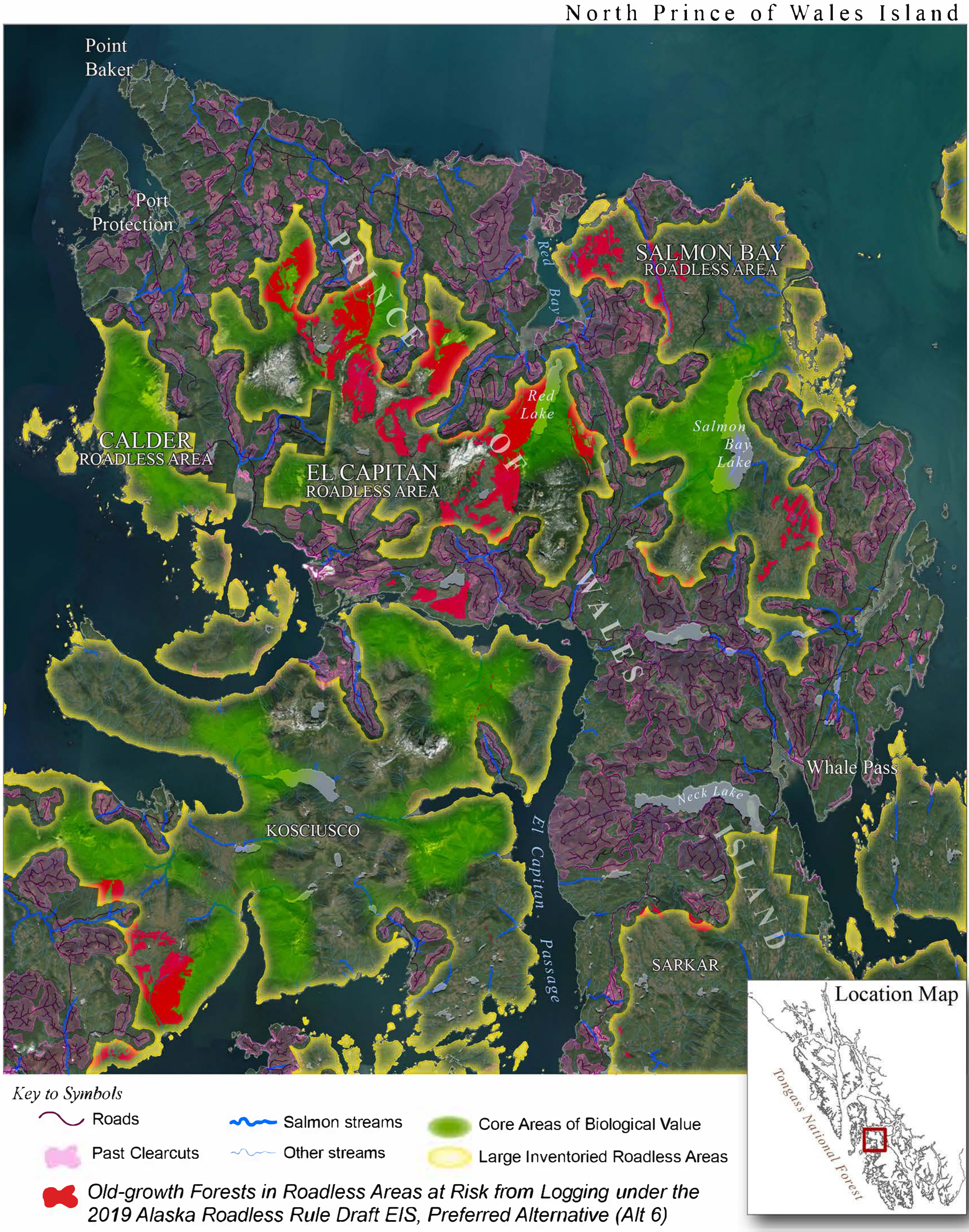
Conservation Significance of

Large Inventoried Roadless Areas

on the Tongass National Forest

North Prince of Wales Island



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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).

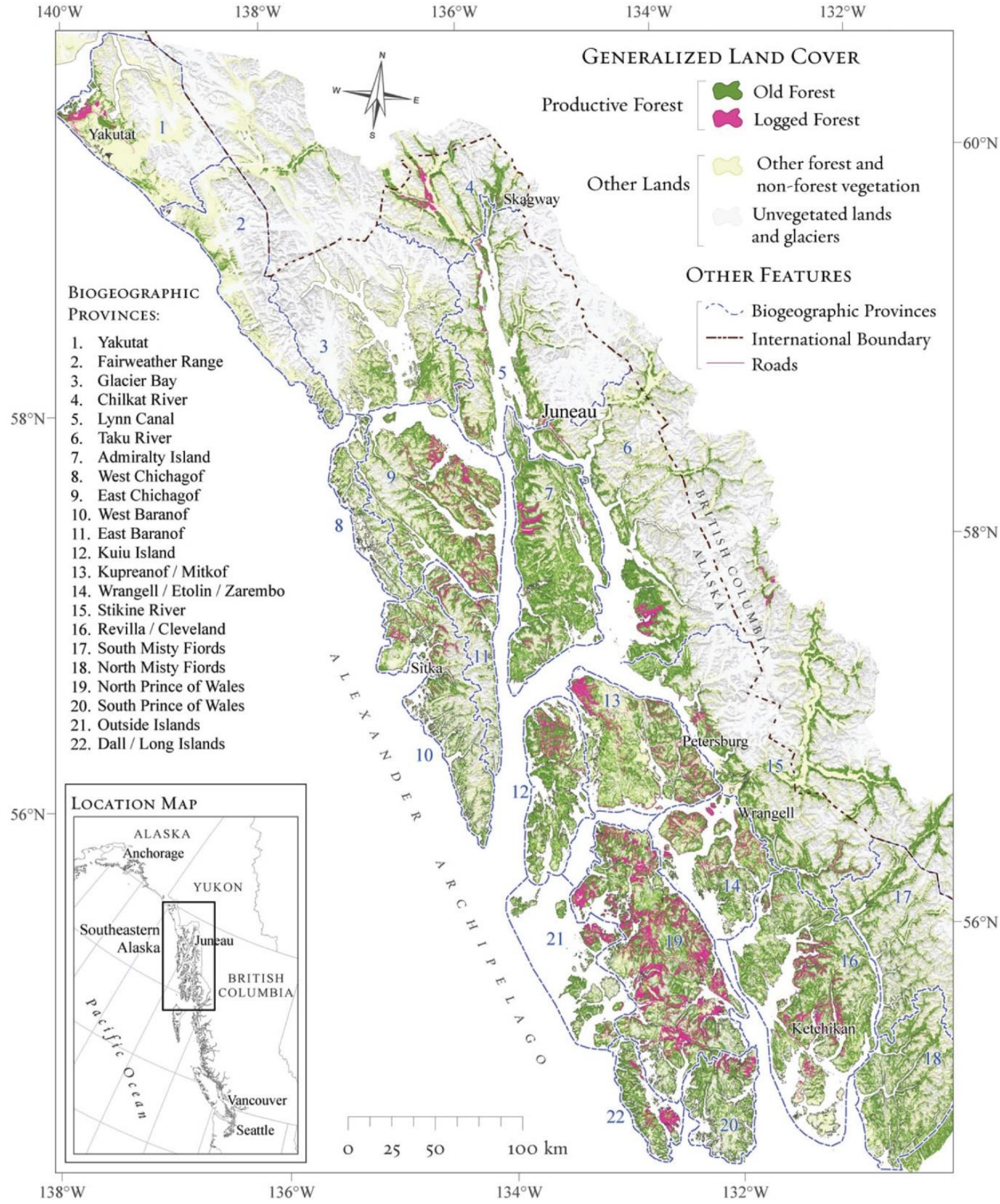

Figure 1. Forest condition and generalized landcover in Southeast Alaska (from Albert and Schoen 2013)

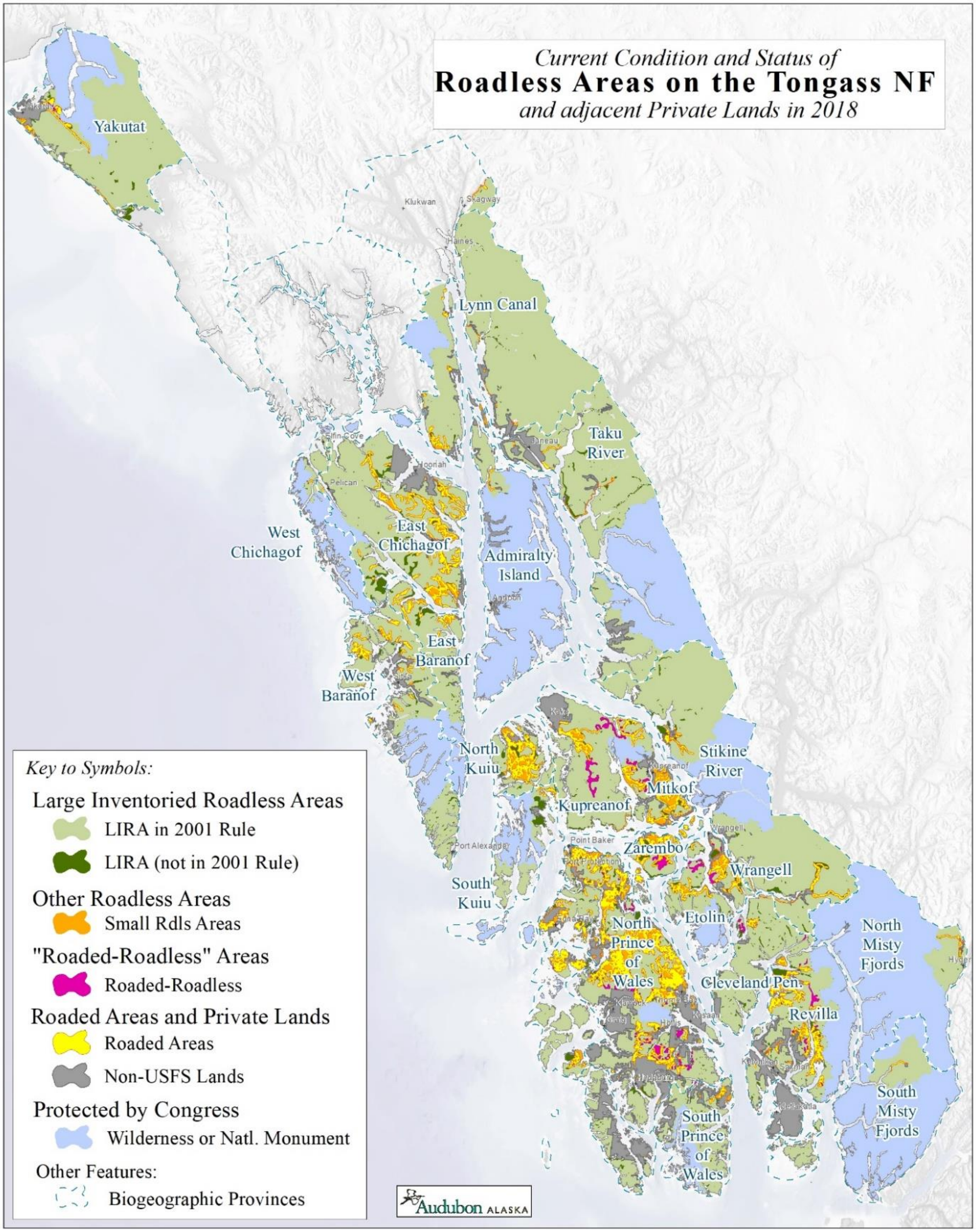

Figure 2. Study area and roadless status of the Tongass National Forest and adjacent private lands.

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).

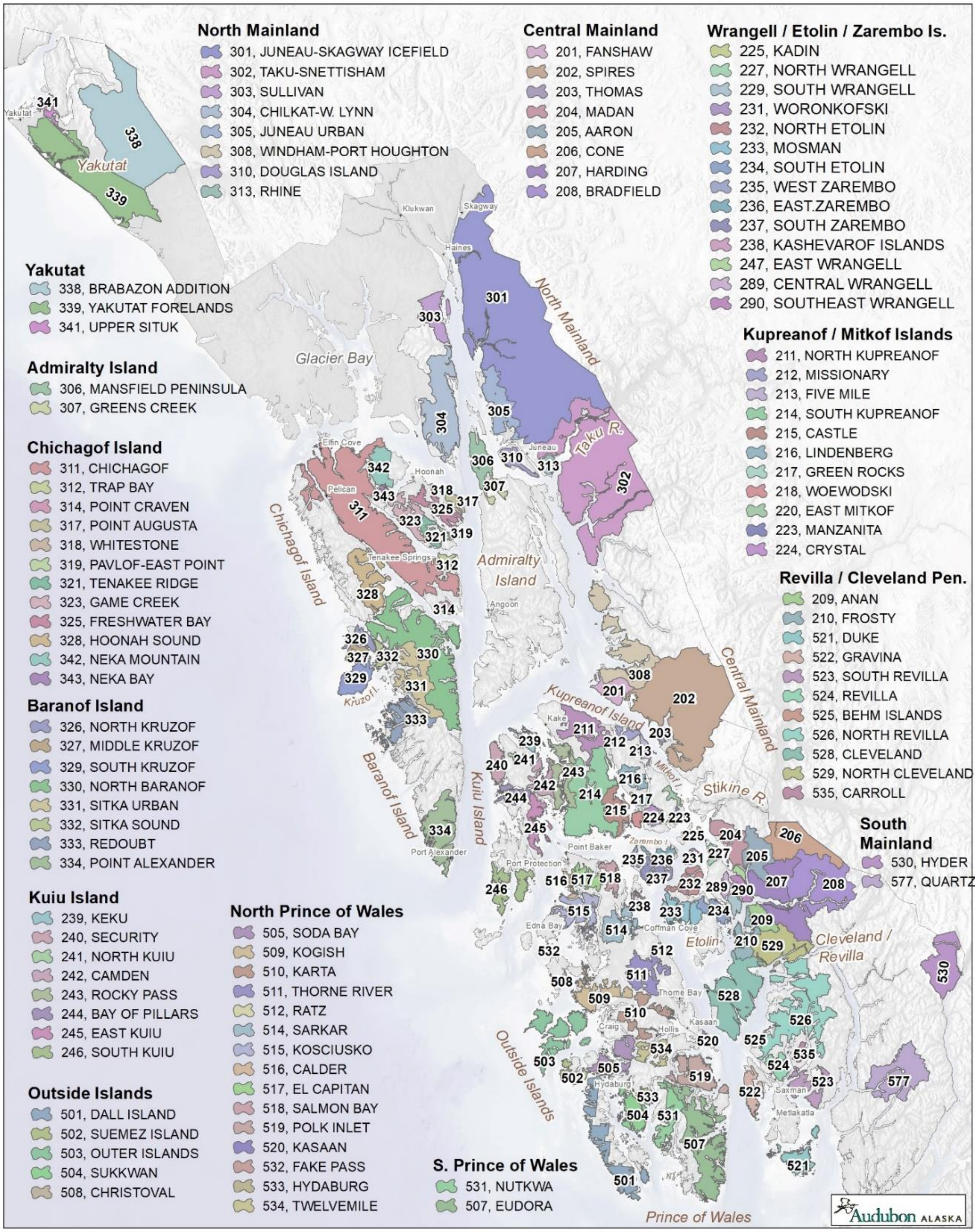

Figure 3. Named roadless areas in 2003 Tongass Roadless Inventory (USFS 2003).

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:

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

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).

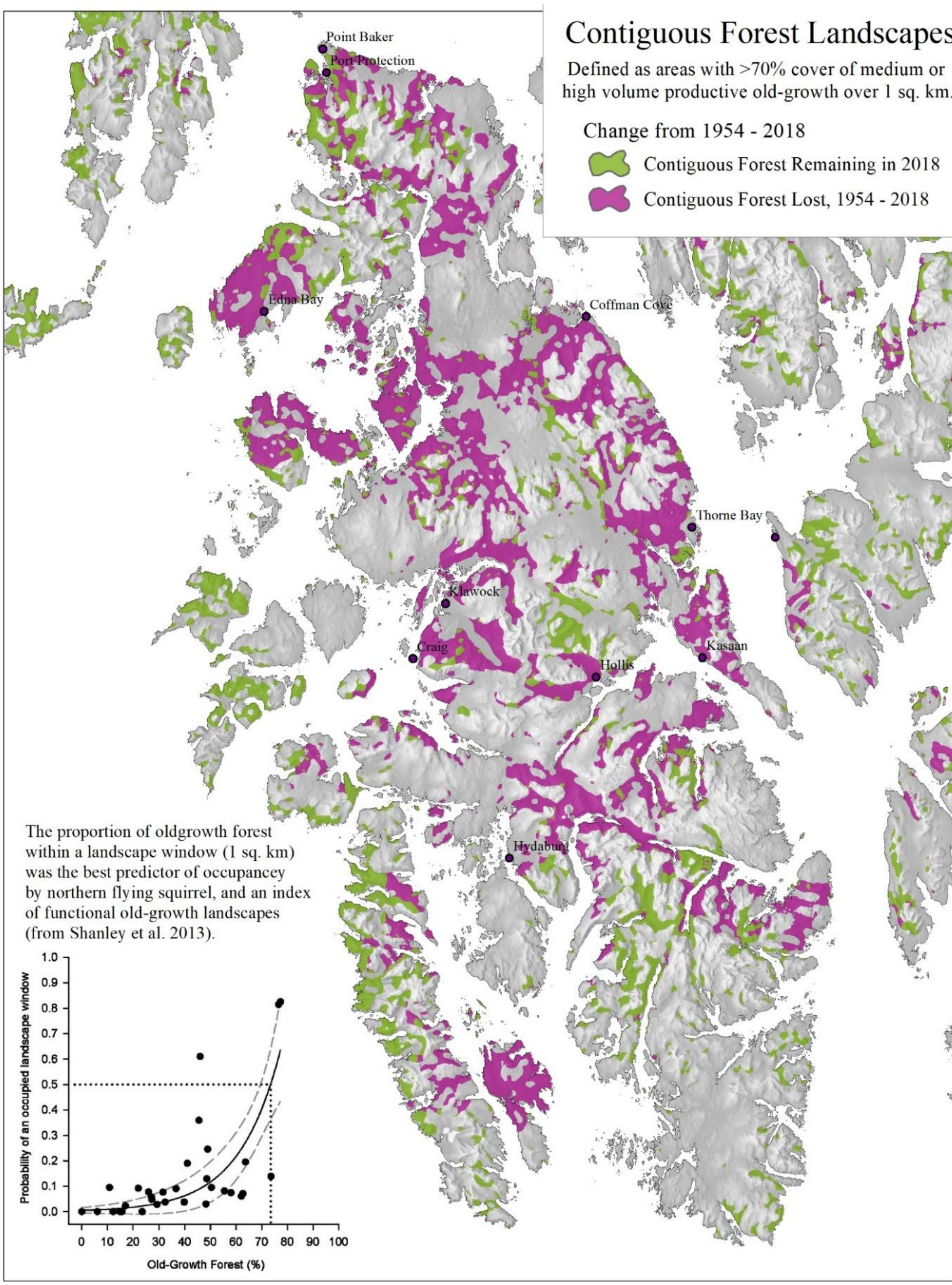

Figure 4. Change in distribution of contiguous forests at a landscape scale (1sq. km), 1954 - 2018

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		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)	**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 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)	**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%**

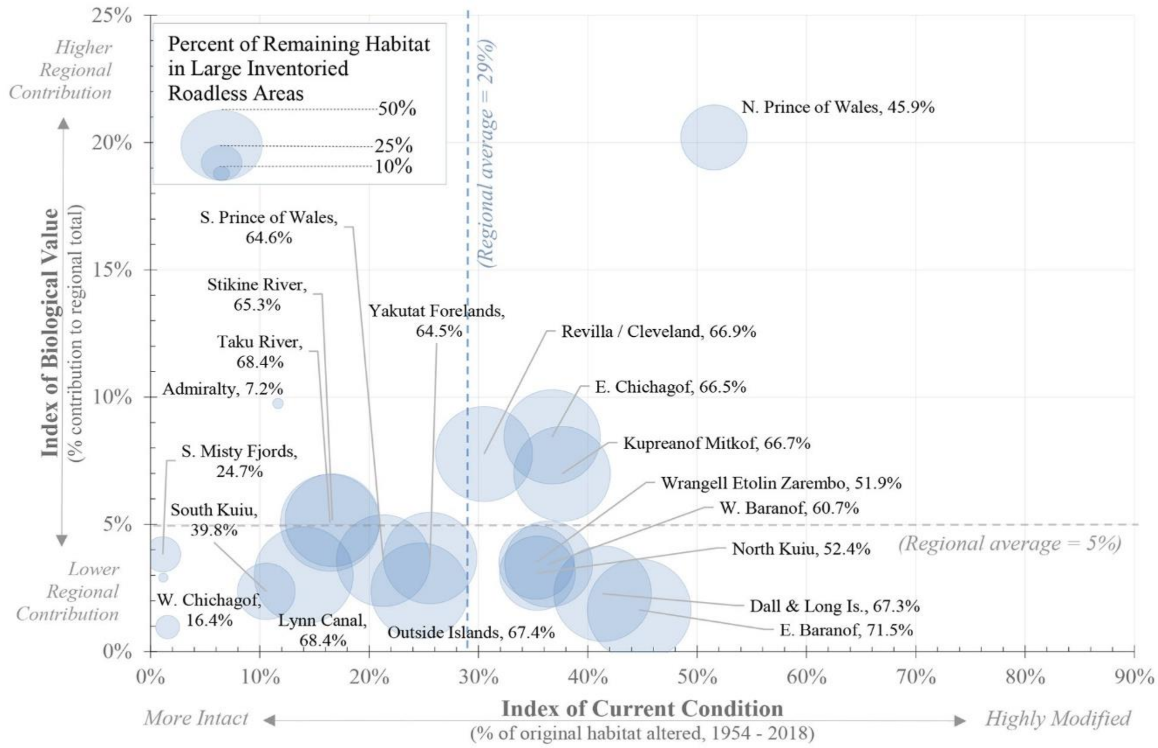

Figure 5(a). A comparison of biological value (y-axis), current condition (x-axis) and percent remaining biological values in large roadless areas (bubble size) among biogeographic provinces.

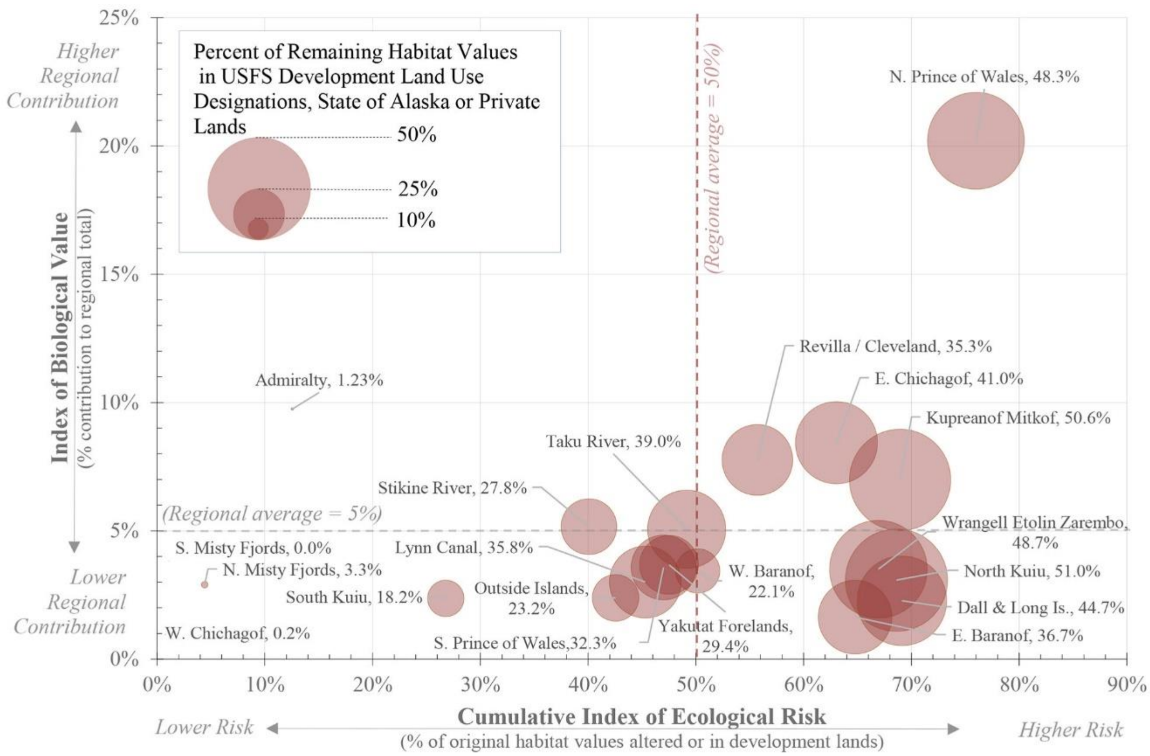

Figure 5(b). A comparison of biological value (y-axis), cumulative ecological risk (x-axis) and percent remaining biological values in development lands (bubble size) among biogeographic provinces.

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.

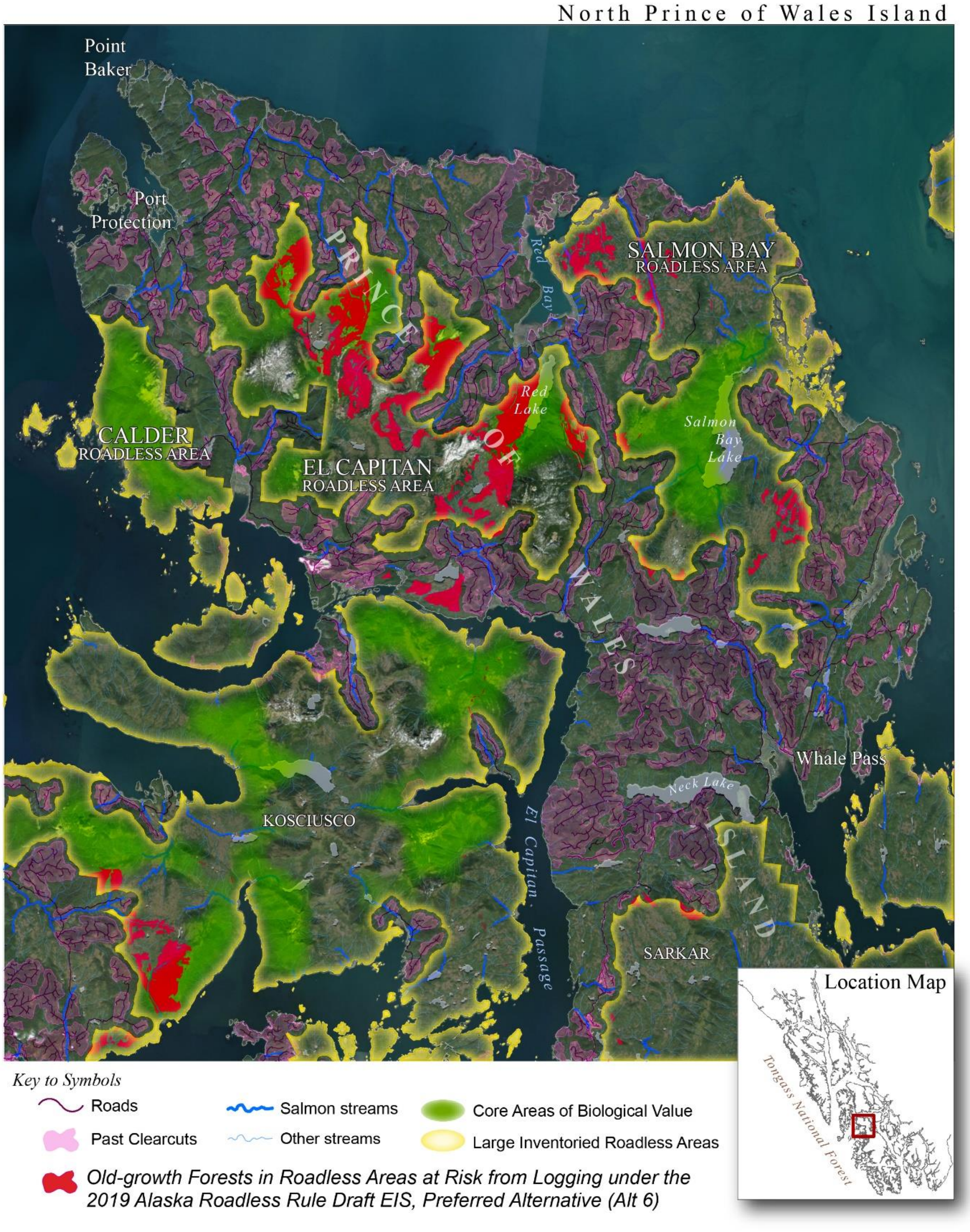

Figure 7. The 2019 Alaska Roadless Rule DEIS does not quantify landscape-scale effects to old-growth forests, yet identifies some of the last remaining contiguous old-growth landscapes on North Prince of Wales Island as "suitable" for logging under the Preferred Alternative (Alt. 6)

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Comments on Fisheries and Water Quality Issues in the US Forest Service Draft Environmental Impact Statement for the Alaska Roadless Rule, December 2019.

FINAL 16 December 2019

1. Introduction

1.1 Scope and Importance of Review

I was commissioned in November and December 2019 by The Wilderness Society to review the US Forest Service's Draft Environmental Impact Statement for the Alaska Roadless Rule (https://www.fs.usda.gov/nfs/11558/www/nepa/109834_FSPLT3_4876629.pdf) (herein after, "DEIS"). The Society asked me to prepare comments on water quality and fisheries effects on the Tongass National Forest, as they are addressed, or not addressed in the DEIS, based on best available scientific information and my professional opinion as an aquatic scientist with expertise in freshwater ecology, fish conservation, watershed processes, environmental impact assessment and land and water resource planning. The observations and opinions in this document are expressly my own.

The resource at risk from logging and road construction on roadless lands of the Tongass National Forest is considerable at a regional and national scale (Byrant 2011, Halupka et al. 2003, Bryant and Everest 1998, Everest et al. 1997). Freshwater habitat on the Tongass National Forest produced roughly 25% of Alaska's commercial salmon catch in the past decade, with an average annual dockside landed value of US$88 million (Johnson et al. 2019). Despite recognized harms to salmon habitat in some watersheds from past timber harvesting and road construction, the Tongass National Forest produces more wild salmon by far than any other national forest in the nation. This globally impressive productivity is in large part attributed to the extensive area of unlogged, roadless watersheds on the national forest, where ecological integrity water quality, biophysical diversity, and the productive capacity of freshwater habitat for salmon remain high (Halupka et al. 2003, Bryant and Everest 1998, Everest et al. 1997).

The proposed Alaska Roadless Rule would exempt the Tongass National Forest from the 2001 Roadless Area Conservation Rule and thereby remove that rule's prohibitions against road construction and timber cutting on all of the 9.2 million acres of inventoried roadless areas in the Tongass. The DEIS evaluates several other alternatives that provide varying levels of protection for Tongass roadless areas, but none are as protective as the No Action alternative.

The Forest Service's evaluation of impacts to fish habitat and salmon harvest are summarized as follows: "Overall effects to fish habitat are expected to be negligible under all alternatives, because of the strong protections to fish habitats provided by Forest Plan LUDs, Forest-wide standards and guidelines including the riparian management strategy, and the lack of old-growth harvest or associated road construction allowed in the T77 watersheds and TNC /Audubon Conservation Priority Areas" (DEIS ES-15). The DEIS further states that "localized effects on fish habitat may occur, but these are expected to be minimal overall" (DEIS ES-15). Consequently, according to the DEIS, "None of the alternatives are expected to have a significant change to the commercial fishing or fish-processing industries" (DEIS ES-13).

For reasons discussed below, these erroneous assumptions and conclusions in the DEIS are based on a grossly inadequate consideration of the best available science regarding the effects of road construction and logging on aquatic ecosystems.

1.2 Qualifications

I am a consulting aquatic ecologist and watershed scientist with expertise in land management and conservation and restoration strategies for fishes and amphibians, with extensive experience with Pacific salmon, native trout and charr. I also serve as Affiliate Research Professor at Flathead Lake Biological Station, the University of Montana. My expertise is outlined in my CV, which is appended to this declaration.

My education is as follows. I hold a Bachelors degree in Zoology from the University of Montana, and Masters and PhD degrees in Fisheries Science from Oregon State University, where the focus of my graduate research was the cumulative effect of land use and watershed disturbance on freshwater ecosystems and fish populations.

I have 30 years of experience as a research scientist in the field of aquatic ecology, fishery and conservation biology, and watershed science, having held research faculty positions at The University of Montana and Oregon State University. I have more than 40 scientific and technical publications in aquatic ecology, fishery and conservation biology, and watershed science, in professional journals, symposia, books, and book chapters, and also am author of more than 30 research reports for various institutions and agencies. I have served as peer reviewer or reviewing editor for more than a dozen professional journals and government research publications. I have served on 13 professional and government panels that provided technical guidance about stream and river protection to state and federal wildlife and forest management agencies in three states, including technical panels that advised Oregon state agencies on water temperature standard development, and forestry landslide prevention rulemaking. I later served on Montana governor's scientific panel to inform that state's restoration strategy for threatened bull trout, and participated in Forest Service expert panels assessing the efficacy of regional plans for conservation of freshwater species, including amphibians. I have commented or served as an expert witness in litigation of numerous national forest plans and federal forest project and programmatic NEPA efforts since about 1980. In Alaska, I sponsored a PhD student who studied ecology and conservation headwater trout populations in southeast Alaska (Hastings 2005); contracted with USEPA to evaluate impacts of roads and pipelines in possible mine development in Bristol Bay; and reviewed environmental impact statements for mine and mine road development in Bristol Bay and the Ambler Mining District of the Brooks Range.

While on the faculty as a researcher at Oregon State University, I was funded to lead a 6-year research project on salmon habitat protection in Oregon coastal rivers. In 1992 I completed my doctoral dissertation on the cumulative effects of land use on salmon habitat in Oregon South Coast rivers. That research focused on the full spectrum of threats to physical habitat of salmon in coastal watersheds, including water temperature, sediment conditions, landslides and road erosion, large wood, and channel dynamics. As the dominant land use in the region, forestry was a primary topic of that research.

For ten years I was a full-time Research Assistant Professor and Research Associate Professor at the University of Montana's Flathead Lake Biological Station, where I continued to conduct research on salmon ecology and freshwater habitat conservation. For 11 years I held the positions (alternately) of Senior Staff Scientist or Conservation and Science Director with the Pacific Rivers Council, where I worked specifically on the interface of scientific information and land management, with considerable involvement in forest management policy development for stream protection and salmon and trout recovery, including in coastal Oregon. My work in particular has focused on the scientific adequacy of federal forest land planning and aquatic conservation policies, and I have special expertise in the manifold impacts on freshwater habitat and salmonid fishes of roads and road development in roadless forested watersheds.

1.3 Overview of Documents Reviewed

In preparing these comments I reviewed relevant portions of the DEIS and other Forest Service planning documents and other reports and articles from the scientific literature, as cited in the text below. In particular in the DEIS, I reviewed material in section 1 on aquatic habitat, soils, and water quality impacts; in section 2 on expected change in salmon harvest and fish habitat; and in section 3 on soils and water, salmon harvest, fisheries, and transportation and roads.

2. Priority Watersheds and the Long-Term Conservation of Salmon Ecosystems

Although salmon in southeast Alaska represent five relatively widely distributed species, homing to natal habitats in combination with a diversity of habitat configurations and conditions has provided a ripe evolutionary field for the emergence of many distinct, locally adapted ecotypes within these species in southeast Alaska (Halupka et al. 2003). This diversity of habitats and locally adapted ecotypes is the very basis of salmon species productivity (Brennan et al. 2019, Schindler et al. 2010). This diversity of habitats and populations serves in turn as the basis of the large trophic and ecological roles that salmon play in ecosystems (Armstrong et al. 2019). This means the conservation of salmon and the manifold roles of salmon in the natural ecosystem and the human economy of southeast Alaska are directly dependent on protection and, where past degradation has occurred, restoration of the full natural diversity of aquatic habitats across the region.

Loss of diversity through increased footprint of human disturbance of watersheds will inexorably reduce the productive capacity of southeast Alaska, and especially the pristine, now roadless watersheds of the Tongass National Forest, for salmon. This fact is well-recognized in the scientific literature (see many aspects of the problem reviewed and cited in the text below), but it is obscured, if not overtly denied, in this DEIS. It seems the DEIS is premised on a covert, unstated, and utterly undocumented assumption that road-building and logging can occur in currently roadless watersheds with no risk of significant harm to aquatic habitat and fisheries. History and the available scientific literature establish clearly that this assumption is wholly untenable. The assumption is also at complete odds with Forest Service planning and policy documents of the past three decades, yet this departure is not explained or reasonably defended in the DEIS.

2.1 Protection of Priority Watersheds is in Question

In recent years the conservation of salmon in the Tongass National Forest has been strategically pinned to the concept of strict protection of a subset of watersheds in the region that are known to have high ecological and fishery values. One iteration is the Tongass National Forest Priority Watershed Classification (https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd622074.pdf), and another is the so-called "T77" watershed network proposed by a coalition of public interest and fishing industry groups (http://www.americansalmonforest.org/the-details.html, http://ak.audubon.org/sites/default/files/t77_subsection_seak_atlas_ch07_human_uses_200dpi.pdf). The DEIS falls short in failing to adequately account for the potential effect of removal of roadless area conservation protections and reclassification of timber suitability on road building and logging in these watersheds, which are heavily keyed to existing roadless areas where habitat, water quality, and watershed conditions remain optimal. Habitat losses and fish populations impacts in these watersheds could disproportionately affect near term salmon production. Other than stating that old-growth harvest will continue to be disallowed in T77 watersheds under the 2016 Tongass Plan, the DEIS is wholly unclear as to the level and kind of protections these priority watersheds would receive under the alternatives. It appears the DEIS is designed to allow new road construction within the boundaries of conservation priority watersheds in order to access timber in adjacent areas, which could be highly detrimental to salmon habitat in these watersheds (see review of the impacts of roads below).

That said, in my opinion the shifting spatial distribution of salmon productivity demonstrated in recent "salmon portfolio" research (e.g., Brennan et al. 2019) calls into question whether a conservation strategy based primarily on protection of these selected watersheds is tenable in the long term. Watersheds that are productive for a given salmon species at the present time may not be those most productive for that species in past decades or centuries, and may not be those that will be most productive in future decades. A triage-based strategy that prioritizes a subset of extant habitat for conservation is warranted when one is considering a tattered landscape with few remaining productive habitats and populations, and the managing agency is in restoration mode. But when the subject is a relatively intact region, and the planning is to program actions that bring intrinsic risk of highly persistent adverse impacts to that habitat (e.g., roadbuilding and logging of primary and old growth forest), protection or restoration will not be the outcome. In fact, the outcome will explicitly be a net loss of habitat and population productivity--with possibly less loss of habitat and populations than if no protection priorities at all had been in place. And the shifting productivity/portfolio research on salmon ecosystems all points to our fundamental inability to anticipate where future production will come from, at least across relatively ecologically intact landscapes such as southeast Alaska.

The portfolio research tells us ultimately that a fixed reserve subset is not a viable means of protecting an existing productive salmon ecosystem, and that characterization certainly applies to the Tongass National Forest. Effective conservation of salmon on those forests will require comprehensive protections that assure no net loss of watershed condition relative to current conditions. That is plainly not the policy put forth in this DEIS, though the DEIS does not make that clear. Rather, the proposed action would risk degrading many watersheds that are currently in pristine roadless condition, while offering no reasoned assurance or defensible evidence that such widespread degradation would be compensated by habitat improvement or restoration elsewhere. Despite efforts in the DEIS to minimize effects through omission and tacit denial, the proposed action is in fact a massive, regional-scale step backward from the level of conservation that salmon enjoy under present forest plans, including the regulatory protection provided by the Roadless Rule.

3. Insufficiency of Riparian Management Areas to Protect Streams from Logging and Roads

While somewhat tacit and not stated in a plain way that could be subject to scrutiny and review, it is clear to an informed observer that the DEIS rests on an unfounded grand underlying assumption that logging and roadbuilding can be pursued in roadless areas with no significant or systematic impact on watershed processes, water quality, fish habitat and fish populations. One rationale for this vague and broad assumption is presumably that riparian protections offered in the Tongass forest plan are themselves sufficient or more than sufficient to fully mitigate any harms that might arise from road building, road use and maintenance, and logging. This is the context within which I evaluate the relevant literature in the following section. Virtually all of the following information is not considered in the DEIS; therefore, these potential and known impacts of logging and roadbuilding are not disclosed to the public therein—despite that they are widely documented in the Forest Service's own research (as cited below, and further within the reference sections of many of the papers and reports cited) and in the agency's own past planning documents.

Leaving unlogged riparian forests is insufficient to mitigate for the effects of upland logging on streams, contrary to the implications in the DEIS. In the sections below I discuss edge effects on windthrow or blowdown, mass erosion and channel erosion resulting from hydrologic changes caused by logging, the effects of roads altering hydrology and erosion processes, and alteration of groundwater temperature by logging. Each of these categories of impact poses consequences for fish habitat and water quality that need to be analyzed on a regional scale to account for potential cumulative impacts of multiple logging projects that we know, from past experience and common sense, can result from a systematic forest plan policy change, such as proposed removal of roadless areas from protection forest-wide. The DEIS arbitrarily and capriciously dismisses, and fails to substantively and accurately address, the environmental effects I discuss below.

3.1 Soils and Water Quality: Unreasoned Assumptions Wholly Inconsistent with Past NEPA Assessments, Plans and Policies.

The DEIS identifies aquatic habitat and the fisheries supported by that habitat as a "key issue" (DEIS 1-7). However, the document proceeds immediately to eliminate soils and water quality from detailed analysis (DEIS 1-8), with only sparse and grossly inadequate explanation. DEIS takes this inexplicable step despite that the mechanisms by which road construction, road use and management, and logging adversely affect soil erosion and water quality are well understood, and are the very mechanisms that in turn impact aquatic habitat and fish populations. This is the first of many inexplicable and wholly unreasoned skips of logic that allow the Forest Service to skirt the issues of risk of impact to salmon habitat and populations of the proposed action and alternatives in the DEIS. I offer a more detailed review of science pertaining to how salmon habitat is affected by alterations of vegetation, soil and water quality that occur when roadless areas are logged.

Specifically, the DEIS (1-8) states that a “preliminary review” of potential soil impacts found that Alternative 6 would increase the amount of land with “high hazard” soils that would be open for commercial logging by 38 percent. This is consistent with a nationwide pattern of relatively high concentrations of “high hazard” or high-erosion risk soils in national forest roadless areas. Indeed, vulnerability of soils to erosion and landsliding is among the major reasons the Forest Service has deferred road construction and logging and in these areas in the past. It is among the principal reasons they remain roadless today. Neverthess, the DEIS fails to address the environmental consequences of the increased area of “high hazard” terrain in lands allocated for logging on the Tongass. Inexplicably, the Forest Service simply claims that “From a broad standpoint, the impacts to soil characteristics and composition from the proposed alternatives would be the same as disclosed in the 2016 Forest Plan Amendment FEIS due to similar harvest levels and Forest Plan standards and guidelines” (DEIS 1-8), then capriciously denies that further analysis is needed. This claim in the DEIS stands in direct contradiction to the increase in “high hazard” soils in the commercial timber base. In my opinion it is near certain any increase in “high hazard” soils within areas open for commercial logging substantially increases the likelihood of damage to water quality and fisheries from post-logging soil erosion and sedimentation, as further described in my comments below.

The fact that the PTSQ remains unchanged, the reason given by the Forest Service as to why environmental effects related to soil erosion will ostensibly not increase under any alternative (DEIS 1-8) does not mitigate against potential increases in mass failure and soil erosion, for several reasons. One reason is that PTSQ is a “soft target” that does not in fact cap the total area logged in any given time period. For example, the same volume of timber can be drawn from a smaller area of concentrated larger trees, or a larger area of lower-volume and lower value trees. Another is that neither the PTSQ nor any other forest-level timber volume target regulates the specific areas logged within the overall area allocated to timber production. By knowingly including more high-hazard soils in the commercial timber base, the Forest Service inexorably increases the likelihood of triggering and increasing the incidence of erosion and landslides through errors of identification of erosion-prone sites and inadequate implementation of necessary mitigation measures (those being primarily *avoidance* of logging in high-hazard locales, see comments below).

For the reasons above, and because soil erosion hazard (including surface erosion, mass failure, and debris flows propagated by landslides) are central causal factors in the harms done by forestry operations to water quality and fishery resources, in my opinion it is arbitrary and utterly indefensible for this DEIS to fail to analyze, consider, and disclose the effects of commercial timber land reallocation and loss of roadless area protection on Tongass National Forest soil, water, and fishery resources.

3.2 Windthrow in Riparian Forests

Logging adjacent to riparian management areas alters the disturbance regime of riparian forests and streams in ways that can adversely affect fish habitat and populations (Moore and Richardson 2012). Logging adjacent to riparian forests often results in increased windthrow of tree within riparian areas (Tongass National Forest Annual Monitoring Report 2007, Tongass National Forest Annual Monitoring Report 2013, Moore and Richardson 2012, Bahuguna et al. 2010, 2012, Rollerson and McGourlick 2001, Everest et al. 1997). Windthrow increased over natural background rates can result in exposure of channels to solar insolation and increased summer temperatures (Macdonald et a. 2003), reduction of future large tree recruitment, and increased channel bed and bank erosion, including landsliding and debris flows (Bahuguna et al. 2010, 2012, Lewis 1998, Mcdonald et al. 2003).

3.3 Landslides Originating from Upslope Cutting Units

Mass failures, including both shallow rapid landslides and deeper, often slower-moving slump-earthflow failures, are common across the Tongass National Forest, and it is well-established that the incidence of landslides is magnified by logging (Johnson et al. 2000, Everest et al. 1997, Swanston and Marion 1991, Wu and Swanston 1980, Wu et al. 1979). Logging not only directly disturbs soils, but associated vegetation removal renders soils vulnerable to mass movement and mass failure by reducing canopy interception and dispersion of rain and snow, by greatly reducing evapotranspiration and causing increased soil moisture conditions, and by destroying root strength that contributes to soil cohesion on forested slopes. The DEIS fails to consider and disclose how logging in currently protected roadless areas will impact mass-erosion-prone slopes, hence altering the frequency, magnitude, and distribution of landslides relative to salmonid habitats across the Tongass National Forest.

It is important to recognize that vegetation removal by logging—whether by clearcutting or thinning-—not only causes many landslides on recognized high-erosion risk terrain (which generally includes the steepest part of the landscape) but also increases the incidence of landslides on parts of the landscape that are usually considered to be of moderate or even relatively low risk of landslide erosion (most often because they are not as steeply sloping). This is a critical point, because the only effective means of preventing large increases in landslide occurrence is by identifying locations prone to failure and prohibiting vegetation removal on those sites, and in up-slope areas that contribute drainage to those sites. Some landside-prone sites occur on areas of the forest with moderate slopes and that are typically not mapped as highly landslide-prone. In many cases no clear surface evidence exists in the field that allows such sites to be identified prior to logging. Because complete avoidance of sensitive sites is impossible, logging will inevitably and cumulatively increase the incidence of landslides in salmon watersheds. The only question is how large the magnitude of increase in landslide erosion will be relative to unlogged watersheds. Previously unlogged roadless areas are likely to show the highest rates of landslide erosion increase if they are logged, because for the most part slopes in those areas have not previously experienced deforested or low-tree-density conditions in recent decades or centuries.

3.4 Headward Channel Expansion Caused by Altered Hydrology

Expansion of headwater channels has been an often-observed cause of post-logging erosion, but has been seldom quantified in Pacific coast watersheds (Frissell 2012). The one study I know of that focused comprehensively on this phenomenon, Reid et al. (2010), makes clear this is a seriously unexamined and too-often overlooked source of sediment delivery to Pacific Coast streams. Reid et al. (2010) reported that second-growth logging of a redwood-dominated forest in Caspar Creek, north coastal California, was followed by a substantial headwater expansion of stream channel density and coalescence of pre-existing discontinuous channels in headwater swales. Despite "robust" riparian buffer strips left in the second round Caspar Creek logging during this study, suspended sediment yields in instrumented tributaries increased significantly after logging. Channel expansion was caused by headward migration of existing channel knickpoints and subsequent channel incision and enlargement, as well as sapping and collapse of subsurface flow macropores and pipes. Acceleration of surface and subsurface channel-forming processes was apparently associated with increased antecedent moisture conditions, soil saturation, and runoff caused by the abrupt reduction of forest canopy interception and evapotranspiration following logging. In addition, back erosion of extant channels increased in linear extent, possibly reflecting increased channel-forming flows possibly coupled with impingement of hillslopes that could have been creeping at faster rates in the years immediately following logging (e.g., see Swanston et al. 1988). Reid et al. (2010) found that channel expansion led to stream density increasing by about 28 percent after logging.

Given that logging of any dense forest cover greatly reduced evapotranspiration of soil water, it is extremely likely the same processes drive erosion, channel expansion and sedimentation of streams after logging of forests of southeast Alaska. Expanded channel networks are associated with persistent increases in peak flow magnitude, which may result from more rapid translation of slower subsurface to rapid surface flow during storms. Erosion, both primary and secondarily associated with expanding or expanded channel networks, may be responsible for sustained elevation of suspended sediment yield and turbidity in Caspar Creek (reported in Reid et al. 2010, Keppeler 2012, Klein et al. 2012, and discussed as a regional concern in the review by Gomi et al. 2005). Expanded channel networks increase surface water connectivity to and sediment delivery from pre-existing erosion sources like landslide scarps and roads, and can itself initiate additional mass erosion through bank collapse and triggering of channel-adjacent landslides.

Reid et al. (2010) observed that boles and living tree roots in riparian forest buffers can partially hinder, but not entirely prevent, channel expansion. Fully controlling channel expansion effects on streamflow, erosion, and sedimentation would require limiting the overall rate of logging within small catchments over time, moderating silvicultural treatments to promote more rapid hydrologic recovery (e.g., via partial cutting rather than clearcutting), and careful consideration of past and future natural events, including wildfire, windthrow, and disease which, independent of or interactively with logging, also alter the hydrologic effects of vegetation.

Roadless areas preserve natural vegetation dynamics and disturbance regimes that maintain catchment hydrology and stream networks within a natural range of variability. Logging as an exotic disturbance in roadless areas is highly likely to alter hydrology such that accelerated stream erosion and stream network expansion result, over a larger area and larger number of watersheds than would occur if roadless areas are protected from logging.

Post-logging fluvial erosion, gullying and channel expansion is a scientifically recognized cumulative impact of logging that affects sediment supply and could potentially degrade salmonid habitat quality in connected waters downstream of headwaters if roadless areas of the Tongass National Forest are logged. This environmental impact has not been addressed or disclosed in the present DEIS.

3.5 Effects of Roads on Hydrology, Erosion and Sedimentation

Roads are well known to alter hydrology and erosion regimes in watersheds of the Tongass National Forest (Everest et al. 1997), just as they do elsewhere (Wemple et al. 2001, Luce and Black 2001, Jones et al. 2000, Trombulak and Frissell 2000). Landslides and gulley erosion initiating at or associated with the hydrological alterations caused by roads and landings not only can penetrate and deliver sediment through even very wide riparian forest buffers, they often initiate debris flows that can travel and directly impact aquatic and riparian habitat a great distance downstream from the point of origin. In either case, riparian forest buffers only confer limited protection against the harmful effects of road-caused mass failures, and in larger events, mass failures can virtually obliterate riparian forests, exposing streams to extremes of summer solar insolation and winter freezing, as well as redistributing large wood, scouring existing habitat structure away or burying it under large sediment deposits, and simplifying habitat structure in runout zones.

It is important to recognize that roads not only cause many landslides on recognized high-erosion risk terrain (which generally includes the steepest part of the landscape) but roads and landings often trigger landslides on parts of the landscape that are considered to be of moderate or even relatively low risk of landsliding under natural conditions. This results from the inexorable distortion of flow paths of both surface water and subsurface water caused by distortions of natural slopes and soils by road construction, use, and maintenance. The result is that road system expansion will inevitably expand both the number and area of occurrence of mass failures and associated debris flows and sediment deposits that adversely affect downstream fish habitat on a large scale. The DEIS utterly fails to consider, explain or disclose what the impact will be of road system expansion into currently roadless areas, many of which contain extensive areas of landslide-prone terrain.

Roads also cause chronic, on-going delivery of sediment at road crossings of small and large streams (Wemple et al. 2001, Jones et al. 2000), and sediment delivered even in the smallest headwater streams can be rapidly transported downstream to harm salmonid spawning and rearing areas (Trombulak and Frissell 2000, Everest et al. 1997, Furniss and others 1991). Seldom can sediment discharges at road crossings be completely eliminated; to do so requires extreme care in crossing design and intensive, frequent within-season road maintenance. In fact, some road maintenance activities that are necessary to reduce the risk of catastrophic failure of forest roads, as well as actions to decommission or remove existing forest roads, themselves generate sediment runoff that can impact streams (Switalski et al. 2004, Luce and Black 2001b). Variability in the cause-effect relations between forest roads and stream sedimentation complicates both remedial practices and preventative practices in road construction and management, resulting in continuing high level of uncertainty about the effectiveness of so called “best management practices” (Al-Chokhachy et al. 2016). In contrast to this recognized uncertainty, the DEIS purports, while offering virtually no evidence, that the impacts of new roads on water quality and fisheries in and downstream of roadless areas will be somehow nonexistent.

The widespread, systemic failure or inadequacy of existing road maintenance resources to mitigate harm from sediment pollution (see Gucinksi et al. 2001), especially at road crossings and other near-stream road segments, is one of the major reasons the US Forest Service implemented the Roads Policy and Roadless Rule nationally (USDA Forest Service 2000). All national forests, including the Tongass, remain unable to adequately maintain the existing road system to reduce its ongoing and future harmful impact on aquatic resources and fisheries. It is clear on the face of it that proposed elimination of Roadless Rule protection on the Tongass, and potentially the Chugach National Forest, is intentionally designed to allow expansion of the existing road network. The DEIS offers no rationale for how harms to the overall road system will be reduced in the face of road system expansion that is supported by the proposed suspension of the Roadless Rule.

Roads may be correlated with watershed condition, but it is important to recognize that such a correlation does not necessarily mean that “fixing” roads will alleviate all of the correlated effects (Al-Chokhachy et al. 2016, Frissell 2012, McDonald and Coe 2007). Road density integrates at least two major and separate categories of phenomena that contribute to erosion and sediment delivery (Trombulak and Frissell 2000). The first is erosion and sediment entering surface waters that is generated by the road itself and operations on the road. This category includes secondary hydrophysical effects of roads, including landsides and gullies that initiate because roads disturbed natural drainage pattern, and maintenance-related runoff. This first category is targeted by road remediation and mitigation measures that reduce erosion or sediment delivery to streams from roadways (Al-Chokhachy et al. 2016, Switalski et al. 2004). The second category is indirect: the erosion and sedimentation that are generated by land use actions and practices that are either supported by or incidental to the road network, as discussed above. Those phenomena in the second category are direct ground disturbance from timber felling and yarding, accelerated windthrow around cutting unit margins, and channel extension, gullying, and bank erosion initiating as a consequence of extensive vegetation removal in the catchment. These erosion and sediment sources are not mitigated by road management measures.

The spatial arrangement of road networks on the landscape relative to slope stability, soil erosion proneness, and stream network locations act to codetermine the extent of impairment of downstream fish habitat by road-generated erosion and sedimentation (Al-Chokhachy et al. 2016, MacDonald and Coe 2007, Jones et al. 2000, Trombulak and Frissell 2000). Within the Pacific Coastal mountains and the Pacific Northwest more broadly, existing roadless areas are often associated with the highest-quality fish habitat, in part because of the limited spatial extent of road impacts and relatively few road crossing locations in their catchments. As a result, watersheds with a high proportion of roadless area tend to be relatively high in fish abundance, salmonid diversity and production, and roadless areas thus are of extreme value in the long-term conservation of salmon and trout populations throughout their ranges (Dellasala et al. 2011, Frissell and Carnefix 2007, Hitt and Frissell 2004, Loucks et al. 2003, Trombulak and Frissell 2000, Baxter et al. 2000). Despite that the proposed suspension of the Roadless Rule is explicitly intended to allow the expansion of the logging road network into presently roadless areas in Tongass National Forest watersheds, the DEIS utterly fails to explain how road system expansion will not be associated with more widespread impacts of salmon streams and more extensive deterioration of high-quality salmonid habitat.

Because road systems span multiple watersheds across large areas of national forest, because their adverse impacts cannot be completely avoided or remediated, and because harms to aquatic ecosystems accrue over many decades and are often triggered or exacerbated by natural events like winter storms and summer drought, as well as by climate change that affects storms and drought at regional scales, the cumulative impacts of expansion of road systems must be addressed at the scale of the national forest or a major portion of a national forest. That is, the cumulative effects of road system expansion into presently roadless areas on fish habitat and fisheries simply cannot be adequately analyzed, disclosed, or effectively remediated at the scale of individual timber or road construction projects (Selva et al. 2015, Hitt and Frissell 2004, Trombulak and Frissell 2000). For example, in many cases existing Forest Service roadless areas act in concert with National Parks, Wilderness, or other permanent land protections to secure fish habitat and other conservation values in a larger downstream stream and river network (e.g., Frissell and Carnefix 2007, Hitt and Frissell 2004, Loucks et al. 2003, Martin et al. 2000, Noss et al. 1999). This fact is a major underlying reason for the Forest Service's decisions to implement the Roadless Rule (Turner 2006, Martin et al. 2000, USDA Forest Service 2000) and Roads Policy as directives systematically augmenting national forest plans and planning procedures across the nation.

3.6 Water Temperature Alteration from Upslope Logging

Logging alters the evapotranspiration demand by directly removing vegetation. At least for the initial decade after logging, until vigorously growing second-growth trees attain significant cover, soil and groundwater tend to increase because vegetation is using less water. Moreover, the removal of canopy cover can expose soils to direct solar heating, and areas of shallow groundwater may warm to a greater degree than they did under full forest cover.

Pollock et al. (2009) found that mean and summer mean and maximum temperature across 40 small streams on the Olympic Peninsula in Washington was substantially higher in streams draining watersheds with a higher proportion of cumulative logged area catchment-wide. The catchment area logged relationship was significantly stronger than the relationship to riparian forest removal by logging. Many streams with high canopy shade warmed substantially when more than half of their catchment area was logged. The results strongly suggest that factors other than direct canopy shade over the stream can drive water temperatures; these may include canopy opening from landslides and debris flows, or may indicate warming of shallow groundwater after extensive loss of soil canopy cover, or both. In either case, riparian buffers failed to protect streams from substantial temperature changes associated with logging.

Macdonald et al. (2003) found that headwater tributaries in BC logged with buffer strips of a wide range of widths all warmed 4-6 degrees C in summer compared to streams in unlogged watersheds. Part of this warming was associated with shade loss and post-logging windthrow, but a significant fraction of warming was unexplained by canopy shade, and is thought to have been associated with catchment-scale changes in shallow groundwater temperature or flow rates.

Research especially in long-term paired watershed studies in BC has shown that putative modest changes in daily mean, maximum, or minimum stream temperature associated with logging can result in biologically significant changes in cumulative thermal exposure. These in turn result in shifts in development rates of and timing of fish population life history events, such as time of emergence of young-of the-year from streambed gravels (Macdonald et al. 1998, Holtby 1988, Holtby and Newcombe 1982). Such developmental rate changes are known to alter salmon survival rates, and can result in population decline or collapse (Bryant 2009, Holtby 1988, Holtby and Newcombe 1982).

The DEIS ignores and fails to consider or disclose these known relationships between logging and alteration of temperature regime in streams that can cause substantial adverse cumulative effects on fish life history and population productivity, especially in Pacific salmon.

4. Climate Change and Resilience of Roadless Watersheds

Watersheds with a large proportion of primary forest and roadless area are likely to be among the most resilient salmonid habitats to the stresses imposed by ongoing and future climate change (Bryant 2009, USDA Forest Service 2000). One principal category of recurring and lasting impact from roads and logging is to introduce stressors that reduce resilience and increase the volatility of watershed responses to climatic stresses like flood and drought. Examples include the increased incidence of landsliding in the face of winter storms or rain-on-snow events, and the potential depletion of stream base flows by a combination of increased water demand by second growth forest and increased drought stress. Another major and extensive source of impact from climate change is likely to be the marine inundation of current estuaries from rising sea level (although in a few cases new estuaries may be created or existing estuaries expand in the face of sea level increases).

The dominant vectors of expected change in climate (Bryant 2009) and the effects of road development and logging in roadless watersheds inexorably increase the vulnerability of freshwater habitats, and the fish populations dependent upon them to recurring climatic stresses like floods and drought. Their inherent resilience to climate variability and extreme weather events is one of the reasons that watersheds associated with roadless areas are considered "safe havens," refugia, or core areas for conservation of salmonid fishes and other sensitive species (Bryant 2011, Dellasala et al 2011, Frissell and Carnefix 2007, Baxter et al. 2000, USDA Forest Service 2000, Bryant and Everest 1998).

Despite the recognized imperative that climate changes places on land managers of coastal and northern regions (Bryant 2009), the DEIS critically fails to consider or analyze the likely effects of road development and logging on the response of currently roadless watersheds to future climate change.

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Selva, N., Switalski, A., Kreft, S., & Ibisch, P. L. 2015. Why keep areas road-free? The importance of roadless areas. *Handbook of Road Ecology*, pp.16-26. Online at: https://www.researchgate.net/profile/Pierre_Ibisch/publication/280372197_Why_Keep_Areas_Road-Free_The_Importance_of_Roadless_Areas/links/5a79650e45851541ce5cc66d/Why-Keep-Areas-Road-Free-The-Importance-of-Roadless-Areas.pdf

Swanston, D. N., & Marion, D. A. 1991. Landslide response to timber harvest in southeast Alaska. *SECTION 10 MAN-CAUSED PROBLEMS AND THEIR CONTROL*. Online at: https://pubs.usgs.gov/misc/FISC_1947-2006/pdf/1st-7thFISCs-CD/5thFISC/5Fisc-V2/5Fsc2-10.PDF#page=50

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Wu, T. H., McKinnell III, W. P., & Swanston, D. N. 1979. Strength of tree roots and landslides on Prince of Wales Island, Alaska. *Canadian Geotechnical Journal* 16(1):19-33.

Curriculum Vitae *19 June 2018*

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Birth: 1 December 1960, Chehalis, Washington

Education: Ph.D. in Fisheries Science, Oregon State University, 1992
M.S. in Fisheries Science, Oregon State University, 1986
B.A. with High Honors in Zoology, University of Montana, 1982

Professional Appointments:

Principal Scientist and founder, Frissell & Raven Hydrobiological and Landscape Sciences, LLC, Polson, MT, 2012-present (affiliated with Kier & Associates, M. Scurlock & Associates, and Pacific Watershed Associates).

Affiliate Research Professor and summer field course instructor, Flathead Lake Biological Station, The University of Montana, 2016-present

Director of Science and Conservation and Senior Staff Scientist, The Pacific Rivers Council, 2000-2012

Research Associate Professor, The University of Montana, Flathead Lake Biological Station, 1998-2000

Research Assistant Professor, The University of Montana, Flathead Lake Biological Station, 1993-1998

Research Assistant Professor, Department of Fisheries and Wildlife, Oregon State University, 1994-1997

Postdoctoral Research Associate (Faculty), Department of Fisheries and Wildlife, Oregon State University, 1992-1994

Research Assistant (Faculty), Oak Creek Laboratory of Biology, Department of Fisheries and Wildlife, Oregon State University, 1985-1992

Fields of Interest:

- Land-aquatic ecosystem linkages and cumulative impacts of natural processes and human activities on stream habitat and stream biota.
- Ecology, biogeography, and conservation biology of fishes and freshwater biota in relation to landscape and hydrologic change.
- Aquatic ecosystem conservation and restoration strategies.
- Geomorphic, hydrophysical, and landscape ecology considerations in design of integrated conservation reserves.
- Restoration and recovery planning and design for freshwater ecosystems and species.

Theses and Dissertations:

Frissell, C.A. 1992. Cumulative effects of land use on salmon habitat in southwest Oregon coastal streams. Doctoral dissertation, Oregon State University, Corvallis.
Frissell, C. A. 1986. A hierarchical stream habitat classification system: development and demonstration. M.S. thesis, Oregon State University, Corvallis.
Frissell. C. A. 1982. Colonization and development of community structure in coexisting Ephemerellid mayflies (Ephemeroptera, Ephemerellidae). Senior Thesis, Watkins Scholarship Program, The University of Montana, Missoula.

Professional Societies:

Society for Conservation Biology, 1991-present
American Fisheries Society, 1985-present
Ecological Society of America, intermittent
North American Benthological Society, intermittent

Graduate Students Mentored

Cavallo, B.J. M.S. in Organismal Biology and Ecology, The University of Montana, 1997. Thesis title: *Floodplain habitat heterogeneity and the distribution, abundance, and behavior of fishes and amphibians in the Middle Fork Flathead River Basin, Montana.*
Adams, S. B. Ph.D.in Organismal Biology and Ecology, The University of Montana, 1999. Dissertation title: *Mechanisms Limiting a Vertebrate Invasion: Brook Trout in Mountain Streams of the Northwestern USA.*
Hitt, N.P. M.S. in Organismal Biology and Ecology, The University of Montana, 2002, *Distribution and potential invasion of introduced rainbow trout in the upper Flathead River drainage.*
Carnefix, G. M.S. in Organismal Biology and Ecology, The University of Montana, 2002. Thesis title: *Movements and ecology of bull trout in Rock Creek, MT.*
Hastings, K. Ph.D.in Organismal Biology and Ecology, The University of Montana, 2005. Dissertation title: *Long-term persistence of isolated fish populations in the Alexander Archipelago.*

Reviewer for Journals and Agency Publications:

Canadian Journal of Fisheries and Aquatic Sciences, Conservation Biology, Ecological Applications, Environmental Management, Fisheries (AFS), Freshwater Biology, North American Journal of Fisheries Management, Oikos, Transactions of the American Fisheries Society, Fundamental and Applied Limnology, USDA Forest Service General Technical Reports

Member of Board of Editors for Journals:

Conservation Biology, 1996-2000

Appointments to Review Panels and Scientific Advisory Committees:

USEPA Bristol Bay Watershed Assessment Team, Subcontractor on road and pipeline impacts, through University of Alaska Anchorage and NatureServe, 2011-2012.

Independent Expert Review Panel for King County Water and Land Resources Division's Project Scoping and Implementation Practices. 2011-12. Subcontractor to MWH (Montgomery Watson Harza) for King County Dept. of Natural Resources and Parks, Seattle, WA. http://www.kingcounty.gov/environment/dnrp/publications/wlrd-expert-review-report.aspx

Umpqua Watersheds Science Advisory Council, Sponsored by Umpqua Watersheds, Inc., 16-17 November 2010, Roseburg, OR.

Wychus Creek Restoration Monitoring Plan Review Panel, sponsored by Upper Deschutes Watershed Council and Bonneville Environmental Foundation. 2 October 2009, Bend, OR.

Landscape Pattern Task Group, *State of the Nation's Ecosystems* report. 2003-2007. H. John Heinz III Center For Science, Economics and the Environment. Washington, DC. http://www.heinzctr.org/Programs/Reporting/Working%20Groups/Fragmentation/index.shtml

Science Review Team, King County Normative Flow Studies Project. 2002-2005, Seattle, WA. http://dnr.metrokc.gov/wlr/BASINS/flows/science-review-team.htm

Science Advisory Panel, Westside. Governor's Salmon Restoration Funding Board, Washington State, February 2000.

Ecological Work Group, Multi-species Framework Process and Subbasin Assessment Process, Northwest Power Planning Council 1998-2000.

Peer review panelist for U.S. Environmental Protection Agency/National Science Foundation Water and Watersheds Grants Program for 1997. 7-9 May 1997.

Scientific Group for the Governor's Bull Trout Restoration Team, State of Montana, 1994-2000

Oregon Department of Environmental Quality, 1992-95: Temperature Standards Review Subcommittee of the Technical Advisory Committee, Triennial Water Quality Standards Review

Scientific Assessment Panel for amphibian species, Eastside Oregon-Washington and Upper Columbia Basin EIS, US BLM and US Forest Service, 1994

Oregon Department of Forestry, 1990-93: Technical Advisory Group for the Forest Practices Monitoring Program; Wetlands Technical Group; Stream Protection Advisory Panel.

Peer-Reviewed Articles Published in Scientific Journals:

Hand, B.K., C. G. Flint, J. A. Stanford, C. A. Frissell, C. C. Mulhfeld, S. P. Devlin, B. P. Kennedy, R. L. Crabtree, W. A. McKee, Gordon Luikart. In Press. The Importance of a Social-Ecological Perspective for Riverscape Management in the Columbia River Basin**.** *Frontiers in Ecology and the Environment.*

DellaSala, D.A., R. Baker， D. Heiken, C. Frissell, J. R. Karr, S.K. Nelson, B. R. Noon, D. Olson, and J. Strittholt. 2015. Building on Two Decades of Ecosystem Management and Biodiversity Conservation Under the Northwest Forest Plan, USA. *Forests 6*(9):3326-3352. http://www.mdpi.com/1999-4907/6/9/3326/htm

DellaSala, D. A., R.G. Anthony, M.L. Bond, Monica, E.S. Fernandez, C.A. Frissell, Chris, C.T. Hanson, and R. Spivak. 2014. Alternative Views of a Restoration Framework for Federal Forests in the Pacific Northwest. *Journal of Forestry* 111(6):420-429. https://www.researchgate.net/profile/Dominick_Dellasala/publication/264457285_DISCUSSION_Alternative_Views_of_a_Restoration_Framework_for_Federal_Forests_in_the_Pacific_Northwest/links/5474b78e0cf245eb436df546.pdf

Williams, J. E., R. N. Williams, R. F. Thurow, L. Elwell, D. P. Philipp, F. A. Harris, J. L. Kershner, P. J. Martinez, D. Miller, G. H. Reeves, C. A. Frissell, and J. R. Sedell. 2011. Native Fish Conservation Areas: a vision for large-scale conservation of native fish communities. *Fisheries* 36:267-277. http://www.tu.org/sites/www.tu.org/files/documents/Williams%20et%20al.%202011%20Fisheries%20NFCA.pdf

Whiteley, A.R., K. Hastings, J. K. Wenburg, C. A. Frissell, J. C. Martin and F. W. Allendorf. 2010. Genetic variation and effective population size in isolated populations of coastal cutthroat trout. *Conservation Genetics* 11(5):1929-1943. DOI: 10.1007/s10592-010-0083-y

Olson, D.H., P.D. Anderson, C.A. Frissell, H.H. Welsh, Jr., and D.F. Bradford. 2007. Biodiversity management approaches for stream-riparian areas: perspectives for Pacific Northwest headwater forests, microclimates, and amphibians. *Forest Ecology and Management* 246(1):81-107. **[Forest Ecology and Management "Highly Cited Author" award for 2007-2010]*

Poole, G.C., J.A. Stanford, S.W. Running, and C.A. Frissell. 2006. Multiscale geomorphic drivers of groundwater flow paths: subsurface hydrologic dynamics and hyporheic habitat diversity. *Journal of the North American Benthological Society* 25(2): 288-303.

Poole, G. C., J. A. Stanford, S. W. Running, C. A. Frissell, W. W. Woessner, and B. K. Ellis. 2004. A patch hierarchy approach to modeling surface and sub-surface hydrology in complex flood-plain environments. *Earth Surface Processes and Landforms* 29**:** 1259–1284.

Articles Published in Scientific Journals, continued:

Karr, J. R., J. J. Rhodes, G. W. Minshall, F. R. Hauer, R. L. Beschta, C. A. Frissell, and D. A. Perry. 2004. The effects of postfire salvage logging on aquatic ecosystems in the American West. *BioScience* 54:1029-1033. http://www.sierraforestlegacy.org/Resources/Conservation/FireForestEcology/SalvageLoggingScience/Salvage-Karr04.pdf

Hitt, N.P., and C.A. Frissell. 2004. A case study of surrogate species in aquatic conservation planning. *Aquatic Conservation: Marine and Freshwater Ecosystems*. 14:625–633. Beschta, ,R.L., J. J. Rhodes, J.B. Kauffman, R.E. Gresswell, G.W. Minshall, J. R. Karr, D.A. Perry, F.R. Hauer, C. A. Frissell. 2004. Postfire Management on Forested Public Lands of the Western United States. *Conservation Biology* 18: 957–967. http://www.researchgate.net/publication/227654964_Postfire_Management_on_Forested_Public_Lands_of_the_Western_United_States?ev=prf_pub

Hitt, N.P., C.C. Muhlfeld, C.A. Frissell, and F. Allendorf. 2003. Hybridization between native westslope cutthroat trout and non-native rainbow trout. *Canadian Journal of Fisheries and Aquatic Sciences* 60:1440-1451. https://www.researchgate.net/profile/Christopher_Frissell/publication/255604868_Spread_of_hybridization_between_native_westslope_cutthroat_trout_Oncorhynchus_clarki_lewisi_and_nonnative_rainbow_trout_Oncorhynchus_mykiss_Can_J_Fish_Aquat_Sci/links/004635206981ce44b6000000.pdf

Ebersole, J. L., W.J. Liss, and C.A. Frissell. 2003. Thermal heterogeneity, stream channel morphology, and salmonid abundance in northeastern Oregon streams. *Canadian Journal of Fisheries and Aquatic Sciences* 60(10):1266-1280. https://www.researchgate.net/profile/Joseph_Ebersole2/publication/237175546_Thermal_heterogeneity_stream_channel_morphology_and_salmonid_abundance_in_northeastern_Oregon_streams/links/552557110cf295bf160e298b.pdf

Ebersole, J. L., W.J. Liss, and C.A. Frissell. 2003. Cold water patches in warm streams: Physicochemical characteristics and the influence of shading. *Journal of the American Water Resources Association* 39:355-368.

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Articles Published in Scientific Journals, continued:

Ebersole, J.L., W.J. Liss, and C. A. Frissell. 2001. Relationship between stream temperature, thermal refugia, and rainbow trout *Oncorhynchus mykiss* abundance in arid-land streams in the northwestern United States. *Ecology of Freshwater Fish* 10:1-10.

Adams, S.A., C.A. Frissell, and B.E. Rieman. 2000. Movements of non-native brook trout in relation to stream channel slope. *Transactions of the American Fisheries Society* 129:623-638

Trombulak, S.C., and C.A. Frissell. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. *Conservation Biology* 14:18-30.

Baxter, C.V., C.A. Frissell, and F.R. Hauer. 1999. Geomorphology, logging roads and the distribution of bull trout *(Salvelinus confluentus)* spawning in a forested river basin: implications for management and conservation. *Transactions of the American Fisheries Society*, 128:854-867.

Williams, R.N., P.A. Bisson, D.L. Bottom, L.D. Calvin, C.C. Coutante, M.W. Erho Jr., C.A. Frissell, J.A. Lichatowich, W.J. Liss, W.E. McConnaha, P.R. Mundy, J.A. Stanford & R.R. Whitney. 1999. Return to the River: Scientific Issues in the Restoration of Salmonid Fishes in the Columbia River. *Fisheries* (Bethesda) 24(3):10-19Currens, K.P., F.W. Allendorf, D. Bayles, D.L. Bottom,. C.A. Frissell, D. Hankin, J.A. Lichatowich, P.C. Trotter, and T.A. Williams. 1998. Conservation of Pacific salmon: response to Wainwright and Waples. *Conservation Biology* 12:1148-1149.

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Ebersole, J.L., W.J. Liss, and C.A. Frissell. 1997. Restoration of stream habitats in the western United States: restoration as re-expression of habitat capacity. *Environmental Management* 21:1-14.

Allendorf, F.W., D. Bayles, D.L. Bottom, K.P. Currens, C.A. Frissell, D. Hankin, J.A. Lichatowich, W. Nehlsen, P.C. Trotter, and T.H. Williams. 1997. Prioritizing Pacific salmon stocks for conservation. *Conservation Biology* 11:140-152.

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Nawa, R., and C.A. Frissell. 1994. Measuring scour and fill of gravel streambeds with scour chains and sliding bead monitors. *North American Journal of Fisheries Management* 13:634-639.

Frissell, C.A. 1993. Topology of extinction and endangerment of native fishes in the Pacific Northwest and California, USA. *Conservation Biology* 7:342-354.

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Frissell, C.A., R.K. Nawa, and R. Noss. 1992. Is there any conservation biology in "New Perspectives?" A response to Salwasser. *Conservation Biology* 6:461-464.

Frissell, C.A., and R.K. Nawa. 1992. Incidence and causes of failure of artificial habitat structures in streams of western Oregon and Washington. *North American Journal of Fisheries Management* 12:182-197.

Frissell, C.A., W.J. Liss, C.E. Warren, and M.D. Hurley. 1986. A hierarchical framework for stream habitat classification: viewing streams in a watershed context. *Environmental Management* 10:199-214. *

**[Recognized as among the ten most cited papers in benthic ecology in Resh, V.H. 2003. J. of the North American Benthological Society 22 (3): 341-35.*

Symposium Articles Published:

Hastings, K., C.A. Frissell, and F. W. Allendorf. 2008. Naturally isolated coastal cutthroat trout populations provide empirical support for the 50/500 rule. Pp. 121-122 in Connolly, P. J., T. H. Williams, and R. E. Gresswell, editors *The 2005 coastal cutthroat trout symposium: Status, management, biology and conservation.* Oregon Chapter, American Fisheries Society, Portland, OR. Online at" http://www.sccp.ca/sites/default/files/species-habitat/documents/CCTS_12-31-2008%20Complete.pdf#page=136

Frissell, C., and G. Carnefix. 2007. The geography of freshwater habitat conservation: roadless areas and critical watersheds for native trout. Pp. 210-217 in R. F. Carline, and C. LoSapio, (eds.) *Sustaining Wild Trout in a Changing World: Proceedings of Wild Trout IX Symposium, October 9-12, 2007, West Yellowstone, Montana.* 308pp. http://www.wildtroutsymposium.com/proceedings-9.pdf

Poole, G.C., J.A. Stanford, S.W. Running, and C.A. Frissell. 2000. A Linked GIS/modeling approach to assessing the influence of flood-plain structure on surface- and ground-water routing in rivers. *Proceedings of the 4th International Conference on Integrating Geographic Information Systems (GIS) and Environmental Modeling*. Held 2-8 September 2000, Banff, Alberta. B. Parks, editor.

Hitt, N. P., & Frissell, C. A. 2000. An evaluation of Wilderness and aquatic biointegrity in western Montana. Pages 23-27 in McCool, SF, DN Cole, W. Borrie, and J. OLoughlin (compilers). Wilderness science in a time of change conference, Vol. 2. Missoula, MT. Proceedings RMRS-P-15-VOL-1, U.S. Department of Agriculture, Forest Service, Ogden, UT. Online at: https://www.wilderness.net/library/documents/science1999/volume2/hitt_2-17.pdf

Symposium Articles Published, continued:

Stahl, R.G., J. Mille, R. Frederick, D. Courtemanch, C. Frissell, M. Kaplan, M., K. Sappington, and M. Zeeman, 1999. Managing Ecological Risks Posed by Multiple Stressors. Pages 51-66 in Foran, J.A., and S. A. Forenc (eds.) *Multiple Stressors in Ecological Risk and Impact Assessment: Proceedings from the Pellston Workshop on Multiple Stressors in Ecological Risk and Impact Assessment.* 13-18 September 1997, Pellston, Michigan. *SETAC Special Publications Series*, SETAC Press, The University of Michigan. 100pp.

Clancy, C., C. Frissell, and T. Weaver. 1998. Removal or suppression of introduced fish to aid bull trout recovery. *Proceedings of the Wild Trout XI Conference*, held August, 1997 in Bozeman, MT. http://www.wildtroutsymposium.com/proceedings-6.pdf

Li, H.W., K. Currens, D. Bottom, S. Clarke, J. Dambacher, C. Frissell, P. Harris, R.M. Hughes, D. McCullough, A. McGie, K. Moore, R. Nawa, and S. Thiele. 1995. Safe havens: refuges and evolutionarily significant units. *American Fisheries Society Symposium* 17:371-380Frissell, C.A., W.J. Liss, and D. Bayles. 1993. An integrated, biophysical strategy for ecological restoration of large watersheds. In D.F. Potts ed., *Changing Roles in Water Resources Management and Policy*. Proceedings of a symposium of the American Water Resources Association, held 27-30 June, 1993, Bellevue, WA.

Frissell, C.A., and R.K. Nawa. 1989. Cumulative impacts of timber harvest on fisheries: "All the King's horses and all the King's men..." In C. Toole, (ed.), *Proceedings of the Seventh California Salmon, Steelhead and Trout Restoration Conference*. February 24-26, Arcata, CA. California Sea Grant Publication UCSGEP-89-02.

Frissell, C.A., and T. Hirai. 1988. Life history patterns, habitat change, and productivity of fall chinook stocks of southwest Oregon. In B. Sheperd (ed.) *Proceedings of the Northeast Pacific Chinook and Coho Workshop*, Bellingham, Washington, 3-4 October 1988. North Pacific International Chapter, American Fisheries Society.

Books and Book Chapters Published:

Frissell, C.A., and C.W. Bean. 2009. Responding to environmental threats. In: Assessing The Conservation Value Of Fresh Waters (Boon, P.J. & Pringle, C. eds.) pp. 91-116. Cambridge University Press Books, Cambridge, UK. 293pp.

Langford T.E.L., & Frissell C.A. 2009. Evaluating restoration potential. Pp. 117-141 in P.J. Boon & C.M. Pringle (eds.) *Assessing the Conservation Value of Freshwaters. An International Perspective*. Cambridge University Press,Cambridge, UK. 293pp.

Stanford, J. A., C. A. Frissell and C. C. Coutant. 2006. Chapter 5: The Status of Freshwater Habitats. Pp. 173-248 in Williams, R. N. (ed.), Return to the River: Restoring Salmon to the Columbia River. Elsevier Academic Press, Amsterdam. 720 pp. http://www.sciencedirect.com/science/book/9780120884148

Books and Book Chapters Published, continued:

Frissell, C.A., N.L. Poff, and M.E. Jensen. 2001. Assessment of biotic patterns in freshwater ecosystems. Chapter 27 in Bourgeron, P., M. Jensen, and G. Lessard (eds.) *A Guidebook for Integrated Ecological Assessments*. Springer-Verlag, NY

Jensen, M.E., I. Goodman, and C.A. Frissell. 2001. Design and use of aquatic biophysical classifications and maps. Chapter 26 in Bourgeron, P., M. Jensen, and G. Lessard (eds). *A Guidebook for Integrated Ecological Assessments.* Springer-Verlag, NY.

Welsh, H.H., T.D. Roelofs, and C.A. Frissell. 2000. Aquatic ecosystems of the redwood region. Pages 165-199 in R. Noss (ed.) *The Redwood Forest: History, Ecology, and Conservation of the Coast Redwoods.* Island Press, Washington, DC.

Frissell, C.A., and S.C. Ralph. 1998. Stream and watershed restoration. Pages 599-624 in R.J. Naiman and R.E. Bilby (eds.) *Ecology and Management of Streams and Rivers in the Pacific Northwest Coastal Ecoregion*. Springer-Verlag, NY.

Frissell, C.A. 1997. Ecological principles. Pages 96-115 in J.E. Williams, M.P. Dombeck, and C.A. Wood (eds.) *Watershed Restoration: Principles and Practices.* The American Fisheries Society, Bethesda, MD.

Frissell, C.A., W.J. Liss, R.K. Nawa, R.E. Gresswell, and J.L. Ebersole. 1997. Measuring the failure of salmon management. Pages 411-444 in D.J. Stouder, P.A. Bisson,and R.J. Naiman (eds.) *Pacific Salmon and their Ecosystems: Status and Future Options*. Chapman and Hall, New York, NY.

Frissell, C.A. 1996. A new strategy for watershed protection, restoration and recovery of wild native fish in the Pacific Northwest. Pages 1-24 in B. Doppelt (ed.) *Healing the Watershed: A Guide to the Restoration of Watersheds and Native Fish in the West*. The Pacific Rivers Council, Eugene, OR.

Frissell, C.A., and D.G. Lonzarich. 1996. Habitat use and competition among stream fishes. Pages 493-510 in F.R. Hauer and G.A. Lamberti (eds.) *Methods in Stream Ecology*. Academic Press, San Diego, CA.

Doppelt, B., M. Scurlock, C. Frissell, and J. Karr. 1993. *Entering the Watershed: A New Aproach to Save America's River Ecosystems* . Island Press, Washington, DC.

Final Research Reports and Miscellaneous Publications since 1993:

Frissell, C.A. 2017. Implications of Perry and Jones (2016) study of streamflow depletion caused by logging for water resources and forest management in the Pacific Northwest. Memo prepared for Oregon Stream Protection Coalition, Portland, OR. 27 January 2017.

Frissell, and R.K. Nawa. 2016. Protecting Coldwater for Salmon and Steelhead on Private Timberland Streams of Oregon's Siskiyou Region: A Synoptic Scientific Look at Stream Warming, Shade, and Logging. Memo prepared for Oregon Stream Protection Coalition, Portland, OR. 31 October 2016.

Final Research Reports and Misc. Publications since 1993, continued:

Rhodes, J.J., and C.A. Frissell. 2015. The High Costs and Low Benefits of Attempting to Increase Water Yield by Forest Removal in the Sierra Nevada. 108 pp. Report prepared for Environment Now, 12400 Wilshire Blvd, Suite 650, Los Angeles, CA. Online at http://environmentnow.org/pdf/Rhodes-and-Frissell-water-logging-report.pdf

Frissell, C.A., R.J. Baker, D.A. DellaSala, R.M. Hughes, J.R. Karr, D. A. McCullough, R.K. Nawa, J. Rhodes, M.C. Scurlock, and R.C. Wissmar. 2014. Conservation of Aquatic and Fishery Resources in the Pacific Northwest: Implications of New Science for the Aquatic Conservation Strategy of the Northwest Forest Plan. Report prepared for the Coast Range Association, Corvallis, OR. 35 pp. Available online at: http://coastrange.org

Frissell, C.A., 2013. Evaluation of proposed reductions of riparian reserve protections in the Northwest Forest Plan: Potential consequences for clean water, streams, and fish. Report prepared for the Coast Range Association, Corvallis, OR. 39 pp. Online at: https://www.researchgate.net/publication/266137611_Evaluating_proposed_reductions_of_riparian_reserve_protections_in_the_Northwest_Forest_Plan_Potential_consequence_for_clean_water_streams_and_fish

Frissell, C.A. 2014. Declaration of Christopher A. Frissell, Ph. D., in support of the U.S. Environmental Protection Agency's and the National Oceanic and Atmospheric Administration's proposal to disapprove the state of Oregon's coastal nonpoint pollution control program for failing to adopt additional management measures for forestry. Prepared for Washington Forest Law Center, Seattle, WA, and Northwest Environmental Advocates, Portland, OR. 85 pp. Online at https://northwestenvironmentaladvocates.org/blog/wp-content/uploads/2014/03/Declaration-of-Christopher-Frissell-3-14-14.pdf

Frissell, C.A., with R. Shaftel. 2013. Foreseeable Environmental Impact of Potential Road and Pipeline Development on Water Quality and Freshwater Fishery Resources of Bristol Bay, Alaska. Appendix G (52pp) in *An Assessment of Potential Mining Impacts on Salmon Ecosystems of Bristol Bay, Alaska, Second External Review Draft*. USEPA, Washington, DC 910-R-004a-c. 30 April 2013. Final Report for University of Alaska Anchorage Environment and Natural Resources Institute And Alaska Natural Heritage Program (NatureServe), under contract to USEP. Available online at: http://ofmpub.epa.gov/eims/eimscomm.getfile?p_download_id=513558

Pacific Rivers Council (Scurlock, M., and C.A.Frissell). 2012. Conservation of Freshwater Ecosystems on Sierra Nevada National Forests: Policy Analysis and Recommendations for the Future. Pacific Rivers Council, Portland Oregon, report prepared for Sierra Forest Legacy. 156pp. http://www.sierraforestlegacy.org/Resources/Conservation/Biodiversity/Conservation%20of%20Freshwater%20Ecosystems%20on%20Sierra%20Nevada%20Forests%202012%20PRC.pdf

Final Research Reports and Misc. Publications since 1993, continued:

Frissell, C.A., M. Scurlock, and R. Kattelmann. 2012. SNEP Plus 15 Years: Ecological & Conservation Science for Freshwater Resource Protection & Federal Land Management in the Sierra Nevada. Pacific Rivers Council Science Publication 12-001. Portland, Oregon, USA. 39 pp. http://www.sierraforestlegacy.org/Resources/Conservation/FireForestEcology/ThreatenedHabitats/Aquatic/RETROSNEP_PRC_Report_2012.pdf

MWH. (Montgomery Watson Harza). 2012. Independent Expert Panel Review of Water and Land Resources Division's Project Scoping and Implementation Practices. Prepared for King County Dept. of Natural Resources and Parks, Seattle, WA. 24 January 2012. 67 pp. + appendices. http://kingcounty.gov/environment/dnrp/publications/wlrd-expert-review-report.aspxFrissell, C.A. 2011. Comment on the environmental effects on Bull Trout (*Salvelinus confluentus*) as considered in the *Supplemental Draft Environmental Impact Statement for the Montanore Project*. Report prepared for Save Our Cabinets, Heron, MT. http://www.earthworksaction.org/files/pubs-others/montanore-comments_christopher-frissell_FINAL_20111220.pdf

Pacific Rivers Council (Wright, B., and C. Frissell). 2010. Roads and Rivers II: An Assessment of National Forest Roads Analyses. Report for the Pacific Rivers Council, Portland, OR. http://pacificrivers.org/science-research/resources-publications/roads-and-rivers-ii/download

Carnefix, G. and C.A. Frissell. 2010. Science for Watershed Protection in the Forest Service Planning Rule: Supporting Scientific Literature and Rationale. Report for the Pacific Rivers Council, 6 October 2010. 22pp. http://pacificrivers.org/files/nfma/supporting-scientific-rationale-for-nfma-language

Carroll, C., D.C. Odion, C.A. Frissell, D.A. Dellasala, B.R. Noon, and R. Noss. 2009. Conservation implications of coarse-scale versus fine-scale management of forest ecosystems: are reserves still relevant? Report for Klamath Center for Conservation Research. http://www.klamathconservation.org/docs/ForestPolicyReport.pdf

Carnefix, G., and C. A. Frissell. 2009. Aquatic and Other Environmental Impacts of Roads: The Case for Road Density as Indicator of Human Disturbance and Road-Density Reduction as Restoration Target, A Concise Review. Pacific Rivers Council Science Publication 09-001. Pacific Rivers Council, Portland, OR and Polson, MT. http://pacificrivers.org/science-research/resources-publications/road-density-as-indicator/download

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Final Research Reports and Misc. Publications since 1993, continued:

Duane,T.P., G. Carnefix, S.Chattopadhyay, C. Davidson, D.A. DellaSala, J.Duffield, C. Frissell, M.P. Hayes**,** M. Jennings, J. Kerkvliet, G. LeBuhn, P. Morton, E. Niemi, D. Spooner, and M. Weber. 2008. Economics of Critical Habitat Designation and Species Recovery: Consensus Statement of a Workshop. Report prepared for Pacific Rivers Council after a two-day workshop, October 4-5, 2007, San Francisco, CA. http://pacificrivers.org/science-research/resources-publications/economics-of-critical-habitat-designation-and-species-recovery-consensus-statement-of-a-workshop-sponsored-by-the-pacific-rivers-council-environmental-studies-program-at-san-francisco-state-university-ecotrust-and-the-national-center-for-conservati/download

Williams, J.E., D.A. DellaSala, J. F. Franklin, C.D. Williams, and C. Frissell. 2004. A new vision for wildfire preparation in the western USA. Media report presented at the Society for Conservation Biology Annual Meeting, Aug. 2, 2004, Columbia University, New York, NY.

Frissell, C. A. and G. Carnefix. 2002. Environmental correlates of spatial variation in spawning abundance of bull trout (Salvelinus confluentus) in Rock Creek Basin, Montana, USA. FLBS Report 168-02. Prepared for Rocky Mountain Research Station, USDA Forest Service, Boise, Idaho by Flathead Lake Biological Station, The University of Montana, Polson, Montana. 76 pp. + 2 appendices.

Merrill, T., D.J. Mattson, and C. Frissell. 2001. Life history, reserve design and umbrella effects: grizzly bears and aquatic systems in western Montana. Unpublished manscript, available online at http://y2y.net/files/673-merrill-reserve-design-and-umbrella-effects.pdf

Franklin, J. F., D.A. Perry, R.F. Noss, D. Montgomery, and C. Frissell. 2000. Simplified Forest Management to achieve watershed and forest health. Report for the National Wildlife Federation, Seattle, Washington. 46pp.

Frissell, C.A., P. H. Morrison, S.B. Adams, L. H. Swope, and N.P. Hitt. 2000. Conservation Priorities: an Assessment of Freshwater Habitat for Puget Sound Salmon. Trust for Public Land, Northwest Regional Office, 1011 Western Suite 605, Seattle, WA. http://www.tpl.org/tier3_cd.cfm?content_item_id=9280&folder_id=262

Frissell, C.A. 1999. An ecosystem approach for habitat conservation for bull trout: groundwater and surface water protection. Flathead Lake Biological Station, Open File Report 156-99, The University of Montana, Polson, MT.

Hitt, N.P. and C.A. Frissell. 1999. Wilderness in a landscape context: a quantitative approach to ranking aquatic diversity areas in western Montana. Paper presented at Wilderness Science Conference, 23-27 May, Missoula, MT.

Montana Bull Trout Scientific Group. 1998. The relationship between land management activities and habitat requirements of bull trout. Report prepared for the Montana Bull Trout Restoration Team, Office of the Governor, Helena, MT.

Final Research Reports and Misc. Publications since 1993, cont:

Frissell, C.A. 1998. Landscape refugia for conservation of Pacific salmon in selected river basins of the Olympic Peninsula and Hood Canal, Washington. Flathead Lake Biological Station, Open File Report 147-98, The University of Montana, Polson, MT.

Frissell, C.A. 1997. Ecological benefits of wildland reserves: The proposed Copper Salmon Wilderness in southwest Oregon. Flathead Lake Biological Station, Open File Report 150-97, The University of Montana, Polson, MT.

Huntington, C.W., and C.A. Frissell. 1997. Aquatic conservation and salmon recovery in the North Coast Basin of Oregon: A crucial role for the Tillamook and Clatsop State Forests. Report prepared for Oregon Trout, Portland, OR.

Williams, R.N., L.D. Calvin, C.C. Coutant, M.W. Erho, Jr., J.A. Lichatowich, W.J. Liss, W. E. McConnaha, P.R. Mundy, J.A. Stanford, R.R. Whitney, D.L. Bottom, and C.A. Frissell. In press. *Return to the River: Restoration of Salmonid Fishes in the Columbia River Ecosystem.* Independent Scientific Group, Northwest Power Planning Council, Portland, OR.

Frissell, C.A., J.L. Ebersole, W.J. Liss, B.J. Cavallo, and G.C. Poole. 1996. Potential effects of climate change on thermal complexity and biotic integrity of streams: seasonal intrusion of non-native fishes. Final Report for USEPA Environmental Research Laboratory, Duluth, MN. Oak Creek Laboratory of Biology, Department of Fisheries and Wildlife, Oregon State University, Corvallis, OR.

Bottom, D.L., J.A. Lichatowich, and C.A. Frissell. 1996. Variability of marine ecosystems and relation to salmon production. Report prepared for Theme 2 of the Pacific Northwest Coastal Ecosystem Region Study Workshop, Troutdale, OR, 12-14 August.

Clancy, C., C. Frissell, and T. Weaver. 1996. Assessment of methods for removal or suppression of introduced fish to aid bull trout recovery. Report prepared by the Montana Bull Trout Scientific Group for the Montana Bull Trout Restoration Team. Montana Fish, Wildlife and Parks, Helena, MT.

Frissell, C.A., J. Doskocil, J. Gangemi, and J. Stanford. 1995. Identifying priority areas for protection and restoration of riverine biodiversity: a case study in the Swan River basin, Montana, USA. Flathead Lake Biological Station, Open File Report 136-95, The University of Montana, Polson, MT.

Beschta, R.L., C.A. Frissell, R. Gresswell, R. Hauer, J.R. Karr, G.W. Minshall, D.A. Perry, and J.J. Rhodes. 1995. Wildfire and salvage logging: recommendations for ecologically sound post-fire salvage logging and other post-fire treatments on federal lands in the West. The Pacific Rivers Council, Eugene, OR.

Frissell, C.A. 1993. The shrinking range of the Pacific Salmon. Report and status and range maps prepared for the Pacific Northwest Salmon Study, The Wilderness Society, Washington, DC.

Final Research Reports and Misc. Publications since 1993, cont:

Frissell, C.A., and W.J. Liss. 1993. Valley segment classification for the streams of Great Basin National Park, Nevada. Report prepared for the National Park Service Cooperative Park Studies Unit, College of Forestry, Oregon State University, Corvallis, OR.

Frissell, C.A. 1993. Panacea or placebo? An ecologist's view of captive breeding. *Wild Fish* July/August 1993:7-12. The Wilderness Society, Portland, OR.

Frissell, C.A. 1993. A new strategy for watershed restoration and recovery of Pacific salmon in the Pacific Northwest. Report prepared for The Pacific Rivers Council, Eugene, Oregon. Oak Creek Laboratory of Biology, Department of Fisheries and Wildlife, Oregon State University, Corvallis, OR.

Selected Papers and Seminars Presented Since 1993 (__=presenter):

Frissell, Christopher A., R.J. Baker, C.V. Baxter, D.A. DellaSala, R.M. Hughes, J.R. Karr, D.A. McCullough, R.K. Nawa, M. M. Pollock, J.J. Rhodes, and R.C. Wissmar. 2017. New Science in the since FEMAT in 1993: Implications for Aquatic Conservation on Federal Forest Lands of the Pacific Northwest. Idaho Chapter, American Fisheries Society, Annual meeting, Special Session on science and stewardship regarding aquatic-terrestrial linkages important to fish and wildlife, Colden Baxter, Convenor. 1 March, 2017, Boise, ID.

Frissell, C., and M. Pollock. 2015. Is thinning of riparian forests ecological restoration? American Fisheries Society Annual Meeting, 16-20 August 2015, Portland OR. https://afs.confex.com/afs/2015/webprogram/Paper21796.html

Wissmar, R. R. Holland, R. Timm, amd C. Frissell. 2015. Steelhead conservation: Coping with thermal barriers in a warming planet. Society for Conservation Biology, 2-6 August 2015, Monpelier, France.

Frissell, C.A., M. Scurlock, and K Crispen. 2011. Forest thinning in Pacific Northwest riparian areas: rationale, risks, and policy calibration. (Abstract) Annual Meeting of the American Fisheries Society, Symposium on Forest Management: Can Fish and Fiber Coexist? 4-8 September, Seattle, WA. http://pacificrivers.org/science-research/resources-publications/dr.-chris-frissells-american-fisheries-society-presentation-on-riparain-thinning/download

Frissell, C.A. 2008. Water, watersheds and forest stewardship: the shared landscape (Abstract). Paper presented at the Western Stewardship Summit: Restoring Community and the Land, Bend, OR, September 24-26 2008.Frissell, C.A., and N.P. Hitt. 2008. Four biological quanta: a conceptual framework for conservation of stream ecosystems. (Abstract) Society for Conservation Biology Annual Meeting Symposium: Advances in Freshwater Conservation Planning. Chattanooga, TN, July 13-19, 2008.

Selected Papers and Seminars Presented Since 1993, continued:

Frissell, C.A. 2008. Ecological impacts of roads in an era of climate change (Abstract). Watershed Restoration and Forest Roads Symposium, Pacific Rivers Council, 4 April 4, Tacoma, WA. http://pacificrivers.org/conservation-priorities/land-management/roads/watershed-restoration-and-forest-roads-symposium

Frissell, C.A., and G, Carnefix. 2007. (Abstract) Spawning abundance of bull trout (*Salvelinus confluentus*) in relation to geomorphology, temperature and roads in tributaries of Rock Creek Basin (Missoula and Granite Counties), Montana, US. Annual Meeting of the Montana Chapter of the American Fisheries Society, 13-16 February, Missoula, MT. http://www.fisheries.org/units/AFSmontana/2007%20MCAFS%20Annual%20Meeting%20Program.pdf

Frissell, C.A. 2007. Setting regional priorities for watershed restoration. 25th Salmonid Restoration Conference, Salmonid Restoration Federation, 9-10, Santa Rosa, CA.

Frissell, C.A. 2006. Post-fire management effects on streams. NCSSF Disturbance, Management, and Biodiversity Symposium, **National Commission for Science and Sustainable Forestry,** 26-27 April, **Denver, CO.**

Frissell, C.A., and G. Carnefix. 2005. (Abstract) Indicators of landscape pattern for freshwater ecosystems. 20th Annual Symposium of the US-International Association for Landscape Ecology, 12-16 March, Syracuse, NY.

Frissell, C.A. 2004. Managing risk and uncertainty: National Forest management and freshwater conservation. Regional Centennial Forum: The Forest Service In the Pacific Southwest Region. US Forest Service, 5-6 November, Sacramento, CA.

Williams, J.E., D.A. DellaSala, J. F. Franklin, C,D.Williams, and C. Frissell. 2004. Scientific findings require a new vision for successful wildlfire preparation. News briefing at the Society for Conservation Biology Annual Meeting, Aug. 2, 2004., Columbia University, New York, NY. http://www.conbio.org/Media/Fire/

Frissell, C.A. 2001. (Abstract) What to do first with limited time, money, and staff. Watershed Restoration Workshop: Integrating Practical Approaches. Oregon Chapter of the American Fisheries Society, 13-15 November, Eugene, OR.

Ebersole, J.L., Colden V. Baxter, Hiram W. Li, and William J. Liss, and Frissell, C.A. 2001. (Extended abstract) Detecting temporal dynamics and ecological effects of smallmouth bass invasion in northeast Oregon streams. *In*: Proceedings, American Fisheries Society Special Symposium: Practical Approaches for Conserving Native Inland Fishes of the West. Montana Chapter and Western Division of the American Fisheries Society, 6-8 June, The University of Montana, Missoula, MT.

Selected Papers and Seminars Presented Since 1993, continued:

Carnefix, G., C. Frissell, and E. Reiland. 2001. (Extended abstract) Complexity and stability of bull trout (*Salvelinus confluentus*) movement patterns in the Rock Creek drainage, Missoula and Granite counties, Montana. *In*: Proceedings, American Fisheries Society Special Symposium: Practical Approaches for Conserving Native Inland Fishes of the West. Montana Chapter and Western Division of the American Fisheries Society, 6-8 June, The University of Montana, Missoula, MT.

Frissell, C.A. 1999. (Abstract) Groundwater processes and stream classification in the montane West. Invited paper, Symposium #7: Aquatic Classification Schemes for Ecosystem Management: Making the Transition from Methods Development to Application and Validation. Annual Meeting of the Ecological Society of America 7-12 August, Spokane, WA.

Frissell, C.A. 1999. Fisheries and watershed processes: strategies for protection and restoration. Invited paper, Annual Meeting of the Cal-Neva Chapter of the American Fisheries Society, 24-27 March, Redding, CA.

Frissell, C.A. 1999. Surface-subsurface flow linkages in rivers and their importance for river flow conservation. Invited paper, Symposium on Water Quality and Hydropower Re-licensing, Annual Meeting of the Cal-Neva Chapter of the American Fisheries Society, 24-27 March, Redding, CA.

Frissell, C.A. 1999. Dams, uncertainty, and the salmon ecosystem. *Keynote Address*, Annual Meeting of the Idaho Chapter of the American Fisheries Society and The Wildlife Society, 4-6 March, Boise, ID.

Frissell, C.A. 1998. Climate forcing of thermal habitat in Pacific Northwest rivers: Buffering effects of floodplain forests and hyporheic processes. (Abstract) Symposium on Climate Change Impacts to Freshwater Fish Habitats, Annual Meeting of the American Fisheries Society, 23-27 August, Hartford, CT.

Frissell, C.A. 1998. Ecosystem concepts in large-scale restoration. (Abstract). Montana Chapter of the American Fisheries Society, 3-5 February, Helena, MT.

Frissell, C.A. and B.J. Cavallo 1997. Aquatic habitats used by larval western toads (*Bufo boreas*) on an intermontane river floodplain and some landscape conservation implications (Abstract). Annual Meeting of the Ecological Society of America, 10-14 August, Albuquerque, NM.

Stanford, J.A. (presented by C.A. Frissell). 1997. Conservation and enhancement of alluvial rivers: the importance of hyporheic linkages. (Abstract). Symposium on Ecological Effects of Roads, Society for Conservation Biology, 7-10 June, Victoria, British Columbia, Canada.

Frissell, C.A., and G.C. Poole . 1997 Management of Riparian Zones in Western Montana: Present Issues and Emerging Challenges. (Abstract). Annual Meeting of the American Fisheries Society, 23-28 August, Monterey, CA.

Frissell, C.A., and J.T. Gangemi. 1997. Roads and the conservation of aquatic biodiversity and ecological integrity. (Abstract). Society for Conservation Biology, Victoria, British Columbia, Canada, 7-10 June.

Selected Papers and Seminars Presented Since 1993, continued:

Frissell, C.A. 1997. Spatial assessment of biological status and biodiversity loss. Invited seminar, National Research Center for Statistics and the Environment, University of Washington, Seattle, WA, 14 January.

Frissell, C.A., and B.J. Cavallo 1996. Thermal and hydrologic diversity of aquatic habitats mediated by floodplain complexity and hyporheic flow exchange in an alluvial segment of the Middle Fork Flathead River, Montana, USA. (Abstract). Annual Meeting of the N. Am. Benthological Society, Kalispell, MT, 3-8 June.

Frissell, C.A. 1995. Ecological principles for watershed restoration. (Abstract). Invited paper for Workshop on Watershed Restoration: Principles and Practices, Annual Meeting of the American Fisheries Society, Tampa, FL, 27-31 August.

Frissell, C.A. 1995. Managing native fish and their ecosystems: let's get (spatially) explicit! (Abstract). Invited panel presentation at Montana Chapter of the American Fisheries Society, Chico Hot Springs, MT, 6-10 February.

Frissell, C.A. 1995. Birth in the fast lane: sediment transport, human disturbance, and reproductive strategies of salmonid fishes in Pacific Northwest streams. (Abstract). Invited paper for Symposium on Influence of Geomorphic Processes on Terrestrial and Aquatic Ecosystem patterns and Processes, Annual meeting of the Ecological Society of America, Snowbird, UT, 31 July-3 August.

Frissell, C.A. 1995. Resource management impacts on bull trout populations. Invited panel presentation for Searching for Solutions: Solving the Bull Trout Puzzle Science and Policy Conference, Andrus Center for Public Policy, Boise State University, Boise, ID, 1-2 June.

Frissell, C.A. 1995. Watershed dynamics: natural pattern and process and some consequences for ecosystem management. Invited presentations at Managing Terrestrial Ecosystems Relative to Past and Present Disturbances: A Workshop Integrating Fire, Range, Fish and Wildlife Habitat and the Practice of Silviculture in the Northern Region. U.S. Forest Service, Missoula, MT, 14-16 March.

Ebersole, J.L., C.A. Frissell, and W.J. Liss (co-presenters). 1995. Invasion of non-native fishes in northeast Oregon and western Montana streams: potential impacts of climate change. (Abstract). Oregon Chapter of the American Fisheries Society, Ashland, OR, 15-17 February.

Frissell, C.A. 1994. Watershed restoration strategies. (Invited presenter and session convenor) Watersheds '94 Expo, US Environmental Protection Agency and Center for Streamside Studies, University of Washington. Bellevue, WA, 27-30 September.

Frissell, C.A. 1994. A hierarchical approach to restoration of riverine ecosystems. Invited paper at Symposium on Aquatic Habitat Restoration in Northern Ecosystems, Alaska Chapter of the American Fisheries Society, Girdwood, AK, 20-22 September.

Selected Papers and Seminars Presented Since 1993, continued:

Frissell, C.A. 1994. An integrated, biophysical strategy for ecological restoration of large watersheds (Abstract). Annual Conference of The Universities Council on Water Resources, Big Sky, MT, 3-5 August.

Frissell, C.A., and J.A. Stanford. 1994. Designing a watershed reserve network to protect and restore aquatic biodiversity in the northern Rocky Mountains (Abstract). Annual meeting of the Montana Chapter of the American Fisheries Society, Billings, Montana, Billings, MT, 9 February.

Frissell, C.A. 1994. The Endangered Species Act: principles for the protection and recovery of fishes. Invited panel presentation, annual meeting of the Idaho Chapter of the American Fisheries Society, McCall, ID, 24-26 February.

Frissell, C.A., W.J. Liss, B. Doppelt, and D. Bayles. 1993. A new, ecologically based restoration strategy for Pacific salmon in the Pacific Northwest (Abstract). Annual meeting of the American Fisheries Society, Portland, OR, 29 August-2 September.

Technical Workshops Organized (selected):

Lead organizer and facilitator, New Science Implications for the Aquatic Conservation Strategy of the Northwest Forest Plan. Sponsored by the Coast Range Association, 2-3 December 2013, Portland, OR.

Co-organizer, with M. Scurlock and R. Kattelmann: SNEP Plus 15 Years: Ecological & Conservation Science for Freshwater Resource Protection & Federal Land Management in the Sierra Nevada. Sponsored by Pacific Rivers Council, Sierra Forest Legacy, UC Berkeley School Environmental Design, UC Davis Center for Watershed Science, and CaliforniaTrout; 12-13 December 2011, Davis, CA.

Organizer and facilitator, Workshop on Science for River and Watershed Conservation. Sponsored by Campaign for Montana's Headwaters, 7 October 2010, Flathead Lake Biological Station, Polson, MT.

Co-convener, with M. Scurlock and Kristen Boyles: Technical Workshop on Science for Forest Planning. Sponsored by Pacific Rivers Council and Earthjustice, 29 June 2010, Seattle, WA.

Organizer and panelist, Umpqua Independent Science Council. Sponsored by Pacific Rivers Council, 2010-2011.

Co-organizer and panelist, with Deanne Spooner and David Bayes: Workshop on Economics of ESA Critical Habitat Policy, sponsored by Pacific Rivers Council and San Francisco State University, October 4-5, 2007, San Francisco, CA.

Organizer and coordinator of Science Panel on Roads and Watersheds, sponsored by Pacific Rivers Council, 10-11 November 2006, Forest Grove, OR.

Organizer and coordinator of the Recovery Science Panel for the Western Native Trout Campaign. Sponsored by Pacific Rivers Council, meeting 2-3 March 2002, Portland, OR.

Technical Workshops Organized (selected), continued:

Organizer and coordinator of Biodiversity Workshop, Consortium for the Study of North Temperate Montane Ecosystems. A cooperative research venture of The University of Montana and Montana State University, supported by the NSF EPSCoR program. 4 February, 1997 Missoula, MT.

Scientific Workshop on Large Basin Restoration: Grande Ronde River (co-organizer). 21-22 March 1993, La Grande, OR. Sponsored by The Pacific Rivers Council.

Scientific Workshop on Large Basin Restoration: South Umpqua River. 16-18 September 1992, Roseburg, Oregon. Sponsored by The Pacific Rivers Council.

Scientific Workshop on Large Basin Restoration: Lower Rogue River. 21-23 October 1992, Gold Beach, OR. Sponsored by The Pacific Rivers Council.

Other Panels and Workshops Attended by Invitation since 1994 (selected):

Invited Review Panelist, Workshop on Linking Habitat Characteristics to Salmon Data. 29-30 September 1999, National Marine Fisheries Service, Northwest Fisheries Science Center, Seattle, WA.

Invited participant, Yellowstone to Yukon Aquatic Conservation Science Workshop. 20-22 August 1999, Flathead Lake Biological Station, The University of Montana, Polson, MT.

Invited Panelist, Workshop on Options for Restoring Salmon Habitat in the Mainstem Snake and Columbia Rivers. Pacific Northwest National Laboratory-Battelle, 19 August 1999, Kennewick, WA

Panelist at State of Oregon/National Marine Fisheries Service Memorandum of Agreement Committee Workshop: Cumulative Effects of State and Private Forest Practices on Salmon Habitat. 21April 1998, Salem, OR.

Invited participant in a scientific workshop, Multiple Stressors in Ecological Risk Management. Sponsored by the Society for Environmental Chemistry and Toxicology and the USEPA, 13-18 September 1997, Pellston, MI.

Society for Conservation Biology Workshop: Communicating with the Media (panel member). 9 June 1997, Victoria, British Columbia, Canada.

Invited speaker for a workshop, Continuing Education in Ecosystem Management. Sponsored by the University of Idaho. Catchment scale processes and linkages between landscape and stream conditions. 31 January 1997, Moscow, ID.

The Nature Conservancy, Aquatic Classification Workshop (invited presenter). 9-11 April 1996, Cedar Creek Farm, MO.

Kenai River Community Forum (keynote speaker and panelist). The Nature Conservancy of Alaska, USEPA and USFWS, 19-21 April, Soldotna, AK.

Conservation Biology and Management of Interior Salmonids (invited presenter and session co-moderator). USDA Forest Service Intermountain Research Station and Utah State University, 4-5 October 1995, Logan, UT.

Eastside Ecosystem Planning Workshop. Sierra Club Legal Defense Fund, 16 December 1994, Portland, OR.

Other Panels and Workshops Attended by Invitation since 1994, continued:

Co-instructor at workshop series on Watershed Restoration and the "Rapid Biotic Response Strategy" for Riverine Ecosystem Restoration, sponsored by The Pacific Rivers Council, 1993-95, California, Oregon, and Washington.

Fire/Salvage and Aquatic Ecosystems Policy Workshop. The Pacific Rivers Council, 15 December 1994, Portland, OR.

Panel on Forest Health Issues, Native Forest Network annual conference, 13 November 1994, Missoula, MT.

Workshop on Watershed/Fisheries Cumulative Effects Analysis, sponsored by Headwaters, The Pacific Rivers Council, USDA Forest Service, and Bureau of Land Management. 29 September-2 October, 1994, Ruch, OR.

Boise Funders' Scoping Meeting, sponsored by Bullit, Harder, and Lazar Foundations, 30-31 August 1994, Boise, Idaho.

Scientists Briefing for U.S. Senate staff on post-fire logging and forest management and freshwater resources. Washington, D.C., 18-19 September 2006.

Other Presentations and Outreach (Selected):

Invited testimony on federal land management and the future of salmon and aquatic biodiversity in the Pacific Northwest, to the U.S. House of Representatives, Subcommittee on National Parks and Public Lands, Washington, D.C., 11 March 1993.

Briefing for Congressional representatives and staff on federal lands management and conservation and recovery of salmonid fishes and riverine ecosystems, Washington, D.C., 22 January 1993.

Invited testimony to the 1991 Oregon State Legislature, on panel representing the Oregon Chapter of the American Fisheries Society, on the status of native fishes, impacts of forest practices on fish habitat, and the need or changes in environmental regulation.

Invited testimony to the Oregon Board of Forestry Forest Issues Forum, December 1990, on cumulative impacts of forest practices on native aquatic species and the need for changes in forest management.

Worked with Oregon Public Broadcasting to describe our research project and its significance in a 15-minute segment of the television program, Oregon Field Guide, first aired in June 1990.

Presented seminars, informal presentations, lectures, and discussions at research review meetings, as guest speaker in classrooms and public interest groups, at state board meetings, at workshops, and on field trips with foresters, geotechnical personnel, fishery and watershed managers, and conservationists.

Conservation
Economics
Institute

Tongass Roadless Rule DEIS Economic Review

December 16, 2019

Alaska Roadless Rule,
USDA Forest Service, Alaska Region
Ecosystem Planning and Budget Staff,
P.O. Box 21628, Juneau, Alaska 99802– 1628.

FROM: Evan Hjerpe, Ph.D., Forest Economist

RE: Alaska Roadless Rule Draft Environmental Impact Statement (DEIS) Review of Economics

To whom it concerns,

I am submitting the following economic comments on the Tongass Roadless Rule DEIS. I am a forest economist with over a decade of professional experience researching the economic values of forest management in the U.S. and internationally. I have a Ph.D. in forest management and economics from Northern Arizona University. I spent five years working in the Tongass National Forest, researching economic forestry solutions that benefited southeast Alaskan communities. With the Draft Environmental Impact Statement (DEIS) to exempt the Tongass National Forest from the Roadless Rule, I am compelled to illustrate the shortfalls in economic analysis contained in the DEIS. My experience in forest economics and on the Tongass makes me highly qualified for reviewing the economic components of the DEIS.

In these comments, I detail how all economic valuations and trends associated with Tongass timber production and roadless protections clearly indicate that both national and Southeast Alaskan residents will incur greater benefits by keeping the Roadless Rule in place in Alaska. In fact, removing roadless protections from the Tongass will result in tremendous costs and damages to other economic sectors, national taxpayers, ecosystem services, and biodiversity. Because of the obvious economic perils and government waste that would result from removing Tongass roadless protections, the only reasonable alternative is the No Action alternative.

The Tongass Roadless Rule DEIS, released on October 17, 2019, is lacking credible economic analysis and falls well short of appropriate NEPA economic requirements. In the DEIS, USDA has ignored the best available economic science, which clearly illustrates that from almost every economic angle, the U.S. and southeast Alaskans are better off keeping the Roadless Rule intact. Not only has USDA ignored the best available science, they also did not provide any economic analysis to show how exempting the Roadless Rule on the Tongass would help Alaska or the nation. The disregard for incorporating the best available science, combined with providing no supporting economic analysis, undermines the validity of appropriate NEPA analysis. These economic issues were flagged in detailed scoping comments,[1] yet were not addressed in the DEIS.

The overarching economic theme presented in the DEIS is that Tongass roadless timber production can occur in a vacuum without damaging the primary economic drivers of the region or the ecological integrity of the Tongass, and without additional costs to the agency. This is perhaps the biggest flaw of the NEPA analysis and illustrates a poor understanding of real-world economics. With numerous deficiencies, USDA's economic analysis in the DEIS does not accord with economic theory and does not meet the acceptable standard for economic analysis on public lands as mandated by NEPA, the NFMA, and appropriate forest planning. With such a paucity of credible economic analysis, this DEIS and its management direction, is fatally flawed and must be withdrawn.

The major deficiencies regarding economics in the DEIS include:

- USDA did not validate the State of Alaska's claims of economic harm from the Roadless Rule, which are meritless and unsupported.
- USDA's purpose and need are irrational, and they have provided no logical rationale, economic or otherwise, to justify the proposed rule.
- USDA's distributional effects analysis shows the proposed rule will result in zero increases in regional employment, output, or income. USDA has thus verified that there is no logical rationale for the proposed rule, as the entire rationale is predicated on providing further economic development to Southeast Alaska.
- The Cost-Benefit Assessment required for this rulemaking is does not pass scientific or legal muster and does not accord with standard economic theory.
- USDA included timber harvesting costs in Tongass IRAs that are erroneously projected to decrease under the proposed rule, but inexplicably did not include any increased road construction, decommissioning, or maintenance costs.
- In the Cost-Benefit assessment, USDA has mistaken distributional effects of changes in industry revenues for costs and benefits to be used in economic efficiency analysis.
- USDA has not quantified any costs or benefits to the US Forest Service (USFS) or society at large, despite numerous cost increases that will result from the proposed rule.
- USDA's net present valuation (NPV) of costs and benefits appears to be wildly inaccurate.
- USDA has provided almost no supporting economic data to support their claims of harvest cost savings, nor any supporting engineering or economic analysis to project road needs and costs for timber production in Tongass IRAs.
- USDA has omitted most of the Tongass economics literature illustrating the severe economic inefficiency of Tongass timber production and peer-reviewed research illustrating conservation benefits for protecting Tongass old growth.
- When including increased road costs and lost conservation benefits, credible cost-benefit analysis illustrates that the proposed rule will result in losses ranging from $26 million to $48 million, at a minimum.
- USDA has not included synthesized economic research showing that the Tongass timber program has an average cost-benefit ratio of 25. That is, for every $1 million received by the

[1] See Tongass Roadless Rule scoping comments submitted by Dr. Evan Hjerpe on 10/15/18.

U.S. Treasury for stumpage fees, U.S. taxpayers pay $25 million in federal agency costs to subsidize timber harvests.

- In the Agency and Regulatory Costs section, USDA has failed to quantify a single cost to the agency, despite many costs to choose from for analysis.
- USDA did not provide an ecosystem services perspective of the proposed rule, despite its current prominence as the USFS's dominant management paradigm.

1. Introduction

The Tongass National Forest (hereafter, the Tongass) is renowned for its pristine old growth rainforests. Tongass roadless forests provide the iconic backdrop to numerous cruise ships that show tourists the Inside Passage. Tongass roadless forests also provide habitat for spawning salmon and directly support one of the biggest economic drivers in the region---commercial fishing. By providing the economic goods and services required to produce the primary regional economic activities of tourism, commercial and sport fishing, and subsistence, Tongass roadless forests are critical to the provision of widespread economic benefits and impacts to Southeast Alaska. Nationally, Tongass roadless forests are also a major source of economic benefit through carbon sequestration and by providing immense passive use value in the form or option, bequest, and existence values held for scarce and pristine coastal temperate old growth rainforests.

Opening Tongass roadless areas to development will result in tremendous economic losses for the American public and residents of Southeast Alaska. Removing roadless protections in the Tongass is certainly NOT in the best interest of Alaskan residents, nor is it in the best interest of national residents. Jeopardizing such valuable landscapes with irreversible environmental damages is extremely short-sighted and will result in damages to every industry except the timber industry. Exempting the Tongass from the Roadless Rule will also perpetuate a corporate welfare program where taxpayers are forced to subsidize a damaging industry to the tune of $30 million a year. The proposed Rule in the DEIS is both fiscally and ecologically irresponsible.

Inventoried Roadless Areas (IRAs) recognized by the 2001 Roadless Rule provide for numerous economic benefits and impacts to adjacent communities and the nation. By keeping roadless areas undeveloped, nature is allowed to provide high quality ecosystem services, or benefits to mankind. The most notable and obvious ecosystem services protected by the Roadless Rule center on water quality and supply, biodiversity, and carbon storage. Roadless forests in the U.S. contain many headwaters, pristine forests, and critical fish and wildlife habitat. While the majority of ecosystem services produced by roadless forests are not traded in financial markets, there are non-timber forest products such as mushrooms, berries, firewood, and wild game and fish that are marketed or act as monetary supplements for grocery budgets. This is especially true of economies that include a high rate of subsistence activities such as Southeast Alaska.

Much like Wilderness areas and other protected lands, roadless forests are a critical component of our national conservation lands. This reserve of conservation lands is akin to a bank account of nature that continually collects interest and becomes more valuable into the future. Natural areas are rapidly diminishing world-wide and in the U.S. As natural landscapes, and their associated natural disturbance regimes, continue to shrink and scarcity increases, remaining natural areas increase in value.[2] These natural areas hold tremendous option value for the future, including potential medicinal cures, refuge for climate change-affected species, and chemical compounds for agriculture and manufacturing. Eliminating the protection for roadless areas could eliminate future options associated with these natural areas.

Nationally, roadless areas are important for regional economic benefits and impacts. Recent research[3] illustrated the overall economic value of Lower 48 roadless areas. Results show over 11 million annual visits to roadless areas in the Lower 48, that provided for $500 million of economic benefit, or personal value to recreationists, and millions of dollars in regional economic impact from outdoor recreationists who purchase goods and services in the small towns adjacent to roadless areas. Roadless areas are also highly regarded for their passive use values such as existence, option, and bequest values, estimated at $8 billion annually in the continental U.S.[4]

A major reason for implementing the original Roadless Rule was to help prevent wasteful government spending, saying that, “budget constraints prevent the Forest Service from adequately maintaining the existing road system.”[5] The original Roadless Rule also indicated that a national rule was necessary because the Forest Service has “the responsibility to consider the ‘whole picture’ regarding the management of the National Forest System, including inventoried roadless areas” and “[l]ocal land management planning efforts may not always recognize the national significance of inventoried roadless areas and the values they represent in an increasingly developed landscape.”[6]

This is very true of the Tongass, where local land management has failed to recognize, or account for, the national significance of Tongass roadless areas and has shown disregard for the “whole picture” as related to total economic benefits provided. Likewise, Alaska has a $68 million Forest Service road maintenance backlog; nationally the USFS road maintenance backlog is estimated at $3.2 billion.[7] With such an extensive backlog of road needs, why is USDA attempting to increase this deficit? Where is the collective national taxpayer voice in this process?

Given that roadless areas are important for wildlife, water quality, and recreation, there is a tremendous need to have the economic values of roadless areas on the Tongass and elsewhere documented in the public record during the NEPA process. There are over nine million acres of IRAs in the Tongass. These roadless areas gained protection under the 2001 Roadless Rule but would be exempted and opened up for extractive development under the proposed rule. Opening Tongass roadless areas to timber harvest will result in significant environmental consequences---effects that must be, but are not, disclosed in the DEIS.

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[2] Holmes, T. P., Bowker, J. M., Englin, J., Hjerpe, E., Loomis, J. B., Phillips, S., & Richardson, R. (2015). A synthesis of the economic values of wilderness. *Journal of Forestry*, *114*(3), 320-328.
[3] Hjerpe, E. and G. Aldrich. 2018. Economic values and contributions of roadless areas. A Conservation Economics Institute Report. 25p. Available at: https://www.researchgate.net/publication/336444790_Economic_Values_and_Contributions_of_Roadless_Areas
[4] *Ibid.*
[5] 36 C.F.R. §§ 294 (2001), Federal Register pp. 3245-3246.
[6] *Ibid*.
[7] USFS responses to Rep. Mike Quigley.

The best way to visualize the economic value of roadless forests is to examine landscapes that have been developed for timber production or mining. That is, what will be lost when roadless forests lose their protection? What is the economic cost associated with land degradation and pollution? These are the costs that need to be clearly assessed in the EIS process but are lacking in the DEIS. What are the benefits of keeping roadless protections, such as avoided costs of pollution and resource damages? A full assessment of the trade-offs associated with this rulemaking needs to be clearly delineated. The current DEIS is insufficient and must be withdrawn and redone.

2. There is No Purpose and Need for a Tongass Roadless Exemption

USDA and the State of Alaska have not come up with any rational purpose and need for a new rulemaking process. Throughout the DEIS, USDA indicates that the impetus for this rulemaking comes from a petition from the State of Alaska. The State of Alaska (SOA)'s petition (DEIS: Appendix A) to USDA for this rulemaking claims the 2001 Roadless Rule has resulted in "extensive damage… to the economic and social fabric of Southeast Alaska…" The Petition also states that a roadless exemption is needed for the socioeconomic well-being of Tongass residents. However, the State of Alaska provides zero evidence of economic damages coming from the 2001 Roadless Rule, and zero evidence that exempting the Tongass from the Roadless Rule will improve the socioeconomic well-being of Tongass residents. In fact, there is overwhelming economic evidence to the contrary. USDA apparently did not verify the economic rationale from the State's petition, nor did they provide any logical economic reasoning for the preferred alternative in the DEIS. In lieu of evidence-based research from the State of Alaska or USDA, I will first illustrate why the purpose and need for this rulemaking are faulty and then provide economic explanations of the trade-offs associated with exempting the Tongass from the Roadless Rule.

2.1 The Rationale from the State of Alaska's Petition is Inaccurate

The rationale throughout SOA's petition is crystal clear: they are asking the USDA "…to support a diverse and robust forest products sector in Southeast Alaska." It is also crystal clear that the SOA wants a forest products sector based strictly on clearcutting old growth forests. Not only does the SOA's petition request USDA to revise the Roadless Rule on the Tongass, it also requests that USDA revise the 2016 TLMP Amendment *and* revise the established transition from old growth to young growth harvests (DEIS: A-4).

The SOA's petition suggests that the Tongass Roadless Rule is an unnecessary protective policy layer, stating that these roadless areas would be protected with or without the Roadless Rule. Not as clearly stated, but deduced by the content of the entire petition, is that the SOA is seeking access and funding to harvest the most accessible and productive old growth stands currently protected by the Roadless Rule---the 165,000 acres of old growth that the preferred Alternative (6) in the DEIS would convert from unsuitable for timber production to suitable. Is the Tongass Roadless Rule unnecessary and duplicative? No--- especially not for the most accessible and productive old growth, areas with some of the greatest ecosystem service production, that would be on the chopping block.

The SOA claims of economic harm from the Roadless Rule are meritless, as are their claims that regional economic and timber industry conditions are the same as 2003. The SOA petitions states:

"Addressing the serious socioeconomic consequences to Alaskans and complying with ANILCA and TTRA are all compelling rationale for a Tongass Exemption today, as they were in 2003….The State respectfully submits this petition for a rulemaking to exempt the Tongass from the Roadless Rule in the interest of the socioeconomic well-being of its residents." (DEIS: A7-A8).

These "serious socioeconomic consequences" of the Roadless Rule are never specified. How exempting the Tongass from the Roadless Rule will be in the best "interest of the socioeconomic well-being of its residents" is never detailed. Despite an overwhelming lack of evidence to back up these claims, USDA rests its entire purpose and need on the SOA's petition. Additionally, economic conditions in Southeast Alaska have changed substantially since 2003. TTRA "market demand" is down to 46 million board feet and Asian export markets are waning due to tariff and trade war effects. Mill capacity is a fraction of that in 2003 and the transition to Tongass second growth has commenced. Regional Tongass timber employment currently represents less than one percent of regional employment.[8] The two largest private industrial sectors in Southeast Alaska are tourism and commercial fisheries, making up about 15% and 10% of regional private employment respectively.[9] These two industries, tourism and seafood production, are the real drivers of the regional economy and are directly dependent upon the protected roadless forests of the Tongass. The economics question is, why would the federal government remove roadless protections to boost a dying industry (i.e., logging) while irreversibly damaging the natural resources that the rest of the regional economy depends on?

The SOA claims that a Tongass exemption from the Roadless Rule is needed for economic development (i.e, clearcutting old growth), but has provided zero economic evidence for this need, nor any details of how societal benefits would outweigh the costs of development. In summary, the only purpose or need for this rulemaking is to direct greater federal tax dollars to build roads to clearcut old growth forests in Southeast Alaska. This is illogical from almost all perspectives and is an insufficient purpose and need for such a damaging rulemaking.

2.2 The DEIS Purpose and Need is Irrational

Likewise, the Forest Service makes bold claims about supposed economic benefits of the proposed rule:

"The proposed rule is expected to yield a range of benefits (or cost reductions) derived from greater flexibility and a positive net benefit (USDA Forest Service 2019b) and economic opportunities for small business. For example, greater flexibility is provided for the selection of future timber sale areas and sale design (depending on the planning areas selected); and could, in turn, potentially improve the Forest Service's ability to offer economic sales that meet the needs of industry." (RIA: 26)

Upon closer examination, only one benefit has been illustrated---cost reduction in felling, yarding, and loading harvest costs. As shown below, this is not a benefit nor is it accurately calculated. There simply is no positive net benefit from the proposed rule. The citation provided to supposedly show positive net benefit contains no document that illustrates increased net benefit. To provide a useless citation as the source for demonstrating improved economics from the rulemaking is suspect and indicates that there

[8] Alexander, B. and R. Gorte. 2014. The Tongass National Forest and the Transition Framework: A New Path Forward? Bozeman, MT: Headwaters Economics, 32p.

[9] *Ibid*.

are actually no positive benefits to report. Finally, the only effects on small businesses demonstrated in the DEIS are adverse effects on small tourism guides and outfitters.

The real purpose and need given in the DEIS is that:

> "The USDA and Forest Service believe the 2001 Roadless Rule prohibitions on timber harvest and road construction/reconstruction can be adjusted for the Tongass in a manner that meaningfully addresses local economic and development concerns and roadless area conservation needs." (DEIS: ES-2).

While this might be a noble intention, the DEIS tells us that neither economic development concerns, nor roadless area conservation needs, will be meaningfully addressed. In the DEIS, it is estimated that there will be no changes in regional employment and no changes in overall timber production. The proposed rule would eliminate all Roadless protections from 9.2 million acres; this certainly does not address roadless conservation needs. How exactly does the preferred rule help the regional economy or address roadless area conservation needs?

We know that timber harvest and road construction miles in Tongass roadless areas will be greater than zero. Otherwise, there is no purpose for this rulemaking. "Alternative 6 is the preferred alternative and provides maximum additional timber harvest opportunity as the full exemption alternative, which was requested by the State of Alaska's petition." (DEIS: 2-16) We also know that a single mile of constructed roads, and a single acre of clearcut old growth, has adverse environmental consequences on water quality, wildlife habitat, fish, deer, and carbon storage. We know that timber harvests in roadless areas will require more road construction than harvests in the roaded timber base. We know a mile of new roads costs substantial amounts of taxpayer dollars, as does road decommissioning. We know that U.S. taxpayers subsidize timber production on the Tongass at a rate from approximately $500--$1,100 per thousand board feet of timber.[10]   These average costs, benefits, and damages are not disclosed in the DEIS. USDA must, at a minimum, cite this information and ultimately this requires major revisions to the DEIS.

Preferably, these quantified economic and ecological values should be incorporated into sensitivity analysis that illustrates overall average costs for anticipated small, medium, and large incursions into Tongass roadless areas (e.g., see section 4.2 later in this document). This is not difficult and would be much more reasonable than acting as if the preferred alternative will have zero repercussions on the ground. If nothing will happen from this rulemaking, there is no need for it. Providing rough averages and details of obvious implications of the various alternatives is required by NEPA. That the DEIS simply ignores critical environmental consequences is a fatal flaw rendering the DEIS unusable. A new DEIS must be conducted to account for these fatal flaws.

3. The Economic Reality Ignored in the DEIS

USDA is hitching their horse to old growth timber harvesting on the Tongass, which is about as economically and environmentally prudent as subsidizing antiquated extractive industries like coal

[10] Alexander, B. and R. Gorte. 2014. The Tongass National Forest and the Transition Framework: A New Path Forward? Bozeman, MT: Headwaters Economics, 32p.

mining. With excessive subsidies already required for any Tongass timber production, opening Tongass roadless areas to timber development will only increase total subsidies. Exempting the Tongass from the Roadless Rule will also cause economic harm to Southeast Alaska residents by threatening tourism, commercial fishing, sport fishing, and subsistence economies. Corporate welfare provided to the timber industry comes at the costs to southeast Alaskan residents, Alaskan residents, and U.S. residents. USDA must incorporate the best available science to come to a decision in this rulemaking process. If the rulemaking process is actually bound by NEPA guidelines, utilizes the best available science, and maintains integrity owed to the public, the obvious conclusion would have been selecting the no-action alternative as the preferred alternative.

3.1 Economic Trends of Tongass Timber Production Will Not be Reversed by Opening Tongass Roadless Areas for Development

Large-scale timber production in Alaska has never been sustainable, nor has it ever been profitable. In total, U.S. taxpayers have paid billions of dollars to fund Tongass old growth logging. Southeast Alaska has suffered from the resource curse, where communities propped up by subsidized resource extraction, are left worse off after the experiment ends. The jobs were never sustainable, and the remaining residents are stuck with heavily damaged forests and watersheds from logging. The Tongass has always been a "last in, first out" supplier of wood due to exorbitant production costs, extreme isolation from markets, and a lower quality of wood.[11] These multiple factors make it impossible to have large-scale industrial timber production on the Tongass *without* massive taxpayer subsidies.

The Tongass is simply too remote and too mountainous to ever be profitable in large-scale timber production.[12] Most of the Tongass includes low-value trees, which has been exacerbated by a legacy of high-grading. The biggest and the best trees have already been cut. With extreme isolation and ruggedness, the Tongass has the highest logging and processing costs anywhere. Compared to British Columbia and the Pacific Northwest (PNW) region of the continental U.S., Southeast Alaska has the highest timber manufacturing costs and the lowest stumpage prices, with logging costs being 66% greater than in the PNW.[13]

While the Tongass has always been the most inefficient timber production region in the U.S, the absurdity of perpetuating Tongass old growth logging is that Tongass timber production is only getting more and more inefficient. Recent research[14] shows that for the last six years, Tongass timber expenses by the USFS are $122.5 million while stumpage received, or revenue, is $3.4 million. With costs exceeding benefits by 36 times, the Tongass timber program is an incredibly wasteful federal program.

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[11] Robertson, G. and D. Brooks. 2001. Assessment of the competitive position of the forest products sector in southeast Alaska, 1985–94. Gen. Tech. Rep. PNW-GTR-504. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 29 p.

[12] Crone, L. 2005. Southeast Alaska economics: A resource-abundant region competing in a global marketplace. Landscape and urban planning 72: 215-233.

[13] Robertson, G. and D. Brooks. 2001. Assessment of the competitive position of the forest products sector in southeast Alaska, 1985–94. Gen. Tech. Rep. PNW-GTR-504. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 29 p.

[14] Taxpayers for Common Sense. 2019. Cutting Our Losses: 20 Years of Money-Losing Timber Sales in the Tongass. Available at https://www.taxpayer.net/wp-content/uploads/2019/09/TCS-Cutting-Our-Losses-2019-.pdf

The inevitable decline in Tongass timber production is obvious. Employment from Tongass timber production currently sits at an all-time low of approximately 61 jobs. (DEIS: 3-28) The economic trends for timber production and jobs have been steadily decreasing since the closure of the region's pulp mills for both Tongass NF associated production and the entire southeast Alaska region. Due to the exorbitant production costs, isolation from markets, and long-term high grading discussed above, a large-scale timber industry from Tongass production simply isn't feasible. The economic trends will not be reversed by removing roadless protections, nor will it be overcome by subsidizing the industry $30 million a year. A visual projection of Tongass timber jobs clearly illustrates the futility of wasting taxpayers' dollars on corporate welfare.

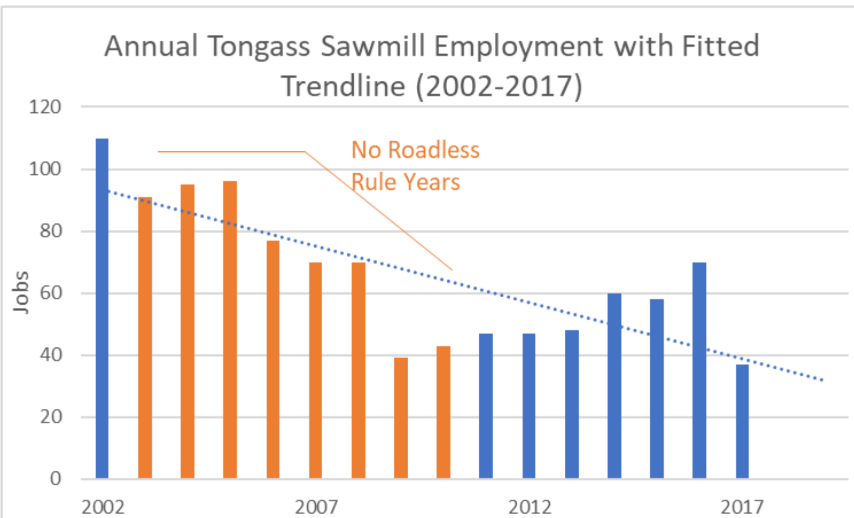

Figure 1: Source for employment data--DEIS Table 3.2-2: 3-28.

Figures 1, 2, and 3 show the steady decline of timber related employment in southeast Alaska and the Tongass. It is important to remember that the last 20 years included multiple Administrations, eight exempt years from the Roadless Rule, and consistent and heavy federal subsidization of logging roads and timber production. For the SOA to claim that the same economic rationale for exempting the Tongass from the Roadless Rule in 2003 exists today is blatantly ignoring all market evidence since then.

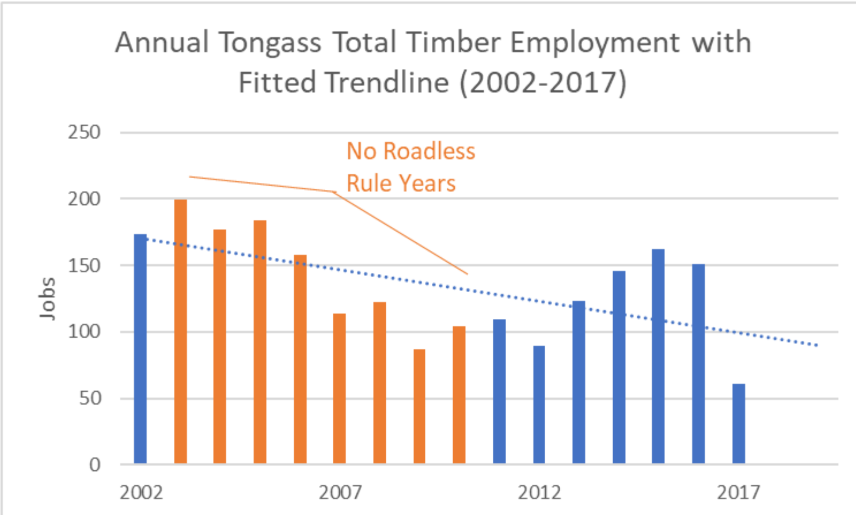

Figure 2: Source for employment data---DEIS Table 3.2-2: 3-28.

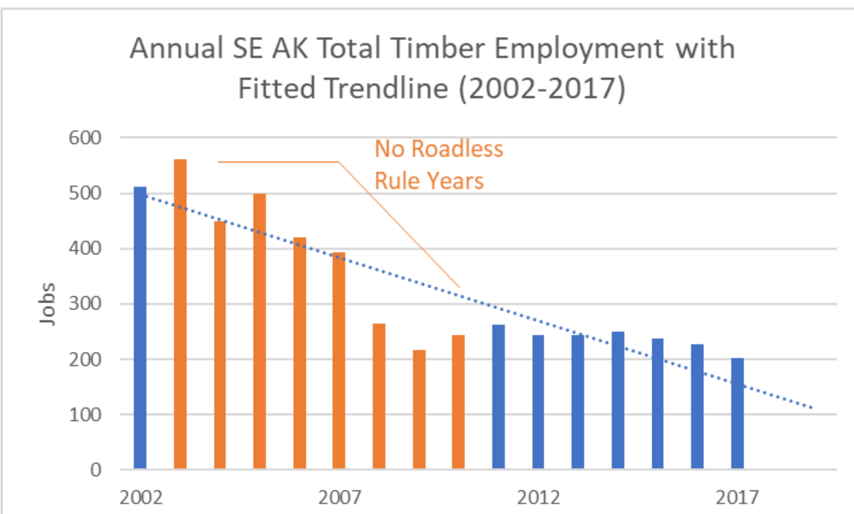

Figure 3: Source for employment data---DEIS Table 3.2-2: 3-28.

The timber industry and Alaska politicians hope that increasing federal timber supply on the Tongass will revive a shell of an industry. However, these hopes are unfounded. Wood supply has never been the problem for the lack of profitability for Tongass timber production. A 2004 legal decision (U.S. Federal Court of Claims, No, 95-153C, Alaska Pulp Corporation (APC) v. United States of America) showed that APC was unprofitable regardless of provisions associated with the Tongass Timber Reform Act (TTRA). Furthermore, recent Tongass timber sales demonstrate that wood supply is still not an issue. From 2000-2010, a period largely exempt from the Roadless Rule, nearly 50 % of Tongass timber sales offered were not bid on at all; of the timber that did sell, approximately 40 % of that supply was defaulted on by the operators or mutually cancelled.[15] The most recent efforts to increase logging by subsidizing prohibitive road construction and timber sale planning costs are still proving to be impossible to overcome the severe lack of profitability. The North Kuiu timber sale has been offered in 2016 and again in 2018. Despite extreme subsidies attached to the timber sale, the sale has received zero bids.[16]

The clear trends indicate that markets and employment for Tongass timber are dying because industrial logging on the Tongass is just too expensive, with or without the Roadless Rule. How can USDA defend its purpose and need for expanding timber opportunities when all evidence shows that exempting the Roadless Rule will not be enough to overcome the dismal economics that characterize southeast Alaskan timber production? Where is the support for SOA's claims in their petition? Where is the scientific evidence in the DEIS? Why is the best available science regarding the lack of economic viability for Tongass timber excluded from the DEIS? This undermines the entire DEIS.

4. The Regulatory Impact Assessment and Cost-Benefit Assessment are Not Credible and are Legally Inadequate

USDA has determined that this rulemaking is a significant rule, per the direction of Executive Orders 13563 and 12866. These orders require federal agencies to conduct a regulatory analysis for economically significant regulatory actions, or those that have an annual economic effect greater than $100 million or adversely affect the economy or economic sectors. As USDA estimates the economic effects of the proposed rule to be less than $100 million annually, the reasoning for determining this as a significant rule is due to anticipated adverse effects to the economy and individual economic sectors. Executive Orders 13563 and 12866 mandate cost-benefit analysis of significant rules and instructs the agency to choose regulatory approaches that "maximize net benefits." From the RIA:

> "Executive Orders 13563 and 12866 direct agencies to assess costs and benefits of available regulatory alternatives and, if regulation is necessary, to select regulatory approaches that maximize net benefits (including potential economic, environmental, public health and safety effects, distributive impacts, and equity). Executive Order 13563 emphasizes the importance of quantifying both costs and benefits, of reducing costs, of harmonizing rules, and of promoting flexibility." (RIA: 4)

Despite the noted importance of quantifying both costs and benefits, USDA has failed to quantify any real costs or benefits in the RIA. One cost and one benefit are quantified---savings in timber harvest costs (which are not really savings) and revenue losses for outfitters and guides. The purported savings in harvest costs are inaccurate and neither one of the costs are appropriate inputs for cost-benefit assessment and should have been included as distributional effects. In addition to inappropriate and inaccurate inputs, the actual calculations of the Net Present Valuation (NPV) appear to be wrong.

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[15] Hjerpe, E. 2011. Seeing the Tongass for the Trees: The Economics of Transitioning to Sustainable Forest Management. Washington: The Wilderness Society, 61p. Available at https://www.researchgate.net/publication/301553259_The_Economics_of_a_Tongass_Transition

[16] https://www.juneauempire.com/news/controversial-timber-sale-cant-find-a-bidder/

In this section, I illustrate the numerous shortfalls in the RIA. These shortfalls are fatal flaws for the entire DEIS, as the economic analysis contained in the RIA is the basis for the environmental consequences in the DEIS. After a review of the analysis included in the RIA, I provide a credible, economically rigorous cost-benefit assessment of the proposed rule that should be used in a revised DEIS. The results of the new CBA clearly show, with reasoned determination, that the benefits of the exempting the Tongass from the Roadless Rule are much less than the costs. That is, the preferred rule is clearly not in the best interest of the public. To meet legal standards for cost-benefit assessments for public lands, USDA must withdraw the net present valuation (NPV) presented in Table 6 (RIA: 35) and incorporate the credible CBA presented at the end of this section in a revised DEIS.

4.1 The Cost-Benefit Assessment is Rudimentary and Wholly Inaccurate

Cost-benefit assessment is used to compare projected management scenarios such as the preferred Alternative to a baseline. In this case, the baseline is the no-action Alternative of keeping the Tongass Roadless Rule in place. The baseline comparison is similar to a with/without analysis. That is, what are the projected changes in costs and benefits if the preferred Alternative (6) is adopted?

Furthermore, it is important to understand the role of Executive Order 13463 and federal guidelines for cost-benefit assessment. Quantifying costs and benefits are emphasized, but if only a few costs and benefits can be quantified, it is still imperative to include "reasoned determination" that the benefits of regulatory actions justify the costs…. "Executive Order 13563 recognizes that a quantifiable analysis is not always possible, but must include a reasoned determination that the benefits justify the regulatory costs." (RIA: 22)

The question being asked at the beginning of the RIA should be "do the benefits justify the costs?" Instead of starting with an open question and working to a reasoned determination, it appears as if USDA worked backwards from a pre-determined answer regarding costs and benefits. There is no other way to account for the errors and lack of economic rigor in the presented CBA. In no way does the RIA and CBA pass scientific or legal muster.

4.1.1 Timber Harvesting Costs Will Increase in Roadless Areas, Not Decrease

Trendlines over time for three timber harvesting costs, out of many, are used to suggest that harvest costs will be reduced by exempting the Tongass from the Roadless Rule. This is the only quantified "benefit" in the CBA. In short, this estimate and the use of this estimate as the only quantified benefit in the CBA, does not constitute credible economic analysis.

For starters, the harvesting costs isolated (felling, yarding, and loading) are just three components of a number of total timber harvest costs and have little meaning when presented in isolation, or cherry picked as done in the DEIS and the RIA. USDA openly admits that the harvest costs presented in the CBA are one set of many harvest costs. For example:

> "In practice, many factors can influence the cost of timber harvest, adding economic risks for potential purchasers and affecting the ability of the Forest Service to offer timber sales. Road construction, helicopter yarding, complex silvicultural prescriptions, setting size, and other factors may increase costs, which then decrease the value of the offering." (RIA: 29).

How the USDA doesn't also include road construction, road decommissioning, and road maintenance costs in this CBA is bewildering, especially as they admit that timber road costs will increase in roadless areas. Furthermore, road construction for timber sales are a cost to the USFS and the public taxpayer[17] whereas felling, yarding, and loading are typically costs covered by timber sale purchasers. USDA has extensive data on the need for more roads per unit of wood harvest in roadless areas, as well as extensive data on road costs. Why were these not included? Why were just a few harvesting costs cherry-picked?

Additionally, the point estimate of reduced harvest costs has no data to back it up and ultimately has nothing to do with the Roadless Rule. Changes in harvesting cost will not be the result of efficiency gains. The USDA's cost-benefit assessment (Table 6, RIA: 35) presents supposed reductions in harvest costs to the timber industry as benefits by comparing timber data for the eight years of the Roadless Rule exemption (2003-2010) to the eight most recent years with the Roadless Rule in place (2011-2018). A simple comparison of the years with and without the Roadless Rule is completely arbitrary and USDA has not made any case on why harvesting costs would change with and without the Roadless Rule.

Science involves developing a hypothesis first, then testing it. But USDA has provided no logical explanation of why harvest costs would be reduced in roadless areas---because they will not be reduced. Tongass timber harvesting costs have been continually increasing for decades, as high grading forces every subsequent timber sale farther up the watershed and towards less valuable wood (greater defect and smaller trees) and less accessible wood (i.e., steeper slopes). While shifting 165,000 acres of Roadless old growth to the suitable timber base may open a few low-elevation, high-volume stands for harvest,[18] overall harvest costs throughout roadless areas will increase due to increased road construction. Felling, yarding, and loading harvest costs are also likely to increase, rather than decrease, when estimating harvest costs across the entire 165,000 acres of old growth---as opposed to just estimating felling, yarding, and loading costs on the most productive 18,000 acres.[19]

Ultimately, USDA has confused the results of a short-term comparison of all timber sales for years before and after the Roadless Rule was back in place (2011), with efficiencies in harvesting costs due to Roadless designation. This is a critical error that undermines the entire CBA. USDA needs to withdraw the current DEIS and revise it to include long-term harvest cost trends dating back to at least the 1980s and adjusted for inflation. Long term harvesting cost trends would likely show continual increases in harvestings costs over time. USDA must also include full engineering and linear programming (e.g. Woodstock model analysis) reports estimating road construction needs, road costs, and other harvesting costs for Roadless old growth forests shifted to the suitable timber base.

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[17] Road construction needed for Tongass timber harvests are fully subsidized by the USFS. When timber sale appraisals are negative, the USFS will tend to pre-road to help sell the timber. Tongass timber managers are directed to reclassify roads as Public Works when dealing with negatively appraised sales (e.g., see R10 Timber Appraisal direction documents). In other sales, the USFS will give purchaser road credits to timber sale purchasers for the estimated cost of road construction. These purchaser road credits are then used for stumpage fee reductions on that sale or other future timber sales, resulting in losses in stumpage revenue to the U.S. Treasury and full subsidization of timber roads by U.S. taxpayers. The budget line item CMRD (Roads Capital Improvements and Maintenance) is used to pay for timber roads and averaged 50% of overall timber budgets from 2001-2008 and 40% of overall timber budgets from 1999-2018.

[18] USDA estimates that only 59,000 acres of the proposed 165,000 acres of Roadless old growth are high-volume.

[19] USDA claims that the projected harvest on the 165,000 acres of Roadless timber for the preferred alternative (6) will only be 18,000 acres over 100 years (DEIS: 3-19). If this is the case, there is no reason to choose Alternative 6 as the preferred alternative. If converting 165,000 acres of Roadless old growth to suitable for timber production, harvesting costs must be estimated for the potential harvest of all acres and must be presented in a revised DEIS.

4.1.2 USDA Has Mistaken Distributional Effects for Costs and Benefits

Another fatal flaw in the CBA is that USDA has only quantified a market impact to the timber industry and a market impact to the tourism industry, not a benefit or cost to the federal government or the public. That is, if there is a reduction of harvest costs (not likely), it will not save the federal government any money; rather, it will save the timber industry a few bucks. This also critically undermines the CBA.

At the beginning of the CBA, USDA states that:

> "Benefits and costs are divided into two parts: 1) those which are realized by any organization or individual, and 2) those realized by the Forest Service. Financial considerations include revenues and costs from the perspective of the Forest Service or other government agencies." (RIA: 22)

Upon review of the RIA, however, there are zero quantified costs and benefits presented for the Forest Service or for the taxpayer at large. Additionally, changes to timber industry harvest costs and costs to the tourism industry are not treated as benefits or costs to individuals or organizations when conducting economic efficiency analysis---they are market changes that are classified as distributional effects according to economic theory. Federal regulatory effects on public lands can have implications for specific industry sectors. While these should be examined, they should **not** be included in cost-benefit assessments. Market impacts are considered distributional effects by economists. Distributional effects do not go into the net present valuation (NPV) calculations---NPV is only for the CBA which is part of the "economic efficiency" analysis required in RIAs and DEISs. Some qualitative effects on individual regional industries are described in the Distributional Effects of the RIA (p. 39) where they belong. But using estimated distributional effects for the timber and tourism industries in the CBA is faulty economics and illustrates a lack of economic rigor in the DEIS and RIA.

The numerous footnotes associated with the damage estimates for the tourism industry in the DEIS and RIA help illustrate why industry effects are not considered as costs or benefits, but rather represent redistributions of wealth. This footnote in the RIA refers to the estimates of lost outfitter and guide revenues due to exempting the Tongass from the Roadless Rule:

> "These estimates provide an upper-bound ceiling for consideration of potential lost revenue, alongside cost savings to the timber industry, and should not be used as precise estimates of roadless area visitor expenditures or losses. Expenses incurred by visitors are not necessarily lost but subject to displacement related changes. While some businesses may lose revenues, if visitors choose not to travel to Southeast Alaska, others may see increases in revenues if visitors choose to stay longer or travel to substitute sites within Southeast Alaska." (RIA: 39)

"Displacement related changes" in markets is the very definition of distributional effects. The recreation industry losses are distributional effects, not a societal cost, even though they represent clear economic harm to the southeast Alaskan tourism industry. This is because visitors will spend their money elsewhere. Despite a lack of footnotes in the RIA explaining this same concept for the timber industry, it should be noted that decreases or increases in timber harvest costs paid for by timber companies are also distributional effects.

4.1.3 Cost-Benefit and Net Present Valuation Calculations Make No Sense

The poor economic analyses presented in the RIA is compounded by illogical Net Present Valuation (NPV) calculations and a lack of clarity. Table 6 in the RIA (p. 35) presents USDA's final CBA as represented by 20-year discounted NPV estimates. Table 6 is difficult to understand for a few reasons. First, costs attributed to the recreation/tourism industry need to be shown as negative numbers, as opposed to currently being presented as positive. Second, a footnote tells the reader that OMB Regulatory Analysis requires the use of two discount rates (3% and 7%). But Table 6 presents NPV estimates under only one discount rate----but which one is not noted. Do the final NPV estimates represent valuation under a 3% discount rate or a 7% discount rate?

Finally, the NPV estimates appear to be wildly inaccurate. Even with incorrect theoretical assumptions for CBA (using distributional effects as costs and benefits), even with arbitrary inputs (incorrect interpretation of reduced harvest costs), the presented NPV estimates still cannot be replicated. If using industry harvest cost reductions of $1 million -- $2 million per year as a benefit in CBA, discounted over 20 years, how does this result in $91 million in NPV for the 46mmbf level and $30 million for the 24mmbf level? From the RIA:

> "Applying cost averages before and after the federal court decision in 2011 ($220 and $265 per MBF, respectively) indicates the proposed rule and Alternatives 2 through 5 could provide approximately $2 million dollars in annual savings at the harvest ceiling of 46 MMBF under the 2016 Forest Plan FEIS." (RIA: 31)

At the upper-bound harvest ceiling of 46 mmbf, harvesting costs reductions are said to be $2 million annually. Specifically, $45/mbf of savings multiplied by 46mmbf equals $2,070,000 of purported savings. To correctly estimate NPV over 20 years, the $2 million in annual savings (or $2.07 million) should be entered as positive cash flow for each of the 20 years. With no discount rate, the NPV would simply be the sum of all 20 years of cash flow, or $41.4 million. However, utilizing a discount rate to account for inflation and a preference for money today as opposed to next year, the $41.4 million NPV is reduced. At a 3% discount rate, the NPV for the 46mmbf level is $30.8 million. At 7% discount rate, the NPV for the 46mmbf level is $21.9 million. The Forest Products Industry—cost savings NPV estimate in Table 6 for the 46mmbf level is $91 million for all alternatives except the No-Action alternative. This estimate is more than three times the real estimate.[20]

The same issues are present for the lower-bound harvest cost NPVs, the Recreation/Tourism cost NPVs, and the final NPVs. USDA needs to clearly articulate how the NPV estimates were calculated. As of now, Table 6 appears to present wildly inaccurate NPV estimates throughout the entire table. Given the numerous problems in the RIA, none of the analysis is to be trusted. None of the analysis is scientifically or legally credible.

4.2 A Credible Regulatory Impact Assessment and Cost-Benefit Assessment

What should have been USDA's approach for assessing costs and benefits of the Tongass Roadless exemption as required in RIAs? That is, what would an economically credible cost-benefit assessment for the Tongass Roadless Rule look like? Below, I detail a scientifically appropriate CBA for the Tongass Roadless Rule to illustrate what is lacking in the DEIS and RIA, and to offer a blueprint for USDA to utilize in a revised DEIS.

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[20] For example, at a 7% discount rate, it would require about $8.5 million in annual savings over 20 years to generate an NPV of $91 million. The USDA has attributed an extra $6.5 million in annual cost savings that do not exist, on top of $1-$2 million of annual harvest cost savings that also don't really exist.

If we are to assume that the preferred Alternative will not increase the overall annual Tongass harvest levels and the Projected Timber Sale Quantity (PTSQ), as stated numerous times in the DEIS, we still know that exempting the Tongass from the Roadless Rule will directly lead to timber harvest in current roadless areas (if there will be no harvest in roadless areas, then there is no need for this rulemaking). Expanding Tongass timber production into roadless areas, even if overall forest harvest levels remain the same, will spur a number of economic costs above and beyond the status quo Tongass timber harvest program. These costs include increased road and overall harvesting costs, decreased conservation values, and damages to the quantity and quality of ecosystem services being produced by intact Tongass roadless areas.

USDA has quantifiable secondary data on increased road costs in Tongass roadless areas. Tongass timber road costs, as opposed to felling, yarding, and loading, are primarily paid for by the USFS. Harvest costs of felling, yarding, and loading are the responsibility of the timber sale purchaser and represent costs to the timber industry, not to the USFS or the public. As discussed above, this means that any effects to the timber industry should be placed under the Distributional Effects section. But, changes in costs to the USFS, such as increased roading costs, are changes in societal wealth and need to be included in the cost-benefit assessment. In fact, agency roads for Tongass timber production are the biggest cost contributor for timber budgets, estimated to be 50% of overall agency timber costs from 2001-2008,[21] and over 40% of overall agency timber costs from 1999-2018.[22]

As discussed above, USDA presented no logical reasoning on why harvesting costs would decrease in roadless areas. Harvest costs, including road costs, on the Tongass steadily increase over time as timber sales are continually pushed higher into watersheds and into less economical timber (this includes roadless areas, as they would have already been harvested prior to the 2001 Roadless Rule if they compared to the productivity of stands that have been harvested since the 1950s). Examining harvest costs based only on a comparison of the eight years without the Roadless Rule (2003-2010) to the eight years with the Roadless Rule (2011-2018) is a poor methodology as these years do not actually correlate well with roaded/roadless logging or include all the relevant costs. Few roadless areas were actually harvested from 2003-2010. The USFS has long term data on harvests occurring in roadless areas and should have engineering reports and estimates on the amount and cost of road construction for the 165,000 acres of Roadless old growth that is shifted into the suitable timber base by the proposed rule.[23] Why has this data not been provided in the DEIS? The only logical conclusion is that USDA has not included this essential data because it illustrates that roadless areas will require much greater timber

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[21] Hjerpe, E. 2011. Seeing the Tongass for the Trees: The Economics of Transitioning to Sustainable Forest Management. Washington: The Wilderness Society, 61p. Available at https://www.researchgate.net/publication/301553259_The_Economics_of_a_Tongass_Transition

[22] Taxpayers for Common Sense. 2019. Cutting Our Losses: 20 Years of Money-Losing Timber Sales in the Tongass. Available at https://www.taxpayer.net/wp-content/uploads/2019/09/TCS-Cutting-Our-Losses-2019-.pdf

[23] For example, forest planning analysis in the 2016 TLMP Amendment estimates that one mile of new road construction will be needed for every 150 acres of old growth harvest (2016 TLMP EIS: B-27). Extrapolated to the 165,000 acres of old growth that will become suitable under the proposed rule, the preferred alternative may lead to the construction of 1,100 miles of new road, requiring a quarter billion dollars of taxpayer funds. USDA claims that the projected harvest on the 165,000 acres of Roadless timber for the preferred alternative (6) will only be 18,000 acres over 100 years (DEIS: 3-19) ---which would still lead to 120 miles of new road. This leads to the question of why Alternative 6 was chosen as the preferred alternative if only 11% of the Roadless old growth acres will be harvested. Thus, USDA's claims are out of alignment and are suspect.

roads, and thus much greater road construction costs, as compared to harvests in the roaded timber base.

With most of the essential data missing from the DEIS, I use the only data provided by USDA on harvesting costs.[24] These data were received only upon request, as the provided reference in the DEIS was a dead end. Harvesting cost data used by USDA have clear findings of inefficiencies in overall timber harvesting costs----specifically increased timber road costs in Tongass roadless areas. The data reveals that the Roadless exemption period (2003-2010) required, on average, three times the miles of new road construction for timber sales as compared to the period when the Roadless Rule was back in place (2011-2018). An annual average of 15.3 miles of new roads were built during Roadless exemption years, but only 5.0 miles of new road were annually constructed with the Roadless Rule in place despite only slightly greater acres harvested in Roadless exemption years (an annual average of 1,700 acres harvested vs 1,400 acres harvested per year from 2011-2018). Clearly, extending timber sales into Tongass Roadless will require many more miles of road as compared to keeping timber sales out of Roadless.

Furthermore, the timber sale information before and after the Roadless Rule change in 2011 show that for every million board feet (mmbf) of Tongass timber harvested during the Roadless Rule exemption, twice as many miles of new roads were constructed as were for every million board feet harvested with the Roadless Rule in place. From 2003-2010, .42 miles of new road were constructed for every million board feet harvested. From 2011-2018, only .21 miles of new road were required for every million board feet harvested, indicating that harvest in Tongass roadless areas will require, on average, .21 more miles of new road construction for each million board feet harvested. While overall Tongass harvest levels may stay the same under the current Roadless rulemaking, overall agency road costs are bound to increase, decreasing Tongass timber production efficiency and increasing federal subsidies. And, as stated earlier, the 2003-2010 to 2011-2018 roadless rule dichotomy is a poor estimate of harvest costs, and the actual increase in roads and road costs for Roadless timber are likely much greater than the data used in this analysis.

While there is variance in Tongass road costs, especially in regard to slope angle, average forest-wide road construction costs were estimated at $185,000 per mile and $50,000 per mile for maintenance in the 2008 TLMP.[25] Adjusting for inflation reveals that current Tongass road construction costs are approximately $225,000 per mile. By incorporating projected timber sale incursions into roadless areas and the increase in average road construction costs, a credible cost-benefit assessment can be conducted. Because the Tongass timber sale program loses substantial amounts of money (i.e., stumpage fees are a fraction of agency timber costs) and damages all other resources and industries, there are no benefits to include in a cost-benefit assessment of exempting the Tongass from the Roadless Rule.

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[24] The USDA reference for Tongass timber harvesting costs presented in the RIA (e.g., p. 29) is presented as "USDA Forest Service 2019b. Timber Sale Summary Reports and Accomplishments, Region 10 RV (Residual Value) Appraisals of Record (1+ MMBF, from 2003 to 2018) available at: https://www.fs.usda.gov/detail/r10/landmanagement/resourcemanagement/." No document with the referenced data was available at the listed website. Upon requesting the source for harvesting cost information, USDA released an Excel spreadsheet titled "Region 10 timber sales before and after 2011 Roadless ip 112219."

[25] 2008 FEIS, TLMP Amendment, Vol. II, App. B at B-11.

While the rulemaking does not authorize site-specific activities, it does authorize a shifting of Tongass timber sales to roadless areas. To provide a general overview of costs and benefits of increasing Tongass timber sales in roadless areas, I examine three potential outcomes: small, medium, and large timber sale incursions into roadless areas.[26] Utilizing the same upper and lower bound of anticipated Tongass timber harvest as presented in USDA's cost-benefit assessment (Table 6 of the RIA, p. 35), I conducted a net present valuation of shifting 25% (small), 50% (medium), and 75% (large) of projected timber sales into roadless areas. Table 1 shows the harvest scenarios and the annual timber road cost increases associated with each scenario.

Table 1: Roadless Timber Incursion Scenarios for Tongass Roadless Rule Cost-Benefit Assessment

Type of Roadless Timber Incursion	Harvest Scenario	MMBF Harvested in Roadless Areas	Additional Roads /mmbf	Addtional Miles of New Road Needed	Road Costs/mile	Annual Timber Road Cost Increase
	Upper-bound--46MMBF harvest ceiling					
Small	25% of timber sales shifted to Roadless	11.5	0.21	2.42	$ 225,000	$ 543,375
Medium	50% of timber sales shifted to Roadless	23	0.21	4.83	$ 225,000	$ 1,086,750
Large	75% of timber sales shifted to Roadless	34.5	0.21	7.25	$ 225,000	$ 1,630,125
	Lower-bound--24MMBF					
Small	25% of timber sales shifted to Roadless	6	0.21	1.26	$ 225,000	$ 283,500
Medium	50% of timber sales shifted to Roadless	12	0.21	2.52	$ 225,000	$ 567,000
Large	75% of timber sales shifted to Roadless	18	0.21	3.78	$ 225,000	$ 850,500

With a range of Roadless harvest scenarios, sensitivity analysis can be conducted to provide a realistic range of road construction cost increases expected under the proposed rule. Table 2 illustrates the NPV for road construction cost increases under two discount rates. These NPVs show tremendous costs over the next 20 years, losses ranging from $3 million to $24 million.

[26] The Roadless timber sale incursion scenarios utilize the USFS-provided data on harvesting and road needs that are based on the eight years with no Roadless Rule (2003-2010) compared to the eight years with the Roadless Rule (2011-2018). As discussed in the text, this short-term comparison of the road/roadless dichotomy is a poor substitute for data focused strictly on timber sales and harvest in roadless areas. The USFS data also only include estimates of new road miles needed per mmbf of harvest. Yet, numerous miles of timber roads have been constructed for sales that go unsold and for large portions of timber sales that are regularly defaulted on. The result is that the presented increase in annual road construction and road costs in this section is likely to be vastly underestimated.

Table 2: Net Present Valuation of 20-Year Discounted Agency Timber Road Cost Increases for Proposed Rule (Alternative 6)[1]

Full Exemption Alternative Scenarios for Proposed Rule		Increased Annual Agency Road Cost	NPV @ 3%	NPV @ 7%
	Upper-bound--46MMBF harvest ceiling			
Small	25% of timber sales shifted to Roadless	($543,375)	($8,084,000)	($5,757,000)
Medium	50% of timber sales shifted to Roadless	($1,086,750)	($16,168,000)	($11,513,000)
Large	75% of timber sales shifted to Roadless	($1,630,125)	($24,252,000)	($17,270,000)
	Lower-bound--24MMBF			
Small	25% of timber sales shifted to Roadless	($283,500)	($4,218,000)	($3,003,000)
Medium	50% of timber sales shifted to Roadless	($567,000)	($8,436,000)	($6,007,000)
Large	75% of timber sales shifted to Roadless	($850,500)	($12,653,000)	($9,010,000)

[1]OMB Circular A-4 - Regulatory Analysis (Sep 17, 2003) requires use of two discount rates (both 3 and 7 percent).

Economic efficiency analysis, or cost-benefit assessment, on public lands must also include the opportunity costs, or benefits foregone, of choosing a preferred land management alternative.[27] That is, what benefits will be foregone by removing Tongass Roadless protections? In the case of the proposed full exemption, the greatest loss of benefits occur to societal conservation values held for pristine and protected Tongass forests. Conservation values are comprised of both use and passive use values held for intact Tongass old growth forests such as those contained in roadless areas. Combined, use and passive use values are known as Total Economic Value (TEV). Use values include direct and indirect use values, such as consumer surplus for recreation and benefits received from ecosystem services produced by roadless areas such as clean drinking water. Passive use values include option, bequest, and existence values held for Tongass roadless areas. Because conservation values are largely comprised of non-market values, they are not as easy to quantify as board feet of timber harvested and typically require direct survey techniques focused on willingness to pay for conservation.

Agencies are traditionally forced to use existing secondary data for analysis as the costs and time for gathering primary data for all regulatory actions is prohibitive. Many national forests may not have existing secondary data on willingness to pay values for forest conservation, to use for quantifying opportunity costs in cost-benefit assessment of development activities. Fortunately, the Tongass does. Recent peer-reviewed research[28] describes a choice experiment quantifying regional Alaska residents' willingness to pay for conserving Tongass old growth forests as opposed to harvesting them. Econometric analysis shows that Alaska residents are willing to pay $150 per acre for the conservation, not harvest, of Tongass old growth in the suitable timber base.[29] As the preferred Alternative (6) shifts

[27] See for example, Freeman, A. M. (2003). The Measurement of Environmental and Resource Values. *Resources for the Future. Washington DC,* p.202; and Hjerpe, E. E., & Hussain, A. (2016). Willingness to pay for ecosystem conservation in Alaska's Tongass National Forest: a choice modeling study. *Ecology and Society*, *21*(2).
[28] Hjerpe, E. E., & Hussain, A. (2016). Willingness to pay for ecosystem conservation in Alaska's Tongass National Forest: a choice modeling study. *Ecology and Society*, *21*(2). Available at https://www.ecologyandsociety.org/vol21/iss2/art8/
[29] *Ibid.*

165,000 acres of Roadless old growth to suitable for timber production, a total conservation benefit value of $24,750,000 (165,000 acres X $150/acre) is lost. These foregone benefits are a one-time societal cost, regardless of how many acres are eventually harvested. Just knowing that these once pristine and roadless areas are open to timber development and have lost their protective status results in the substantial losses in ecosystem conservation value.

Adding in lost conservation benefits[30] as opportunity costs associated with the proposed rule allows for a complete cost-benefit assessment to be estimated, one that appropriately accords with economic theory. Table 3 shows a full cost-benefit assessment of the proposed rule under two discount rates and under six Roadless timber incursion scenarios.

Table 3: Net Present Valuation of 20-Year Discounted Costs and Benefits for Proposed Rule (Alternative 6) Under Six Roadless Incursion Scenarios[1,2,3]

Full Exemption Alternative Scenarios for Proposed Rule		Increased Annual Agency Road Cost	Lost Conservation Benefits*	NPV @ 3%	NPV @ 7%
Upper-bound--46MMBF harvest ceiling					
Small	25% of timber shifted to Roadless	($543,375)	($24,750,000)	($32,113,000)	($28,887,000)
Medium	50% of timber shifted to Roadless	($1,086,750)	($24,750,000)	($40,197,000)	($34,644,000)
Large	75% of timber shifted to Roadless	($1,630,125)	($24,750,000)	($48,281,000)	($40,400,000)
	Lower-bound--24MMBF				
Small	25% of timber shifted to Roadless	($283,500)	($24,750,000)	($28,247,000)	($26,134,000)
Medium	50% of timber shifted to Roadless	($567,000)	($24,750,000)	($32,465,000)	($29,138,000)
Large	75% of timber shifted to Roadless	($850,500)	($24,750,000)	($36,682,000)	($32,141,000)

*Loss of conservation benefits are entered as a one-time cost in Year 1 only.

[1]The baseline for comparison is a continuation of the 2001 Roadless Rule (No-Action Alternative). The No-Action Alternative would produce zero increased costs and has an NPV of $0, a substantially higher NPV than the preferred Alternative.

[2]As there are no economic benefits for exempting the Tongass from the Roadless Rule, the cost-benefit analysis is comprised only of costs and all scenarios result in negative NPV estimates.

[3]OMB Circular A-4 - Regulatory Analysis (Sep 17, 2003) requires use of two discount rates (both 3 and 7 percent).

[30] WTP estimates in Hjerpe and Hussain (2016) are comprised of both use and passive use values. Choice experiment respondents were provided information on environmental damages from Tongass timber production, along with tradeoffs such as providing for timber employment. The average WTP for conserving Tongass old growth includes the societal value for passive use, such as bequest values for knowing that our children will have pristine old growth forests. It also includes the value society holds for avoiding the associated environmental damage that comes from clearcutting old growth. This value includes direct and indirect use values such as damages to subsistence ability (direct use value) and damages to carbon sequestration that affects climate change (indirect use value). The overall WTP is a value known in economics as Total Economic Value (TEV) and is currently the best way to capture societal value held for avoiding environmental damages and foregone conservation benefits when protected areas lose their protective designation.

The cost-benefit assessment shows that all scenarios result in negative NPV, losses ranging from $26 million to $48 million. But the reality is that adoption of the proposed rule will result in much greater losses than illustrated in Table 3. The presented cost-benefit assessment is conservative in every analyzed cost. Not included in this assessment are the additional road decommissioning costs that will be spurred by greater road construction in roadless areas along with greater road maintenance costs. If nearly all of the newly constructed timber roads in roadless areas will be decommissioned, as stated in the DEIS,[31] then the additional roads needed for timber harvest in roadless areas will also result in additional road decommissioning needs. Roads that are not decommissioned will require maintenance. Road maintenance and decommissioning will likely increase overall road costs used in this analysis by 50%. It is strongly recommended that USDA incorporate increased road decommissioning costs in a revised DEIS.

Administrative costs associated with increased road building in roadless areas are estimated to be 40% of overall timber program costs.[32] Additional road construction needs in roadless areas will lead to much greater USFS administration, contracts, and site development needs. Instead of working on restoration projects and land management activities that benefit fish and wildlife, more USFS employees will be needed to administer road construction in roadless areas. In the revised DEIS, USDA should include additional taxpayer costs in indirect and overhead expenses associated with additional road construction that will be spurred by the proposed rule.

Mean willingness to pay estimates used for determining lost conservation benefits were only extrapolated to Alaskan residents[33] and are also very conservative estimates. Given the importance and uniqueness of the Tongass as spectacular public lands, we know that old growth conservation values for the Tongass extend to some degree throughout the rest of the U.S. Given its vast carbon stores, Tongass roadless areas are valued for their conservation throughout the entire world. Research[34] has shown that willingness to pay values, especially for the conservation of iconic and scarce landscapes such as coastal temperate rainforests, extend thousands of miles from the valuation site. USDA should model lost Tongass conservation benefits for the entire U.S. in the revised DEIS.

Finally, other opportunity costs of a Tongass Roadless Rule exemption are omitted in the RIA and DEIS. Increased agency costs from the proposed rule could be used for other, more sustainable, Tongass opportunities instead. For example, if it is "jobs-in-the-woods" that USDA and the State of Alaska are seeking, the focus should not be on developing Tongass roadless areas. The focus and subsidies should

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[31] Page 43 of the RIA… "Nearly all new roads constructed under the regulatory alternatives would be closed following harvest."

[32] Hjerpe, E. 2011. Seeing the Tongass for the Trees: The Economics of Transitioning to Sustainable Forest Management. Washington: The Wilderness Society, 61p. Available at https://www.researchgate.net/publication/301553259_The_Economics_of_a_Tongass_Transition

[33] See Hjerpe, E. E., & Hussain, A. (2016). Willingness to pay for ecosystem conservation in Alaska's Tongass National Forest: a choice modeling study. *Ecology and Society*, *21*(2).

[34] For dam removal and salmon WTP, Loomis (1996) found that the rest of the U.S. households reflected 97% of the benefits. For protecting California old growth forests from fire, Loomis and Gonzalez-Caban (1996) found that nonresidents WTP declined by only 1% for each 1000-mile increase. See: Loomis, J. B. 1996. How large is the extent of the market for public goods: evidence from a nationwide contingent valuation survey? *Applied Economics* 28:779-782 and Loomis, J. B., and A. Gonzalez-Caban. 1996. The importance of the market area determination for estimating aggregate benefits of public goods: testing differences in resident and nonresident willingness to pay. *Agricultural and Resource Economics Review* 25:161-169.

be directed at vastly increasing Tongass recreation and restoration budgets. The Forest Service estimates that there are 500 miles of Tongass fish streams in need of in-channel restoration, along with 15,000 acres of riparian second growth in need of thinning (USFS 2006).[35] There are also 2,300 miles of closed roads on the Tongass, over 500 miles of which represent opportunities for improving water quality and fish habitat (USFS 2006).[36] USDA must focus on community stability and job creation that *help* maintain and restore environmental functions, as opposed to coming at the *cost* of the environment.

4.3 Cost-Benefit Assessment of the Tongass Timber Program

In addition to the cost-benefit of the proposed rulemaking that must be presented in the RIA, USDA should also include overall cost-benefit assessments of increasing Tongass logging. That is, because the proposed rule without limitation on future plan amendments opens the door to substantially greater roadless intrusions over time, the RIA needs to consider the potential costs and benefits of longer range and broader scale old growth logging and road construction than it currently does. An overview of costs and benefits for the Tongass timber program, above and beyond the Roadless rulemaking, would properly frame the significant taxpayer losses associated with any rulemaking aimed at maintaining or increasing Tongass timber harvests. Illustrating the huge subsidies required to produce Tongass timber would more clearly demonstrate that any federal policy that will boost the timber industry will exacerbate existing economic inefficiencies (i.e., increase the costs to benefits ratio).

From a societal perspective, timber production on federal lands have costs associated with preparing timber sales and lost conservation values. Correlating benefits are associated with revenue, or stumpage fees paid by private corporations to the USFS for access to publicly owned timber. In the last decade, there have been four studies that have quantified overall costs and benefits of the Tongass timber program. Interestingly, only one of these studies is acknowledged in the DEIS and RIA. To fill the gap in the Tongass timber program cost-benefit literature, I present the details of the four studies in Table 4.

Table 4: Research on Cost-Benefit Ratios for Tongass Timber Program

Source	Years	Costs	Benefits (Revenue)	Cost-Benefit Ratio	Notes
Taxpayers for Common Sense (2019)	1999-2018	$632 million	$33.8 million	18.7	Includes road costs
Hjerpe and Hussain (2016)	2008, 2012	$108.5/mbf	$7.12/mbf	15.2	Does **not** include road costs; includes lost conservation benefits
GAO (2016)	2005-2014	$12.5 million/year	$1.1 million/year	11.4	Does **not** include road costs
Hjerpe (2011)	2001-2008	$255 million	$7 million	36.4	Includes road costs

Sources: Taxpayers for Common Sense. (2019). Cutting Our Losses: 20 Years of Money-Losing Timber Sales in the Tongass; Hjerpe, E. E., & Hussain, A. (2016). Willingness to pay for ecosystem conservation in Alaska's Tongass National Forest: a choice modeling study. *Ecology and Society*, *21*(2); USGAO. (2016). Tongass National Forest: Forest Service's Actions Related to Its Planned Timber Program Transition. GAO-16-456; Hjerpe, E. (2011). Seeing the Tongass for the Trees: The Economics of Transitioning to Sustainable Forest Management. Washington: The Wilderness Society, 61p.

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[35] USFS. 2006. Investing in habitat improvements vital for ecological sustainability, local economies, subsistence users. Alaska Region Newsletter, June 2006. 2p.
[36] *Ibid.*

From 1999 to 2018, USFS spending on roads in the Tongass made up more than 40% of all timber sale expenses.[37] To compare similar cost-benefit ratios, I update two of the estimates that previously did not include road costs by adding in road costs at 40% of total costs. Table 5 illustrates complete cost-benefit ratios for the Tongass.

Table 5: Research on Full Cost-Benefit Ratios for Tongass Timber Program

Source	Years	Total Costs	Total Benefits (Revenue)	Cost-Benefit Ratio
Taxpayers for Common Sense (2019)	1999-2018	$632 million	$33.8 million	**18.7**
Hjerpe and Hussain (2016)	2008, 2012	$181/mbf	$7.12/mbf	**25.4**
GAO (2016)	2005-2014	$20.8 million/year	$1.1 million/year	**18.9**
Hjerpe (2011)	2001-2008	$255 million	$7 million	**36.4**

Throughout different periods over the last 20 years, the Tongass timber program has a total cost-benefit ratio ranging from 18.7—36.4, with an average cost-benefit ratio of 25. That is, on average, for every $1,000,000 received by the U.S. Treasury in Tongass timber stumpage fees, U.S. taxpayers pay $25,000,000 in federal agency costs to subsidize timber harvest. It is important to note that these timber program costs do not include associated indirect and overhead expenses which were estimated at 40% of total costs for Tongass timber from 2001—2008.[38]

With costs exceeding benefits by 25, and only 61 total Tongass timber jobs supported by millions in taxpayer dollars, the Tongass timber program makes zero economic sense. Over the years, the federal government loses billions of dollars while causing substantial ecological damage. The original Roadless Rule was put in place to eliminate this exact government waste and to avoid this exact ecological destruction. Any federal rulemaking related to Tongass timber production, and specifically the current proposed Roadless exemption, should start with economic facts that clearly show that any attempts to maintain or increase Tongass timber production will only create greater societal losses. Only when dealing with the economic facts can a reasonable determination be made that exempting the Tongass from the Roadless Rule is bad business.

4.4 Agency Costs and Control of Regulatory Costs

In the RIA section "Agency Costs including Control of Regulatory Costs" (RIA: 37), USDA provides no evidence that agency costs will be reduced. USDA conflates incorrectly presumed timber industry savings in reduced harvest costs to reduced agency costs. This is incorrect. The economic reality is that

[37] Taxpayers for Common Sense. 2019. Cutting Our Losses: 20 Years of Money-Losing Timber Sales in the Tongass. Available at Available at https://www.taxpayer.net/wp-content/uploads/2019/09/TCS-Cutting-Our-Losses-2019-.pdf

[38] Hjerpe, E. 2011. Seeing the Tongass for the Trees: The Economics of Transitioning to Sustainable Forest Management. Washington: The Wilderness Society, 61p. Available at https://www.researchgate.net/publication/301553259_The_Economics_of_a_Tongass_Transition

agency costs will sharply increase under the proposed rule, especially for road construction, road decommissioning, and road maintenance.

The Introduction section of the RIA states:

> "If costs from potential displacement of recreationists accrued they would occur alongside cost reduction from more acres of land available for timber harvest. Timber harvest levels on the Tongass NF are set by the 2016 Forest Plan (USDA Forest Service 2016) and continual timber demand monitoring, currently 46 million board feet (MMBF). The propose rule (Alternatives 6) would increase flexibility for timber managers for designing timber sales that appraise positive." (RIA: 6)

How would agency "cost reductions" occur by making more acres of land available for timber harvest? This is nonsensical. Expanding the Tongass woodshed will increase costs and will certainly **not** lead to cost reductions.

The section continues:

> "Cost savings from improved flexibility could, in turn, potentially improve the Forest Service's ability to offer economic sales that meet the needs of industry. Areas closer to markets, either a mill or export facility, are also more likely to offer more economic timber sale options. More distant areas would be relatively expensive to harvest and less likely to be accessed." (RIA: 6)

Cost savings for the agency are never divulged in the RIA or DEIS. What are these costs savings and how would they occur? By the USDA's own admission, agency costs for timber production would substantially increase in roadless areas. Purported harvest costs reductions accrue to the timber industry only. These are not savings for the agency, nor public taxpayer savings. This statement is wholly inaccurate and is simply is not supported in the RIA. This appears to be an attempt to mislead the public and an attempt to satisfy Executive Order 13771. Contrary to this concluding statement, the CBA and RIA conducted by USDA fails the most basic tests for economic rigor and have certainly not illustrated a maximization of net benefits, nor that benefits would outweigh the extremely expensive costs of exempting the Tongass from the Roadless Rule.

The concluding paragraph in the Agency Costs section states:

> "Cost savings from improved flexibility for the agency and timber industry would accrue alongside other benefits, displayed in Table 5 and discussed above; including reduced cost for leasable mineral availability, renewable energy development potential, potential for development of state roads and other transportation projects, and benefits to Alaska native customary and traditional uses." (RIA: 45).

No essential energy or transportation projects have been stopped by the Tongass Roadless Rule. Other purported benefits are also red herrings. As stated above, these "cost savings" are never divulged because they won't actually occur. Expanding the Tongass timber footprint into roadless areas will universally increase all agency costs. Other presumed benefits in this statement are questionable to say the least. It is difficult to even understand what is meant by "reduced cost for leasable mineral availability?" Regardless, the Environmental Effects analysis shows that there are no leasable minerals on the Tongasss (DEIS: 3-155). So how will non-existent costs be reduced?

As shown in the previous section, the agency costs for Tongass timber are already out of control and will escalate under the preferred Alternative (6). Alaska USFS already has a road management backlog estimated at $68 million.[39] Part of the annual Tongass timber agency costs, and miniscule benefits, are acknowledged in the RIA:

> "On average, the Forest Service spent approximately $12.5 million per year to administer Tongass timber sales from 2005-2014, excluding road building costs, and received approximately $1.1 million in revenue per year (GAO 2016)." (RIA: 38)

However, none of the increased road costs that will occur under the proposed rule are presented in the Agency Costs section. At a minimum, per mile road construction, decommissioning, and maintenance costs for the Tongass must be presented in a revised DEIS. Furthermore, USDA must address current road maintenance backlogs in the Tongass, necessary culvert replacements, and watershed restoration needs and estimate current costs. Also not reported in the Agency Costs section, is the estimated $5 million dollar price tag for conducting this rulemaking, much of which has gone to the State of Alaska and to the Alaska timber industry lobby group (Alaska Forest Association).[40] With no rational purpose or need, and without verifying any of the state's claims of economic harm, this rulemaking should have never been initiated and is a large waste of taxpayer dollars. Excessive agency spending will be required if the Tongass is exempted from the Roadless rule. How are these myriad costs not acknowledged in the Agency Cost section?

4.5 The Distributional Effects Show the Preferred Rule will Have Zero Impact on Regional Employment

If the proposed rule is "intended to provide for economic development opportunities in Southeast Alaska" (RIA: 45), then surely the DEIS and RIA would contain economic analysis showing how the rule would increase economic activity and increase regional employment. However, the RIA and the Distributional Effects section does not project any increased economic activity or employment from the proposed rule. This is the case even for the timber industry: "Thus no change in timber related employment or income is expected as a result of the proposed rule or other regulatory alternatives." (RIA: 40)

The primary component of distributional effects used in the NEPA process for public lands rulemaking is economic impact analysis. Economic impact analysis, also known as economic contribution analysis, measures the resulting market impacts associated with a change in regional final demand resulting from a changed land policy. Economic impacts are part of distributional effects because they represent shifts in regional wealth. This shift in final demand results in distributional effects that have a greater impact on industries favored by the rulemaking.

That the Distributional Effects section of the RIA shows zero changes in market impacts or regional employment is clear evidence that the entire purpose and need for this rulemaking is not legitimate. Rhetoric and propaganda from Alaska politicians and the current Administration hold no water. For example, Alaska Governor Michael Dunleavy stated on November 20th that, "Exempting the Tongass from the Roadless Rule will create new jobs and economic activity in a region hit hard by the misguided

[39] USFS responses to Rep. Mike Quigley.
[40] "Congressional Democrats ask for investigation into Alaska use of forest grant." Alaska Daily News, 12/1/19.

policies of a previous administration."[41] Apparently Gov. Dunleavy and his staff have not read the DEIS and the Distributional Effects section in the RIA, where it is clearly divulged that there will be NO new jobs and NO new economic activity spurred by the proposed rule.

5. An Ecosystem Service Valuation for Tongass Roadless Areas

When viewed through an ecosystem services lens, it becomes abundantly clear that exempting the Tongass from the Roadless Rule will damage all other aspects of the Southeast Alaska economy in order to prop up the timber industry. Ecosystem services broadly represent nature's benefits to humans and can be classified into regulating, supporting, provisioning, and cultural. Expanding the Tongass timber harvesting woodshed by increasing the suitable timber base will have adverse environmental consequences on a bevy of ecosystem services currently protected by the Roadless Rule. Because the DEIS does not include an ecosystem service perspective and has failed to even qualitatively describe the full environmental consequences from removing the Tongass Roadless Rule, despite explicit flagging of these economic issues in the scoping process, the DEIS must be withdrawn and a new one must be produced.

Even if one were to accept USDA's insistence that Tongass harvest levels will not increase with the removal of the Roadless Rule, as stated numerous times in the DEIS, the Tongass timber footprint will greatly expand. The habitat fragmentation, sediment alterations, and stream damage from new incursions into Tongass roadless areas will come at a steep price. Unfortunately, secondary data is often missing for quantifying natural resource damages incurred due to expanding the timber footprint into Tongass roadless areas. These resource damages stemming from timber development include reduced water quality, loss of wildlife habitat, and increased carbon emissions. Despite not having easily transferable quantified economic values for damages to ecosystem services, adverse effects from timber production need to be included in a revised DEIS.

A review of the scientific literature paints a very clear picture: Tongass roadless forests provide much greater economic value than the logged over forests. Developing roadless forests for clearcutting of Tongass old growth has been shown to have adverse effects on critical regulating and supporting ecosystem services by increasing erosion[42] and sedimentation of salmon streams.[43] Tongass timber harvests alter hydrologic processes through erosion[44] and reduce large woody debris recruitment to streams resulting in degraded salmon habitat.[45] Road construction needed to access timber also limits

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[41] *Ibid*.
[42] Kahklen, K and W. Hartsog. 1998. Results of road erosion studies on the Tongass National Forest. Unpublished report for USDA Forest Service, Juneau Forestry Sciences Laboratory. 47p.
[43] Tiegs, S., D. Chaloner, P. Levi, J. Ruegg, J. Tank, and G. Lambert. 2008. Timber harvest transforms ecological roles of salmon in southeast Alaska rainforest streams. Ecological Applications 18(1): 4-11.
[44] Gomi, T, R. Sidle, and D. Swanston. 2004. Hydrogeomorphic linkages of sediment transport in headwater streams, Maybeso Experimental Forest, southeast Alaska. Hydrological Processes 18: 667-683.
[45] Heifetz, J., M. Murphy, and K. Koski. 1986. Effects of logging on winter habitat of juvenile salmonids in Alaskan streams. North American Journal of Fisheries Management 6(1): 52-58.

fish passage due to perched culverts.[46] Edges of Tongass clearcuts lose wind firmness, increasing blow down near harvest sites and leading to unraveling of stream buffers.[47]

These adverse effects on regulating and supporting Tongass ecosystem services associated with opening up roadless forests for development will have cascading effects on all biodiversity, particularly salmon. Ultimately, developing Tongass roadless areas will result in fewer salmon for recreational fishing, guided sport fishing, subsistence fishing, and commercial fisheries. This will, in turn, negatively affect economic activities and employment in industries that are much more important to Southeast Alaska than the timber industry. These are the economic trade-offs that must be analyzed and acknowledged in a revised DEIS.

The damage to streams and rivers is just part of the ecosystem service degradation legacy left by Tongass logging. Clearcutting Tongass old growth is also very problematic for forest structure and wildlife habitat. Due to extended decades of stem exclusion phases after clearcut regeneration, Tongass second growth becomes a liability to wildlife dependent on understory forbs and plants. This is particularly problematic for Sitka black-tailed deer,[48] but has cascading adverse effects on wolves and biological regulation functions of the forest.[49] Overstory bird species, such as goshawks and murrelets, also face declining habitat whenever Tongass old growth is clearcut.[50]

Tongass roadless forests represent vast carbon reservoirs. If these forests are opened to timber harvest, carbon will be released contributing to increased climate change. Since Tongass old growth forests have been estimated to contain about eight percent of the coterminous U.S.' carbon stocks[51] and some of the last old growth temperate rainforest in the world,[52] the Tongass also holds tremendous global value and is a critical component in helping mitigate climate change. Using international carbon markets,

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[46] Dunlap, R. 1997. Summary of the 1997 Fish Habitat Risk Assessment Panel, Tongass National Forest, Juneau, Alaska. May 7, 1997.

[47] Harris, A. 1999. Wind in the forests of southeast Alaska and guides for reducing damage. Gen. Tech. Rep. PNW-GTR-244. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 63 p.

[48] Schoen, J., M. Kirchhoff, and M. Thomas. 1985. Seasonal distribution and habitat use by sitka blacktailed deer in southeastern Alaska. Division of Game, Alaska Department of Fish and Game, Juneau, AK; Mazza, R. 2003. Hunter demand for deer on Prince of Wales Island, Alaska: an analysis of influencing factors. Gen. Tech. Rep. PNW-GTR-581. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 21 p.

[49] Person, D., C. Darimont, P. Paquet, and R. Bowyer. 2001. Succesion debt: effects of clear-cut logging on wolf-deer predator-prey dynamics in coastal British Columbia and Southeast Alaska. Paper presented at Canid Biology and Conservation: An International Conference. Oxford University.

[50] Flatten, C., K. Titus, and R. Lowell. 2001. Northern goshawk population monitoring, population ecology and diet on the Tongass National Forest. Alaska Department of Fish and Game. Juneau, AK; Cotter, P. and M. Kirchoff. 2007. Marbled Murrelet. In J. Schoen and E. Dovichin, eds. 2007. The coastal forests and mountain ecoregion of southeastern Alaska and the Tongass National Forest. Audubon Alaska and The Nature Conservancy, Anchorage, Alaska.

[51] Leighty, W., S. Hamburg, and J. Caouette. 2006. Effects of management on carbon sequestration in forest biomass in southeast Alaska. Ecosystems 9: 1051-1065.

[52] DellaSala, D. A., Moola, F., Alaback, P., Paquet, P. C., Schoen, J. W., & Noss, R. F. (2011). Temperate and boreal rainforests of the Pacific Coast of North America. In *Temperate and boreal rainforests of the world: ecology and conservation* (pp. 42-81). Island Press, Washington, DC.

researchers have estimated a market value of $3 to $7 million a year for stopping Tongass old growth harvesting.[53]

5.1 Ecosystem Service Damage from Roadless Timber Development Adversely Impacts the Regional Economy

Resource damage from pursuing Tongass timber production in roadless areas manifests in various economic forms and leaves a natural capital debt for future generations. Reduced black-tailed deer populations and reduced salmon have a direct economic effect on Southeast Alaska's largest private sector industries of tourism and seafood production. Subsistence activities, which comprise a large share of many Alaska residents' annual food budgets, are also degraded by reducing the number of animals for harvest and increasing the time and resources needed to fill the freezer. These resource damages cause economic harm to residents. The natural resource damages must be accounted for in the rulemaking process and must be countered with mitigation efforts.

For example, the latest economic impacts assessment for Tongass recreation shows that recreational visits are increasing and are at almost three million visits per year.[54] Visitors spend money in Tongass gateway communities for transportation services, food, gear, and lodging. In total, Tongass visitor expenditures are estimated at about $400 million annually, resulting in over $100 million in personal income for Southeast Alaska residents. Tongass recreational expenditures support approximately 4,000 direct local jobs, and over 5,000 jobs when including multiplier effects.[55]

The primary appeal for recreating on the Tongass is to enjoy its wildness and ecologically intact attributes that result in abundant native fish and wildlife. Sport fishing and hunting adventures in Southeast Alaska are considered to be "bucket list" trips for avid fisherman and hunters. Wildlife viewing and the ability to view unspoiled old growth forests, glaciers, and mountains spur numerous cruise ship passengers and do-it-yourselfers to pay substantial money to visit the Tongass.

The pristine nature of the Tongass *is* its comparative economic advantage for attracting tourists and recreationists from the Lower 48. If Tongass roadless areas are opened up for greater road building and clearcutting, this comparative advantage is decreased and will diminish the attractiveness of the Tongass for recreation. Are a handful of new subsidized logging jobs worth damaging the vibrant recreation industry on the Tongass? Are a handful of subsidized sawmill jobs worth damaging the vibrant commercial and sport fisheries associated with the Tongass? Economic theory indicates the answer is a resounding no.

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[53] Leighty, W., S. Hamburg, and J. Caouette. 2006. Effects of management on carbon sequestration in forest biomass in southeast Alaska. Ecosystems 9: 1051-1065.
[54] USDA. 2017. Economic effects of national forest recreation in Alaska. Alaska Region Briefing Paper, March 2017.
[55] *Ibid.*

Analysis of Carbon Storage in Roadless Areas of the Tongass National Forest

Prepared by Dominick A. DellaSala, Ph.D, in consultation with Brian Buma, Ph.D

We have reviewed the Draft Environmental Impact Statement (DEIS) for the proposed Alaska Roadless Rulemaking and, in particular, its analysis of carbon storage in the inventoried roadless areas of the Tongass National Forest. The DEIS substantially undervalues the global and national importance of old-growth trees on the Tongass for carbon storage. Research shows, for example, that primary (unlogged) forests on the Tongass store much more carbon than logged forests because of the relatively high percentage of old growth and long stable residence times of carbon stored in these forests. The DEIS incorrectly assumes the carbon emitted from logging represents a zero-sum game with carbon recapture in wood product pools and reforestation – this argument is completely false (see below).

- The Tongass is part of a global network of temperate rainforests that make up ~2.5% of the world's total forest coverage but these rainforests have exceptional carbon stores for their relatively small spatial extent and are critically important in climate regulation collectively and individually.[1]

- The Tongass is one of only 4 other temperate rainforests world-wide that is still largely intact, which is a value of global importance grossly undervalued in the DEIS.[2]

- The Tongass occurs within the Pacific Coastal Temperate Rainforest bioregion (extends from Coast Redwoods to Alaska) that includes temperate rainforest ecoregions and climatically distinguishable subregions (subpolar, perhumid, seasonal, warm temperate) considered globally outstanding for their biodiversity and that collectively comprise over one-third of the world's entire temperate rainforest biome based on latest rainforest mapping that should be cited and elevated in importance in the DEIS.[3]

- Tongass carbon stores are substantially greater than any other national forest in the US and are irreplaceable as carbon sinks.[4]

- Primary (unlogged) forests on the Tongass store much more carbon than logged forests because of the relatively high percentage of old growth and long stable residence times of carbon stored in these forests, and in fact old growth forests are accruing biomass at a rate of approximately a Teragram a year.[5] The DEIS incorrectly assumes the carbon

[1] DellaSala et al. 2011.

[2] DellaSala et al. 2011.

[3] DellaSala et al. 2011.

[4] Leighty et al. 2006; Keith et al. 2009; Buma and Thompson 2019. Also, using the dataset in Krankina et al. 2014, the Tongass is a national carbon champion.

[5] *See* Leighty et al. 2006; Keith et al. 2009; Buma and Barrett 2015

emitted from logging represents a zero sum game with carbon recapture in wood product pools and reforestation – this is completely false (see below).

- The Tongass may function as a climate refuge for species facing more extreme climatic conditions in the interior of Alaska and coastal rainforests further south if managed to protect old-growth forests and roadless areas, based on climate envelope modeling and downscaled climate projections for the region.[6]

- Globally, wilderness and intact areas have been declining at an accelerated rate, contain irreplaceable biodiversity and carbon stores, and these losses can be attributed to the "degazetting" (removal of protection status) globally – while roadless areas are not designated wilderness per se – the DEIS continues the alarming global trend of degazetting wild, irreplaceable places.[7] Instead, maintaining and restoring the integrity of intact forests and wild places is an urgent global priority for conservation and sustainability efforts designed to halt the biodiversity and climate crises.[8] Intact areas are also much more likely to retain their native biodiversity than fragmented areas in a rapidly changing climate.[9]

- Large, old growth trees are critically important globally and scientists are calling for protecting places like the Tongass where large trees are especially concentrated to help avoid a biodiversity crisis.[10]

- Because of the global importance of primary (unlogged) forests and high concentration of old-growth forests on the Tongass, scientists are calling on governments to manage these forests to reach their maximum carbon potential via "proforestation" (nature-based climate solutions that allow forests to mature) in order to mitigate climate change.[11]

- The best option for storing carbon long term on public lands is the "no harvest option" for the Tongass and all US public timberlands.[12] Forgoing timber harvest in these areas is projected to result in a net increase of 43% in carbon stores nation-wide, for instance, and an increase in sequestration potential on the national forests such as the Tongass[12]. The DEIS needs to reflect these published estimates and provide a science-based assessment of carbon stored by old forests and estimated emissions from proposed logging given the national and global significance of the Tongass.

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[6] DellaSala et al. 2015.

[7] Watson et al. 2016a.

[8] Watson et al. 2017; Ripple et al. 2019.

[9] Watson et al. 2016b.

[10] Keith et al. 2009; Lindenmayer et al. 2012, 2013; Krankina et al. 2014.

[11] Mackey et al. 2014; Moomaw 2019.

[12] Leighty et al. 2006; Depro et al. 2008

In sum, the Forest Service is responsible for stewarding arguably the most important national forest in the nation and has an ethical-moral and legal obligation to maintain remaining untrammeled areas on the Tongass as irreplaceable assets within the national forest system (as noted by 234 scientists in an October 2019 letter calling on land managers to leave the Roadless Rule in place in Alaska). These irreplaceable values need to be fully acknowledged and protected for their national and global significance.

Additionally, the Forest Service is taking unacceptable climate and biodiversity risks at a time when thousands of scientists have been calling for stricter protections as climate mitigation/adaptation strategies due to the global biodiversity and climate crises we now face.[13] The best alternative for storing carbon long term on public lands is a "no harvest option" for the Tongass and all US public timberlands.[14] Forgoing timber harvest in these areas is projected to result in a net increase of 43% in carbon stores nation-wide, for instance, and an increase in sequestration potential on national forests such as the Tongass. The DEIS needs to reflect these published estimates and provide a science-based assessment of carbon stored by old forests and emitted from proposed logging given the national and global significance of the Tongass and in relation to these cited studies.

A. THE DEIS UNDERVALUES FOREST CARBON AND GROSSLY UNDERESTIMATES EMISSIONS ATTRIBUTABLE TO LOGGING.

NEPA regulations state that:

> NEPA procedures must insure that environmental information is available to public officials and citizens before decisions are made and before actions are taken. The information must be of high quality. Accurate scientific analysis, expert agency comments, and public scrutiny are essential to implementing NEPA.[15]

To ensure that the agency has taken the required "hard look," courts hold that the agency must utilize "public comment and the best available scientific information."[16]

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[13] Watson et al. 2016a,b; Ripple et al. 2017; Ripple et al. 2019.

[14] Leighty et al. 2006; Depro et al. 2008.

[15] 40 C.F.R. § 1500.1(b).

[16] *Biodiversity Cons. Alliance v. Jiron*, 762 F.3d 1036, 1086 (10th Cir. 2014) (internal citation omitted). Regulations implementing the planning provisions of National Forest Management Act (NFMA) also require the use of the best available scientific information (BASI). 36 C.F.R. § 219.3. As noted above, the proposed action includes adding 185,000 acres to the suitable timber base, which requires that the Forest Service amend the Tongass Forest Plan. The Forest Service's planning regulations apply to Forest Plan amendments. 36 C.F.R. § 219.1. Even if they do not apply, they establish sound agency practice and comport with NEPA's mandates regarding best available scientific information and high quality data.

Further, NEPA requires agencies to explain opposing viewpoints and their rationale for choosing one viewpoint over the other.[17] Federal courts have set aside NEPA analysis where the agency failed to respond to scientific analysis that calls into question the agency's assumptions or conclusions.[18]

The DEIS does not present or consider the best available scientific information about the impact of the proposed action on forest carbon. The DEIS presents a contradictory, scientifically flawed, inappropriately scaled and biased accounting of forest carbon losses associated with suspending the national roadless conservation rule on the Tongass. Not a single forest carbon life cycle analysis is presented, yet, the Forest Service draws sweeping conclusions that undervalue the global importance of carbon stored in old growth and roadless areas (IRAs) on the Tongass, while inappropriately minimizing the emissions footprint from roadless entry at a time when overwhelming scientific consensus urges governments to avoid additional emissions from forest degradation and to store more carbon in forest ecosystems.[19] Because agencies and academics have quantified and compared the carbon emissions of alternative logging proposals, the Forest Service cannot fail to undertake a similar analysis on the basis that it is too complex or complicated. Dr. DellaSala's 2016 report addressed carbon stores from wood products and concluded that logging Tongass old-growth forest under the 2016 Forest Plan would result in net annual CO2 emissions totaling between 4.2 million tons and 4.4 million tons, depending on the time horizon chosen.[20] The Bureau of Land Management a decade ago completed an EIS for its Western Oregon Resource Management Plan in which that agency also predicted and quantified the net carbon emissions from its forest and other resource management programs.[21]

Opening up roadless areas and logging in old-growth forests, as the proposed rule would do, conflicts with published research showing the most effective/efficient means to maintain the

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[17] 40 C.F.R. § 1502.9(b) (requiring agencies to disclose, discuss, and respond to "any responsible opposing view").

[18] *See Ctr. for Biological Diversity v. U.S. Forest Serv.*, 349 F.3d 1157, 1168 (9th Cir. 2003) (finding Forest Service's failure to disclose and respond to evidence and opinions challenging EIS's scientific assumptions violated NEPA); *Seattle Audubon Soc'y v. Moseley,* 798 F. Supp. 1473, 1482 (W.D. Wash. 1992) ("The agency's explanation is insufficient under NEPA – not because experts disagree, but because the FEIS lacks reasoned discussion of major scientific objections."), *aff'd sub nom. Seattle Audubon Soc'y v. Espy,* 998 F.2d 699, 704 (9th Cir. 1993) ("[i]t would not further NEPA's aims for environmental protection to allow the Forest Service to ignore reputable scientific criticisms that have surfaced"); *High Country Conservation Advocates v. Forest Service*, 52 F. Supp. 3d 1174, 1198 (D. Colo. 2014) (finding Forest Service violated NEPA by failing to mention or respond to expert report on climate impacts).

[19] Mackey et al. 2013, Mackey 2014, Mackey et al. 2016a,b, Griscom et al. 2017, Law et al. 2018, Ripple et al. 2019, Moomaw 2019.

[20] D. DellaSala, *The Tongass Rainforest as Alaska's First Line of Climate Change Defense and Importance to the Paris Climate Change Agreements* (2016) at 14, and available at https://forestlegacies.org/wp-content/uploads/2016/01/tongass-report-emissions-2016-01.pdf (last viewed Dec. 13, 2019).

[21] *See* Bureau of Land Management, Western Oregon Proposed RMP Final EIS (2009) at 165-181, excerpts attached.

enormous Tongass carbon sink is to protect all remaining old-growth forests from logging.[22] The DEIS carbon assessment does not present the best scientific information, particularly in reference to the global climate emergency[23] or the importance of keeping carbon tied up in Tongass forests as recommended by scientists.[24] In fact, the DEIS goes as far as to boldly proclaim, without a single published scientific reference, that "the management mechanisms applied in all alternatives are consistent with internationally recognized climate change adaptation and mitigation practices identified by the IPCC (IPCC 2000, 2007)."[25] To the contrary, the IPCC (2018)[26] does not endorse roadless development as an appropriate climate mitigation/adaptation strategy. Rather, the IPCC has repeatedly recommended storing more carbon in ecosystems by avoiding additional emissions in the land sector.[27] The same is true for the published sources cited in these comments. We are unaware of any other research that supports the DEIS assertion that clearcutting old-growth rainforests and building roads into intact watersheds is consistent with adaptation and mitigation strategies.

Based on the recent IPCC assessment (2019), an estimated 23% of total anthropogenic greenhouse gas emissions (2007-2016) derive from agriculture, forestry, and other land use. Thus, IPCC recommends avoiding additional emissions from these sectors.

Notably from the IPCC (2019)

> "Achieving land degradation neutrality will involve a balance of measures that avoid and reduce land degradation, through adoption of sustainable land management, and measures to reverse degradation through rehabilitation and restoration of degraded land. Many interventions to achieve land degradation neutrality commonly also deliver climate change adaptation and mitigation benefits. The pursuit of land degradation neutrality provides impetus to address land degradation and climate change simultaneously (high confidence)."

There are at least two fundamental flaws (inherent *biases*) in the DEIS carbon assessment: (1) undervaluing long-term carbon stored in intact watersheds and old-growth forests compared to logged areas; and (2) understating cumulative emissions from logging and road building by using an inappropriate analysis scale and by overstating wood product stores that do not comport with recent published estimates (discussed below).

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[22] Leighty et al. 2006.

[23] Ripple et al. 2019.

[24] Leighty et al. 2006, DellaSala et al. 2011, Moomaw 2019.

[25] DEIS at 3-128.

[26] Given the large size of this report and the fact that the IPCC report is readily available online, we have provided only the only link and not the full pdf - https://report.ipcc.ch/sr15/pdf/sr15_spm_final.pdf.

[27] *See also* Griscom et al. 2017, Moomaw 2019.

The DEIS also does not sufficiently meet the Forest Service's substantive obligation to protect Tongass resources because it: (1) proposes to enter intact watersheds that are acting as irreplaceable strongholds for fish and wildlife populations in a changing climate;[28] and (2) degrades intact areas containing nationally recognized carbon sinks at a time when scientists recommend avoiding entry into intact areas as critical to preventing the escalating climate and biodiversity crises underway globally.[29] Specifically, the DEIS should continue *to protect, preserve, manage, and restore* natural systems (roadless, old growth) on the Tongass, rather than degrade them by development, and then expecting them to somehow be miraculously restored and recovered with all emissions offset by regrowth and wood product stores – an assumption directly contradicted by the best available science (see below).

To assess properly the impacts of the proposed exemption on carbon emissions and sequestration, the agency must address the following key elements and information not now considered in the DEIS.

Trees accumulate carbon over their entire lifespan. While growth efficiency declines as the tree matures, corresponding increases in a tree's total leaf area overcome this slow down as the **whole-tree carbon accumulation rate increases with age and tree size** (Figure 1 – the figure below and some of the text in this section was modified from materials sent to DellaSala by M.G. Anderson, pers. comm). A study of 673,046 trees across six countries and 403 species found that at the extreme, a large old tree may sequester as much carbon in one year as growing an entire medium size tree.[30] At one site, large trees comprised 6 percent of the trees but 33 percent of the annual forest growth. More recent studies show the largest 1% of trees in old-growth forests worldwide store ~50% of the total stand level carbon.[31] In the Tongass, old growth forests continue to accrue biomass and carbon at an amazing rate[32]. In sum, young trees grow fast, but old trees store a disproportionate amount of carbon over time given the larger leaf surface area for absorption and massive tree trunks and root wads that represent centuries of accumulated carbon.

Quoting directly from the abstract in Lutz et al. (2018):

> Main conclusions: Because large-diameter trees constitute roughly half of the mature forest biomass worldwide, their dynamics and sensitivities to environmental change represent potentially large controls on global forest carbon cycling. We recommend managing forests for conservation of existing large-diameter trees or those that can soon

[28] *See* DellaSala et al. 2011, DellaSala et al. 2015, Watson et al. 2016a,b; 2017.

[29] Watson et al. 2016a,b; 2017; Ripple et al. 2019.

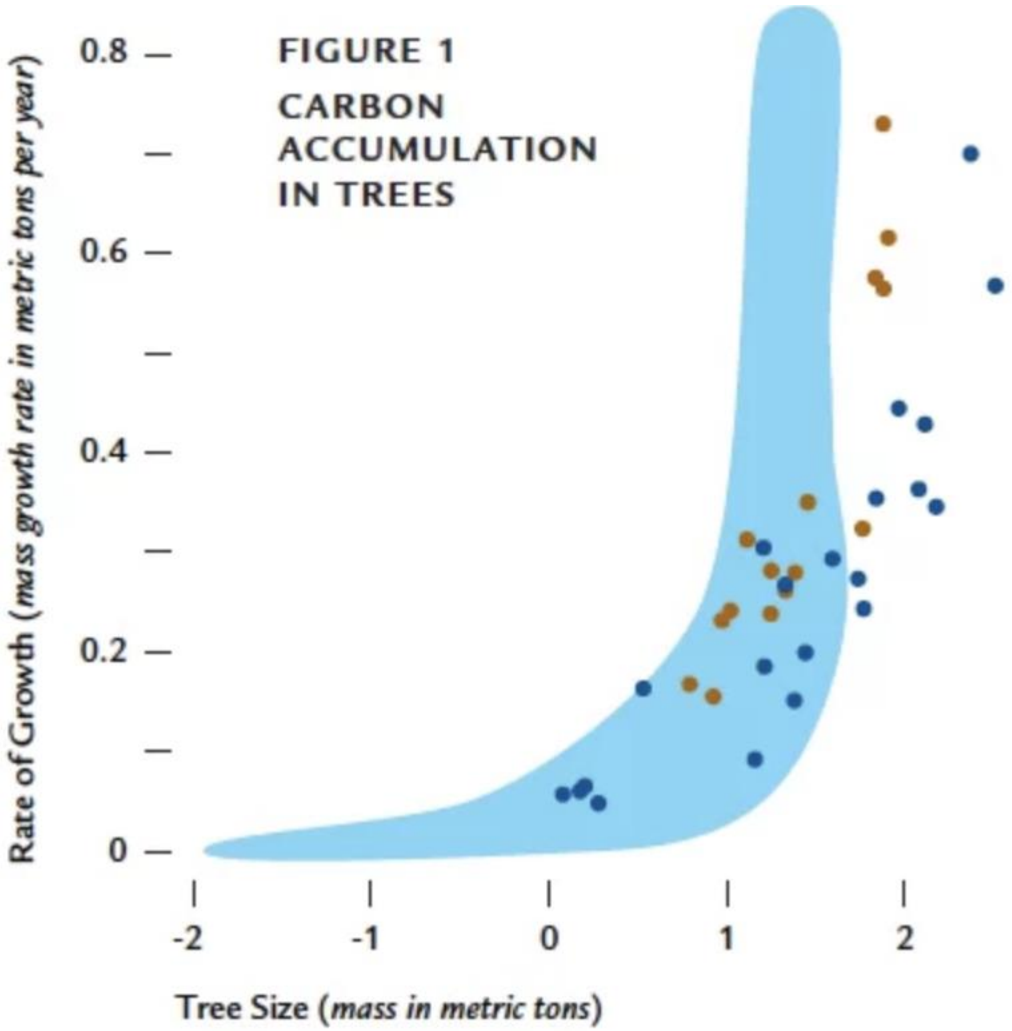
[30] Stephenson et al. 2014.

[31] Lutz et al. 2018.

[32] Buma and Barrett 2015

[33] Lutz et al. 2018

reach large diameters as a simple way to conserve and potentially enhance ecosystem services.[33]



Aboveground mass growth rates for 58 species (shaded area) juxtaposed with two of the most massive tree species on earth: Swamp Gum (*Eucalyptus regnans*—brown dots) and Coast Redwood (*Sequoia sempervirens*—blue dots). Mass growth rate equals the total mass accumulated each year after accounting for respiration. The mass of a tree is primarily carbon, so the figure shows that annual carbon accumulation increases with the size of the tree. (Adapted from Stephenson et al. 2014.)

Old forests accumulate carbon and contain vast quantities of it. Although individual trees experience an increasing rate of carbon sequestration, forest stands experience an “S-curve” of net sequestration rates (e.g. slow, rapid, slow).[32] The expected decline in older stands is due to tree growth balanced by mortality and decomposition. For instance, an international team of scientists reviewed 519 published forest carbon-flux estimates from stands 15 to 800 years old and found that, in fact, net carbon storage was positive for 75 percent of the stands over 180 years old and the chance of finding an old-growth forest that was carbon neutral was less than 1 in 10.[33] They concluded that old-growth forests are substantial carbon sinks, steadily accumulating carbon over centuries and containing vast quantities of it in relatively stable form.

Old forests accumulate carbon in soils. Soil organic carbon levels in old forests are generally thought to be in a steady state. However, as Alaska's climate increasingly overheats (twice the rate of the rest of the US), soils will be exposed to increased drying and reduced snowpack, and this will lead to methane release. Notably, Tongass soils store >50% of the carbon in the already incredibly dense ecosystem[33]. Moreover, protecting remaining unlogged forests provides for more stable microclimates (with less desiccation and lower temperatures). In fact, recent research shows that old-growth forests may act as a climate buffer as studies comparing logged vs. old growth in the Oregon Cascades found that old growth reduced maximum spring and summer air temperatures as much as 2.5 degrees C.[34] Thus, scientists have repeatedly acknowledged the superior climate benefits inherent to old-growth forests that are irreplaceable in human lifetimes.

Forests share carbon among tree species. Trees compete for sunlight and soil resources, and competition for resources is commonly considered the predominant tree species interactions in forests. However, recent research on carbon isotope labeling has shown that trees interact in more complex ways, including substantial exchange and sharing of carbon below ground. Aided by mycorrhiza networks, interspecific transfer among trees accounts for 40% of the fine root carbon: totally ~280 kg ha-1 per year tree-to-tree transfer.[35] Morrien et al. (2017), found that mycorrhiza soil networks become more connected and take up more carbon as forest succession progresses even without major changes in dominant species composition. Notably, old-growth forests compared to young growth contain more complex below-ground processes that connect trees at the subsurface level.[36] Thus, the Forest Service needs to provide information on the impacts of logging on soil microbial and mycorrhizae carbon exchange before concluding it is insignificant. Failure to include such information would violate NEPA's hard look and BASI mandates.

Primary forest carbon can help slow climate change. Griscom et al. (2017) systematically evaluated 20 conservation, restoration, and improved land management actions that increase carbon storage and avoid greenhouse gas emissions. They found that the maximum potential of

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[33] McNicol et al. 2019

[33] Luyssaert et al. 2014.

[34] Frey et al. 2016.

[35] Klein et al. 2016.

[36] Morrien et al. 2017.

natural climate solutions was ~2.4 Pg of carbon per-year while safeguarding food security and biodiversity.[37] To put the Tongass in this perspective – total Tongass stores = 2.8 Pg carbon with 16%-23% of that in IRAs – additionally, by maximizing carbon in IRAs and old growth (the scientifically recommended climate strategy) – the entire national forest benefits through the maintenance of linked ecosystem services and biodiversity (i.e., multifunctionality of forests maintained via carbon management).[38] New research (see below) suggests this strategy is the most cost-feasible option by a large margin[39] (also see below) and it should receive highest priority as a policy consideration[40] especially on the Tongass.[41] In addition to carbon, old forests also build soil, cycle nutrients, mitigate pollution, purify water, release oxygen, and provide habitat for wildlife at levels far superior than logged forests.[42]

Primary (unlogged) forests are far superior to logged forests in climate mitigation and biodiversity benefits. Globally, primary forests store 30-50% more carbon than logged forests (which is similar to the estimates provided in the DEIS on mature vs. logged Tongass forest stores[43]) and up to half of the carbon stored in a forest is represented by the largest/oldest 1% of trees at the stand level as noted.[44] As stated, logging primary forests results in a net carbon debt and other irreplaceable losses that are not made up for via reforestation or wood product stores as the carbon present in primary forests and soils takes centuries to accumulate compared to much shorter-lived wood products that represent only a fraction of the original forest store.

In part because the DEIS analysis fails adequately to account for this basic scientific information relevant to an assessment of the impact of the proposed exemption on carbon and climate impacts, the DEIS is flawed in at least the specific ways described herein.

Tongass carbon stores need to be prioritized as globally and nationally significant climate mitigation/adaptation strategies to be protected, preserved, and managed as unique ecological communities. Old-growth forests, in general, store massive amounts of carbon in trees, foliage, and soils. Pacific coastal rainforests, in particular, are global champions in this regard.[45] Of relevance, temperate rainforests in Alaska store >2.8 Petagrams (Pg) C (1 Pg = 1 billion tonnes) in biomass and soils, the equivalent of >8% of the carbon in all contiguous US forests, most of which is on the Tongass.[46] Based on FIA datasets, Tongass roadless areas

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[37] Griscom et al. 2017.

[38] *See* Brandt et al. 2014.

[39] Moomaw et al. 2019.

[40] McKinley et al. 2011.

[41] Leighty et al. 2006; Buma and Thompson 2019

[42] Mackey et al. 2014, Brandt et al. 2014.

[43] DEIS at 3-124.

[44] Lutz et al. 2018.

[45] Leighty et al. 2006, Keith et al. 2009, Krankina et al. 2014.

[46] Leighty et al. 2006; Buma and Thompson 2019; McNicol et al. 2019

represent ~16% to 23% of total carbon on the Tongass forest depending on categories used (Table 1, 2). Thus, roadless areas – especially those with old-growth forests – are uniquely valuable as a long-term stable carbon sink compared to logged areas that emit most of their carbon (see below).

The Tongass stores a massive amount of carbon--the total carbon stored in Tongass roadless areas are equivalent to annual emissions of ~128, 550-watt coal-fired power plants.[47] Keeping carbon in forests is a fundamental climate mitigation strategy directly responsive to the climate emergency[48] and essential to offsetting some of the emissions from the energy sector. The Tongass stores a massive amount of carbon in its old growth forests, at levels that if emitted into the atmosphere would approach the emission equivalents of coal-fired power plants. At a time when the world is looking for leadership on cutting emissions at all scales, removing protection for this carbon storage is unsupportable. Table 1 provides a breakdown of Tongass old-growth roadless carbon values (including congressionally withdrawn areas), Table 2 just the IRA carbon values, and Figure 1 shows the spatial distribution of carbon stores on Tongass IRAs. Table 3 shows that Alternative 6 will place at risk 71.5% of the carbon stored in old-growth forests and soils, with most of that carbon emitted to the atmosphere (see Leighty et al. 2006). Table 4 provides an economic estimate of the carbon value at risk to logging on the Tongass under Alternative 6 (>$234 million), which may far exceed timber values. Additionally, if the Forest Service enters all roadless areas in this century >$2.2 billion in carbon assets will be squandered away, should an offset market develop. All these data were available to the Forest Service (Forest Inventory Assessment - FIA) and they need to be fully analyzed in the DEIS to provide reliable estimates of carbon assets and their relative (to timber), tradeoffs involved, and the economic importance on the Tongass of carbon, along with reliable estimates of emissions from logging. Disclosing these tradeoffs is especially relevant at a time when the IPCC (2018, 2019) and other reports (Ripple et al. 2017, 2019) have warned that we have about 10 years before severe climate impacts are locked in with irreversible consequences to biodiversity and the planet's life-giving systems.

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[47] https://www.oregonlive.com/business/2010/12/pges_coal-fired_boardman_plant.html.

[48] *See* Moomaw 2019, Ripple et al. 2019.

Table 1. Estimated carbon biomass in old-growth forest among categories of roadless areas on the Tongass NF						
OwnerType_2019	**USDA FOREST SERVICE**					
POG	**OG Only**					
	low estimate	**high estimate**	**Total area**		**Estimate C in OG forest biomass**	
Row Labels	**Average of Carbon_ratio 58**	**Average of Carbon_ratio 46**	**Sum of GIS_Hectares**		**(low estimage in Mg)**	**(high est. in Mg)**
Roadless in 2001 Rule	264.7	333.7	999,179		264,443,913	333,444,106
Lg. Roadless Areas not in	257.1	324.1	76,166		19,580,156	24,689,023
Small Rdls Areas	242.4	305.6	58,329		14,139,031	17,828,070
Roaded-Roadless	249.3	314.4	14,357		3,579,634	4,513,860
Roaded Areas	263.3	332	156,023		41,076,507	51,794,893
Wilderness or NM	247.7	312.3	662,496		164,101,837	206,915,638
Non-USFS Lands	261.5	329.8	4,171		1,090,861	1,375,453
Unknown	187.5	236.5	982		184,209	232,273
Grand Total	**255.6**	**322.3**	**1,971,704**		**503,969,209**	**635,467,036**

Table 2. Carbon stored in roadless area categories on the Tongass.

Large Roadless Areas Average Mg per ha	Total Mg Carbon	"Roaded Roadless" Average Mg per ha	Total Mg Carbon	Small Rdls Areas Average Mg per ha	Total Mg Carbon	Roaded Areas Average Mg per ha	Total Mg Carbon	Protected by Congress Average Mg per ha	Total Mg Carbon	Non-USFS Lands Average Mg per ha	Total Mg Carbon	Total Average Mg per ha	Total Total Mg Carbon
242.58	**47,208,021**	**274.78**	**98,058**	**313.89**	**1,867,886**	**361.48**	**10,026,227**	**207.71**	**66,457,805**	**263.80**	**5,436,143**	**260.64**	**131,094,140**
245.92	2,081,610					317.13	83,671	224.49	36,976,406	205.86	248,378	224.82	39,390,064
224.39	7,939,491	248.04	7,679	361.21	317,926	374.39	1,469,914	179.03	2,579,177	277.13	198,836	277.09	12,513,023
255.70	18,610,022	295.11	85,792	305.53	1,322,520	356.44	6,423,528	210.15	11,972,020	286.92	3,550,567	278.05	41,964,449
231.40	17,172,289	226.63	4,587	304.03	227,439	371.92	2,025,237	144.80	7,123,632	252.95	1,407,175	261.84	27,960,360
190.38	1,404,610					234.51	23,876	185.47	7,806,570	228.97	31,187	192.89	9,266,244
232.20	**58,182,471**	**262.79**	**1,429,232**	**261.26**	**4,248,583**	**303.66**	**15,895,643**	**196.32**	**22,381,595**	**253.61**	**11,984,173**	**249.11**	**114,121,697**
236.71	9,363,695	232.25	279,800	213.54	756,243	291.33	3,979,300	167.72	2,705,767	252.31	1,048,227	244.24	18,133,031
248.42	4,621,788			282.27	61,790	345.31	264,235	231.39	6,290,381	200.47	149,533	246.54	11,387,728

201.63	14,044,010	240.78	675,871	236.58	1,737,670	276.70	4,000,336	199.16	2,694,688	216.69	3,418,960	225.90	26,571,535
289.39	4,013,721	317.04	8,473	337.44	1,008,771	340.32	3,176,035	284.31	1,032,343	291.65	521,090	311.71	9,760,434
237.96	26,139,257	301.06	465,088	286.21	684,109	320.59	4,475,736	177.93	9,658,416	268.36	6,846,362	254.25	48,268,969
229.96	**31,318,111**	**247.66**	**892,278**	**238.48**	**2,941,262**	**290.26**	**16,874,911**	**239.86**	**16,293,468**	**268.92**	**21,060,394**	**255.37**	**89,380,425**
264.73	5,634,563			226.80	397	356.33	2,846			265.96	3,679,426	266.56	9,317,233
219.88	15,720,049	244.81	775,492	234.97	2,586,253	287.67	15,078,975	258.07	7,425,974	261.59	14,491,136	252.13	56,077,879
281.10	2,088,047	230.67	21,443	251.59	236,829	294.96	1,465,398	196.99	4,999,443	315.98	468,652	278.44	9,279,811
231.49	7,875,451	293.14	95,343	284.60	117,783	322.67	327,692	192.56	3,868,051	296.39	2,421,180	256.94	14,705,501
186.13	**53,884,796**	**336.78**	**287,412**	**333.72**	**595,565**	**312.46**	**2,942,711**	**149.44**	**66,534,550**	**259.89**	**5,757,139**	**213.28**	**130,002,173**
192.56	11,619,409	369.34	120,627	327.18	275,972	313.76	861,295	118.57	3,208,927	268.13	1,822,554	235.07	17,908,784
62.94	1,228,345			368.10	96,490	136.68	78,974	159.84	18,154,192	284.05	46,875	168.06	19,604,876
						123.88	45	181.02	31,003,210	148.94	170	179.52	31,003,425
187.62	21,671,798	288.49	136,481	309.91	31,943	325.86	1,478,419	118.41	7,974,912	260.51	721,358	212.07	32,014,912
192.02	19,365,243	314.33	30,304	440.91	191,161	322.72	523,978	118.67	6,193,309	251.30	3,166,182	215.24	29,470,176
225.32	**190,593,399**	**264.38**	**2,706,980**	**265.82**	**9,653,295**	**312.40**	**45,739,492**	**196.09**	**171,667,419**	**263.11**	**44,237,849**	**247.37**	**464,598,434**

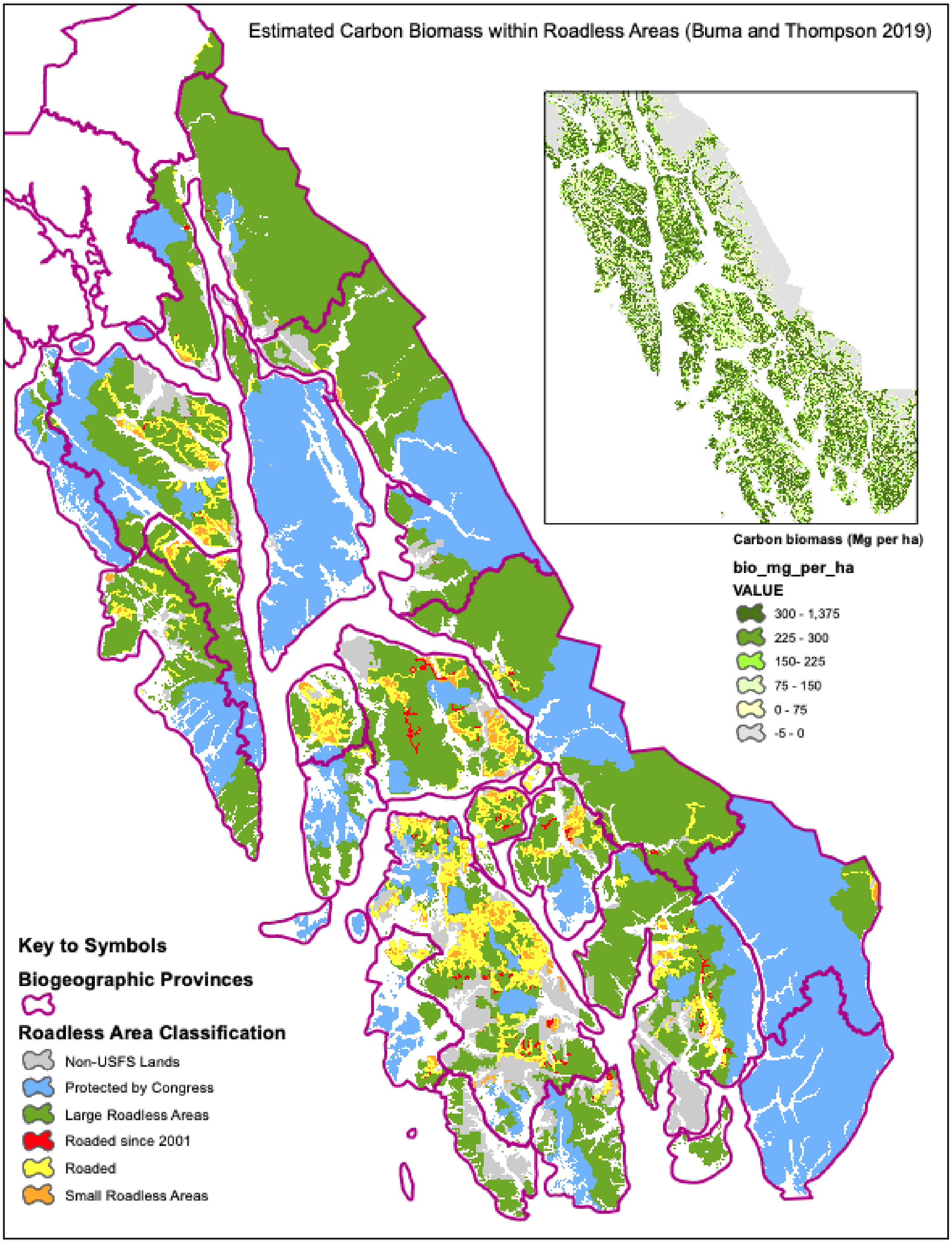
Estimated Carbon Biomass within Roadless Areas (Buma and Thompson 2019)
Carbon biomass (Mg per ha)
bio_mg_per_ha
VALUE
300 - 1,375
225 - 300
150- 225
75 - 150
0 - 75
-5 - 0
Key to Symbols
Biogeographic Provinces
Roadless Area Classification
Non-USFS Lands
Protected by Congress
Large Roadless Areas
Roaded since 2001
Roaded
Small Roadless Areas

Table 3. Estimated Mg of forest and soil carbon on lands suitable for old-growth logging under DEIS Alternatives

	Alternatives					
Forest & Soil Carbon Estimates	**1**	**2**	**3**	**4**	**5**	**6**
Suitable Acres (with Data)	229,564	249,888	307,778	387,941	394,997	394,997
Net Change from Alt 1 (acres)	0	20,325	78,214	158,377	165,433	165,433
Suitable Hectares (w/data)	92,901	101,126	124,554	156,994	159,850	159,850
Net Change from Alt 1 (hectares)	0	8,225	31,652	64,093	66,948	66,948
Total Forest C (low est)	23,625,799	25,643,535	31,591,558	39,655,731	40,508,557	40,508,557
% Increase from Alt 1 (low est)	0.0%	8.5%	33.7%	67.8%	71.5%	71.5%
Total Forest C (high est)	29,790,661	32,334,884	39,834,901	50,003,261	51,078,589	51,078,589
% Increase from Alt 1 (high est)	0.0%	8.5%	33.7%	67.8%	71.5%	71.5%
Total Soil C	34,284,875	37,153,086	45,699,226	56,497,163	57,468,262	57,468,262
% increase from Alt 1 (soil)	0.0%	8.4%	33.3%	64.8%	67.6%	67.6%
Forest + Soil C (low)	57,910,675	62,796,621	77,290,783	96,152,894	97,976,819	97,976,819
Forest + Soil C (high)	64,075,536	69,487,970	85,534,126	106,500,424	108,546,851	108,546,851
% Increase from Alt 1 (high)	0.0%	8.4%	33.5%	66.2%	69.4%	69.4%

Table 4. Economic value of at-risk carbon (Alternative 6 plus all suitable)

	Alt 6 suitable timber at-risk	All suitable timber at-risk
Acres	42,500	394,997
Low est total carbon	40,508,577	40,508,577
CO2 (carbon x 3.67)	148,666,478	148,666,478
Value of CO2 at-risk in suitable timber base* at $15/ton CO2	$240,839,694 40% logged in first decade = $96.3 million	$2.2 billion

*Suitable timber base = 10.8% of at-risk carbon under Alt 6, 100% at risk under all suitable acres

Carbon emissions assessment by the Forest Service provides a misleading comparison to other emissions and fails to include a social cost analysis. The DEIS is woefully inadequate as it compares emissions (prior and current logging) on the Tongass to gross emissions from the **entire US electric power sector in 2012** and **all US emissions in 2017**.[49] Federal courts have rejected this kind of skewed comparisons.[50] This arbitrary baseline ignores the incremental nature of carbon emissions and impacts and is inconsistent with recommendations of the IPCC (2018) to avoid additional emissions, and with the broader scientific consensus of fully protecting carbon sinks like the Tongass.[51] To comply with NEPA, the Forest Service must, at a minimum, explain why it is choosing to ignore these expert conclusions. The global community also has signaled its intent to protect carbon sinks under Article 5 of the Paris Climate Agreement. While the US is irresponsibly withdrawing from the agreement, it is also irresponsible for the Forest Service to downplay the substantial regional emissions from Tongass roadless and old growth logging when the rest of the world is looking for ways to reduce and avoid emissions **at all scales**. Instead, the agency should choose the alternative with the least

[49] DEIS at 3-124.

[50] *See High Country*, 52 F. Supp. 3d at 1190 ("Beyond quantifying the amount of emissions relative to state and national emissions and giving general discussion to the impacts of global climate change, [the agencies] did not discuss the impacts caused by these emissions."); *Mont. Envtl. Info. Ctr. v. U.S. Office of Surface Mining*, 274 F. Supp. 3d 1074, 1096–99 (D. Mont. 2017) (rejecting the argument that the agency "reasonably considered the impact of greenhouse gas emissions by quantifying the emissions which would be released if the [coal] mine expansion is approved, and comparing that amount to the net emissions of the United States"); *WildEarth Guardians v. Zinke*, 368 F. Supp. 3d 41, 76-78 (D.D.C. 2019) (holding BLM's conclusion that the emissions from oil and gas leases "represent an incremental contribution to the total regional and global GHG emissions level" was arbitrary and capricious because it was not supported by any data).

[51] Keith et al. 2009, DellaSala et al. 2011, Stephenson et al. 2014, Mackey et al. 2014, Law et al. 2018, Moomaw et al. 2019.

emissions – no action – and compare alternatives against no action with respect to reliable and accurate direct, indirect, and cumulative emissions. This also needs to be expressed in carbon dioxide equivalents to estimate the socio-economic cost of carbon. Additionally, the emissions need to be expressed at an appropriate **regionally specific scale**, as for instance, coal-fired power plant equivalents as mentioned above so that the public understands the true regional climate consequences of opening roadless areas to logging and development.

Further, the DEIS falsely asserts that "it is difficult and highly uncertain to ascertain the indirect effects of emissions resulting from these alternatives on global climate."[52] The Forest Service could easily express the indirect impacts of climate emissions by quantifying or estimating climate pollution volumes by alternative (as noted above in our analysis) and then using the social cost of carbon (SCC) to assess and compare the significance of the effects on global climate. The very purpose of the SCC is to assist decisionmakers in (conservatively) estimating the marginal damages from each additional ton of greenhouse gas emissions. To avoid this analysis irresponsibly kicks the emissions can down the road.

The DEIS incorrectly states that most of the carbon in trees after logging will be recovered via reforestation and stored in wood products for buildings instead of stored in forest ecosystems and this is completely false. As noted, a substantial portion of the total forest carbon is contained in foliage, branches and bark, root wads and soils.[53] Because much of the carbon in logs hauled to mills becomes waste, only a relatively minor portion of the total tree carbon ultimately ends up in wood products.[54] Up to 40% of the harvested material does not become forest products and is burned or decomposes quickly on site, and a majority of manufacturing waste is burned for heat. One study found that 65% of the carbon from West Coast forests logged over the past 100 years is still in the atmosphere with just 19% stored in long-lived products; the remainder is in landfills.[55] Additionally, Leighty et al. (2006) reported that a century of Tongass logging has emitted 6.4-17.2 Tg C that is still in the atmosphere (again – it matters most what the atmosphere "sees" more than what is stored in wood products). Further, Hudiburg et al. (2019) note that state and federal reporting of emissions has erroneously excluded some product-related emissions, resulting in 25-55% underestimation of total CO2 emissions from logging. Thus, the Forest Service needs to fully disclose and provide reliable estimates on how much carbon is emitted by clearcutting given the substantial fall down and problems with underestimating emissions as noted. Large amounts of logs, stumps, root wads and slash are left on the ground after clearcutting and soils are noticeably disturbed by heavy equipment. This cannot be simply dismissed as an insignificant impact in the DEIS.

It is also wrong for the Forest Service to assert that carbon stored in Tongass saw logs (wood product pools) compensates for carbon emitted by logging long-lived (hundreds of years) trees in

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[52] DEIS at 3-127

[53] Campbell et al. 2007.

[54] *See*, *e.g.*, Harmon et al. 1990, Harmon et al. 1996, Ingerson 2008, Law et al. 2018, Harmon 2019.

[55] Hudiburg et al. 2019.

the Tongass old-growth carbon sink.[56] The carbon debt created by expansive clearcut logging (past, present, future) must be calculated using reliable and accurate estimates via a carbon life cycle analysis that accounts for how long carbon remains in the atmosphere (after all, it's what the atmosphere "sees" that matters most in the long run). Thus, at a minimum, NEPA requires that the Forest Service conduct a carbon life cycle analysis using published sources and the Forest Service should use FIA/timber stand data on estimated carbon uptake and stores in old growth vs. young growth to calculate age-related differences in carbon stores and associated emissions from logging (e.g., using the carbon values for Tongass old growth and IRAs in our comments) at the regional scale. The following analysis components should be included in the DEIS:

- In-boundary emissions – at the stand and landscape level, this includes carbon entering the atmosphere from the substantial "fall down" and defect of uneconomical logs, slash, and stumps – based on Tongass timber stand inventory data (2016-18) fall down alone (uneconomical material) may be as high as 70% of felled trees (carbon emitted directly to the atmosphere) with old-growth defect at least 30%.

- Out-of-boundary emissions – this includes: (1) carbon emitted via wood processing waste at the mill (see Law et al. 2018 for example); (2) fossil fuels used in transport and manufacture of wood products, including emissions from log exports sent to China and then exported for distribution as products, the lower 48 states and elsewhere (note - transport emissions are easily obtained from the Alaska Department of Environmental Conservation Division of Air Quality (greenhouse gas emission inventory[57]; and (3) estimated emissions from road building.[58]

- Use more recent studies on wood product substitution estimates – Harmon (2019), for instance, re-examined substitution assumptions questioning their *reliability* in life cycle analysis and concluding that any benefits depend on duration of fossil carbon displacement, longevity of buildings being assumed, and nature of the forest supplying building materials (also see below):

  "Substitution of wood for more fossil carbon intensive building materials has been projected to result in major climate mitigation benefits often exceeding those of the forests themselves. A reexamination of the fundamental assumptions underlying these projections indicates long-term mitigation benefits related to product substitution may have been overestimated *2- to 100-fold (emphasis added)*. This suggests that while product substitution has limited climate mitigation benefits, to be effective the value and duration of the fossil carbon displacement, the longevity of buildings, and the

[56] *See, e.g.*, DEIS at 3-127.

[57] *See* https://dec.alaska.gov/air/anpms/projects-reports/greenhouse-gas-inventory)

[58] *See* Loeffler et al. 2008 for how to estimate this -note – this is a Forest Service publication easily accessible to the agency.

nature of the forest supplying building materials must be considered."[59] Failure to address this scientific study would violate NEPA's and NFMA's mandate that the Forest Service use the best available science and that the agency explain why its approach differs from that of experts.

- The need for reliable published references to estimate wood product stores– Researchers report most carbon is emitted to the atmosphere when old trees are logged, accounting for wood product stores is only a fraction of the carbon pool (e.g., ~35% of the live carbon is rapidly emitted when an old-growth forest is logged with another 30% emitted at the mill and even more in transportation).[60]

- The reference to an albedo effect in the DEIS (at 3-123) is unreliable, cannot be verified, is inconsistent with the BASI requirement, and should be dropped. The DEIS provides no citation or support for its unsubstantiated albedo assumption, which likely was extrapolated from the boreal regions where albedo has been reported as having a potential cooling affect because of the reflectance properties of snow. The Forest Service cannot make this same claim for the Tongass given that low-elevation temperate rainforests experience relatively little snow (and therefore have low albedo/reflectance properties), especially in a changing climate (as noted in the DEIS). Without a life cycle analysis that first estimates logging emissions and then compares emissions to whatever insignificant albedo effect is anticipated in temperate regions with little snow, the albedo cooling assumption is falsified and cannot be used for disclosing climate impacts of Tongass logging. In sum, large regional and ecosystem type variations have been observed in albedo and one cannot compare albedo from one region to another or one forest type to another.

In this regard, the DEIS echoes unsupportable claims and assumptions by the wood products industry that substituting wood for concrete and steel reduces the overall carbon footprint of buildings and thus is unreliable and inaccurate. The agencies' wood production substitution claim has been refuted by recent analyses that reveal forest industries have been using unrealistic and erroneous assumptions in their models, overestimating the long-term mitigation benefits of substitution by 2- to 100-fold.[61] An additional recent analysis concluded that the carbon footprint of wood is 6% higher than concrete (Stiebert et al. 2019), and that assessment did not include the reduced forest carbon sequestration and storage caused by forest losses as discussed. Importantly, a very recent breakthrough in solar energy production will soon make it possible to dramatically reduce the carbon footprint of concrete and steel even further.[62] Additionally, regarding the noted problems with exaggerated wood substitution benefits,[63] there is no

[59] Harmon 2019. –

[60] *See* Harmon et al. 1990, Harmon et al. 1996, Law et al. 2018, Harmon 2019.

[61] As discussed, Law et al. 2018, Harmon 2019.

[62] https://www.cnn.com/2019/11/19/business/heliogen-solar-energy-bill-gates/index.html.

[63] *See* DEIS at 3-123.

assurance that concrete and steel replaced by wood will not be used in application somewhere else (i.e., leakage from using steel/concrete used elsewhere). For the substitution benefit to accrue, an equivalent amount of concrete or steel would need to not be produced and used in construction; otherwise, substitution is purely speculative (not best science) and unreliable. Further, the DEIS did not account for the high recycled content in most steel or recent/future anticipated advances in reducing the carbon footprint of concrete. For instance, changing manufacturing methods impact embodied energy, as for example, if fly ash is added to concreate it could yield 22-38% reductions in embodied energy required in manufacturing processes, thereby reducing the displacement value of wood.[64] Using clean, renewable energy instead of coal in concrete and steel manufacturing also can lower the substitution value and is part of the mix of energy sources being expand upon by the global community (i.e., over the next few decades new energy sources and processing efficiencies will emerge to reduce concrete/steel emissions and this needs to be factored into a "best case scenario" for energy efficiency upgrades in the DEIS). This change is already underway.[65]

To construct a proper life cycle analysis that provides a science-based assessment of carbon stocks and flows on the Tongass, the DEIS should adopt a method similar to the approach used by Hudiburg et al. in their 2019 life cycle analysis of emissions from logging. The following abstract summarizes their methodologies:

> Abstract
> Atmospheric greenhouse gases (GHGs) must be reduced to avoid an unsustainable climate. Because carbon dioxide is removed from the atmosphere and sequestered in forests and wood products, mitigation strategies to sustain and increase forest carbon sequestration are being developed. These strategies require full accounting of forest sector GHG budgets. Here, we describe a rigorous approach using over one million observations from forest inventory data and a regionally calibrated life-cycle assessment for calculating cradle-to-grave forest sector emissions and sequestration. We find that Western US forests are net sinks because there is a positive net balance of forest carbon uptake exceeding losses due to harvesting, wood product use, and combustion by wildfire. However, over 100 years of wood product usage is reducing the potential annual sink by an average of 21%, suggesting forest carbon storage can become more effective in climate mitigation through reduction in harvest, longer rotations, or more efficient wood product usage (emphasis added). Of the∼10,700 million metric tonnes of carbon dioxide equivalents removed from west coast forests since 1900, 81% of it has been returned to the atmosphere or deposited in landfills (emphasis added). Moreover, state and federal reporting have erroneously excluded some product-related emissions, resulting in 25%–55% underestimation of state total CO2 emissions. For states seeking to reach GHG reduction mandates by 2030, it is important that state CO2 budgets are

[64] Harmon 2019.

[65] *See* J. Gillis, The Steel Mill That Helped Build the American West Goes Green, The New York Times (Oct. 16, 2019) (describing Colorado steel mill's decision to manufacture steel using only renewable energy), available at https://www.nytimes.com/2019/10/16/opinion/solar-colorado-steel-mill.html (last viewed Dec. 13, 2019).

effectively determined or claimed reductions will be insufficient to mitigate climate change.[66]

Logging involves transportation of trucks and machinery across long distances between the forest, the mill, and point of distribution and the DEIS needs to properly disclose these emission sources. For every ton of carbon emitted from logging, an additional ~17% is estimated from fossil fuel consumption to support transportation, extraction, and processing of wood[67], not including the significant emissions from building roads.[68] There is no indication that this was even accounted for in the DEIS.[69] As noted, the Forest Service should consult with state emissions data to obtain reliable estimates of emissions from transport and manufacturing of wood products, particularly the incredibly long hauling distances involved with exporting logs to China and the burning of fossil fuels to get them there (plus when manufactured products are shipped again to retail and distribution areas). In the Tongass this is an especially valid concern given the remote location, no road access (necessitating saltwater barges), and weather which requires extensive and long transportation chains.

The DEIS does not account for the reduction in carbon sequestration and storage potential in forests due to logging-caused soil compaction and nutrient loss. This is despite the fact that these combined impacts can reduce forest carbon storage potential contributing to an overall carbon debt not explained or assessed in the DEIS. We note that this debt is not trivial because ~60% of the carbon lost through logging since 1700s has not yet been recovered by the land sector[70] and 81% of carbon previously stored in West Coast forests has been returned to the atmosphere via logging since 1900.[71] These are centuries-long atmospheric carbon emissions coming at a time when we are in a climate emergency.[72] This is why scientists are calling for policies that avoid emissions and store more carbon in forests compared to wood product pools.[73] Additionally, there are other greenhouse gas effects such as methane and nitrous oxide emissions from soil impacts that will impact the climate from logging.[74]

[66] Hudiburg et al. 2019.

[67] Ingerson 2008.

[68] *See* Loeffler et al. 2008.

[69] The DEIS at 3-127 includes "transporting wood products" in a laundry list of potential cumulative impacts to consider in its climate analysis, but provides no analysis at all of the scale or nature of that impact, violating NEPA's hard look mandate.

[70] McKinley et al. 2011.

[71] Hudiburg et al. 2019.

[72] Ripple et al. 2019.

[73] Hamon et al. 1990, 1996, Leighty et al. 2006, McKinley et al. 2011, Mackey et al. 2016a,b, Law et al. 2018, Moomaw 2019.

[74] McKinley et al. 2011.

In sum, the DEIS fails to include peer-reviewed science on forest carbon and emissions that shows: (1) primary (unlogged) forests are far superior to logged forests at carbon uptake and storage long term; (2) trees accumulate carbon over their entire lifespan; older trees capture and store far more carbon than young trees; (3) old, primary forests accumulate far more carbon than they lose through decomposition and respiration, thus acting as net carbon sinks; (4) logged forests are an emission source for at least the first decade and never fully recapture the emitted carbon stored in the pre-logged old-growth forest due to short rotation harvests and carbon losses throughout the wood product distribution chain; and (5) the superior carbon benefits of old forests are especially evident when taking into account the role of undisturbed soils (which may contain ~50% of carbon stores[75],) and below ground carbon exchange losses from logging and climate change impacts.

B. DEIS CLAIMS ABOUT TEMPERATE RAINFORESTS AND FOREST MANAGEMENT ARE NOT BASED ON BEST AVAILABLE SCIENCE

In addition to failing to analyze important information about the Tongass and its value for climate and carbon storage, the DEIS fails to analyze important information about the value of temperate rainforests.

- **Temperate rainforest amount reported in the DEIS is incorrect** – The DEIS grossly underestimates the global importance of coastal temperate rainforests, including the Tongass, for carbon regulation (0.5% global cover; no citation given).[76] DellaSala et al. (2011) provided the first computer generated map of all the world's temperate rainforests reporting that the total area for this rainforest biome is actually 2.5% of all forests globally (5 times that reported in the DEIS). The Pacific Coastal rainforests (California Coast Redwoods to Alaska) are globally significant as they represent over one-third of all temperate rainforests world-wide and because the Tongass is one of only 4 other relatively intact temperate rainforests (Great Bear – BC; Valdivia – Chile; Russian Far East; Southern Siberia). Thus, even though the overall global footprint of this rainforest biome is relatively small, the climate regulation properties of these forests – because of their enormous carbon stores – along with their myriad biodiversity and ecosystem benefits[77] – are globally significant and irreplaceable.[78] The Forest Service therefore has a national and global responsibility to maintain the intactness of this region and opening up roadless areas will have global ramifications contributing to the pace and scale of forest degradation globally. This is why 234 scientists signed a letter urging the Forest Service to protect the region's roadless areas (attached). The decision to open up roadless areas therefore is not based on best available science. At an absolute minimum, the Forest Service must correct its evaluation of the global importance of the Tongass's temperate rain forests and respond to these expert reports.

[75] Campbell et al. 2007; McNicol et al. 2019

[76] DEIS at 3-122.

[77] Brandt et al. 2014.

[78] DellaSala et al. 2011.

- **Unsubstantiated claims are made about management activities approximating and promoting natural processes** – The Forest Service states, without a single citation, that logging and prescribed fire tend to approximate and promote natural processes and that such actions can result in long-term carbon uptake and storage that somehow increases resilience.[79] We note that prescribed fire is not even relevant on the Tongass rainforest and has no purpose in this DEIS. The statement overall also has no basis in the ecological literature, and certainly none for the Tongass's temperate rainforest, and seems to imply that forest degradation is a net gain in carbon and ecosystem processes even though the IPCC (2018, 2019) and numerous scientific studies indicate otherwise.[80] As discussed, the Forest Service needs to provide a reliable life cycle analysis and evidence-based review of the literature to back assertions that clearcut logging and road building somehow resemble natural disturbance processes – including effects on biodiversity (e.g., deer, wolves, murrelets and other old growth species). The statement, in fact, is reflective of old-school forestry ideologies long dismissed in the ecological literature and even by many foresters. Notably, given the lack of fire on the Tongass, primary disturbance agents are blow down from wind storms (canopy gap, stand, landscape level), landslides (watershed-landscape level), and tree mortality (stand level – canopy gaps – and watershed-landscape yellow cedar death from climate impacts). In no way do clearcuts, roads, mines, dams, etc. resemble any of these natural disturbances as natural disturbances leave prodigious amounts of biological legacies[81] that "life-boat" a forest through successional stages while these developments in old growth and IRAs will remove nearly all biological legacies. The long return interval of natural disturbances allows for old growth to develop over centuries, whereas, logged areas can be logged again in <100 years; this is insufficient time for forests to recoup carbon emitted from logging and to reach their maximum carbon potential.[82] We note that Public Law 113-291 (2014) allows up to 15,000 acres of young growth to be logged from 2016-2025 in stands < 95% CMAI and there is flexibility in NFMA to allow a continuation of harvesting at young ages beyond 2025 – thus, the carbon debt from re-logging these forests on a sustained yield basis is never recaptured and remains in the atmosphere for over a century at a time when we are in a climate emergency. The Forest Service needs to properly account for this carbon debt in the DEIS.

[79] DEIS at 3-123.

[80] *See e.g.*, Harmon et al. 1990, Harmon et al. 1996, Mackey et al. 2014, Law et al. 2018, Moomaw 2019.

[81] DellaSala 2019; Buma et al. 2019.

[82] Moomaw 2019.

The following recent literature summary was prepared by Benjamin Bograd (Princeton University) of road impacts and roadless area importance using 3 search engines (ScienceDirect, Scopus, Google Scholar) to gather the road impact pdfs in our comments. The Forest Service must assess the information described in the following studies in the EIS for the proposed rule.

Link/Title/ Author(s)	**Year**	**Region**	**Abstract/Synopsis**
Roadless in the Pacific Northwest: Ecology and History - James Furnish	2019	PNW	A notable but unexpected outcome of this dramatic policy shift is a significant increase in stored forest carbon following logging reductions. Such carbon gains team with other "free" environmental services like clean water and air, and high quality wildlife and fish habitat to illustrate important non-commercial forest values.
Roadless Areas as Key Approach to Conservation of Functional Forest Ecosystems - Monika Hoffman, Stefan Kreft, Vassiliki Kati, Pierre Ibisch	2019	General	Among all terrestrial ecosystems, roadless forests are the single most important strongholds of regulating ecosystem services: among others, soil protection, water retention, buffering of the local and regional climate and mitigation of global climate change via capturing of atmospheric carbon. Large roadless areas can serve as a measurable surrogate for the most pristine and functional ecosystems. Roadlessness is a property of areas, which are not impacted by roads; it can be used as a proxy for assessing ecosystem integrity and the absence of many anthropogenic disturbances (note – ecosystem or ecological integrity is covered under the 2012 forest planning rule). We recommend that policy-makers give roadless areas conservation priority over areas that have already been fragmented. It is essential to establish roadlessness as a criterion for the planning of ecosystem-based, cost-effective sustainable development.. Even if "climate-friendly" renewable energy was available for road transport on a large scale, the construction, existence and operation of roads would continue to severely impair ecosystem functionality.
On the Variable Effects of Climate Change	2019	Columbia River Basin	Water temperature has manifold effects on the biology of Pacific salmon. Thermal optima enable Pacific salmon to maximize growth while temperatures above thermal

on Pacific Salmon - Xiao Zhang, Hong-Yi Li, Zhiqun Deng, L. Ruby Leung, John Skalski, Steven Cooke			optima can induce stress and lead to mortality. This study investigated the impacts of climatic changes and water management practices on Chinook and Steelhead smolts in the Columbia River Basin using an integrated earth system model and a multiple regression model that incorporated nonlinear survival responses to water temperature. Results revealed that the effects would vary significantly with the species, location, and climate change scenario. Mean survival rates may increase by more than 10% in Upper Columbia River, while reduce by 1˜13% and 2˜35% for Chinook and Steelhead smolts respectively, in the Lower Columbia River by 2080s. This study highlights the importance of integrating the nonlinear response of survival rate to river temperature and water management effects in climate change vulnerability analysis for salmonid stocks.
Assessing the risk to the conservation status of temperate rainforest from exposure to mining, commercial logging, and climate change: A Tasmanian case study - Brendan Mackey, Sean Cadman, Nicole Rogers, Sonia Hugh	2017	Tasmania, Australia	Allowing structural degradation and fragmentation to intact rainforest blocks will reduce their capacity to buffer meso-climatic variability and resist fire events thereby undermining their ecosystem integrity.
Assessing the value of roadless areas in a conservation reserve strategy: biodiversity and landscape connectivity in	2005	Northern Rockies	• Roadless areas on Forest Service lands hold significant potential for the conservation of native biodiversity and ecosystem processes, primarily because of their size and location. • Roadless areas, when added to existing federal-protected areas in the northern Rockies, increase representation of virtually all land-cover types, some by more than 100%, and increase the protection of relatively undisturbed lower elevation lands, which

the northern Rockies - Michele Crist, Bo Wilmer, Gregory Aplet			are exceedingly rare in the northern Rockies. In fact, roadless areas protect more rare and declining land-cover types, such as aspen, whitebark pine, sagebrush and grassland communities, than existing protected areas. • Roadless areas adjacent to protected areas increase connectivity by creating larger and more cohesive protected area ‘patches.’ Roadless areas enhance overall landscape connectivity by reducing isolation among protected areas and creating a more dispersed conservation reserve network, important for maintaining wide-ranging species movements. We advocate that the USDA Forest Service should retain the Roadless Area Conservation Rule and manage roadless areas as an integral part of the conservation reserve network for the northern Rockies.
A global map of roadless areas and their conservation status - Pierre L. Ibisch, Monika T. Hoffmann, Stefan Kreft, Guy Pe’er, Vassiliki Kati, Lisa Biber-Freudenberger, Dominick A. DellaSala, Mariana M. Vale, Peter R. Hobson,Nuria Selva	2017	Comprehen-sive and global in scope	Roads fragment landscapes and trigger human colonization and degradation of ecosystems, to the detriment of biodiversity and ecosystem functions. About 80% of Earth’s terrestrial surface remains roadless, but this area is fragmented into ~600,000 patches, more than half of which are <1 square kilometer and only 7% of which are larger than 100 square kilometers. Global protection of ecologically valuable roadless areas is inadequate. International recognition and protection of roadless areas is urgently needed to halt their continued loss.
USDA Forest Service Roadless Areas: Potential Biodiversity Conservation Reserves - Colby Loucks, Nicholas Brown, Andrea	2003	United States	We found that more than 25% of IRAs are located in globally or regionally outstanding ecoregions and that 77% of inventoried roadless areas have the potential to conserve threatened, endangered, or imperiled species. IRAs would increase the conservation reserve network containing these species by 156%. We further illustrate the conservation potential of IRAs by highlighting their contribution to the conservation of the grizzly bear (Ursos

Loucks, and Kerry Cesareo			arctos), a wide-ranging carnivore. The area created by the addition of IRAs to the existing system of conservation reserves shows a strong concordance with grizzly bear recovery zones and habitat range. Based on these findings, we conclude that IRAs belonging to the U.S. Forest Service are one of the most important biotic areas in the nation, and that their status as roadless areas could have lasting and far-reaching effects for biodiversity conservation.
Roadless and Low-Traffic Areas as Conservation Targets in Europe – Nuria Selva • Stefan Kreft • Vassiliki Kati • Martin Schluck • Bengt-Gunnar Jonsson • Barbara Mihok • Henryk Okarma • Pierre L. Ibisch	2011	Europe	With increasing road encroachment, habitat fragmentation by transport infrastructures has been a serious threat for European biodiversity. Areas with no roads or little traffic (‘‘roadless and low-traffic areas’’) represent relatively undisturbed natural habitats and functioning ecosystems. They provide many benefits for biodiversity and human societies (e.g., landscape connectivity, barrier against pests and invasions, ecosystem services). Roadless and low-traffic areas, with a lower level of anthropogenic disturbances, are of special relevance in Europe because of their rarity and, in the context of climate change, because of their contribution to higher resilience and buffering capacity within landscape ecosystems. We propose that the few remaining roadless and low-traffic areas in Europe should be an important focus of conservation efforts; they should be urgently inventoried, included more explicitly in the law and accounted for in transport and urban planning. Considering them as complementary conservation targets would represent a concrete step towards the strengthening and adaptation of the Natura 2000 network to climate change.
A review of environmental impacts of winter road maintenance - Hrefna Run Vignisdottir, Babak Ebrahimi, Gaylord Kabongo Booto, Reyn O'Born, Helge Brattebø, Holger	2018	Cold Climates	The need for winter road maintenance (WRM) is changing in cold regions due to climate change. How the different modes of WRM will contribute to future overall emissions from infrastructure is therefore of great interest to road owners with a view to a more sustainable, low-carbon future. In the quest for near-zero-emissions transport, all aspects of the transport sector need to be accounted for in the search for possible mitigation of emissions. This study used 35 peer-reviewed articles published between 2000 and 2018 to map available information on the environmental impacts and effect of WRM and reveal any research gaps. The articles were categorized according to their research theme and focus. They were

Wallbaum, Rolf André Bohne			found to focus mainly on the local effects of WRM with emphasis on effects on water. Of the reviewed works, 27 contain information related to the environmental effects on a local level while five focused on global impact, which was mainly caused by fuel consumption. Only two articles took a holistic look at the system to identify emission sources and the effectiveness of possible changes in operations methods or material selection. Furthermore, a life-cycle approach could reveal ways to mitigate emissions through effectively comparing possible changes in the system without shifting the problem to other aspects of road transport.
Land use and climate change impacts on lake sedimentation rates in western Canada - Erik Schiefer, Ellen L. Petticrew, Richard Immell, Marwan A. Hassan, Derek L. Sonderegger	2014	Western Canada	Although sedimentation was highly variable, increasing trends in accumulation corresponded with cumulative land use and, to a lesser degree, with climate change. Road density was the most important variable, but the inclusion of timber harvesting density further improved model fits significantly.
Biodiversity, roads, & landscape fragmentation: Two Mediterranean cases - Matteo Marcantonio, Duccio Rocchini, Francesco Geri, Giovanni Bacaro, Valerio Amici	2013	Mediterranean	The most pervasive threats to biological diversity are directly or indirectly linked to the road networks. For this reason, over the last few decades, interest in the study of the ecological characteristics of the edges associated with roads has increased. Our findings indicated a clear relationship between road distance and different plant biodiversity facets, which showed its maximum effect in the first 0–20 m forest-to-road segment and a mitigation after the 200 m threshold. The few remnants of core forest habitats in the Mediterranean basin highlight the need to recognize that road construction and maintenance have several ecological implications and accordingly require long-term monitoring programs.
Does the effect of forest roads extend a few	2010	France	We studied the effect of forest road distance on plant understory diversity at 20 sites in young and adult oak stands in a French lowland forest with a long history of

meters or more into the adjacent forest? A study on understory plant diversity in managed oak stands - Catherine Avon, Laurent Bergès Yann Dumas Jean-Luc Dupouey			management and road construction. Even if the depth of forest road effect measured in lowland managed stands was narrow, building of a new forest road has non-negligible effects on plant population dynamics. Forest managers should take into account the impacts of roads on biodiversity, since the expected intensification of silviculture in response to global changes is set to accentuate the effect of forest roads.
A Global Strategy for Road Building - William F. Laurance, Gopalasamy Reuben Clements, Sean Sloan, Christine S. O'Connell, Nathan D. Mueller, Miriam Goosem, Oscar Venter, David P. Edwards, Ben Phalan, Andrew Balmford, Rodney Van Der Ree & Irene Burgues Arrea	2014	Global	The number and extent of roads will expand dramatically this century. Globally, at least 25 million kilometres of new roads are anticipated by 2050; a 60% increase in the total length of roads over that in 2010. Nine-tenths of all road construction is expected to occur in developing nations, including many regions that sustain exceptional biodiversity and vital ecosystem services. Roads penetrating into wilderness or frontier areas are a major proximate driver of habitat loss and fragmentation, wildfires, overhunting and other environmental degradation, often with irreversible impacts on ecosystems.
Estimating Diesel Fuel Consumption and Carbon Dioxide Emissions from Forest Road Construction - Dan Loeffler, Greg Jones,	2008	General	Forest access road construction is a necessary component of many on-the-ground forest vegetation treatment projects. However, the fuel energy requirements and associated carbon dioxide emissions from forest road construction are unknown. We present a method for estimating diesel fuel consumed and related carbon dioxide emissions from constructing forest roads using published results from a study designed to measure road construction costs together with machine productivity and fuel consumption rates. Our resulting estimate of diesel

Nikolaus Vonessen, Sean Healey, Woodam Chung			fuel required per mile of road constructed on slopes up to 50% using a cut-fill construction method is 590 gallons, with 13,400 pounds of carbon dioxide emitted per mile of road built. Using a full bench road construction method on slopes greater than 50% where volume of material handled and moved is very sensitive to hill slope and soil type, we estimated between 3,265 and 8,000 gallons of diesel fuel are required per mile of road emitting between 74,400 to 182,700 pounds of carbon dioxide.
Biodiversity Impact Assessment of roads: an approach based on ecosystem rarity - David Geneletti	2003	General	A sound Biodiversity Impact Assessment (BIA) in road planning and development needs to be coupled to other commonly considered aspects. This paper presents an approach to contribute to BIA of road projects that focuses on one type of impact: the direct loss of ecosystems. The first step consists in mapping the different ecosystem types, and in evaluating their relevance for biodiversity conservation. This is based on the assessment of ecosystem's rarity. Rarity is a measure of how frequently an ecosystem type is found within a given area. Its relevance is confirmed by the fact that the protection of rare ecosystems is often considered as the single most important function of biodiversity conservation. Subsequently, the impact of a road project can be quantified by spatially computing the expected losses of each ecosystem type. To illustrate the applicability of the methodology, a case study is presented dealing with the assessment of alternative routes for a highway development in northern Italy.