1988). Cyanolichens such as *R. amplissima* are considered more susceptible to air pollution damage than lichens with only a green algae photobiont.

At particular risk are the Warren Cove (EO #7) and Head of Egg Harbor (EO #10) populations, which are known to inhabit areas with elevated levels of nitrogen and sulfur. No air quality measurements have been taken at other *Ricasolia amplissima* subsp. *sheiyi* sites.

Recreation
Many of the recreation sites on Tongass National Forest are located on or near beaches and are accessible only by boat. Recreational wood harvesting (unscheduled cutting) and other anthropogenic disturbances represent a threats to *Ricasolia amplissima* subsp. *sheiyi* populations. Since whole populations of this lichen are most commonly restricted to a single tree, cutting of just one tree could result in population extirpation. However, the probability of such events are quite low given the rarity of *Ricasolia amplissima* subsp. *sheiyi*, the large amount of beach-fringe habitat, and the small number of people harvesting trees in the region. Lichen populations near communities and in areas with good anchorages are more likely to be impacted from recreational harvest.

Recreation-related threats are not limited to unscheduled cutting. At the Narrow Point population (EO #5), an old tent platform is nailed to both trees that host *Ricasolia amplissima* subsp. *sheiyi*. The Sukoi Islands (EO #31), Canon Beach (EO #29), Explorer Basin (EO #21), and Windfall Island (EO #30) populations occur near popular recreation areas on the Tongass National Forest, and the Southeast Kruzof Island (EO #27) population occur within 1 km of the Mt. Edgecumbe trailhead. Due to elevated levels of human traffic (or as human use increases due to greater access to remote locations, these populations may be at increased risk of disturbance. Should any managerial decisions be made to restrict firewood and free-use cutting on the beach fringe in Tongass National Forest, these occurrences should be prioritized when posting restriction notices.

Herbivory
Herbivory by gastropods has been documented on *Ricasolia amplissima* subsp. *amplissima* in Norway and has been found to play a role in the distribution and spatial patterns of epiphytic lichens in gastropod-rich environments (Asplun et al., 2009). Whether gastropod grazing occurs in Alaskan populations has not been systematically investigated (though circumstantial evidence suggests it may be occurring) and even less is known on the extent to which herbivory affects the distribution and spatial patterns of North American *Ricasolia amplissima* subsp. *sheiyi.*

Known occurrences of herbivory-related damage include the Warren Cove (EO #7) and the Explorer Basin (EO #21) population. Both populations were observed to have algae mined from their thalli, though the identity of the herbivore remains unknown. Continuing to document evidence of herbivory during TESP surveys will help to whether such herbivory poses a threat to population persistence.

Disease/Forest Health
Picea sitchensis is by far the most common substrate used by *Ricasolia amplissima* subsp. *amplissima*, accounting for more than half of the known occurrences. This spruce species is plagued by a number of pest insects, including weevils, beetles, and aphids. Though white pine weevil (*Pissodes strobi*) is the foremost agent of damage to *P. sitchensis*, its range does not extend far enough north to threaten spruce trees on the Tongass (Overhulser et al., 1974). Of greater concern are the spruce aphid (*Elatobium abietinum*) and the spruce beetle (*Dendroctonus rufipennis*). The spruce aphid, though primarily a pest of ornamental trees in urban areas, does impact spruce trees along the coastline, particularly following mild winters (Graham, pers. comm.). The spruce beetle is particularly problematic in British Columbia, but inflicts damage upon *P. sitchensis* populations throughout its range (Furniss & Carolin, 1977). Spruce beetle damage in southeastern Alaska appears to be limited in extent: near Prince of Wales Island, in the Stikine River drainage, and near Haines (USFS FHP & ADNR, 2000, Graham pers. comm.).

As more than half of known populations are known only from a single tree (see Appendix A. Table 1 for EO numbers), damage or mortality of host trees from spruce aphids or spruce beetles may pose a threat to *Ricasolia amplissima* subsp. *sheiyi* populations, where loss of a single tree could result in population extirpation. At the Narrow Point population (EO #5), one host tree was dead and the other was "declining in vigor," but no indication of pest damage was noted. Any future monitoring projects should consider collecting data on pest damage so that land managers might better assess this potential threat.

Potential Risk from Flood, Drought, Wildfire, and Other Natural Threats
In addition to the insect pests mentioned above, a primary source of *Picea sitchensis* mortality is blow-down from storms and other high wind events. At the Craig Cemetery Island population (EO #4), one host tree has already fallen into the ocean; given the lichen's affinity for open, exposed

sites, it seems likely that other host trees will meet a similar fate. The beach at Egg Harbor, Coronation Island, is unraveling at the head of the bay due to tidal surges, producing windthrow and threatening *Ricasolia amplissima* subsp. *sheiyi* population (EO #10). Climate models for the next half-century predict increased storm intensity and frequency, suggesting that this threat will only grow with time.

At particular risk for such stochastic losses are those populations of *R. amplissima* concentrated on prominent, exposed points and those that consist of a single host tree. The former category includes three occurrences: a portion of the Explorer Basin population (EO# 21), which consists of "three trees along the shore at prominent points"; and the Point Ellis (EO# 23) and Windfall Island (EO# 30) populations, which both consist of a "few trees concentrated at point".

Climate Change Vulnerability

As changing climates are already recognized to be affecting habitats and species worldwide (e.g., Parmesan 1996) and the rate of temperature increase in Alaska is approximately double the global average (Chapin et al. 2014), concern over the future status of rare species in the Tongass is warranted. Climate change vulnerability of a species is recognized to be a function of the exposure to (or degree of) climate change that populations will experience, the sensitivity of the species, and the capacity to adapt to the changes (Turner et al. 2003). A number of vulnerability assessment tools have been developed that incorporate all three elements (exposure, sensitivity, and adaptive capacity) such as NatureServe Climate Change Vulnerability Index 2.1 (Young et al. 2011) and the U.S. Forest Service System for Assessing the Vulnerability of Species (Bagne et al. 2011). However, these systems require substantially more information than is available on the sensitivity and adaptive capacity of the species, are not appropriate for plants and lichens, or require environmental data not developed for Alaska. Further these three methodologies often do not produce similar vulnerabilities for the same species (Lankford et al. 2014). Due to these limitations, we focus on estimations of the degree of climate change expected in the species' current range (i.e. "exposure") in the Tongass in a qualitative manner and discuss any known or suspected sensitivities and adaptive capacities of the species in a light of the degree of expected change.

"Climate" incorporates a vast array of factors, such as mean annual temperature, summer precipitation, and maximum wind speed for example, of differing importance for any one species. It is impractical to attempt to review all potential factors that compose the climate and we therefore focus on two factors: average summer temperature and average annual precipitation and compare current and predicted 2060 conditions. For most plants and lichens at higher latitudes, summer warmth (or mean July temperature) is well correlated with their distribution (Young 1971, and see Walker et al. 2005), indicating a strong association of the measure with biological limitations. Additionally plants, lichens, and the habitats they are found in are well-known to be sensitive to soil/substrate and air moisture, and mean annual precipitation as a climate variable is expected to be most correlated with substrate and air moisture.

The current and predicted 2060 climates were developed for Alaska and western Canada by the Scenarios Network for Alaska & Arctic Planning (SNAP) at University of Alaska Fairbanks (UAF). Climate data generated by SNAP is downscaled using the Parameter-elevation Regressions on Independent Slopes Model (PRISM) from the five best-performing General Circulation Models

(GCMs) for Alaska. The data selected for this analysis is derived from the A2 emissions scenario, which represents a realistic future emissions projection based on current trends. Data is available at a 771 m grid. While this resolution is relatively fine-scale, interpretations are restricted to broad regions. Interpretations of micro-climate at population-sized sites for sensitive species are not appropriate. To avoid generalizing trends based on stochastic annual climate events, SNAP has provided decadal averages for all data (Fresco et al. 2014). 2010-2019 is selected to represent the current time frame. The 2060s decade is selected to represent the future time-frame because 50 years in the future is far enough to observe meaningful trends without being so far in the future that it cannot be meaningfully compared to current management objectives.

Southeastern Alaska has a strong Pacific Maritime climate with low variation and relatively warm temperatures and high precipitation, much of which falls as rain at low to mid elevations. Both total annual precipitation and mean annual temperature generally decrease along a south to north gradient through the Tongass National Forest. Mean July temperatures is predicted to increase in the Tongass National Forest from the 2010s to the 2060s by between 1.0 to 2.0°C (Figure 9). Areas around *Ricasolia amplissima* subsp. *sheiyi* populations are expected to increase by between 1.4 to 2.2°C in 50 years. The percent change is expected to remain largely constant throughout the region. Mean July temperature is predicted to increase 10 to 20% within the majority of the Tongass National Forest by the 2060s relative to the current mean July temperature (Figure 9).

Annual precipitation is predicted to increase across the Tongass National Forest by the 2060s, but no regional gradients are apparent, largely because of competing patterns for summer and winter precipitation (Figure 10). Annual precipitation is predicted to increase by 9 to 12% for most of the Tongass National Forest. Precipitation is predicted to increase around known populations by between 211 mm at a Prince of Wales location to 611 mm at a Baranof Island location; all populations are expected to experience an increase in annual precipitation of between 9 and 11%.

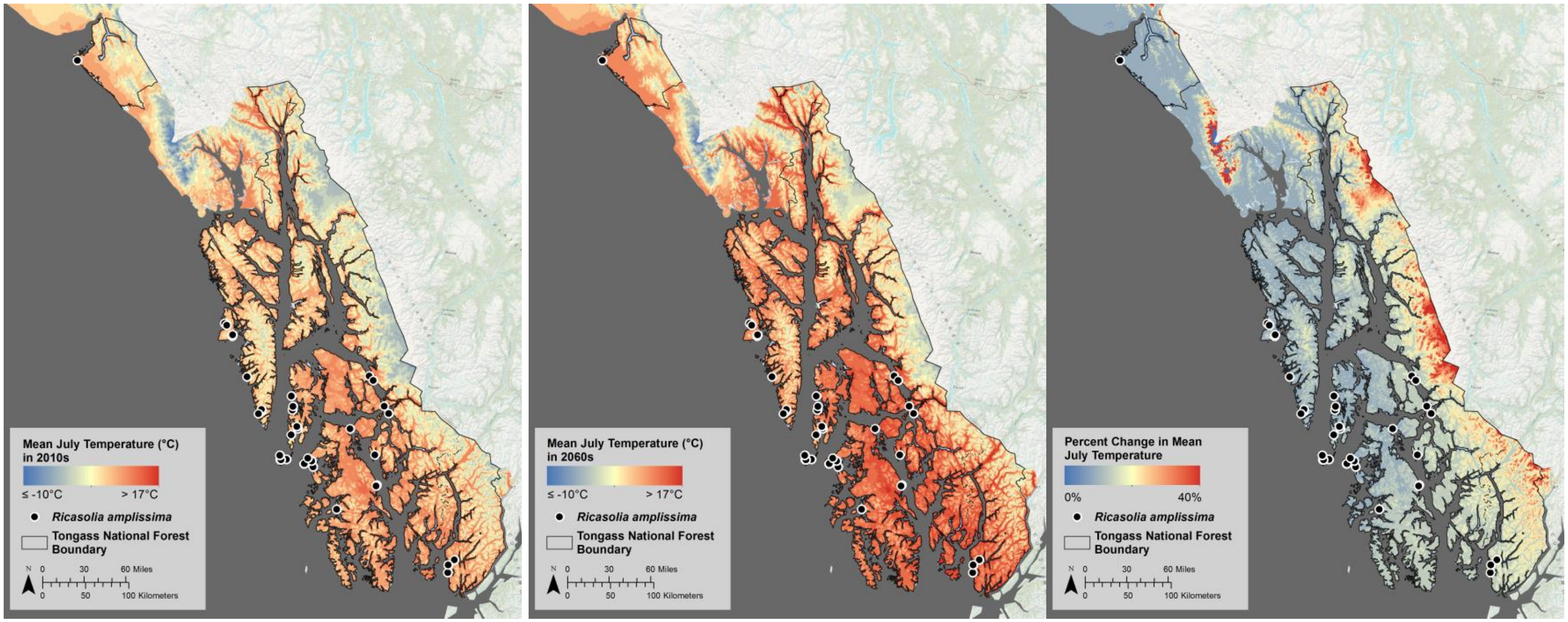

Figure 9. Current (left), predicted 2060 (center) and percent change (right) in mean July temperature (˚C) in the Tongass National Forest. Locations of *Ricasolia amplissima* ssp. *sheiyi* populations are shown as black dots.

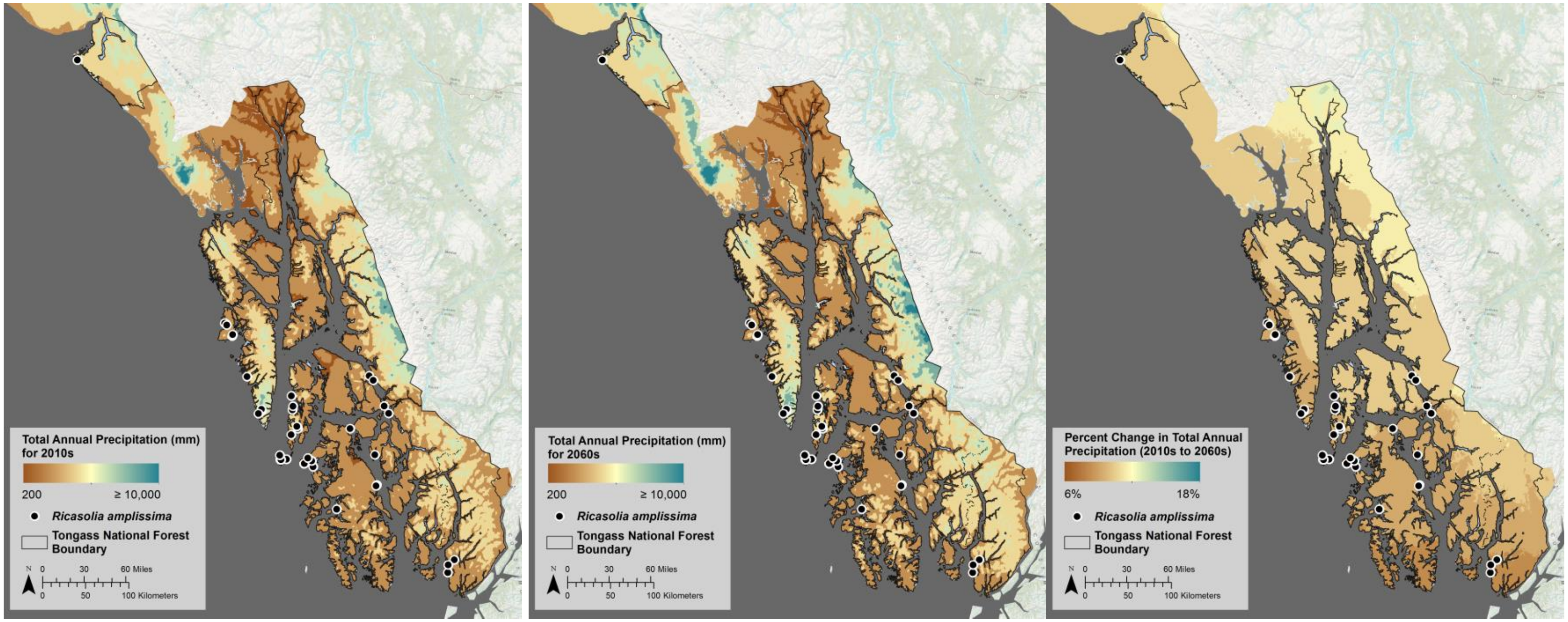

Figure 10. Current (left), predicted 2060 (center) and percent change (right) in mean annual preciptation (˚mm) in the Tongass National Forest. Locations of *Ricasolia amplissima* ssp. *sheiyi* populations are shown as black dots.

Vulnerability of *Ricasolia amplissima* subsp. *sheiyi* to climate change is likely low in the near term. The predicted increases in summer temperature could increase evaporative stress, but when coupled with increased precipitation this danger seems low. Precipitation for all seasons is projected to increase and snow-day fractions (the fraction of days per month where precipitation falls as snow) are expected to decrease (McAfee et al., 2013). The potential for thermal stress (e.g., decreased physiological capacity) for elevated temperatures is not known. In general however, these predicted changes in conditions are likely not unfavorable to *Ricasolia amplissima* subsp. *sheiyi*.

One suspected deleterious consequence of climate change, however, is an increase in storm intensity and/or frequency, resulting in higher wind speeds larger storm swells, and more windthrow related disturbance events. Specifically, wind speed is projected to increase 2-4% by 2050 (Abatzoglou and Brown 2011). Such conditions, and associated windthrow events, pose a threat to virtually all *Ricasolia amplissima* subsp. *sheiyi* populations, as all occur on the immediate coast. At particular risk are those populations that occur on exposed sites. These sites also provide ideal habitat for the lichen, as they maximize exposure to light and nutrient-rich ocean spray.

Another potential indirect threat to *Ricasolia amplissima* subsp. *sheiyi* populations to changing climates is an increasing risk of the primary host tree, *Picea sitchensis*, to insect pests. The white pine weevil (*Pissodes strobi*) that can also impact Sitka spruce, is currently limited to warmer latitudes of the Pacific Northwest (Overhulser et al., 1974); however, climate warming may facilitate a northward expansion of its range. The spruce beetle (*Dendroctonus rufipennis*) is also currently limited in its Alaskan extent, but increased temperatures may allow for more widespread outbreaks on the Tongass National Forest (USFS FHP & ADNR, 2000). Additionally the spruce aphid (*Elatobium abietinum*) is limited primarily by winter temperatures in the region and is likely to become more problematic with increasing frequency of mild winters (Graham pers. comm.).

Conservation Status in the Alaska Region and Tongass National Forest

There is currently insufficient data on the distribution and abundance of *Ricasolia amplissima* subsp. *sheiyi* to confidently infer whether the species is declining on Tongass National Forest. Since initial discoveries, five sites have been revisited. Three are similar in size, one site is presumably extinct, and another population may be extinct. The vulnerability of this species primarily lies in the fact that it is a narrow habitat specialist whose preferred habitat is inherently limited and risk-prone. On the Tongass National Forest, this lichen is restricted to the beach-forest ecotone and has not been found anywhere other than the immediate coast. The beach fringe on Tongass National Forest remains a vulnerable habitat: because its proximity to the coastline increases the lichen's vulnerability to natural disturbances such as wind-throw or beach erosion.

Potential Management of the Species on the Tongass National Forest and the Alaska Region

Implications and Potential Conservation Elements

Limiting disturbance to beach-fringe habitats is regarded as the primary management consideration to avoid loss of populations of *Ricasolia amplissima* subsp. *sheiyi*. Continued restrictions on timber harvest of old growth forests along the beach fringe (see USDA, 2008) serves as a primary protection against potential loss of habitat and populations. Minimizing other disturbances near known populations, including construction of log transfer facilities (LTFs), road construction, and unscheduled timber harvest, including that for free-use and recreation, would also reduce threats to *Ricasolia amplissima* subsp. *sheiyi* populations.

Though information on North American *Ricasolia amplissima* subsp. *sheiyi* is limited, the lichen's highly specific habitat preferences suggest a few potential avenues for proactive management. By securing fragments to nearby *Picea sitchensis* trees and monitoring the transplanted individuals' persistence, pilot studies could easily evaluate whether manual population augmentation is a viable option for proactive management. Similarly, fragments of the lichen could be secured to *Picea sitchensis* trunks in forest edge habitats outside of the beach fringe (e.g., riparian corridors or lakesides) to investigate whether the lichen is capable of surviving outside the forest-beach ecotone. Such studies, though straightforward and relatively inexpensive, could provide valuable information to guide proactive management options.

Tools and Practices

Inventory and Monitoring of Populations and Habitat
Inventory and monitoring of lichens primarily occurs with the Air Resource Management (ARM) program on the Tongass National Forest. During the early years of biomonitoring with lichens, *Ricasolia amplissima* subsp. *sheiyi* was not found in air monitoring plots. Since 2001, most of the *R. amplissima* populations on the Tongass were located during the research of the epiphytic lichens from the forest-marine ecotone (Dillman, 2004) and establishment of air biomonitoring plots in wilderness (Dillman et al 2007).

Including *Ricasolia amplissima* subsp. *sheiyi* on the Alaska Natural Heritage Program rare plant list and USFS Sensitive Species list provides an easy and cost-effective means of raising awareness and interest in the taxon among botanists in the state and promotes identification of new populations. Since the lichen was added to the Alaska Region Sensitive Species list, several populations have been found, including many of those in the Thorne Bay Ranger District.

Adhering to the Threatened, Endangered, and Sensitive Plant (TESP) Survey protocols in future surveys will also be helpful, as some records in the database are missing valuable locality or habitat data. These survey protocols alone, however, are deficient in some respects for measuring changes in epiphytic lichens through time. Inclusion of repeat photography of tree boles with *Ricasolia amplissima* subsp. *sheiyi* thalli and digital comparison could facilitate estimation of longevity, growth rates, and survivorship rates (see Shriver et al. 2012). Consistency in monitoring is critical to the program's success, and the information collected should facilitate a more complete understanding of the lichen's life history, population trends and potential threats (see Elzinga et al., 1998).

Because the lichen is apparently slow-growing, the monitoring interval need not be annual, so long as the information collected during each visit is standardized and precise. Until more detailed information on the lichen's ecology is available to develop proactive management strategies, maintaining known populations is regarded as the primary goal. Population trends can be tracked by revisiting known populations at three- to five-year intervals and estimating population sizes, in terms of both total thalli present or area of tree boles' covered in thalli and number of trees occupied. These data are relatively straightforward and would allow for quantitative analyses of change through time.

In addition to quantitative data on population sizes, collection of ecological data would also be of high value. Collection of consistent ecological site data at each site (e.g., associated species, percent cover, canopy cover, substrate pH, microclimate, etc.) would also help to elucidate the habitat and niche requirements of this species. Additionally, to infer whether insect pests or invertebrate grazing pose a threat to populations, any evidence of pest damage to the trees or grazing damage to the thalli should be noted or quantified. Finally, because the reproductive biology of North American *Ricasolia amplissima* subsp. *sheiyi* populations is so poorly understood, thalli should be examined for the presence of sexual or vegetative reproductive structures including apothecia, isidia, soredia, and pycnidia.

Information Needs

Significant gaps in our understanding of *Ricasolia amplissima* subsp. *sheiyi* the development of truly effective management strategies. Virtually no aspects of the lichen's ecology or biology are understood in sufficient detail to develop proactive management recommendations. The considerations outlined above may help to ensure the persistence of known populations, but based on information currently available, it is difficult to suggest management actions that might benefit the species or contribute to restoration. Until the taxonomic investigations currently underway are completed, time and money might best spent developing and implementing monitoring protocols so as to provide better data on population trends and potential threats.

The general distribution of *Ricasolia amplissima* subsp. *sheiyi* is relatively well understood in Alaska, but whether the gap in its southeastern Alaskan distribution, between Baranof Island and Yakutat, reflects a true absence of populations is unknown. Targeted surveys on Chichagof and Admiralty islands, and lands surrounding Lynn Canal, Cross Sound, and Icy Strait would help establish its actual distribution in the state. Second, whether its range on the Tongass National Forest represents the northwestern extent of its range in North American range is unknown. Surveys in appropriate sites along the Lost Coast and Prince William Sounds would inform the northwestern range limits of the species. Given the lichen's known habitat preference, and the report of a population in northern California, it seems likely that the lichen occurs within the British Columbian extension of the Alexander Archipelago and potentially along the Washington and Oregon coasts. Elucidating its full North American range will require coordination with land management agencies in British Columbia, Washington, and Oregon.

Establishing a monitoring program for *Ricasolia amplissima* subsp. *sheiyi*, as described in 'Tools and Practices,' would provide much-needed insight into the lichen's population trends. By establishing baseline population numbers and monitoring these populations over time, land managers could better evaluate the population-level effects of natural disturbance and management activities.

The data collected during monitoring may also expand our understanding of the lichen's life history. Much about reproductive biology of *Ricasolia amplissima* subsp. *sheiyi* is still unknown, and our understanding might benefit from more detailed examinations of live specimens for the presence of reproductive structures. Its primary mode of reproduction (whether it is capable of sporulation or vegetative propagation, or whether can only reproduce via fragmentation) will affect our understanding of its inherent vulnerabilities. Monitoring populations of *Ricasolia amplissima* subsp. *sheiyi* may also help to determine whether grazing by invertebrates occurs on the Tongass National Forest, and if so, whether it affects the distribution of or poses a threat to this lichen.

REFERENCES

Abatzoglou, J.T., and T.J. Brown. 2011. A Comparison of Statistical Downscaling Methods Suited for Wildfire Applications. International Journal of Climatology 32: 772–780.

Alaska Natural Heritage Program. 2016. Alaska Rare Plant Data Portal. < http://aknhp.uaa.alaska.edu/maps-js/integrated-map/rare_plants.php#metadata/011bfaa2-cff0-11e3-92d1-00219bfe5678> (Site accessed December 2016).

Allen, T.F. and T.W. Hoekstra. 2015. Toward a unified ecology. Columbia University Press.

Aproot, A., and R. Zielman. 2004. *Lobaria amplissima* and other rare lichens and bryophytes on lava rock outcrops in the Eifel (Rheinland-Pfalz, Germany). Herzogia 17: 87–93.

Asplun, J., P. Larsson, S. Vatne, and Y. Gauslaa. 2010. Gastropod grazing shapes the vertical distribution of epiphytic lichens in forest canopies. Journal of Ecology 98: 218–225.

Bagne, K.E., M.M. Friggens, and D.M. Finch. 2011. A System for assessing vulnerability of species (SAVS) to climate change. USDA Forest Service Gen. Tech. Rep. RMRS-GTR-257. 28 p.

British Lichen Society. 1998. Fascicle 3: The Foliose Physciaceae (*Anaptychia, Heterodermia, Hyperphyscia, Phaeophyscia, Physcia, Physconia, Tornabea*). *In* Seaward M.R.D. (Ed.) Lichen Atlas of the British Isles. 112 p.

Brodo, I, S., D. Sharnoff, and S. Sharnoff. 2001. Lichens of North America. Yale University Press, New Haven and London. 795 p.

Cameron, R.P., and D.H.S. Richardson. 2006. Occurrence and abundance of epiphytic cyanolichens in protected areas of Nova Scotia, Canada. Opuscula Philolichenum 3: 5–14.

Chapin, F.S., III, S.F. Trainor, P. Cochran, H. Huntington, C. Markon, M. McCammon, A.D. McGuire, and M. Serreze. 2014. Ch. 22: Alaska. Climate Change Impacts in the United States: The Third National Climate Assessment, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program: 514-536. doi:10.7930/J00Z7150.

Chen, J., J.F. Franklin, and T.A. Spies. 1995. Growing season microclimate gradients from clearcut edges into old-growth Douglas fir forests. Ecological Applications 5: 74–86.

Cornejo, C. and C. Scheidegger. 2015. Multi-gene phylogeny of the genus *Lobaria*: Evidence of species-pair and allopatric cryptic speciation in East Asia. American Journal of Botany 102: 2058–2073.

Cornejo, C., C. Derr, and K. Dillman. 2017. *Ricasolia amplissima* (Lobariaceae): one species, three genotypes and a new taxon from south-eastern Alaska. The Lichenologist, 49(6), 579–596.

De Notaris, G. 1846. Frammenti lichenografici di un lavoro inedito. Giornale Botanico Italiano. 2: 174–224.

Derr, C., Stein, M., Geiser, L. 2005. Conservation Assessments for 11 species of Coastal Lichens, 151 p.

Derr, C. 2010. Air Quality Biomonitoring on the Chugach National Forest: 1993 and 1994. Methods and Baselines Using Lichens. Chugach National Forest. 63 p.TP R10-147.

Dillman, K. 2004. Epiphytic lichens from the forest-marine ecotone in Southeastern Alaska. Master's Thesis, Arizona State University, Tempe.

Dillman 2011. Conservation Assessment of *Lobaria amplissima* (Scop.) Forss. USDA Forest Service, Region 10. Tongass National Forest.

Dillman Brenner, G. and Geiser, L. 2007. Air Quality Biomonitoring with Lichens, Tongass National Forest. US Forest Service, Tongass National Forest, Air Resource Management Program Internal Report.

EcoAdapt. 2014. A Climate Change Vulnerability Assessment for Aquatic Resources in the Tongass National Forest. EcoAdapt, Bainbridge Island, WA.

Elix, J.A. and T. Tønsberg. 2006. Notes on the chemistry of Scandinavian *Lobaria* species. Graphis Scripta 18: 27–28.

Elzinga, C.L., D.W. Salzer, and J.W. Willoughby. 1998. Measuring & Monitoring Plant Populations. BLM Technical Reference 1730-1.

Forssell, K.B.J. 1883. Studier öfver cephalodierne. Bih. Kongliga. Svenska Vetenskapsakademiens Handlingar. 8: 1–12.

Fresco, N., A. Floyd, and M. Lindgren. 2014. Climate Change. *In*: Trammell, E. J., M.L. McTeague, and M.L. Carlson (eds.), Yukon River Lowlands – Kuskokwim Mountains – Lime Hills Rapid Ecoregional Assessment Technical Supplement. Prepared for the U.S. Department of the Interior, Bureau of Land Management, Denver, Colorado. Pp. B1-B50.

Furniss, R.L., and V.M. Carolin. 1977. Western forest insects. U.S. Department of Agriculture, Miscellaneous Publication 1339. Washington, DC. 654 p.

Geiser, L. 2004. Manual for Monitoring Air Quality Using Lichens on National Forests of the Pacific Northwest. USDA-Forest Service Pacific Northwest Region Technical Paper, R6-NR-AQ-TP-1-04. 126 p.

Geiser and G. Brenner. 2007. Air Quality Biomonitoring with Lichens on the Tongass National Forest, USDA Forest Service, Tongass National Forest. <http://gis.nacse.org/lichenair/index.php?page=reports#R10>.

Geiser K. Dillman, C. Derr, and M. Stensvold. 1994a. Lichens of Southeast Alaska, an inventory. USDA Forest Service, Alaska Region, Admin. Doc. R10-TB-45.

Geiser C. Derr and K.L. Dillman. 1994b. Air Quality Monitoring on the Tongass National Forest: Methods and Baselines using Lichens. USDA Forest Service. Alaska Region Admin. Doc. R10-TB-46.

Geiser K. Dillman, C. Derr, and M. Stensvold. 1998. Lichens and allied fungi of southeast Alaska. *In* M. Glenn, R. Harris, R. Dirig and M. Cole (eds.). *Lichenographia Thomsoniana*: North American Lichenology in Honor of John W. Thomson. Mycotaxon Limited, Ithaca, New York. pp. 201–243.

Gries, C. 1996. Lichens as indicators of air pollution. *In* T.H. Nash III (ed.). Lichen Biology. Cambridge University Press, Cambridge.

Hallingbäck, T. 1989. Occurrence and ecology of the lichen *Lobaria scrobiculata* in southern Sweden. Lichenologist 21: 331–341.

Krivorotov, S. 1998: Change of coverage and number of *Lobaria pulmonaria* (L.) Hoffm. due to anthropogenic pollution in the mountain forests of the north-western Caucasus. Pp. 112-113. *In* S.Y. Kondratyuk, B.J. Coppins (eds.). Lobarion Lichens as Indicators of the Primeval Forests of the Eastern Carpathians. M. H. Kholodny Institute of Botany, Ukrainian Phytosociological Centre, Kiev.

Krosse, P. 2014. Modified for use by Region10, Tongass National Forest *From* Blankenship, A., Burns, K., Hayward, G.D., Kratz, A., Sidle, J.G., Swift-Miller, S.M. and Warder, J. 2001. Protocol defining process and procedure to develop species assessments for the Region 2 Species Conservation Project. USDA Forest Service.

Lankford, A.J., L.K. Svancara, J. Lawler, K. Vierling. 2014. Comparison of climate change vulnerability assessments for wildlife. Wildlife Society Bulletin 38: 386-394.

Maass, W. and D. Yetman. 2002. COSEWIC status report on the Boreal Felt Lichen (*Erioderma pedicellatum*) Atlantic population boreal population in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

McCune, B., and L. Geiser. 2009. Macrolichens of the Pacific Northwest. 2nd edition. Oregon State University Press. 464 p.

Moncada, B., R. Luecking, and L. Betancourt-Macuase. 2013. Phylogeny of the Lobariaceae (lichenized Ascomycota: Peltigerales), with a reappraisal of the genus *Lobariella*. The Lichenologist 45: 203–263.

Natural Resources Information System (NRIS), a database tool of the U.S.D.A. Forest Service Natural Resource Manager (NRM). Accessed December 3, 2014.

NatureServe. 2002. Element Occurrence Data Standard. Published in Cooperation with the Network of Natural Heritage Programs and Conservation Data Centers.

NatureServe. 2009. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7. NatureServe, Arlington, Virginia. Available: http://www.natureserve.org/explorer.

NatureServe. 2015. Conservation Rank Calculator [web application]. Version 3.186. NatureServe, Arlington, Virginia. Available: http://www.natureserve.org/conservation-tools/conservation-rank-calculator (Updated March 20, 2015).

Nilsson, J. and P. Grennfelt. 1988. Critical loads for sulphur and nitrogen. Air Pollution and Ecosystems. Springer Netherlands, pp. 85–91.

Orange A., P.W. James, and F.J. White. 2001. Microchemical Methods for the Identification of Lichens. British Lichen Society, London, pp. 6, 101.

Overhulser, D.L., R.L. Gara, and B.J. Hrutfiord. 1974. Site and host factors as related to the attack of tile Sitka spruce weevil. University of Washington Center for Ecosystem Studies, College of Forest Resources, 1974 Annual Report. Seattle. 52 p.

Parmesan, C. 1996. Climate and species' range. Nature 382: 765–766.

Platt, J.R., 1964. Strong inference. Science 146: 347–353.

Purvis, O.W., B.J. Coppins, D.L. Hawksworth, P.W. James & D.M. Moore 1992. The lichen flora of Great Britain and Ireland. Natural History Museum Publications, Cromwell Road, London.

Richardson, D.H.S. 1992. Pollution Monitoring with Lichens. Richmond Publishing, Slough.

Richardson and R.P. Cameron. 2004. Cyanolichens: their response to pollution and possible management strategies for their conservation in northeastern North America. Northeastern Naturalist 11: 1–22.

Shriver, R. K., K. Cutler, D. F. Doak. 2012. Comparative demography of an epiphytic lichen: support for general life history patterns and solutions to common problems in demographic parameter estimation. Oecologia 170: 137–146.

Sillett, S.C. and T. Goward. 1998. Ecology and conservation of *Pseudocyphellaria rainierensis*, a Pacific Northwest endemic lichen. *In* M.G. Glenn, R.C. Harris, R. Dirig and M.S. Cole (eds.). Lichenographia Thomsoniana: North American Lichenology in Honor of John W. Thomson. Mycotaxon Limited, Ithaca, New York. pp. 377–388.

Tønsberg T. and T. Goward. 2001. *Sticta oroborealis* sp. nov., and other Pacific North American Lichens forming Dendriscocauloid Cyanotypes. Bryologist 104: 12–23.

Türk, R. & J. Hafellner, 1999. Rote List gefährdeter Flechten (Lichenes) Ősterreichs. 2. Fassung. In: Niklfeld, H. (ed.). Rote Listen gefährdeter Pflanzen Ősterreichs. 2. Auflage. Grüne Reihe des Bundesministeriums für Umwelt, Jugend und Familie, Band 10: 187–228.

Turner, B. L., R. E. Kasperson, P. A. Matson, J. J. McCarthy, R. W. Corell, L. Christensen, N. Eckley, J. X. Kasperson, A. Luers, M. L. Martello, C. Polsky, A. Pulsipher, and A. Schiller. 2003. A framework for vulnerability analysis in sustainability science. Proceedings of the National Academy of Sciences of the United States of America 100: 8074–8079.

Turner, R.L. 2012. Habitat suitability models for five sensitive plant species on the Tongass National Forest, southeastern Alaska. Unpublished report, US Forest Service, Juneau, AK.

University of Alaska Museum (ALA). 2015. Herbarium specimen data accessed through the Consortium of Pacific Northwest Herbaria web site, www.pnwherbaria.org, accessed 1 May 2015.

U.S.D.A. Forest Service. 2008. Tongass Land and Resource Management Plan. R10-MB-603b.

U.S.D.A. Forest Service. 2011. National Forest System Land Management Planning: Assessment. 36 CFR 219.6(b).

U.S.D.A. Forest Service. 2011. National Forest System Land Management Planning: Diversity. 36 CFR 219.9.

U.S.D.A. Forest Service. 2011. Forest Service Manual. Threatened, Endangered and Sensitive Plants and Animals: Sensitive Species. FSM 2670.22.

U.S.D.A. Forest Service. 2011. Forest Service Manual. Threatened, Endangered and Sensitive Plants and Animals: Definitions. FSM 2670.5.

U.S.D.A. Forest Service. 2012. Forest Service Handbook. Planning Rule Final Directives. FSH 1909.12.

U.S.D.A. Forest Service. 2015. Proposed Land and Resource Management Plan. R10-MB-769c.

U.S.D.A. Forest Service. 2014. Tongass Young Growth Management Strategy. 133 pp.

U.S.D.A. Forest Service. FHP & ADNR. 2000. Insect & Disease Aerial Detection Survey.

Walker, D.A., Raynolds, M.K., Daniëls, F.J.A., Einarsson, E., Elvebakk, A., Gould, W.A., Katenin, A.E., Kholod, S.S., Markon, C.J., Melnikov, E.S., N.G., M., Talbot, S.S., Yurtsev, B.A., and CAVM Team. 2005. The Circumpolar Arctic Vegetation Map. Journal of Vegetation Science. 16: 267–282.

Wirth, V. 1988. Phytosociological approaches to air pollution monitoring with lichens. Pp. 91–107. *In* T.H. Nash III (ed.) Lichens, Bryophytes and Air Quality. J. Cramer, Stuttgart.

Wirth, V., H. Schöller, P. Scholz, G. Ernst, T. Feuerer, A. Gnüchtel, M. Hauck, P. Jacobson, V. John, and B. Litterski. 1996. Rote Liste der Flechten (Lichenes) der Bundesrepublik Deutschland. Schrifttenreihe Vegetationsk. 28: 307–368.

Yoshimura, I. 1971. The genus *Lobaria* of Eastern Asia. Journal of the Hattori Botanical Laboratory 34: 231.

Young, B.E., E. Byers, K. Gravuer, K.R. Hall, G.A. Hammerson, and A. Redder. 2011. Guidelines for Using the NatureServe Climate Change Vulnerability Index. NatureServe, Arlington, Virginia, USA.

Young, S.B. 1971. The Vascular flora of Saint Lawrence Island, with special reference to floristic zonation in the arctic regions. Contributions from the Gray Herbarium of Harvard University 201: 11–115.

DEFINITIONS

Lichen-Specific Terminology
(From Brodo, Sharnoff & Sharnoff., 2001)

Apothecia (*s:* **apothecium**) are disk- or cup-shaped fruiting bodies of Ascomycetes (called an ascoma), usually with an exposed hymenium (the spore-bearing layer of the ascoma)

Ascospores are spores produced in an ascus, which is a sac-like structure in which the sexual fusion of nuclei and subsequent reduction division occur, thereby forming spores

Cephalodia (*s:* **cephalodium**) are small, gall- or wart-like growths that contain cyanobacteria and occur on the surface of some lichens

The **cortex** is the outer protective layer of the lichen thallus or apothecium; it is completely fungal in composition and is generally composed of hyphae with thick, gelatinized walls

Cyanolichen refers to a lichen that has cyanobacteria as the photobiont

Foliose (lichen) refers to lichen whose thallus is more or less "leafy" and distinctly dorsiventral; foliose lichens vary in their degree of attachment to the substrate

Isidia (*s:* **isidium**) are minute thalline outgrowths that contain both cortical and photobiont tissues, are easily detached from the thallus, and serve as vegetative reproductive units

P**ycnidia** (*s:* **pycnidum**) are asexual fruiting bodies, produced by fungi in Order Sphaeropsidales, that usually somewhat spherical and whose internal cavities are lined by asexually-produced spores (conidiophores)

Soredia (*s:* **soredium**) are vegetative propagules consisting of a few algal cells entwined with and surrounded by fungal filaments; these lack cortex tissue and are usually produced either in localized masses (called *soralia*) or as large, diffuse patches on the lichen thallus

Thallus (*pl*: thalli) refers to the vegetative body of the thallus, consisting of both algal and fungal components

General Definitions

Ecoregion is a geo-spatial unit in the national hierarchy framework resulting in the ECOMAP classification (Bailey 1994). Ecoregions are defined primarily by climate and potential natural vegetation. The size of individual ecoregions is generally millions to tens of thousands of square miles. The Tongass N.F. has finer scale ecological units mapped at the Ecological Subsection scale which may be used as a reference (Nowacki et. al 2001).

Emphasis species are species that require specific attention in forest planning and plan implementation.

Focal species will be employed by forests to evaluate changes in ecosystem diversity. The key characteristic of a focal species is that its status and trend provide insights to the integrity of the larger ecological system to which it belongs [from November 2000 regulations (36 CFR 219.20

(a)(2)(i)(A) and 36 CFR 219.36)]. To accomplish this task, focal species are defined as "surrogate measures used in the evaluation of ecological sustainability including species and ecosystem diversity" [from November 2000 regulations (36 CFR 219.36)].

Forest Service managers are persons who make and implement policy decisions about natural resources (United States Department of Agriculture 1997). In a broader sense, manager can include the staff that support managers who make policy decisions. However, resource specialists (defined in this section) represent management staff who perform tasks that tend to be associated strongly with management but require a strong science background.

Habitat quality refers to physical characteristics of the environment (e.g., soil characteristics for plants or channel morphology for fish) that influence the fitness of individuals. This is distinguished from habitat quantity which refers to spatial extent.

Scale refers to the physical or temporal dimension of an object or process (e.g., size, duration, frequency). In this context, extent defines the overall area coved by a study or analysis and grain defines the size of individual units of observation (sample units).

Peer is a person with recognized scientific or resource management expertise. For peer review, we expect a variety of qualifications, however, in all cases, the reviewer will have demonstrable expertise based on experience (jobs held), credentials, or publications. Peers will be defined based on a high standard for the Species Conservation Project, rather than relative to the author of a particular assessment.

Researchers or scientists are persons engaged in inquiries that involve scientific processes and normally lead to peer-reviewed publications (United States Department of Agriculture 1997). However, in the sense of collaborative planning, where science is integrated into management, scientists also includes persons who do not currently publish peer-reviewed publications but who are recognized as experts in the biology and ecology of the systems being managed. The 'expert' status of these persons may be identified by advanced educational degrees in conjunction with demonstrated maintenance of the scientific expertise that is symbolized by those degrees.

Resource specialists are persons who work as staff for management and generally have a background in a scientific discipline. Examples of resource specialists include botanists working for National Forests, fish and wildlife biologists working on Districts, or silviculturists and range conservationists working on National Forests. Many resource specialists earned advanced academic degrees and have a strong understanding of science. However, following their academic training their career did not focus on the direct pursuit of knowledge but instead application of current knowledge to resource management

Species in this protocol is used in a broad sense to refer to a variety of taxonomic levels (e.i., genus, species, subspecies, variety).

Species of Conservation Concern: A species, other than federally recognized threatened, endangered, proposed, or candidate species, that is known to occur in the plan area (i.e. the Tongass N.F.) and for which the regional forester has determined that the best available scientific information indicates substantial concern about the species' capability to persist over the long-term in the plan area. (36 CFR 219.9(b)(3))

Species viability is used in a most general way throughout the document and outlines. In general, the term refers to the probability of persistence for a species over some specified temporal scale. Throughout this document, the term 'population' could be substituted for 'species'. Because biologists can identify (as in name) and define 'species' more easily than populations, that term is used here. However, the dynamics of persistence take place at the level of the population (Wells and Richmond 1995) and NFMA focuses on populations. Therefore, our process targets species populations and species.

Viability is a focus of this Project. Viability and persistence are used to represent the probability of continued existence rather than a binary variable (viable vs. not viable). We note this because of the difficulty in referring to 'probability of persistence' throughout the manuscript.

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AUTHORS BIOGRAPHY

The current version of the *Lobaria amplissima* Conservation Assessment was revised by the Botany Program of Alaska Natural Heritage Program (AKNHP), University of Alaska Anchorage (UAA). AKNHP collects, synthesizes, and validates information on Alaska's animal and plant species of concern and their habitats, ecosystems of concern, and invasive species. This information is provided by AKNHP to government, business, land managers, scientists, conservation groups, and the public. Additionally, AKNHP helps organizations develop conservation plans.

The botany program conducts research on the biology of rare and invasive plant species and participates in citizen science initiatives. The program is directed under Dr. Matthew Carlson, who also teaches in the Department of Biological Sciences at UAA. Areas of research expertise for the botany program include habitat modeling, biogeography of rare and invasive plants, reproductive ecology and evolution, and ecological impacts of non-native plants. The botany program also offers a wide range of related services including field surveys, monitoring studies, mapping, and conservation planning services.

The botany program is the central repository of biological information on Alaska's rare and invasive plant species and tracks over 600 plant species. Information and reports of native and non-native plant species are collected and verified into databases. Lists of vascular plants and lichens of conservation concern and a field guide to selected rare plants of Alaska are located on the Rare Plants page of the AKNHP website. Data maintained in the AKNHP databases are an integral part of ongoing research and reflect the observations of many scientists and institutions. AKNHP works closely with botanists across Alaska in an effort to ensure the most comprehensive and accurate data sets.

Appendix A. Location Information and Occurrence Descriptions

Table 1. Location information, general site descriptions, and observation dates for all known *Ricasolia amplissima* subsp. *sheiyi* occurrences on the Tongass National Forest.

General location	Substrate	Abundance	Collector	Collection Date	Last Observed
Misty Fjords, DeLong Island. EO #1.	*Picea sitchensis* (branch)	One tree	Karen Dillman #2003-289	7/29/2003	
Misty Fjords, Kah Shakes Island. EO #2.	*Tsuga heterophylla* (bole)	One tree	Karen Dillman #2003-441	7/31/2003	
Misty Fjords, Boca de Quadra. EO #3.	*Thuja plicata* (branch)	One tree	Linda H. Geiser	7/31/2003	
Craig Cemetery Island. EO #4.	*Picea sitchensis* (bole)	One tree	Karen Dillman #2009-213	4/30/2009	Kristen Lease 2012 *Extinct*
Prince of Wales Island, east coast, S of Narrow Point. EO #5.	unknown	Few trees, ten patches & Two trees, seven patches	Mike Ausman, Rory Nichols	7/7/2011 & 6/21/2011	
Whale Head Island, south of Kosciusko Island. EO #6.	*Picea sitchensis*	One tree	Emily Drew #219	7/9/2010	
Warren Island, Warren Cove. EO #7.	*Picea sitchensis* (bole)	20-25 trees; most abundant EO in Tongass	Karen Dillman #2005-131	7/13/2005	Karen Dillman 2016
Coronation Island, Windy Bay, north shore. EO #8.	*Picea sitchensis*	Few trees	Karen Dillman #2009-205	7/26/2009	Kristen Lease 6/12/2012
Coronation Island, Gish Bay. EO #9.	unknown	Four trees	Kristen Lease	6/11/2012	
Coronation Island, Head of Egg Harbor. EO #10.	*Picea sitchensis*	Several trees	Karen Dillman #2003-917	8/12/2003	Karen Dillman 7/2016
Southern Kosciusko Island, Survey Cove. EO #11.	unknown	Five patches	Kristen Lease	6/23/2012	

General location	Substrate	Abundance	Collector	Collection Date	Last Observed
Coronation Island, Mouth of Egg Harbor, Nation Point. EO #12.	*Picea sitchensis*	One tree	Karen Dillman #2003-916	8/12/2003	Kristen Lease 6/14/2012 *Potentially extirpated*
Kosciusko Island, SW. EO #13.	unknown	One tree, two patches	Pamela Jones, Kristen Lease	8/7/2012	
Etolin Island, Cooney Cove. EO #14.	*Alnus rubra*	One thallus, one tree	Karen Dillman #2006-127	6/20/2006	
Kuiu Island, Kell Bay. EO #15.	*Picea sitchensis* (branch)	One tree	Karen Dillman # 2003-179	8/13/2003	
Kuiu Island, Big Bear Harbor, peninsula, EO #16.	*Malus fusca* & *Picea sitchensis*	Two trees	Karen Dillman #2004-03/04	7/17/2004	
Clarence Strt, Rookery Islands. EO #17.	*Tsuga heterophylla*	One tree	Karen Dillman #2010-01	5/22/2010	
Baranof Island, Tenfathom Anchorage. EO #18.	unknown	unknown	Brad Krieckhaus	7/24/2012	
Baranof Island, Big Branch Bay, approx. 2.5km SW of Grouse Peak. EO #19.	unknown	unknown	Brad Krieckhaus	7/24/2012	
Baranof Island, Big branch Bay, approx. 2.5km W of Ptarmigan Peak. EO #20.	unknown	Fifteen patches	Brad Krieckhaus	7/24/2012	
Kuiu Island, Explorer Basin, Tebenkof Bay. EO #21.	*Picea sitchensis*	Several trees, scattered along shore	Karen Dillman #2003-639/144	6/30/2003 &7/1/2003	
Kadin Island. EO #22.	*Malus fusca* (bole)	One tree	Karen Dillman #2004-02	6/22/2004	
Kuiu Island, Point Ellis. EO #23.	*Picea sitchensis*	Few trees, many thalli; concentrated at point	Karen Dillman #2007-01	6/30/2007	

General location	Substrate	Abundance	Collector	Collection Date	Last Observed
Southern Mitkof Island. EO #24.	*Tsuga heterophylla* (bole)	One tree	Karen Dillman #2003-1105	8/29/2003	
Southwest Baranof Island, 45 km S of Sitka. Yamani Islets, east island. EO #25.	*Picea sitchensis*	One tree	Tor Tønsberg #27868	9/12/1999	
McDonald Island, Frederick Sound. EO #26.	*Picea sitchensis*	One tree	Karen Dillman #2008-602	8/19/2008	
SE Kruzof Island, 0.5 km S of mouth of Fred's Creek Mt Edgecumbe trailhead. EO #27.	unknown	Two patches	Brad Krieckhaus	7/18/2011 & 7/20/2011	
Shelikof Bay, Kruzof Island. EO #28.	unknown	Approx. 85 patches	Brad Krieckhaus	5/4/2011 & 6/22/2011	Brad Krieckhaus 6/26/2013
Yakutat, Canon Beach. EO #29.	*Picea sitchensis* (bole)	one thallus	Linda H. Geiser	7/7/2005	
Windfall Island, Tebenkof Bay. EO #30.	*Picea sitchensis* (bole)	Few trees, concentrated at point	Karen Dillman #2003-721	7/2/2003	
Sukoi Islands, on south end of eastern island. EO #31.	*Picea sitchensis*	Few trees	Chiska C. Derr #920	8/2/1992	Karen Dillman 3/18/2003