A Comparison of Relative Biological Value, Habitat Vulnerability, and Cumulative Ecological Risk among Biogeographic Provinces in Southeastern Alaska

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Because species, populations and ecological processes occur at a range of spatial scales, it is vital to incorporate a multi-scale approach into an assessment of ecological condition and conservation measures (Poiani et al. 2000). This is consistent with the National Forest Management Act which requires the maintenance of viable and well distributed populations throughout all national forest lands. Thus, an understanding of the relative distribution of habitat values among biogeographic provinces, as well as the current condition and management/conservation status of those values is central to the long-term conservation of species and management of ecological risk throughout the region.

INDEX OF RELATIVE BIOLOGICAL VALUE

As described in Chapter 2, we selected a suite of focal species and ecological systems that provide the best indicators of large-scale changes that have occurred in this region, primarily associated with industrial logging and road construction, as well as more localized urbanization. For this analysis, focal species included salmon (*Oncorhynchus* spp.), brown (*Ursus arctos*) and black (*U. americanus*) bear, Sitka black-tailed deer (*Odocoileus hemionus*), and marbled murrelet (*Brachyramphus marmoratus*), while ecological systems included large-tree forests and estuaries. Habitat values for deer, bear, and murrelet were estimated using habitat models that reflect key aspects of each species life history (Chapter 2, Tables 7, 9, 13). 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 and steelhead (*O. mykiss*) (Chapter 2, Fig 10), while the distribution of forest types and estuaries was based on an integrated regional database of vegetation and landcover (Chapter 2, Table 2, Fig 6). 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 focal species or ecological system, as well as their distribution among biogeographic provinces.

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

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

where:

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

Biogeographic provinces in the region vary widely in the relative distribution and value of habitats for this set of focal species and ecological systems (Table 1). Based on combined resource values, North Prince of

Wales ranked highest in biological value with particularly high contribution to the regional distribution of large-tree forests, salmon, and deer habitat. Admiralty ranked 2nd in biological value with high large-tree forest, brown bear, and deer habitat. East Chichagof and the Stikine River Mainland have high values based on the distribution of salt marsh estuarine habitats, while Yakutat ranks 2nd in the region for total freshwater salmon habitat. Thus, these indices can be useful for single-species comparison as well as for all focal resources combined. Given that this suite of focal targets represents a range of terrestrial, freshwater and nearshore marine ecosystems, we believe that this provides a reasonably robust ranking of biological values associated with coastal forest ecosystems.

TABLE 1. A comparison of relative biological value for focal species and ecological systems among biogeographic provinces in southeastern Alaska.

	Index of relative biological value for focal species and ecological systems						
Biogeographic Province	**Large-tree forest**	**Murrelet**	**Salmon**	**Bear**	**Deer**	**Estuary**	**All (avg.)**
North Prince of Wales	22.3%	9.8%	14.8%	9.4%	19.1%	6.4%	13.6%
Admiralty Island	17.0%	10.8%	4.5%	8.9%	13.0%	6.9%	10.2%
E. Chichagof Island	6.4%	7.4%	7.8%	7.0%	8.3%	15.9%	8.8%
Revilla Is. / Cleveland Pen.	5.5%	10.9%	5.3%	7.9%	13.2%	2.8%	7.6%
Stikine River / Mainland	3.6%	6.6%	6.6%	6.3%	--	13.3%	7.3%
Kupreanof / Mitkof Islands	3.6%	5.4%	7.7%	7.0%	8.7%	9.7%	7.0%
Yakutat Forelands	4.7%	0.6%	10.3%	5.4%	--	8.1%	5.8%
Taku River / Mainland	4.1%	6.9%	4.1%	5.5%	--	8.4%	5.8%
Kuiu Island	6.2%	5.2%	4.2%	3.8%	9.0%	3.8%	5.4%
South Misty Fiords	2.4%	5.9%	3.4%	6.0%	--	1.8%	3.9%
Lynn Canal / Mainland	2.9%	3.8%	3.9%	3.6%	--	5.2%	3.9%
South Prince of Wales	7.4%	3.2%	2.0%	2.8%	5.9%	0.4%	3.6%
North Misty Fiords	2.8%	4.4%	4.1%	5.0%	--	1.6%	3.6%
W. Baranof Island	0.8%	3.4%	3.9%	4.3%	6.7%	2.5%	3.6%
Etolin / Zarembo / Wrangell	2.1%	4.0%	2.4%	3.1%	5.2%	1.7%	3.1%
Chilkat River Complex	3.6%	3.0%	4.7%	2.4%	--	1.5%	3.0%
Glacier Bay	0.0%	1.9%	2.2%	2.9%	--	5.4%	2.5%
Outside Islands	2.3%	1.8%	1.6%	1.7%	4.0%	0.2%	1.9%
Dall / Long Island Complex	1.6%	1.8%	1.1%	1.4%	3.4%	0.2%	1.6%
E. Baranof Island	0.3%	1.5%	1.7%	1.8%	1.7%	1.6%	1.5%
W. Chichagof Island	0.3%	1.1%	1.3%	1.8%	1.9%	1.2%	1.3%
Fairweather Range	0.0%	0.6%	2.3%	2.0%	--	1.5%	1.3%
All	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

INDEX OF ECOLOGICAL CONDITION

A key understanding developed in Chapter 2 was the estimation of change in the distribution of forest types and associated habitat values since the initiation of industrial-scale logging in southeastern Alaska (Southeast) since 1954. To estimate the distribution of forest types that had been logged, we used available data on logging activity from 1986 to the present (Chapter 2, Table 3) as a conservative estimate of the percent change in the rare, large-tree forest types over time. However, because logging practices have changed over time, it is important to recognize this comparison likely represents a significant underestimate of the original distribution of large-tree

forest types. We used these estimates to calculate the original distribution of large-tree forests, and to estimate the original capability of nesting habitat for marbled murrelet (Chapter 2, Table 10), winter habitat for deer (Chapter 2, Table 8) and summer habitat for brown and black bear (Chapter 2, Table 15). We estimated conditions of habitat for salmon by measuring the percent of flood plain forests associated with salmon streams that had been logged (Chapter 2, Table 12). While these estimates (Table 2) are not expected to directly predict population size or abundance, they can be used as a conservative index to the degree of change from natural conditions, which in turn provides insight into the robustness of these systems in the face of population and environmental variability (e.g., climate change). The greatest percentage change in original habitat conditions has occurred on North Prince of Wales, East Baranof, East Chichagof, Etolin / Zarembo / Wrangell, Kupreanof / Mitkof, and West Baranof provinces (Table 2).

TABLE 2. Estimated percent change in habitat conditions for focal species and ecological systems within biogeographic provinces in southeastern Alaska.

	% of original habitat remaining intact[a]					
Biogeographic Province	**Large-tree forest[b]**	**Murrelet**	**Salmon[c]**	**Bear**	**Deer**	**All (avg.)**
North Prince of Wales	60.2%	60.3%	65.0%	48.0%	62.2%	59.1%
E. Baranof Island	33.3%	81.0%	59.3%	70.0%	73.9%	63.5%
E. Chichagof Island	64.4%	79.6%	75.4%	66.0%	74.5%	72.0%
Etolin / Zarembo / Wrangell	50.1%	80.2%	89.1%	65.0%	77.4%	72.4%
Kupreanof / Mitkof Is.	51.9%	79.5%	86.0%	67.0%	78.1%	72.5%
W. Baranof Island	45.7%	88.6%	67.2%	75.0%	87.2%	72.7%
Chilkat River Complex	78.3%	90.1%	69.6%	60.0%	--	74.5%
Dall / Long Island Complex	55.1%	86.0%	81.4%	85.0%	77.6%	77.0%
Revilla / Cleveland Pen.	60.1%	86.7%	87.4%	73.0%	84.9%	78.4%
Yakutat Forelands	83.8%	83.5%	79.6%	72.0%	--	79.7%
Kuiu Island	80.7%	88.7%	82.6%	70.0%	87.2%	81.8%
Outside Islands	71.6%	85.7%	89.9%	78.0%	83.8%	81.8%
Taku River / Mainland	79.2%	93.3%	85.0%	85.0%	--	85.6%
Stikine River / Mainland	82.8%	95.8%	81.5%	87.0%	--	86.8%
South Prince of Wales	89.3%	87.8%	87.4%	86.0%	89.4%	88.0%
Lynn Canal / Mainland	90.1%	96.8%	88.5%	77.0%	--	88.1%
Admiralty Island	92.7%	94.8%	86.6%	89.0%	94.0%	91.4%
Glacier Bay	--	99.6%	100.0%	87.0%	--	95.5%
Fairweather Range	--	100.0%	100.0%	93.0%	--	97.7%
North Misty Fiords	100.0%	100.0%	100.0%	95.0%	--	98.8%
W. Chichagof Island	100.0%	100.0%	100.0%	96.0%	100.0%	99.2%
South Misty Fiords	100.0%	100.0%	100.0%	97.0%	--	99.3%
All	71.9%	85.6%	80.0%	74.0%	78.8%	78.1%

[a] Regional data on condition and management of estuaries were not available for this analysis.
[b]These values are likely overestimated based on the conservative estimate of large-tree harvest since 1986.
[c]Habitat condition was based on intactness of flood plain forests adjacent to anadromous fish streams.

INDEX OF CONSERVATION AND VULNERABILITY

A measure of the effectiveness of a conservation strategy is the degree to which high-value habitats are conserved within a landscape context where ecosystem functions are likely to remain intact. This depends on both the structure of the design (i.e., size and spacing) as well as the implementation of that design (i.e., whether specific areas are included or not). As an indicator of the adequacy of both the

design and implementation of the existing conservation strategy in Southeast, we attempted to estimate the percent of habitat values for focal species and ecological systems that are designated within conservation areas (Table 3). For this analysis, we combined congressional protections, all conservation measures under the 1997 Tongass Land Management Plan, and other conservation designations on state and private lands (Chapter 2, Fig. 3). The inverse of habitats included within conservation areas is the percent of habitats designated for timber production and other extractive uses, and is referred to as an index of vulnerability (Margules and Pressey 2000), where: Index of Vulnerability = 1 – (% of existing habitat protected). The provinces with the least conservation protection include Chilkat River, Kupreanof / Mitkof, North Prince of Wales, Etolin / Zarembo / Wrangell, and East Chichagof.

TABLE 3. Conservation status of habitat values for focal species and ecological systems[a] among 22 biogeographic provinces in southeastern Alaska.

	Percentage of existing habitat protected					
Biogeographic Province	**Large-tree forest**	**Murrelet**	**Salmon**	**Bear**	**Deer**	**All (avg.)**
Chilkat River Complex	10.5%	10.3%	90.2%	30.0%	--	35.3%
Kupreanof / Mitkof Is.	54.8%	40.8%	38.2%	40.0%	49.1%	44.6%
North Prince of Wales	58.7%	53.0%	55.8%	43.0%	54.2%	52.9%
Etolin / Zarembo / Wrangell	59.9%	51.5%	85.4%	52.0%	63.4%	62.4%
E. Chichagof Island	74.3%	56.0%	72.8%	49.0%	63.0%	63.0%
Kuiu Island	57.5%	70.0%	64.2%	65.0%	72.0%	65.7%
Taku River / Mainland	60.9%	64.5%	77.0%	66.0%	--	67.1%
Stikine River / Mainland	74.9%	70.3%	54.4%	70.0%	--	67.4%
Dall / Long Island	87.4%	70.2%	69.2%	53.0%	65.7%	69.1%
Revilla Is. / Cleveland Pen.	69.9%	66.9%	86.8%	58.0%	65.8%	69.5%
Lynn Canal / Mainland	65.5%	72.1%	78.1%	71.0%	--	71.7%
E. Baranof Island	76.9%	59.3%	99.3%	67.0%	62.7%	73.0%
S. Prince of Wales Is.	71.3%	68.7%	98.8%	67.0%	72.0%	75.6%
Outside Islands	71.6%	82.8%	70.0%	80.0%	78.5%	76.6%
Yakutat Forelands	63.9%	82.0%	78.1%	85.0%	--	77.3%
W. Baranof Island	81.0%	81.6%	99.4%	83.0%	80.2%	85.0%
North Misty Fiords	95.4%	97.2%	64.2%	99.0%	--	89.0%
South Misty Fiords	99.7%	99.8%	65.8%	99.0%	--	91.1%
Admiralty Island	95.9%	97.7%	77.6%	95.0%	95.9%	92.4%
W. Chichagof Island	99.3%	98.7%	80.4%	96.0%	94.9%	93.9%
Glacier Bay	100.0%	99.5%	81.4%	95.0%	--	94.0%
Fairweather Range	100.0%	99.9%	97.1%	98.0%	--	98.8%
All	70.0%	70.1%	71.8%	69.0%	68.6%	69.9%

[a] Regional data on condition and management of estuaries were not available for this analysis.

A comparison of biological value and vulnerability among biogeographic provinces reveals a significant trend that potentially reflects an imbalance in management for conservation in the region. Biological value is distributed along the y-axis, with North Prince of Wales, Admiralty Island, East Chichagof, Revilla Is / Cleveland Peninsula, Stikine River, and Kupreanof / Mitkof exhibiting the highest levels (Fig 1). These provinces contain extensive areas of large-tree forests, salmon streams, estuaries and high value habitat for deer and bear. Provinces with relatively lower biological value (based on the focal resources used in this analysis) include the mainland provinces of the Fairweather

Range and Glacier Bay, as well as the island provinces of West Chichagof and East Baranof. Relative vulnerability is distributed along the x-axis, with the Chilkat River Complex, Kupreanof / Mitkof, North Prince of Wales, Etolin / Zarembo / Wrangell, and East Chichagof demonstrating the highest proportion of habitats designated for extractive uses on national forest, private, or state lands (Table 3). Significantly, 6 of the 9 most productive provinces have high vulnerability (Fig 1, upper right quadrant) while those with the highest levels of conservation (e.g., wilderness areas or parks with low vulnerability) are also among the lowest in terms of biological value (lower left quadrant). This imbalance reflects a high-risk strategy in terms of long-term protection of biodiversity and ecosystem integrity in the region (Gaston et al. 2002). The notable exception is Admiralty Island, which is the only province that is both highly productive for the full suite of focal resources and also managed primarily for fish and wildlife conservation and ecosystem integrity.

According to this analysis, provinces in the upper-right quadrant (Fig.1), including North Prince of Wales, East Chichagof, Revilla / Cleveland, Kupreanof / Mitkof and others rank as the highest priorities for additional conservation and restoration measures (Margules and Pressey 2000).

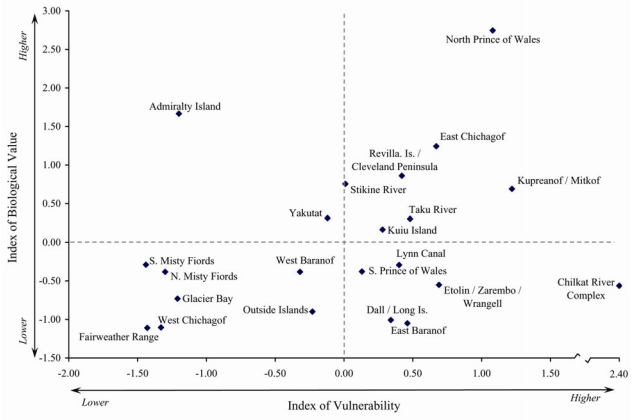

FIG. 1 The index of biological value is a combined index based on relative contribution of each province to the regional distribution of habitat values, and the index of vulnerability reflects the percent of habitat values within each province that are designated within development LUDs or private lands. Values were normalized (mean=0, std. dev.=1) to facilitate comparison among provinces.

INDEX OF CUMULATIVE ECOLOGICAL RISK

Cumulative ecological risk is an estimate of the combined effects of change in habitat values resulting from past activities such as timber harvest, road construction and urbanization (Table 2), as well as the expectation of future change based on current management designations and conservation systems (Table 4):

Cumulative Ecological Risk =
1 – [(% of original habitat remaining intact) x
(% of existing habitat protected)]

This is the primary tool for evaluating risks resulting from the cumulative effects of habitat alteration on private, state, and national forest lands, and is particularly important given the fragmented nature of the island provinces (Fig. 2). The provinces estimated to face the greatest ecological risks include the Chilkat River Complex, North Prince of Wales, Kupreanof / Mitkof, Etolin / Zarembo / Wrangell, East Chichagof, and East Baranof. Those provinces with the least ecological risks include the Fairweather Icefields, West Chichagof, South Misty Fjords, Glacier Bay, North Misty Fiords, and Admiralty Island.

To reiterate, this is simply a measure of the degree to which habitat values for these focal species and ecological systems are expected to remain intact over the current planning horizon. This does not imply that species declines will or will not occur, 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. This analysis does not address special ecological features inherent in specific provinces such as unique salmon stocks (Halupka et al. 2000) or centers of endemism (Cook and MacDonald 2001, Cook et al. 2006, also refer to Chapter 6.7 in this report).

An effective conservation strategy for Southeast must address each province's special features (Chapter 4) as well as areas of importance for community or subsistence use. With those caveats in mind, this assessment of cumulative ecological risk provides resource managers and conservationists with an additional tool for prioritizing conservation and restoration actions throughout Southeast.

FIG 2. A relative index of the cumulative risk to biodiversity and ecosystem values over time was estimated by multiplying the percent of original habitat values for focal species and ecological systems that currently remain intact by the percent of these values that are designated for long-term conservation in the region.

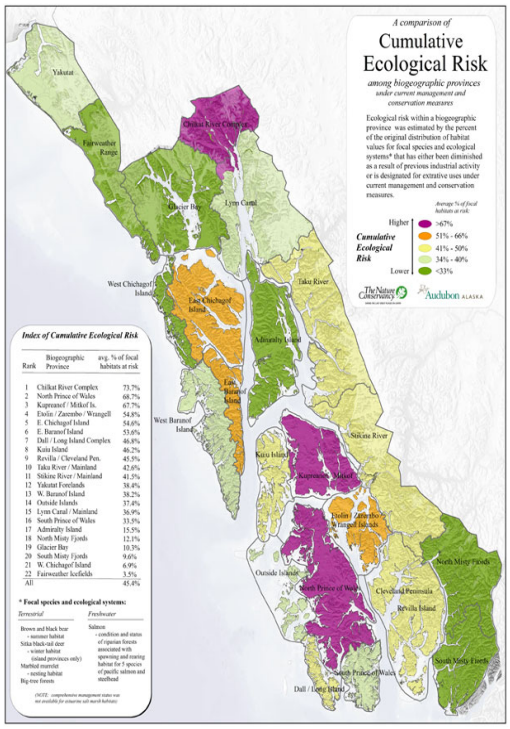

TABLE 4. Cumulative ecological risk based on projected total change in habitat values for focal species and ecological systems [a] within 22 biogeographic provinces in southeastern Alaska.

	Percentage of original habitat values at risk					
Biogeographic Province	**Large-tree forest**	**Murrelet**	**Salmon**	**Bear**	**Deer**	**All (avg.)**
Chilkat River Complex	91.8%	90.7%	37.2%	82.0%	--	73.7%
North Prince of Wales	64.7%	68.0%	63.7%	79.4%	66.3%	68.7%
Kupreanof / Mitkof Is.	71.6%	67.6%	67.1%	73.2%	61.7%	67.7%
Etolin / Zarembo / Wrangell	70.0%	58.7%	23.9%	66.2%	50.9%	54.8%
E. Chichagof Island	52.2%	55.4%	45.1%	67.7%	53.1%	54.6%
E. Baranof Island	74.4%	52.0%	41.1%	53.1%	53.7%	53.6%
Dall / Long Island Complex	51.8%	39.6%	43.7%	55.0%	49.0%	46.8%
Kuiu Island	53.6%	37.9%	47.0%	54.5%	37.2%	46.2%
Revilla / Cleveland Pen.	58.0%	42.0%	24.1%	57.7%	44.1%	45.5%
Taku River / Mainland	51.8%	39.8%	34.6%	43.9%	--	42.6%
Stikine River / Mainland	38.0%	32.7%	55.7%	39.1%	--	41.5%
Yakutat Forelands	46.5%	31.5%	37.8%	38.8%	--	38.4%
W. Baranof Island	63.0%	27.7%	33.2%	37.8%	30.1%	38.2%
Outside Islands	48.7%	29.0%	37.1%	37.6%	34.2%	37.4%
Lynn Canal / Mainland	41.0%	30.2%	30.9%	45.3%	--	36.9%
South Prince of Wales	36.3%	39.7%	13.6%	42.4%	35.6%	33.5%
Admiralty Island	11.1%	7.4%	32.8%	15.5%	9.9%	15.5%
North Misty Fiords	4.6%	2.8%	35.8%	6.0%	--	12.1%
Glacier Bay	--	0.9%	18.6%	17.4%	--	10.3%
South Misty Fiords	0.3%	0.2%	34.2%	4.0%	--	9.6%
W. Chichagof Island	0.7%	1.3%	19.6%	7.8%	5.1%	6.9%
Fairweather Range	--	0.1%	2.9%	8.9%	--	3.5%
All	49.7%	40.0%	42.6%	48.9%	45.9%	45.4%

[a] Regional data on condition and management of estuaries were not available for this analysis.

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