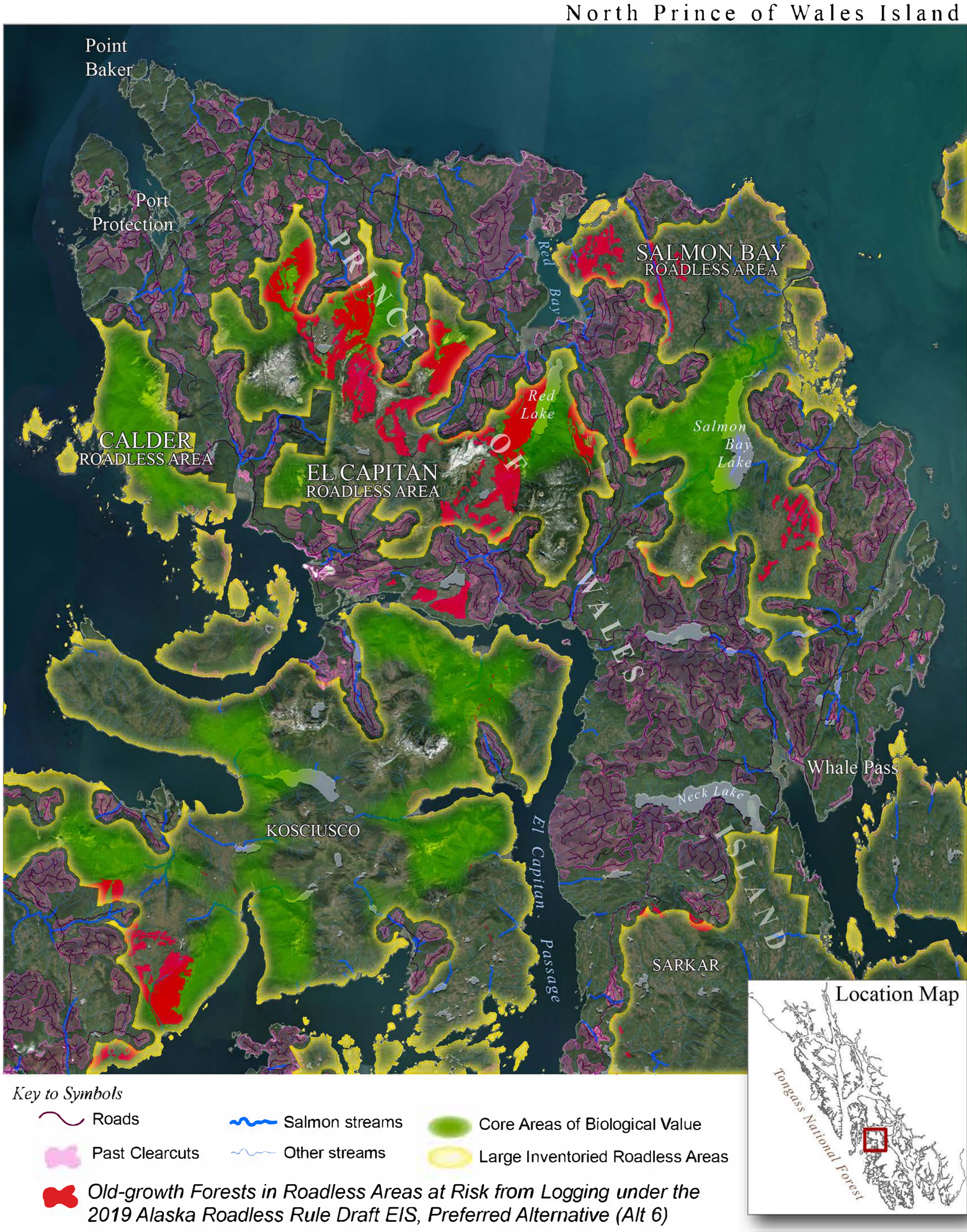
Conservation Significance of
Large Inventoried Roadless Areas
on the Tongass National Forest

North Prince of Wales Island



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David M. Albert

CONSERVATION SIGNIFICANCE OF LARGE INVENTORIED ROADLESS AREAS ON THE TONGASS NATIONAL FOREST

David M. Albert, Juneau AK

ABSTRACT

We evaluated the conservation significance of large inventoried roadless toward the goal of maintaining viable and well-distributed populations of fish and wildlife across the Tongass National Forest. We used the best available data to calculate indicators of habitat condition for 5 important species and forest systems. The significance of roadless areas was evaluated based the relative distribution of habitat values among biogeographic provinces, the degree to which habitats have been altered relative to historical conditions, the proportion of remaining values contained in large inventoried roadless areas; and the proportion of remaining values in lands potentially available for future development. No biological indicators exceeded the 40% threshold based on current alteration from original conditions region-wide, although loss of contiguous forest landscapes was approaching that value with a decline of 39.2%. However, within biogeographic provinces 25% of all indicators exceeded this threshold, with highest levels of alteration within the Prince of Wales Island group. The average decline across all indicators was 29% from historical conditions, regionwide. Consideration of lands potentially available for future development with removal of the Roadless Rule would result in a Cumulative Risk Index of 50.4% across all indicators. Large inventoried roadless areas contain approximately 48.8% of all remaining habitat values, including a high proportion of remaining contiguous old-growth forest landscapes that have been severely reduced elsewhere. Reduction of current protections for large inventoried roadless areas by the USFS would likely increase the vulnerability of remaining rare and high value habitats for fish and wildlife to future logging.

INTRODUCTION

Southeastern Alaska encompasses one of the largest remaining portion of old-growth temperate rainforest on earth (DellaSala 2011). These globally rare forests continue to support abundant populations of fish and wildlife such as brown bears (*Ursus arctos*), wolves (*Canis lupus*) and Pacific salmon (*Oncorhynchus sp*.) and other species that have declined or become threatened in southern portions of their ranges. With increasing evidence of large-scale changes in wildlife and ecosystem function world-wide (Birdlife International 2018, Bowyer et al. 2019), and the services these systems provide to people (Millennium Ecosystem Report 2005), there is a similarly increasing need for quantitative tools to compare of management alternatives, evaluate risks and inform decision-making (Martin et al. 2009)

Industrial logging in the region increased rapidly with the Tongass Timber Act of 1947, and long-term contracts to supply pulp mills in Ketchikan and Sitka by 1954 (Beier et al. 2009). Since then, timber harvest and road construction have selectively penetrated many of the most biologically productive forest lands of region, with a disproportionate loss of the large-tree stands, low elevation valley bottom and karst forests, and landscapes of contiguous old-growth forest (Albert and Schoen 2013). This pattern of disproportionate logging also has consequences for old-growth dependent species (Shanley et al. 2013), and the ability of managers to maintain viable and well-distributed populations across this region fragmented by islands, mountains and ice fields (Cook et al. 2006, Dawson et al. 2007).

Much of the remaining high-value old-growth forests and contiguous forest landscapes only occur within roadless areas. Some portion of remaining large inventoried roadless areas were granted protection from logging under the 2001 Roadless Rule, and upheld as part of a stakeholder agreement implemented by US Forest Service in the 2016 Amendment to the Tongass National Forest Plan. However, in response to a 2018 petition by the State of Alaska, the USFS has released a Draft Environmental Impact Statement (DEIS) to consider remove these protective measures, with public review and comment available through December 2019 (USFS 2019).

In this paper we evaluate the significance of biological values associated with roadless areas on the Tongass NF. We stratified the analysis among biogeographic provinces and account for spatial isolation and biogeography effects of the Alexander Archipelago (Albert & Schoen 2007a). For each of these biogeographic provinces, we calculated indices of (1) *relative biological value* based on indicators of forest, fish and wildlife habitats, (2) *ecological condition* to estimate the proportion of habitats altered by past logging, including cumulative effects of both public and private lands, and (3) the *vulnerability* of remaining habitat within all Development Land Use Designations (LUDs) under the 2016 TLMP. Finally, we combined the indices of ecological condition and vulnerability to develop a *cumulative index of ecological risk*.

This index describes the proportion original habitats that have been altered by past logging and the proportion that may be altered under future management scenarios (Albert and Schoen 2007b). This index provides a quantitative index for stakeholders and decision-makers to weigh alternatives and design strategies to achieve desired social, ecological and economic outcomes (Martin et al. 2009).

STUDY AREA

Southeast is dominated by the Alexander Archipelago, made up of thousands of islands. This coastal ecosystem has a marine shoreline of more than 18,000 mi (30,000 km) with over 250,000 acres (101,200 ha) of intertidal habitats providing a rich environment that ranks among the most productive salmon spawning regions in the world. The climate of Southeast is maritime with cool, wet weather predominating throughout most of the year.

Although Southeast is best known for its rainforest, more than 45% of the land area of the region is unforested rock, ice, alpine, or muskeg bog, and less than one-third of the land base of Southeast is considered productive forest land. Much (~89%) of the forest land in Southeast is still old growth (>150 years old), dominated by western hemlock (*Tsuga heterophylla*)-Sitka spruce (*Picea sitchensis*) (Fig. 1). Approximately 72,000 people live in Southeast distributed throughout approximately 30 communities, of which Juneau—the state capital—is the largest. Over 500,000 acres (200,000 ha) of logging has occurred on the Tongass, and nearly 350,000 acres (141,000 ha) on state and private lands throughout Southeast, including construction of over 7,500 miles of roads.

METHODS

The study area for this project included approximately 17.6 million acres, which included the Tongass NF (~16.6 million acres) and adjacent private lands (~1.0 million acres) to account for cumulative effects of past and future logging (Fig. 2). The study further categorized the area into 20 Biogeographic Provinces representing gradients in climate, geology, vegetation and mammal diversity (McDonald & Cook 1996, Cook & McDonald 2001, USFS 1997). We used the best available data on forest conditions and habitat values using agency datasets and published models (Johnson and Blossom 2017, USFS 1998) to estimate the relative contribution of each biogeographic province to the total regional distribution (Albert & Schoen 2007b).

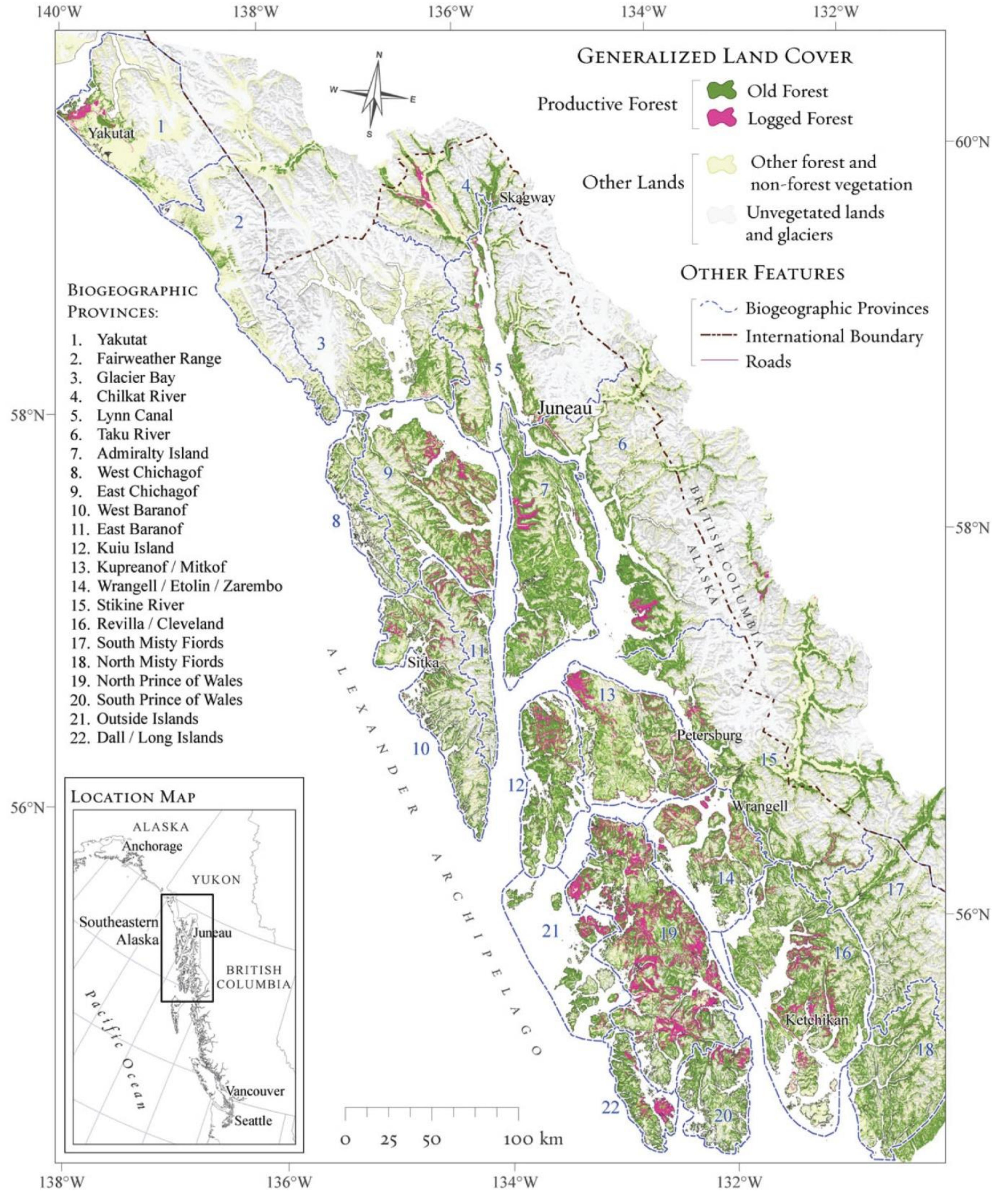

Figure 1. Forest condition and generalized landcover in Southeast Alaska (from Albert and Schoen 2013)

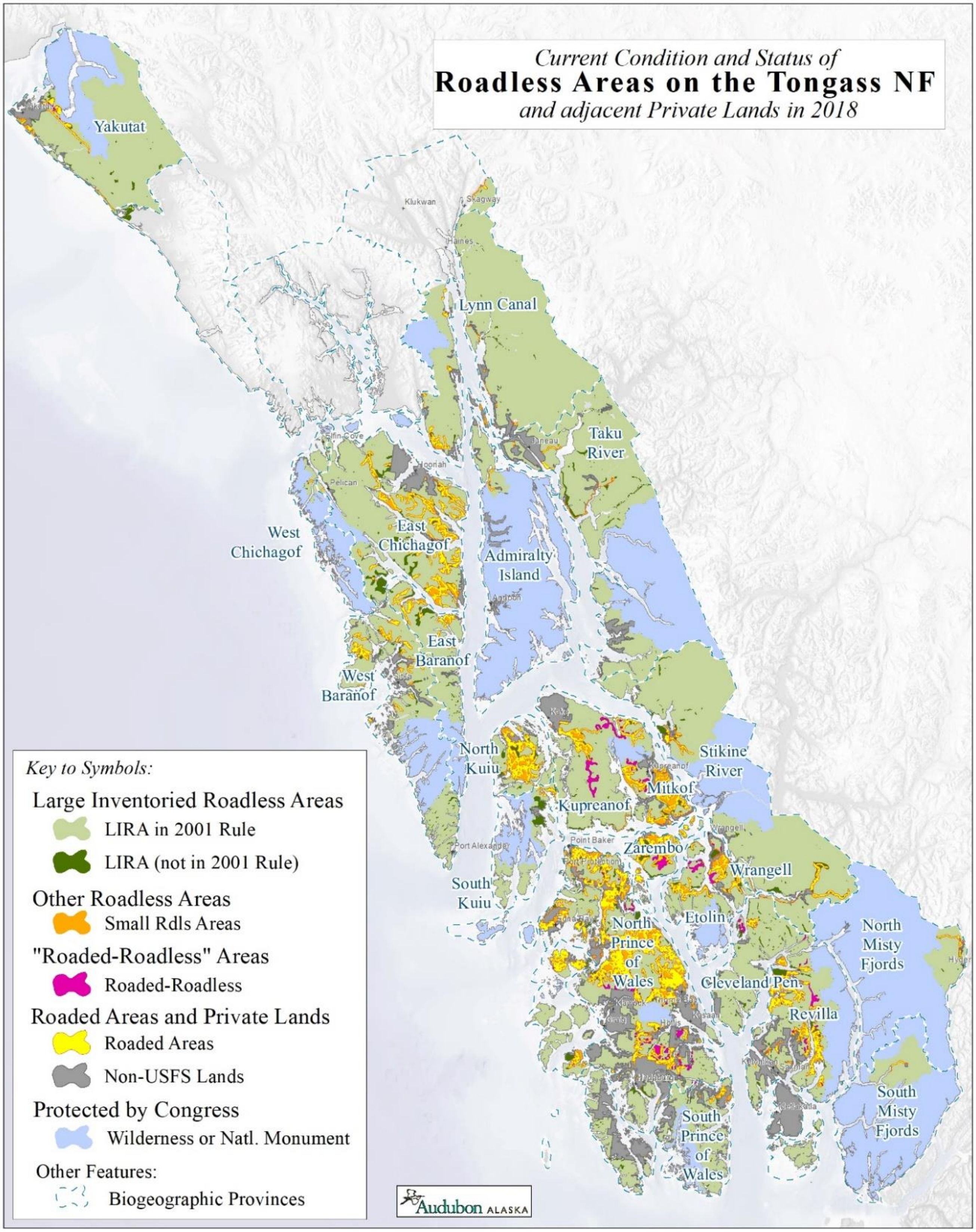

Figure 2. Study area and roadless status of the Tongass National Forest and adjacent private lands.

Indicators of Forest, Fish and Wildlife Habitat

To quantify the spatial distribution and of habitat values and evaluate change over time, we selected 5 indicators of biological value (Groves 2003), including large-tree forests (>21" quadradic mean diameter; Caouette & DeGayner 2005) and contiguous old-growth forest landscapes (Shanley et al. 2013), floodplain forest associated with 5 species of Pacific salmon (*Oncorhynchus spp*.; Paustian et al. 1992, USFS 1996, Albert & Schoen 2007a), summer habitat for brown (*Ursus arctos*) and black bear (*Ursus americanus*; Schoen et al 1994), and winter habitat for Sitka black-tailed deer (*Odocoileus hemionus sitkensis*; Schoen & Kirchhoff 1990, Suring et al. 1994). For further details on methods and model development, see Albert & Schoen (2007a). These indicators represent forest, fish and wildlife habitats with high ecological, social and economic values that are known to be sensitive to logging originally developed as part of the Audubon-TNC Conservation Assessment (Albert & Schoen 2007a). We updated the best available information on most recent forest conditions using the latest inventory of timber harvest on USFS lands, the All Lands Young-growth Inventory published as part of the 2016 Tongass Advisory Committee process and augmented with more recent harvest using Google Earth imagery. These data on forest condition were then used to update habitat models for deer, bear and floodplain forests associated with salmon streams.

We followed USFS definitions to characterize forest lands based on timber volume, tree size and stand density, as well as landscape-scale forest characteristics (Albert & Schoen 2013). Productive forests were defined by USFS as lands that contain >8 thousand board-feet (mbf) per acre, and father categorized based structural characteristics of tree size and stand density (Cauoette & DeGayner 2008). To evaluate forest composition at a landscape scale, we identified areas with >70% coverage of medium-to-high volume POG (>16 mbf / acre) within 0.39 mile^2 (1 km^2) as contiguous old-growth forest landscapes. This has been identified as a functional threshold for landscapes to support old-growth dependent species such as the Northern flying squirrel (Shanley et al. 2013). For each of these metrics, we used the best available information to estimate pre-logged forest conditions and evaluate changes over time (Albert & Schoen 2013). We used the USFS Roadless Inventory as developed in the 2003 Supplemental EIS to the Tongass Land Management Plan (TLMP; USFS 2003), the 2001 Roadless Rule, along with the current extent of roads and roadless areas to characterize the contribution of roadless areas to the remaining distribution of forests, fish and wildlife values (Fig. 3).

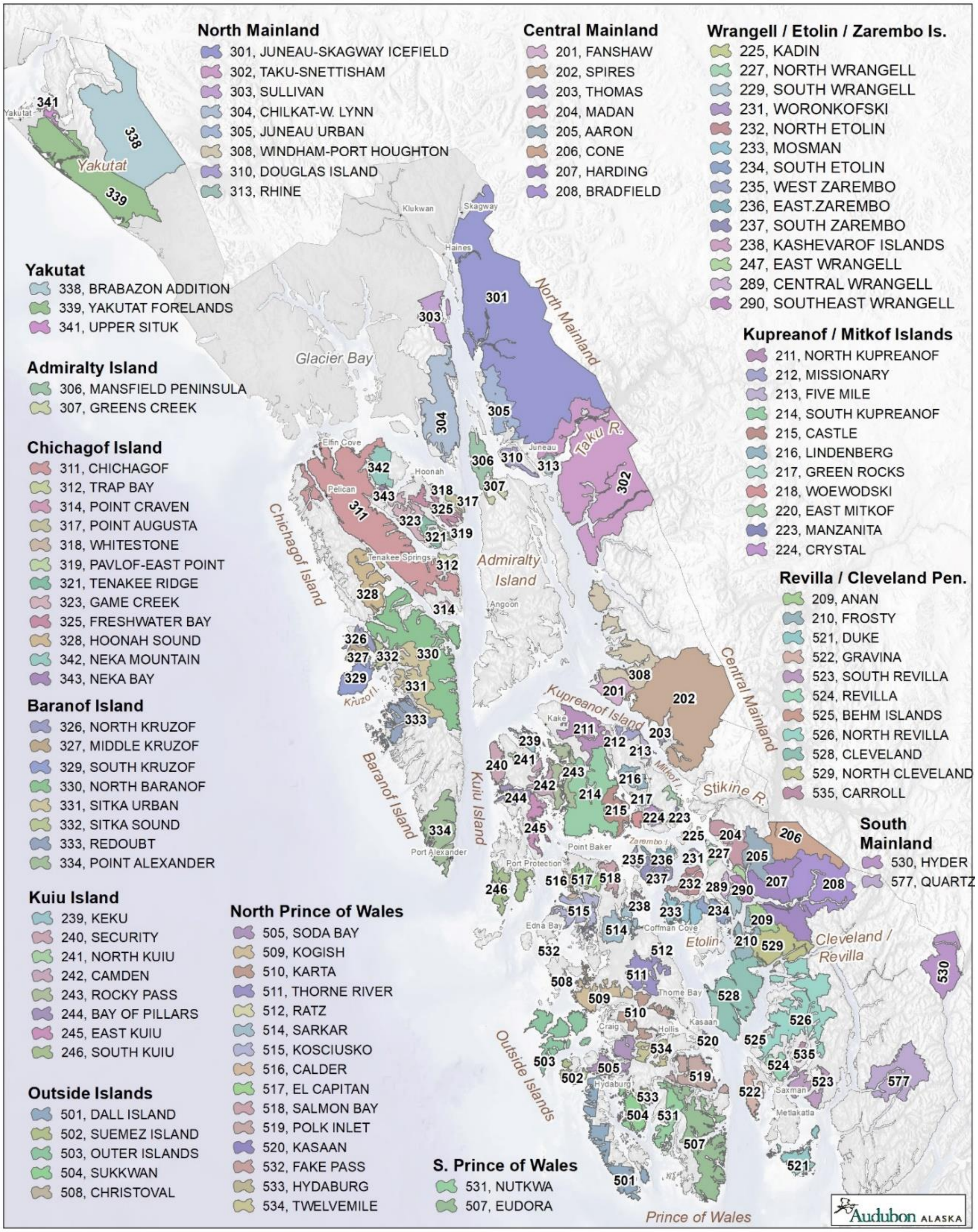

Figure 3. Named roadless areas in 2003 Tongass Roadless Inventory (USFS 2003).

Index of Relative Biological Value

As described above, we selected 5 indicators of biological value that are sensitive to changes associated with industrial logging and road construction. For this analysis, focal species included salmon, brown and black bear, Sitka black-tailed deer, large-tree forests and contiguous forest landscapes. Values in these models reflect key aspects of each species life history. Our estimate of habitat values for salmon was based on the distribution of freshwater habitat used for spawning or rearing by each of the 5 species of pacific salmon, while the distribution of forest types was based on an integrated regional database of vegetation and landcover (Albert & Schoen 2013) that was updated to reflect current conditions. These data were extensively reviewed by interagency biologists and local experts and have been judged to adequately describe the large-scale patterns of distribution and abundance of habitat values in this region. Based on these data, we were able to evaluate the current and original abundance of habitat values for each indicator, as well as their relative distribution among biogeographic provinces.

We defined an index of relative biological value (RBV) as the percent contribution of each biogeographic province to the total distribution of habitat values for each species or ecological system:

$$\mathrm{RBV}_p = \frac{\sum_{i=1}^{n}\left(h_p/h_{total}\right)}{n}$$

where:

p	=	biogeographic province
n	=	number of target species or systems within province (p)
h_p	=	habitat value for species (i) contained within province (p)
h_{total}	=	total habitat for species (i) in the region

Index of Ecological Condition

The index of ecological condition is an estimate of the degree to which forests and associated habitat values have been altered as a result of past human activity. This index is presented as a percentage of the original habitat values that have been altered, rather than a strict interpretation as decline in habitat values. This reflects the complex spatial and temporal dynamics by which logging and associated activities affect habitat values for fish and wildlife, such as the time-lag in forest succession and associated habitat values (Alaback 1982, Person and Brinkman 2013).

$$\text{Index of Ecological Condition } 2018_p = \frac{\sum_{i=1}^{n}\left(1-(h_{curr}/h_{orig})\right)}{n}$$

where:

p	=	biogeographic province
n	=	number of target species or systems within province (p)
h_{curr}	=	habitat value for species (i) contained within province (p)
h_{orig}	=	original habitat for species (i) within province (p)

For each biological indicator, we estimated the original condition of the forest and wildlife values, based on the best available data. For example, we estimated that the regional distribution of large-tree forests was reduced from a total of 795,680 acres in 1954 to 542,846 acres in 2018 (Table 2). In this case, the remaining distribution is 68.2% of the 1954 total, so the Index of Current Condition is (1 – 0.682 = 0.318), reflecting a 31.8% decline in the regional distribution of large-tree forests (Table 2). The overall index is the average decline across in habitat values across all 5 indicators, including large tree forest, contiguous forest, salmon floodplain forest, bear habitat and deer habitat (Table 7).

In some cases, we needed to make informed assumptions to estimate the original condition. For example, in some cases the original forest composition was unknown, so to estimate the distribution of large-tree that had been logged, we used available data on selectivity in logging from 1986 - 2006 (Albert & Schoen 2013) as a conservative estimate of the percent change in the rare, large-tree forest types over time since 1954. We used these estimates to calculate the original distribution of large-tree forests, and to estimate the original capability of winter habitat for deer and summer habitat for brown and black bear. We estimated conditions of habitat for salmon by the percent of forests located within the floodplain of documented salmon streams that had been logged. While these estimates are not expected to directly predict trends in population size or abundance, they can be used as a conservative index to the departure from natural conditions, which in turn provides insight into the robustness of these systems for continued production of goods and services on which people rely, as well as resilience to future variability such as climate change (Orians and Schoen 2013, Person and Brinkman 2013).

Index of Relative Vulnerability

We calculated an index of relative vulnerability as a percent of remaining habitat values that occur within landscapes available for future logging or other development:

$$\text{Index of Vulnerability } 2018_p = \frac{\sum_{i=1}^{n}(h_{devp}/h_{total})}{n}$$

where:

p	=	biogeographic province
n	=	number of target species or systems within province (p)
h_{devp}	=	2018 habitat value for species (i) designated within development landscapes in province (p)
h_{total}	=	2018 total habitat for species (i) within province (p)

This index allows for comparison of relative vulnerability among scenarios as part of forest planning and public review. In this analysis, we included all TNF lands designated as Timber Production, Modified Landscape, and Scenic Viewshed under the 2016 Amendment to the Tongass Land Management Plan (USFS 2016). Lands owned by the State of Alaska, the Alaska Mental Health Land Trust, Alaska Native Corporations and other private lands were also considered to be available for development in this analysis.

This is a landscape-scale index that estimates the percentage of habitat values contained within development LUDs, and does not consider stand-scale suitability for logging (USFS 2016). Limiting such an analysis only to effects of stand-scale disturbance or suitability for logging would underestimate the cumulative vulnerability to secondary effect of logging and infrastructure on wildlife, such as habitat loss from road construction, edge effects and fragmentation, and downstream effects of altered stream hydrology and sedimentation on aquatic habitats (Lindenmeyer and Franklin, 2002).

Index of Cumulative Ecological Risk

Finally, cumulative ecological risk is an estimate of the total proportion of original habitat values that have been altered or are potentially at risk from potential future alteration under management scenarios.

This index was calculated by adding the percent of original habitat values that have been altered (Index of Current Condition) and the percent of remaining values that occur within development lands, adjusted to reflect a percent of original condition (Index of $\text{Vulnerability}_{\text{adj}}$):

$$\%\text{Cumulative Risk}_p = \%\text{Ecological Condition}_\text{p} + \%\text{Vulnerability}_\text{p-adj}$$

This adjustment in the Index of $\text{Vulnerability}_{\text{adj}}$ is necessary so that the Index of Cumulative Risk can be interpreted as a proportion of the total original (circa 1954) value for each individual and combined biological indicators. For example, assume that the current distribution of a biological indicator (e.g., large-tree forest acres) is 70% of its original value. In this case, the Index of Ecological Condition is 30%. Further assume that 40% of the remaining values are designated within development landscapes or private lands, for an Index of Vulnerability of 40%. However, to calculate the cumulative risk as a measure of pre-industrial (~1954) habitat conditions, the vulnerability score needs to be adjusted as a percentage of that value. In this example, the current vulnerability (40%) is multiplied by the proportion of habitat remaining (70%) to yield an "adjusted" Index of $\text{Vulnerability}_{adj}$ of 28% (i.e., 0.4 * 0.7 = 0.28). Finally, in this example the Index of Cumulative Risk is 52% (i.e., 0.3 + 0.28 = 0.52). The interpretation is that an estimated 52% of the original distribution of a biological indicator (e.g., large-tree forest), or the average of all indicators combined, either have already been altered or are vulnerable to potential future alteration at a landscape scale under this scenario. This is simply a measure of the degree to which habitat values for this set of indicators are expected to remain intact over the current planning horizon. This does not imply that species declines will or will not occur, but simply that the risk of instability is related to the cumulative change in habitat values relative to the natural range of variability within coastal forest ecosystems (Albert & Schoen 2007b).

RESULTS

The Tongass NF and adjacent private lands cover an area of approximately 17.6 million acres. About 2/3 of this area is unvegetated, non-forest or non-commercial forest land cover types, including glaciers, alpine forests and extensive peatlands (Table 1). Productive forests cover the remaining 1/3 of the region or approximately 6.1 million acres (Table 1). Of these productive forest lands, approximately 863,000 acres (14.1 %) have been logged since 1954, including both public and private lands (Table 1). The distribution of this logging has been selective, with the highest concentrations on Prince of Wales and neighboring islands, where approximately 420,000 acres (30.4%) of productive forests have been logged. Region-wide, Prince of Wales and neighboring islands have sustained 48.6% of all logging in the region, within a group of islands that contained only 22.6% of all productive forests (Table 1).

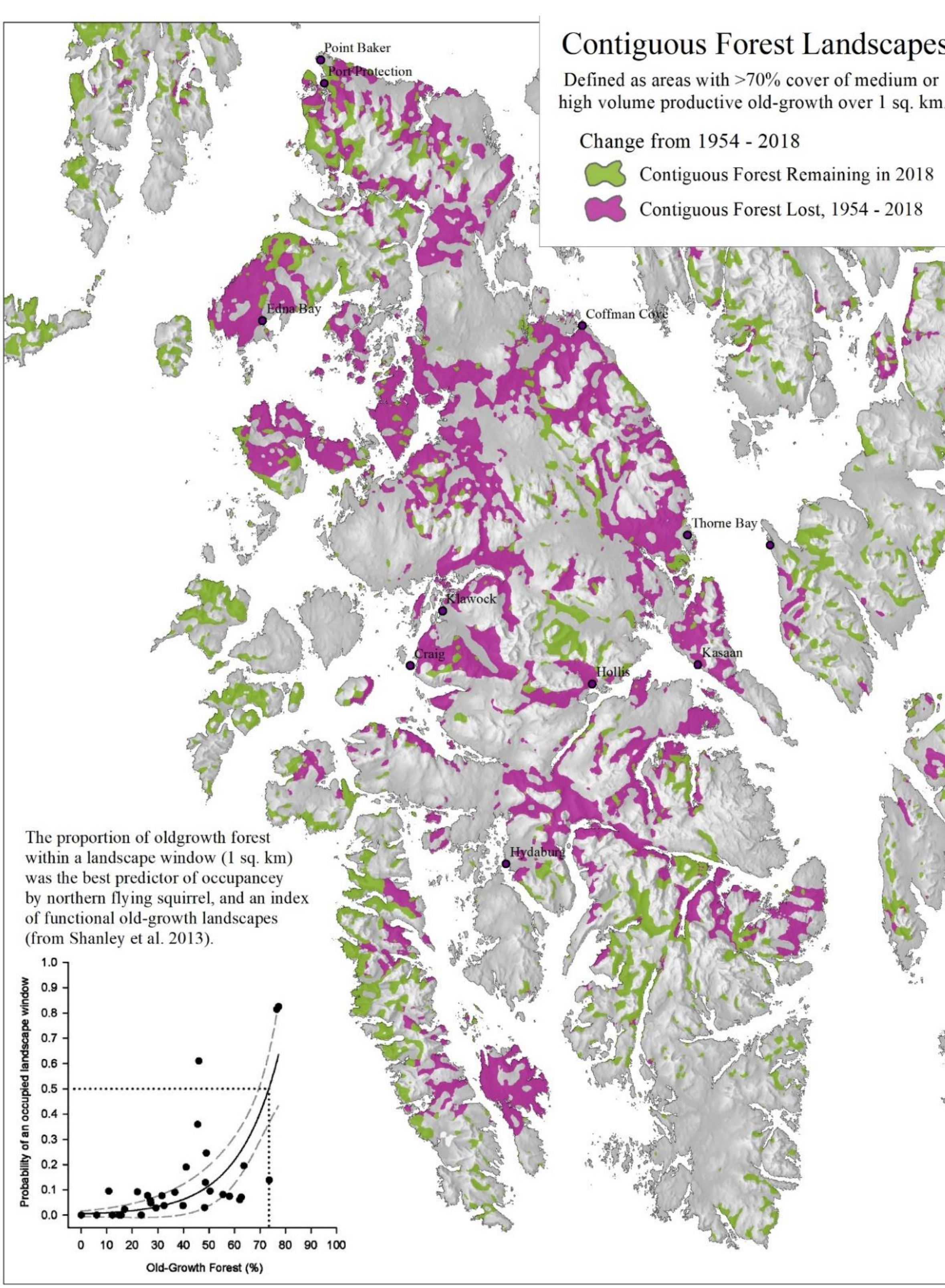

Figure 4. Change in distribution of contiguous forests at a landscape scale (1sq. km), 1954 - 2018

Large-tree POG Forests

Large-tree forests (defined as stands with tree-size >21” quadratic mean diameter) occur on approximately 542,800 acres and represent approximately 10% of all productive forest lands (Table 2). We conservatively estimate that the original distribution of large-tree old-growth forests was 795,680 acres, which represents a region-wide decline of 31.8% from pre-industrial forest conditions (Albert & Schoen 2013). In this region naturally isolated among islands and further fragmented by high elevation mountains and extensive wetlands, contiguous forest landscapes were always relatively rare. We estimate that in 1954, approximately 39.4% of all productive forests (2.4 million acres) were part of contiguous old-growth forest landscapes, and the remaining 60.6% (3.7 million acres) were in fragmented patches at a landscape scale. In 2018, only 27.6% of old-growth forests (1.5 million acres) were part of contiguous forest landscapes and the remaining 72% (3.8 million acres) were characterized by fragmented old-growth forest landscapes. Thus, contiguous forest landscapes have been reduced by 39.4% region-wide, with the highest loss evident on North Prince of Wales Island, where contiguous old-growth landscapes have been reduced by 77.5% (Table 3).

Contiguous Old-growth Forest Landscapes

Forests that are contiguous over a landscape scale (defined as >70% canopy of medium-to-high volume productive old growth forest per sq. km) originally accounted for approximately 2.5 million acres region-wide, tended to occur on the southern and central islands (Table 3). The Prince of Wales Island group originally accounted for 27.7% of the regional total, with 10.2% of that found on North Prince of Wales alone. Regionwide, these forests have been reduced by 39.2% to approximately 1.5 million acres in 2018. Likewise, the proportional loss of contiguous forest has been the most dramatic on North Prince of Wales (Fig. 4), where contiguous forests have been reduced by 77.5%, followed by Kupreanof / Mitkof (55.9% loss), East Baranof (55.5% loss) and West Baranof (50% loss). East Baranof has a very small proportion of the regional distribution (1.3%), but 93.1% of that is found in large inventoried roadless areas. Other provinces with the highest proportion of remaining contiguous forests in LRIA include East Chichagof (78.3%), West Baranof (77.4%), Dall Island Complex (76.8%), and Lynn Canal (75.9%). The province with the highest proportion of contagious forests vulnerable to future development include Kupreanof / Mitkof (48.5%), East Baranof (45.4%) and Etolin / Zarembo

(43.2%). The cumulative ecological risk region-wide, considering both past and potential for future fragmentation represents approximately 54.1% of the original distribution of these types of forests. Provinces with the highest cumulative risk include North Prince of Wales (85.2%), Kupreanof / Mitkof (77.3%), East Baranof (75.7%) and Etolin / Zarembo (70.4%) (Table 3).

Summer Habitat Capability Model for Brown and Black bear

Brown and/or black bears are present throughout the region. According to the Interagency habitat capability model, the largest contribution to the regional distribution of bear habitat was from North Prince of Wales (15.7%), East Chichagof (8.6%), Kupreanof / Mitkof Islands (8.3%) and Admiralty Islands (8.0%) (Table 4). Further, this model suggested that region wide, habitat values had declined from 1954 - 2018 by an estimated 36.9% (Table 4). Provinces with largest declines in estimated habitat capability included North Prince of Wales (62.4%), North Kuiu (56.2%), Dall & Long Islands (62.4%), followed by E. Chichagof (48.6%), Kupreanof / Mitkof (47.9%) and Etolin / Zarembo (46%). An estimated 49.6% of remaining bear habitat was found in Large Inventoried Roadless Areas, with the largest contributions found in the Outside Islands (77.6%), Yakutat Forelands (75.5%), and Taku River (74.3%). An estimated 24.8% of the remaining habitat capability for brown and black bear were located in development LUDs within the Tongass NF or on State of Alaska or private lands. The largest potential vulnerability to future development occurred on N. Kuiu Island (54.8%), Dall Island Complex (52%) and N. Prince of Wales (51.8%) (Table 4). Overall the cumulative ecological risk, including both past modification and potential future development, is estimated at 52.8% of the original habitat for brown and black bear region wide. Individual provinces with the highest cumulative risk include N. Prince of Wales (81.9%), N. Kuiu (80.2%), Dall Island Complex (78.1%), Kupreanof / Mitkof Island (75.5%), Wrangell / Etolin / Zarembo (72.5%) and E. Chichagof Island (70.3%).

Winter Habitat Capability Model for Sitka black-tailed Deer

Winter deer habitat capability as represented in the Interagency Deer Model is governed by forest type, elevation, aspect and winter snow depth. Provinces with highest contribution of winter deer habitat to the region-wide total include N. Prince of Wales (19.3%), Admiralty Island (9.3%), Revilla / Cleveland Peninsula (9.3%) and Kupreanof / Mitkof Islands (8.1%). Region-wide, we estimated that winter habitat for deer has declined by 16.7% (Table 5), with largest declines in N. Prince of Wales (35.5%), Dall Island (22.2%), N. Kuiu (21%), E. Chichagof

(20.5%) and E. Baranof (20%). Large inventoried roadless areas contain approximately 49.8% of the remaining winter deer habitat, with largest roadless contribution in E. Baranof (70.6%), Kupreanof / Mitkof (69.2%) and Stikine River (66.6%). Region-wide, an estimated 34.3% of remaining winter deer habitat is located in development lands, including both Tongass NF and adjacent state or private lands. The largest proportion of remaining habitat in development lands was found on N. Prince of Wales (55.1%), Dall Island (54.9%), Kupreanof / Mitkof (54.4%), N. Kuiu (52.7%) and Wrangell / Etolin / Zarembo (51.1%). Overall the combination of past logging and potential future development result in an Index of Cumulative Ecological Risk of 45.3% of the estimated 1954 habitat. Highest cumulative risk occurred on N. Prince of Wales (71.1%), Dall Island Complex (64.9%), N. Kuiu (62.6%) and Kupreanof / Mitkof Islands (62.6%) (Table 5).

Floodplain Forests Associated with Salmon Spawning and Rearing

Salmon streams occur on floodplains and other lands that cover approximately 1 million acres of on the Tongass NF and adjacent lands (Table 6). Of those, approximately 500,000 are characterized as productive forest, with approximately 395,484 acres (78.6%) of old-growth forest and 107,706 acres (21.4%) of post-logging young growth forest (Table 6). The largest regional contribution of anadromous floodplain old-growth forests in Southeast Alaska were found on N. Prince of Wales Island (20.6%), E. Chichagof Island (10.3%), Kupreanof / Mitkof Islands (8.0%) and the Stikine River (7.6%). Provinces with the largest percent of anadromous floodplain forests logged included E. Baranof (42%), N. Prince of Wales (36.6%), W. Baranof (34.2%) and North Kuiu (29.2%). Overall, approximately 46% of remaining old-growth anadromous floodplain forests occur within large roadless areas, and approximately 36.5% of remaining old-growth floodplain forests in Tongass Development LUDs, state or private lands Biogeographic provinces with the largest proportion of remaining old-growth salmon forests in large roadless areas include Kupreanof / Mitkof (70.6%), Yakutat Forelands (68.8%), Outside Islands (67.9%) and S. Prince of Wales Island (65.3%). Provinces with the highest proportion of remaining old-growth salmon forests located in development lands included Dall Island (59.3%), North Prince of Wales (57.5%), North Kuiu (56%) and East Chichagof (50.8%). Taken together, the Index of Cumulative Ecological Risk of past logging and potential future development represents 50.1% of all floodplain forests associated with anadromous fish in Southeast Alaska, with highest proportions found on North Prince of Wales Island (73.1%), Dall Island (70%), North Kuiu (68.9%), East Chichagof (63.9%) and East Baranof (62%).

Combined Indicators of Forest, Fish and Wildlife Habitat

The final step in our analysis was to combine all indicators of biological value to get 'average' values for the relative distribution among biogeographic provinces (Index of Relative Biological Value), the degree to which these values have been altered by past logging and road construction (Index of Current Condition), the proportion of remaining values that are located within large roadless areas, the proportion of remaining values that are located in lands available for development, either within the Tongass NF or adjacent lands, and finally the combination of past harvest with potential future development (Index of Cumulative Ecological Risk) (Table 7). These results are similar in pattern to the previous tables: North Prince of Wales contains by far the largest proportion of biological values among any biogeographic province (20.2%), followed by Admiralty Island (9.7%), East Chichagof Island (8.4%), Revilla / Cleveland Peninsula (7.8%) and Kupreanof / Mitkof Islands (7.0%). On average, 29% of the original distribution of these value has been altered by past logging and road construction (Fig. 5a), including largest proportions altered on North Prince of Wales (51.5%), East Baranof (44.7%), Dall Island (41.4%) and Kupreanof / Mitkof (37.6%). Region-wide, an average of 48.8% of remaining values were located in large roadless areas, and an average of 29.7% of remaining values were located in lands available for development, including both Tongass NF and adjacent lands. Provinces with the highest remaining proportions in roadless areas included Lynn Canal (68.4%), Taku River (68.4%), Revilla / Cleveland (66.9%), Kupreanof / Mitkof (66.7%) and Stikine River (65.3%). Provinces with the highest proportion of remaining values located in lands available for future development include North Kuiu (51%), Kupreanof / Mitkof (50.6%), Wrangell / Etolin / Zarembo (48.7) and North Prince of Wales (48.3%). Taken together, the cumulative effect of past logging and potential for future development within lands designated on the Tongass NF or adjacent State of Alaska or private lands, represents approximately 50% of the original distribution of biological values for these indicators region-wide (Fig. 5b). Among biogeographic provinces, this cumulative ecological risk was highest on North Prince of Wales (76%), followed by Dall Island (69.1%), Kupreanof / Mitkof (68.9%), North Kuiu (68.6%), Wrangell / Etolin / Zarembo (66.9%), East Baranof (64.8%) and East Chichagof (63%) (Table 7).

Table 1. Regional distribution and current condition of productive forest lands among biogeographic provinces (all lands).

Biogeographic Provinces	Old Growth		Young Growth		All		% of POG Logged
	(acres)	(%)	(acres)	(%)	(acres)	(%)	
ABC Islands (all)	**1,412,130**	**26.9%**	**147,815**	**17.3%**	**1,559,945**	**25.5%**	**9.5%**
Admiralty Island	596,482	11.4%	32,371	3.8%	628,853	10.3%	5.1%
E. Baranof Island	88,612	1.7%	14,365	1.7%	102,977	1.7%	13.9%
E. Chichagof Island	426,305	8.1%	80,994	9.4%	507,299	8.3%	16.0%
W. Baranof Island	228,347	4.3%	20,085	2.4%	248,432	4.1%	8.1%
W. Chichagof Island	72,385	1.4%		0.0%	72,385	1.2%	0.0%
Central Islands (all)	**1,388,861**	**26.4%**	**229,482**	**26.9%**	**1,618,343**	**26.5%**	**14.2%**
Wrangell Etolin Zarembo	222,139	4.2%	46,127	5.5%	268,266	4.4%	17.2%
N. Kuiu Island	125,545	2.4%	26,822	3.2%	152,367	2.5%	17.6%
S. Kuiu Island	156,370	3.0%	4,196	0.5%	160,566	2.6%	2.6%
Kupreanof / Mitkof	343,116	6.5%	76,590	8.9%	419,706	6.9%	18.2%
Revilla Island / Cleveland	541,691	10.3%	75,748	9.0%	617,439	10.1%	12.3%
Prince of Wales Complex (all)	**959,743**	**18.3%**	**419,671**	**48.0%**	**1,379,414**	**22.6%**	**30.4%**
Dall Island Complex	97,516	1.9%	39,096	4.5%	136,612	2.2%	28.6%
North Prince of Wales	587,988	11.2%	338,944	38.6%	926,932	15.2%	36.6%
Outside Islands	112,792	2.1%	20,039	2.4%	132,831	2.2%	15.1%
South Prince of Wales	161,447	3.1%	21,591	2.5%	183,038	3.0%	11.8%
Mainland (all)	**1,409,622**	**26.8%**	**45,094**	**5.3%**	**1,454,716**	**23.8%**	**3.1%**
Lynn Canal	209,374	4.0%	6,568	0.8%	215,942	3.5%	3.0%
North Misty Fjords	215,885	4.1%	17	0.0%	215,902	3.5%	0.0%
South Misty Fjords	312,729	6.0%		0.0%	312,729	5.1%	0.0%
Stikine River	331,532	6.3%	15,679	1.9%	347,211	5.7%	4.5%
Taku River	340,101	6.5%	22,830	2.7%	362,931	5.9%	6.3%
Yakutat (all)	**81,262**	**1.5%**	**20,855**	**2.5%**	**102,117**	**1.7%**	**20.4%**
Yakutat Forelands	81,262	1.5%	20,855	2.5%	102,117	1.7%	20.4%
Grand Total	**5,251,618**	**100%**	**862,916**	**100%**	**6,114,534**	**100%**	**14.1%**

Table 2. A comparison of the regional distribution of large-tree forests, change over time, contribution of large inventoried roadless areas, and cumulative risk among biogeographic provinces (all lands).

Biogeographic Provinces	Large-tree Forest 1954	Large-tree Forest 2018	Index of Relative Biological Value	Index of Current Condition (% altered)	% of Remaining in Large Roadless	% of Remaining in Devp. or Private Lands	Index of Cumulative Risk (% of original)
ABC Islands (all)	**186,693**	**143,383**	**23.5%**	**23.2%**	**24.0%**	**11.3%**	**31.9%**
Admiralty Island	107,848	98,364	13.6%	8.8%	7.2%	0.9%	9.6%
E. Baranof Island	6,126	1,918	0.8%	68.7%	74.4%	38.0%	80.6%
E. Chichagof Island	60,188	36,457	7.6%	39.4%	64.3%	37.2%	61.9%
W. Baranof Island	10,530	4,645	1.3%	55.9%	44.9%	23.8%	66.4%
W. Chichagof Island	2,000	2,000	0.3%	0.0%	18.2%	0.0%	0.0%
Central Islands (all)	**165,966**	**98,728**	**20.9%**	**40.5%**	**58.8%**	**44.9%**	**67.2%**
Etolin Zarembo Island Complex	25,292	11,777	3.2%	53.4%	51.5%	51.4%	77.4%
N. Kuiu Island	31,686	23,828	4.0%	24.8%	46.3%	61.6%	71.1%
S. Kuiu Island	12,424	11,194	1.6%	9.9%	49.6%	22.7%	30.3%
Kupreanof / Mitkof Islands	42,783	20,342	5.4%	52.5%	66.3%	51.9%	77.1%
Revilla Island / Cleveland Peninsula	53,780	31,586	6.8%	41.3%	69.3%	33.4%	60.9%
Prince of Wales Group (all)	**305,924**	**182,960**	**38.4%**	**40.2%**	**48.3%**	**43.6%**	**66.3%**
Dall Island Complex	20,105	8,650	2.5%	57.0%	85.1%	21.9%	66.4%
North Prince of Wales Complex	219,553	120,243	27.6%	45.2%	39.6%	47.6%	71.3%
Outside Islands	18,513	12,642	2.3%	31.7%	53.3%	33.4%	54.5%
South Prince of Wales Island	47,751	41,425	6.0%	13.2%	67.7%	37.7%	46.0%
Mainland (all)	**103,984**	**90,771**	**13.1%**	**12.7%**	**52.2%**	**27.0%**	**36.3%**
Lynn Canal / Mainland	18,186	16,261	2.3%	10.6%	71.7%	35.5%	42.3%
North Misty Fjords	16,398	16,393	2.1%	0.0%	10.0%	7.1%	7.1%
South Misty Fjords	14,105	14,105	1.8%	0.0%	32.3%	0.0%	0.0%
Stikine River / Mainland	25,301	20,707	3.2%	18.2%	55.3%	35.1%	46.9%
Taku River / Mainland	29,994	23,305	3.8%	22.3%	77.8%	44.2%	56.6%
Yakutat (all)	**33,114**	**27,003**	**4.2%**	**18.5%**	**77.4%**	**36.1%**	**47.9%**
Yakutat Forelands	33,114	27,003	4.2%	18.5%	77.4%	36.1%	47.9%
Grand Total	**795,680**	**542,846**	**100.0%**	**31.8%**	**45.9%**	**32.1%**	**53.7%**

Table 3. A comparison of contiguous landscape forests among biogeographic provinces, change over time, contribution of large inventoried roadless areas, Index of Vulnerability and Index of Cumulative Risk in Large Roadless Areas.

Biogeographic Provinces	Contiguous Landscape Forest 1954	Contiguous Landscape Forest 2018	Index of Relative Biological Value	Index of Current Condition (% altered)	% of Remaining in Large Roadless	% of Remaining in Devp. or Private Lands	Index of Cumulative Risk (% of original)
ABC Islands (all)	**605,064**	**420,243**	**23.5%**	**30.5%**	**33.4%**	**12.0%**	**38.9%**
Admiralty Island	310,967	268,361	12.1%	13.7%	8.7%	0.9%	14.4%
E. Baranof Island	32,839	14,623	1.3%	55.5%	93.1%	45.4%	75.7%
E. Chichagof Island	203,577	101,743	7.9%	50.0%	78.3%	34.2%	67.1%
W. Baranof Island	51,281	28,815	2.0%	43.8%	77.4%	22.7%	56.5%
W. Chichagof Island	6,400	6,700	0.2%	-4.7%	21.0%	0.1%	-4.6%
Central Islands (all)	**630,766**	**358,675**	**24.5%**	**43.1%**	**62.3%**	**32.4%**	**61.6%**
Wrangell Etolin Zarembo Islands	93,938	48,972	3.6%	47.9%	66.9%	43.2%	70.4%
N. Kuiu Island	95,502	52,293	3.7%	45.2%	73.6%	39.3%	66.7%
S. Kuiu Island	67,039	61,162	2.6%	8.8%	33.3%	16.1%	23.5%
Kupreanof / Mitkof Islands	145,691	64,315	5.7%	55.9%	55.1%	48.5%	77.3%
Revilla Island / Cleveland Peninsula	228,597	131,933	8.9%	42.3%	73.0%	25.3%	56.9%
Prince of Wales Group (all)	**712,701**	**241,072**	**27.7%**	**66.2%**	**66.1%**	**29.0%**	**76.0%**
Dall Island Complex	76,128	39,636	3.0%	47.9%	76.8%	32.5%	64.9%
North Prince of Wales Complex	494,468	111,108	19.2%	77.5%	60.0%	34.1%	85.2%
Outside Islands	75,924	47,719	2.9%	37.1%	70.5%	12.1%	44.8%
South Prince of Wales Island	66,181	42,609	2.6%	35.6%	68.1%	32.0%	56.2%
Mainland (all)	579,796	517,498	**22.5%**	**10.7%**	**57.0%**	**26.3%**	**34.2%**
Lynn Canal / Mainland	90,291	80,461	3.5%	10.9%	75.9%	30.9%	38.4%
North Misty Fjords	60,747	60,824	2.4%	-0.1%	8.2%	3.3%	3.1%
South Misty Fjords	72,241	72,505	2.8%	-0.4%	30.0%	0.1%	-0.3%
Stikine River / Mainland	154,501	131,551	6.0%	14.9%	70.6%	26.2%	37.2%
Taku River / Mainland	202,016	172,157	7.8%	14.8%	66.5%	43.3%	51.7%
Yakutat (all)	**47,151**	**27,598**	**1.8%**	**41.5%**	**43.6%**	**42.3%**	**66.2%**
Yakutat Forelands	47,151	27,598	1.8%	41.5%	43.6%	42.3%	66.2%
Grand Total	**2,575,478**	**1,565,086**	**100%**	**39.2%**	**53%**	**24.5%**	**54.1%**

Table 4. A comparison of the regional distribution of brown and black bear habitat capability, change over time, contribution of large inventoried roadless areas and cumulative risk in southeastern Alaska.

Biogeographic Provinces	Habitat Capability Index		Index of Relative Biological Value	Index of Current Condition (% altered)	% of Remaining in Large Roadless	% of Remaining in Devp. or Private Lands	Index of Cumulative Risk (% of original)
	1954	2018					
ABC Islands (all)	**4,226**	**2,860**	**24.7%**	**32.3%**	**37.7%**	**16.1%**	**43.2%**
Admiralty Island	1,373	1,136	8.0%	17.2%	5.4%	1.0%	18.1%
E. Baranof Island	358	219	2.1%	38.7%	66.0%	25.6%	54.4%
E. Chichagof Island	1,463	752	8.6%	48.6%	70.3%	42.3%	70.3%
W. Baranof Island	786	525	4.6%	33.3%	58.5%	14.2%	42.7%
W. Chichagof Island	247	228	1.4%	7.6%	15.5%	0.3%	7.9%
Central Islands (all)	**4,141**	**2,305**	**24.2%**	**44.3%**	**61.1%**	**42.0%**	**67.7%**
Etolin Zarembo Island Complex	622	336	3.6%	46.0%	48.9%	49.2%	72.5%
N. Kuiu Island	380	167	2.2%	56.2%	52.0%	54.8%	80.2%
S. Kuiu Island	343	257	2.0%	25.0%	37.8%	16.4%	37.3%
Kupreanof / Mitkof Islands	1,418	739	8.3%	47.9%	72.1%	53.0%	75.5%
Revilla Island / Cleveland Peninsula	1,378	806	8.1%	41.5%	65.6%	34.6%	61.8%
Prince of Wales Group (all)	**3,624**	**1,603**	**21.2%**	**55.8%**	**56.5%**	**42.3%**	**74.5%**
Dall Island Complex	210	96	1.2%	54.4%	63.2%	52.0%	78.1%
North Prince of Wales Complex	2,683	1,009	15.7%	62.4%	50.5%	51.8%	81.9%
Outside Islands	297	212	1.7%	28.5%	77.6%	15.9%	39.8%
South Prince of Wales Island	434	286	2.5%	34.0%	60.7%	26.3%	51.4%
Mainland (all)	**4,102**	**3,376**	**24.0%**	**17.7%**	**43.4%**	**14.8%**	**29.9%**
Lynn Canal / Mainland	629	426	3.7%	32.3%	74.3%	21.7%	47.0%
North Misty Fjords	741	697	4.3%	5.9%	4.3%	0.9%	6.8%
South Misty Fjords	852	804	5.0%	5.6%	12.9%	0.0%	5.7%
Stikine River / Mainland	1,000	751	5.8%	24.9%	66.4%	26.9%	45.1%
Taku River / Mainland	879	698	5.1%	20.6%	74.3%	28.6%	43.3%
Yakutat (all)	**1,009**	**651**	**5.9%**	**35.5%**	**75.5%**	**10.6%**	**42.4%**
Yakutat Forelands	1,009	651	5.9%	35.5%	75.5%	10.6%	42.4%
Grand Total	**17,101**	**10,795**	**100.0%**	**36.9%**	**49.6%**	**24.8%**	**52.5%**

Table 5. A comparison of the regional distribution of Sitka black-tailed deer habitat capability, change over time, contribution of large inventoried roadless areas and cumulative risk in southeastern Alaska.

Biogeographic Provinces	Habitat Capability Index 1954	Habitat Capability Index 2018	Index of Relative Biological Value	Index of Current Condition (% altered)	% of Remaining in Large Roadless	% of Remaining in Devp. or Private Lands	Index of Cumulative Risk (% of original)
ABC Islands (all)	**80,272**	**70,779**	**24.4%**	**11.8%**	**37.4%**	**19.5%**	**29.0%**
Admiralty Island	30,514	28,738	9.3%	5.8%	7.0%	2.1%	7.8%
E. Baranof Island	4,573	3,657	1.4%	20.0%	70.6%	41.9%	53.5%
E. Chichagof Island	24,144	19,206	7.4%	20.5%	63.4%	44.7%	56.0%
W. Baranof Island	15,609	13,755	4.8%	11.9%	64.2%	21.9%	31.2%
W. Chichagof Island	5,432	5,423	1.7%	0.2%	15.5%	0.3%	0.5%
Central Islands (all)	**92,572**	**78,644**	**28.2%**	**15.0%**	**60.8%**	**43.3%**	**51.9%**
Etolin Zarembo Island Complex	15,229	12,407	4.6%	18.5%	53.1%	51.1%	60.2%
N. Kuiu Island	8,819	6,971	2.7%	21.0%	59.5%	52.7%	62.6%
S. Kuiu Island	11,306	10,937	3.4%	3.3%	45.5%	16.9%	19.7%
Kupreanof / Mitkof Islands	26,578	21,818	8.1%	17.9%	69.2%	54.4%	62.6%
Revilla Island / Cleveland Peninsula	30,641	26,512	9.3%	13.5%	64.1%	39.0%	47.2%
Prince of Wales Group (all)	**99,195**	**71,187**	**30.2%**	**28.2%**	**52.0%**	**47.4%**	**62.3%**
Dall Island Complex	10,553	8,211	3.2%	22.2%	55.9%	54.9%	64.9%
North Prince of Wales Complex	63,453	40,907	19.3%	35.5%	46.5%	55.1%	71.1%
Outside Islands	11,117	9,393	3.4%	15.5%	62.5%	24.0%	35.8%
South Prince of Wales Island	14,072	12,675	4.3%	9.9%	59.9%	36.1%	42.4%
Mainland (all)	**48,135**	**45,858**	**14.7%**	**4.7%**	**44.9%**	**23.7%**	**27.3%**
Lynn Canal / Mainland	7,647	7,316	2.3%	4.3%	67.7%	37.8%	40.5%
North Misty Fjords	5,666	5,671	1.7%	-0.1%	6.3%	2.5%	2.4%
South Misty Fjords	11,333	11,337	3.5%	0.0%	11.1%	0.0%	0.0%
Stikine River / Mainland	12,486	11,541	3.8%	7.6%	66.6%	34.8%	39.8%
Taku River / Mainland	11,003	9,993	3.4%	9.2%	63.4%	39.6%	45.1%
Yakutat (all)	**8,186**	**6,951**	**2.5%**	**15.1%**	**63.7%**	**23.3%**	**34.8%**
Yakutat Forelands	8,186	6,951	2.5%	15.1%	63.7%	23.3%	34.8%
Grand Total	**328,361**	**273,418**	**100.0%**	**16.7%**	**49.8%**	**34.3%**	**45.3%**

Table 6. A comparison of the regional distribution of floodplain forests associated with anadromous fish habitat, forest condition, contribution of large inventoried roadless areas and cumulative risk among biogeographic provinces in southeastern Alaska.

Biogeographic Provinces	Anadromous Flood Plain All Lands (acres)	Anadromous Flood Plain Old-growth forest	Anadromous Flood Plain Young-growth forest	Index of Relative Biological Value	Index of Current Condition (% altered)	% of Remaining in Large Roadless	% of Remaining in Devp. or Private Lands	Index of Cumulative Risk (% of original)
ABC Islands (all)	**189,964**	**88,554**	**30,412**	**23.6%**	**25.6%**	**37.8%**	**29.2%**	**47.3%**
Admiralty Island	44,956	26,466	5,532	6.4%	17.3%	9.4%	1.5%	18.5%
E. Baranof Island	16,940	6,204	4,495	2.1%	42.0%	54.5%	34.4%	62.0%
E. Chichagof Island	76,682	38,213	13,862	10.3%	26.6%	51.8%	50.8%	63.9%
W. Baranof Island	38,419	12,544	6,523	3.8%	34.2%	55.7%	31.2%	54.8%
W. Chichagof Island	12,966	5,127	0	1.0%	0.0%	15.8%	0.1%	0.1%
Central Islands (all)	**208,840**	**94,661**	**16,863**	**22.2%**	**15.1%**	**55.8%**	**45.8%**	**54.0%**
Etolin Zarembo Complex	24,705	11,968	1,752	2.7%	12.8%	42.8%	49.6%	56.1%
Kuiu Island	17,362	10,710	676	2.3%	5.9%	36.8%	24.6%	29.0%
Kupreanof / Mitkof Islands	72,184	34,232	5,907	8.0%	14.7%	70.6%	45.7%	53.7%
North Kuiu	20,584	10,426	4,292	2.9%	29.2%	35.0%	56.0%	68.9%
Revilla Island / Cleveland Pen	74,004	27,325	4,237	6.3%	13.4%	58.2%	48.7%	55.6%
Prince of Wales (all)	**224,503**	**89,869**	**42,835**	**26.4%**	**32.3%**	**41.1%**	**53.1%**	**68.2%**
Dall Island Complex	14,816	5,657	2,024	1.5%	26.4%	56.6%	59.3%	70.0%
N. Prince of Wales	166,986	65,787	37,931	20.6%	36.6%	32.9%	57.5%	73.1%
Outside Islands	20,053	8,779	1,098	2.0%	11.1%	67.9%	36.2%	43.3%
S. Prince of Wales	22,648	9,646	1,783	2.3%	15.6%	65.3%	35.1%	45.2%
Mainland (all)	**290,805**	**105,638**	**13,379**	**23.7%**	**11.2%**	**44.6%**	**21.9%**	**30.7%**
Lynn Canal	49,240	14,612	1,996	3.3%	12.0%	57.1%	50.3%	56.3%
North Misty Fjords	60,126	16,058	0	3.2%	0.0%	4.3%	3.2%	3.2%
South Misty Fjords	40,261	23,732	0	4.7%	0.0%	32.7%	0.0%	0.0%
Stikine River	79,364	30,439	7,725	7.6%	20.2%	55.5%	18.2%	34.7%
Taku River	61,813	20,797	3,658	4.9%	15.0%	64.9%	47.1%	55.0%
Yakutat (all)	**167,569**	**16,764**	**4,217**	**4.2%**	**20.1%**	**68.8%**	**28.1%**	**42.6%**
Yakutat Forelands	167,569	16,764	4,217	4.2%	20.1%	68.8%	28.1%	42.6%
Grand Total	**1,081,681**	**395,484**	**107,706**	**100.0%**	**21.4%**	**46.0%**	**36.5%**	**50.1%**

Table 7. A comparison of combined indicators of biological value among biogeographic provinces, including current condition, % of remaining in large roadless areas, % of remaining in development lands, and cumulative ecological risk.

Biogeographic Provinces	Index of Relative Biological Value	Index of Current Condition (% altered)	% of Remaining in Large Roadless	% of Remaining in Devp. or Private Lands	Index of Cumulative Risk (% of original)
ABC Islands (all)	**24.2%**	**24.6%**	**34.4%**	**17.1%**	**37.5%**
Admiralty Island	9.7%	11.7%	7.2%	1.2%	12.6%
E. Baranof Island	1.6%	44.7%	71.5%	36.7%	64.8%
E. Chichagof Island	8.4%	36.7%	66.5%	41.0%	63.0%
W. Baranof Island	3.4%	36.4%	60.7%	22.1%	50.2%
W. Chichagof Island	1.0%	1.6%	16.4%	0.2%	0.8%
Central Islands (all)	**23.7%**	**31.6%**	**59.7%**	**41.0%**	**59.8%**
Wrangell / Etolin / Zarembo	3.5%	35.3%	51.9%	48.7%	66.9%
N. Kuiu Island	3.1%	35.4%	52.4%	51.0%	68.6%
S. Kuiu Island	2.4%	10.6%	39.8%	18.2%	26.8%
Kupreanof / Mitkof Islands	7.0%	37.6%	66.7%	50.6%	68.9%
Revilla Island / Cleveland Peninsula	7.8%	30.5%	66.9%	35.3%	55.7%
Prince of Wales Group (all)	**28.4%**	**44.5%**	**52.8%**	**42.2%**	**68.9%**
Dall Island Complex	2.3%	41.4%	67.3%	44.7%	69.1%
North Prince of Wales Complex	20.2%	51.5%	45.9%	48.3%	76.0%
Outside Islands	2.4%	24.6%	67.4%	23.2%	42.5%
South Prince of Wales Island	3.6%	21.3%	64.6%	32.3%	47.0%
Mainland (all)	**20.0%**	**11.1%**	**48.4%**	**21.9%**	**30.6%**
Lynn Canal	3.0%	14.0%	68.4%	35.8%	45.3%
North Misty Fjords	2.9%	1.2%	6.3%	3.3%	4.4%
South Misty Fjords	3.8%	1.1%	24.7%	0.0%	1.1%
Stikine River	5.2%	16.6%	65.3%	27.8%	40.1%
Taku River	5.1%	16.4%	68.4%	39.0%	49.1%
Yakutat (all)	**3.7%**	**25.6%**	**64.5%**	**29.4%**	**47.5%**
Yakutat Forelands	3.7%	25.6%	64.5%	29.4%	47.5%
Grand Total	**100.0%**	**29.0%**	**48.8%**	**29.7%**	**50.4%**

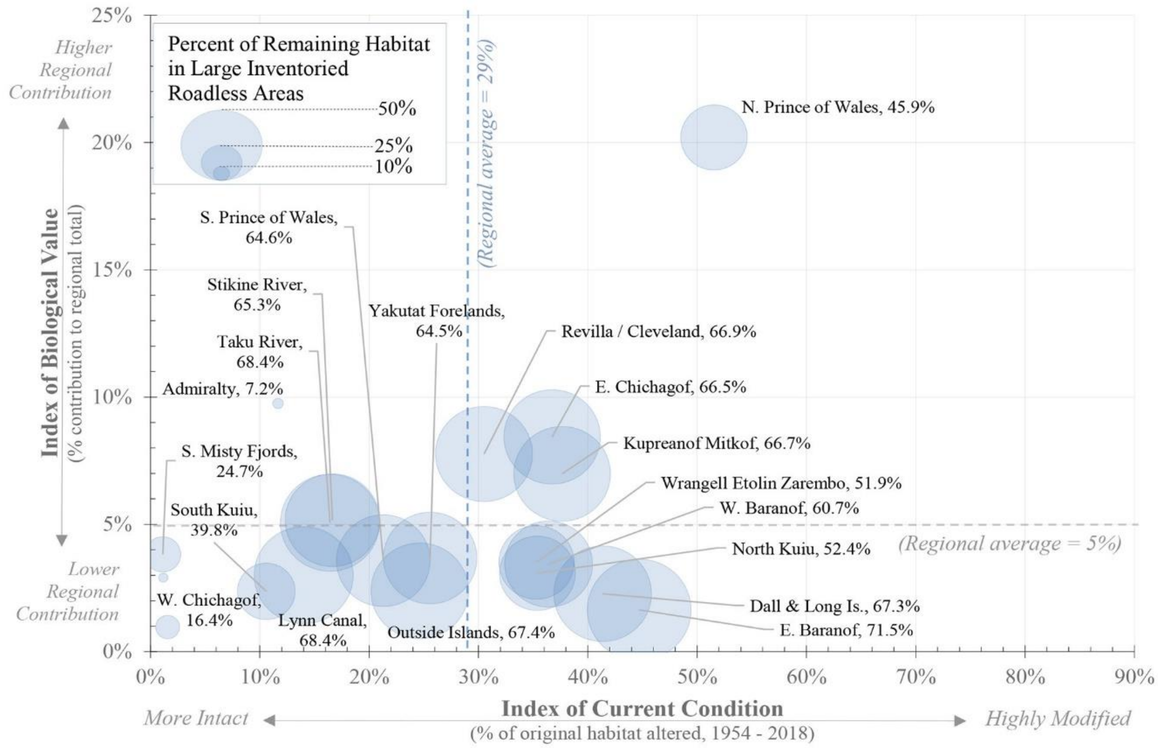

Figure 5(a). A comparison of biological value (y-axis), current condition (x-axis) and percent remaining biological values in large roadless areas (bubble size) among biogeographic provinces.

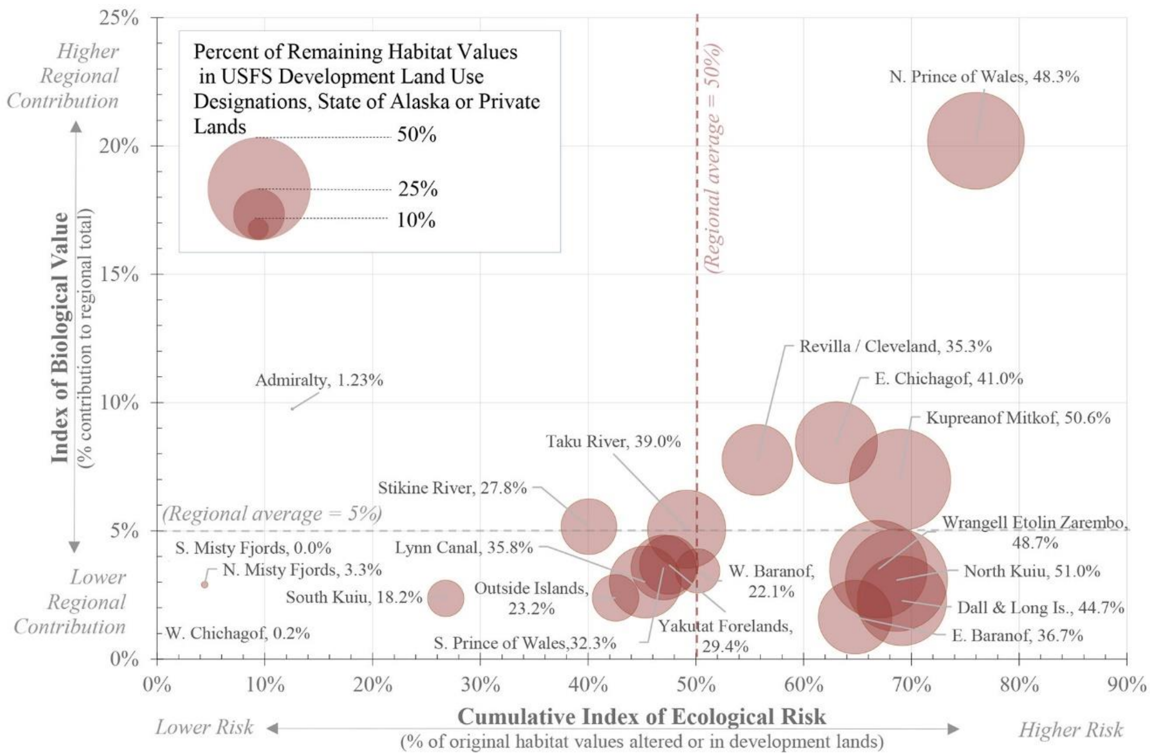

Figure 5(b). A comparison of biological value (y-axis), cumulative ecological risk (x-axis) and percent remaining biological values in development lands (bubble size) among biogeographic provinces.

DISCUSSION

In this study, we evaluated the importance of roadless areas toward the goal of maintaining viable and well distributed populations of fish and wildlife in Southeast Alaska. We based this assessment on 4 criteria: (1) the relative distribution of fish and wildlife habitat values among biogeographic provinces; (2) the current condition of habitats compared with pre-industrial conditions; (3) the proportion of remaining habitat values that are located within large roadless areas; and (4) the proportion of remaining values located in lands open to future development. Provinces that contain a disproportionate share of all habitat values within the region, those with high levels of past logging and/or vulnerable to future development, as well as those with a high proportion of remaining resources located in roadless areas are all candidates for special consideration.

Specific thresholds at which habitat alteration affects population viability is difficult to determine (Fahrig 2001). However, results of a review of habitat thresholds literature (to inform forest planning in coastal British Columbia) indicated that maintaining loss of habitat below 40% of historical abundance poses a low risk to most species, whereas declines above that level result in less confidence that risks of extirpation will remain low (Price et al. 2009). We used this general rule of thumb that modification of >40% of the original distribution for any biological indicator can no longer be considered low risk and warrants further detailed investigation.

No biological indicators exceeded the 40% threshold based on current alteration from original conditions region-wide, although loss of contiguous old-growth forest landscapes was approaching that value with a decline of 39.2% (Table 3). Within individual provinces, a total of 25 indicators exceeded the 40% threshold, including loss of contiguous forest landscapes (9 provinces; Table 3), decline in bear habitat (8 provinces; Table 4), loss of large-tree forests (7 provinces; Table 2) and logging of salmon floodplain forests (1 province; Table 6). Among provinces, 3 provinces exceeded this threshold of 40% decline for all indicators combined, including North Prince of Wales, Dall & Long Islands and East Baranof (Fig. 5a). Based on this analysis, the 2 indicators that were least sensitive to effects of past logging were total POG (Table 1) and deer habitat (Table 5).

Figure 6. North Prince of Wales Island contains the highest proportion of biological values of any biogeographic province (20.2% of regional total), but also the highest degree of alteration from historical conditions (51.5%), and the highest index of cumulative ecological risk under the ‘full exemption’ alternative (75%).

Potential future change in ecological conditions is particularly difficult to predict, but our Index of Cumulative Risk is a reasonable approximation to describe the proportion of fish and wildlife habitat values located within landscapes generally designated for various levels of resource development. According to this accounting, 4 of 5 indicators we evaluated surpassed the 40% threshold region-wide, with deer habitat being the only exception (Table 7). Regionwide, the average decline across all these indicators was 50.4%, and 15 of the 20 biogeographic provinces exceeded that threshold (Fig. 5b).

In this context, the remaining 48.8% ecological values contained in large inventoried roadless areas represents an important opportunity to maintain viable and well-distributed populations of fish and wildlife, and the variety of services these species provide (Table 7). Provinces with the highest proportion of remaining habitat located in large roadless areas included both highly modified provinces, such as East Baranof (71.5%), and the relatively intact provinces of the northern mainland, including Lynn Canal and Taku River (68.5%; Fig. 5a).

North Prince of Wales Island stands out as the most biologically important province in the region (Fig. 5a), with highest levels of both past logging and potential future modification based on land ownership and management (Fig 5b). Indeed, the entire Prince of Wales Island Group already exceeds the 40% threshold for habitat modification based on the average of 5 indicators we examined (Table 7). The degree of modification and fragmentation evident in the central portion of Prince of Wales Island (Fig. 6) is unique in Southeast Alaska, and more reminiscent of areas in the Pacific Northwest where populations of important fish and wildlife species have been listed under the Endangered Species Act and experience ongoing challenges (Spies et al. 2018). To avoid that fate, we recommend that remaining roadless areas on North Prince of Wales Island be given special consideration to maintain these rare forest conditions.

Of all the biological indicators that we examined, the 77.5% loss of contiguous forests on North Prince of Wales was the single greatest indicator of risk in the entire region (Fig. 4). In addition, most remaining contiguous old-growth forest landscapes only occur in large roadless areas, both on North Prince of Wales (60%) and region-wide (53%; Table 3). This was the highest association of a biological indicator to large roadless areas of any that we examined. This is of particular concern on Prince of Wales because contiguous old-growth forest landscapes there provide critical habitat for a sub-species of northern flying squirrel endemic to these islands

(Smith 2005). Moreover, recent studies have demonstrated that the composition and spacing of old-growth reserves in the Tongass Land Management Plan may not support viable populations over the long term (Pyare and Smith 2005), and habitat requirements of this species make it unlikely to persist in more fragmented landscapes (Shanley et al. 2013). The El Capitan and Salmon Bay roadless areas on the north end of Prince of Wales Island are particularly vulnerable under the Preferred Alternative to the Alaska Roadless Rule DEIS (Fig. 7).

The DEIS recognizes that proposed actions to remove protective measures for existing roadless areas would contribute to the cumulative reduction in POG and increase risks to biological diversity from fragmentation and loss of connectivity among old growth forests (USFS 2019: p. 3-68). Nonetheless, the DEIS does not calculate the degree to which human-caused fragmentation has already occurred, the relative severity of fragmentation among biogeographic provinces (Fig 5a), or adequately quantitatively evaluate the consequences of such fragmentation on biological diversity (USFS 2019, P2-28). This is a particularly serious omission given recent studies that document the degree to which past logging has disproportionately targeted contiguous, high-volume forest landscapes (Albert & Schoen 2013). Our study determined that region-wide, the loss of contiguous forest landscapes was 383% more severe (Table 3) than loss of POG in general (Table 1) and may be an important metric for evaluation in Tongass National Forest planning processes.

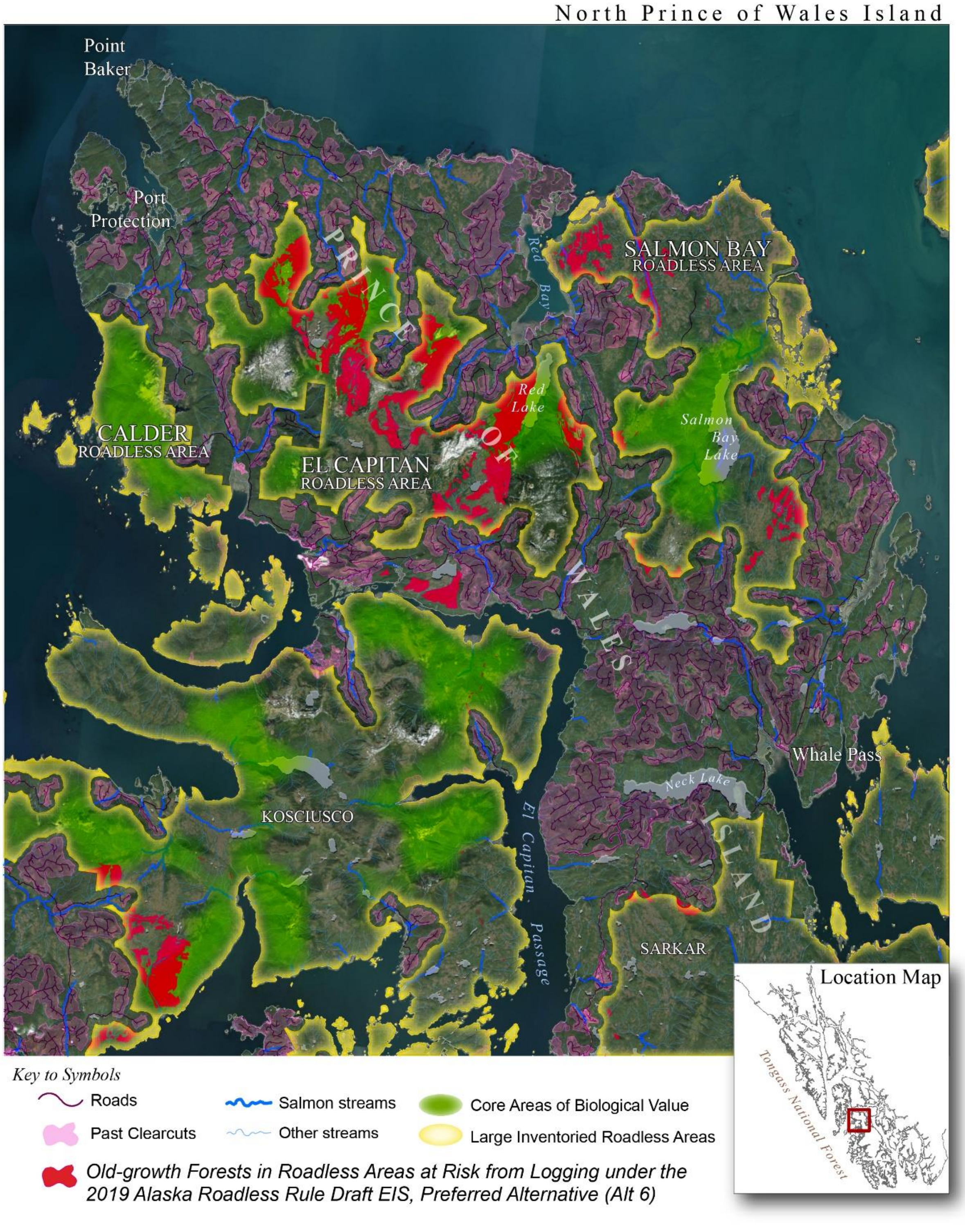

Figure 7. The 2019 Alaska Roadless Rule DEIS does not quantify landscape-scale effects to old-growth forests, yet identifies some of the last remaining contiguous old-growth landscapes on North Prince of Wales Island as “suitable” for logging under the Preferred Alternative (Alt. 6)

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