Landscape Assessment of the Degree of Protection of Alaska's Terrestrial Biodiversity

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Abstract: *We assessed the degree to which Alaskan lands reflect the state's biodiversity by dividing the entire state into four categories of land protection ranging from highly protected to minimally protected in terms of potential for future development. We then compared the percentage of each ecoregion and plant-cover type in each land protection class. We assumed that 12% protection represents an acceptable minimum and examined the percentage of site records of rare plants in protected and unprotected areas. Of 28 ecoregions in Alaska, 15 (63.4%) have <12% of their area in highly protected areas. Similarly, 11 of 21 vegetation-cover types (43.7%) have <12% protection. For 32 rare vascular plants, an average of 27% of records occur on highly protected lands. Seventy-five percent of the rare plants had <50% of their records from highly protected lands. Less than 1% of Alaska has been permanently altered by human activity. In contrast to the lower 48 states, time remains to plan development that preserves biodiversity while permitting an economically sustainable economy—if the effort is made now.*

Evaluación de Paisaje en el Grado de Protección de la Biodiversidad Territorial de Alaska

Resumen: *Evaluamos el grado al cual las tierras de Alaska reflejan el estado de la biodiversidad al dividir el estado en cuatro categorías de protección de la tierra, desde altamente protegidas hasta mínima protección en términos de potencial para un desarrollo futuro. Posteriormente comparamos el porcentaje de cada ecoregión y tipo de cobertura de plantas para cada clase de protección. Asumimos que 12% de protección representa un mínimo aceptable y examinamos los porcentajes de casos de sitios con plantas raras en áreas protegidas y no protegidas. De las 28 ecoregiones de Alaska, 15 (63.4%) tienen <12% de su área en zonas altamente protegidas. Similarmente, 11 de 21 tipos de cobertura vegetal (43.7%) tiene <12% de protección. Para 32 plantas vasculares raras, un promedio de 27% de los registros ocurre en tierras altamente protegidas. Setenta y cinco por ciento de las plantas raras tienen <50% de sus registros en tierras altamente protegidas. Menos de 1% de Alaska ha sido permanentemente alterado por actividades humanas. En contraste con los otros 48 estados, aún hay tiempo para desarrollar un plan que preserve la biodiversidad al igual que permita una economia sustentable si el esfuerzo se lleva a cabo ahora.*

Introduction

Most of the United States has been transformed by human activity (e.g., Cronon 1983). Deforestation, elimination of carnivores, and transformation of wildlife habitat to farmland, cities, and suburbs have permanently reduced much of the country to a simplified and narrow range of ecosystems. In contrast, Alaska remains substantially unchanged, with intact ecosystems, despite often grandiose past plans to alter it by damming interior rivers (Coates 1991) or using nuclear explosions to carve high Arctic harbors (O'Neill 1994). Less than 1% of the state has been heavily affected by intensive human

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settlement and activity (Yaeger & Channdonnet 1993). Less intensive activities occur in most of the state, including hunting, fishing, subsistence activities, hiking, snowmobiling, seismic exploration for oil, and activities causing fallout of airborne pollutants.

Alaska faces a variety of development pressures. Logging in the Tongass National Forest in southeast Alaska has generated considerable controversy (Soderberg & DuRette 1988; Ketchum & Ketchum 1994), as has proposed logging in Chugach National Forest on the south-central coast and in Tanana State Forest in the interior (Matz 1995). Proposed oil exploration in the Arctic National Wildlife Refuge, the National Petroleum Reserve-Alaska, and Cook Inlet represents a contentious extension of existing oil development (Strohmeyer 1993). Public roads to the North Slope oil fields and to Whittier in Prince William Sound will generate development in pristine areas (Alaska Geographic Society 1983). Development along Alaska's existing road system is occurring, especially between Anchorage and Denali National Park and on the Kenai Peninsula. Native corporations, owners of 11.8% of Alaska lands, operate as westernized, profit-making businesses; some have begun clearcutting and mineral extraction on Alaskan Native lands, formerly used only for traditional hunting and fishing (Rude 1996).

Alaska's biodiversity is generally considered depauperate. This is true only if species richness is considered. Alaska, however, preserves ecological and geological processes—such as deglaciation, migrations of ungulates, anadromous fish runs, undammed rivers, and viable populations of terrestrial and marine large carnivores—that have vanished from much of the rest of the United States (Pielou 1991; Duffy 1997). Alaska also preserves ecosystems that have become scarce elsewhere. Only 11% of its coastal temperate rainforest has been logged, compared with 96% in Oregon, 75% in Washington, and 55% worldwide (Kellogg 1992). Similarly, only 0.1% of wetlands in Alaska were lost between the 1780s and 1980s, compared to a 53% loss in the conterminous Unites States (Dahl 1990 in Noss et al. 1995). Alaska, as part of Beringia, is also a key to the origins of North American human, plant, and animal life, preserving traces of the Bering land bridge species and communities (Hopkins et al. 1982; Elias 1995). Finally, and perhaps most important, Alaska is one of the few places left in the world where beleaguered, but intact, indigenous communities of hunter-gatherers have a realistic chance of a sustainable future (Berger 1985).

Alaska's economy is driven by petroleum (Strohmeyer 1993; Institute of Social and Economic Research 1997). Other industries, such as mining, fishing, forestry, and tourism, although locally important, don't produce the revenue that oil does (Institute of Social and Economic Research 1997). Oil production has been declining, and the state has begun to step up utilization of other resources to compensate, as well as making more areas available for oil exploration. The stage is set for an escalation in what is already a vigorous and often vituperous debate over limits to development. Where will the state find the resources to maintain services in its vast territory and rugged northern climate without damaging its natural heritage? How can resource development expand without affecting Native Alaskan traditional use of natural resources?

One of the keys to any successful outcome is the availability of information that identifies natural features at risk from development. This information can help steer development away from the most sensitive areas or species, focus research on establishing effective protected areas, and develop new techniques that minimize disturbance or ameliorate unavoidable disturbance (e.g., Rebelo & Siegfried 1992; Pressey et al. 1993).

The Alaska National Interest Lands Conservation Act (1980) attempted to protect the full range of ecosystems found in the state, but the success of this effort in preserving representative natural communities and species has never been analyzed. We provide a first analysis to determine which ecosystems are at risk in Alaska. We examine the degree of protection for different ecoregions, land-cover types, and highly vulnerable plant species to undertake a coarse-scale assessment of whether existing protected lands are adequate in size and location to preserve Alaska's biodiversity in the face of current and future development.

Methods

To evaluate whether conservation areas contain the biotic and abiotic environments that represent the range of variation in biodiversity found within Alaska, we conducted a representativeness assessment (Austin & Margules 1986; Mackey et al. 1988). Such an assessment should include species, communities (Scott et al. 1988), and landscape-scale ecosystems (Ehrlich & Ehrlich 1981; Foreman & Godron 1986) at both fine-filter (threatened species and critical habitats) and coarse-filter (communities and landscapes) levels (Jenkins 1985; Noss 1987).

Several methods have been used to evaluate the amount of land necessary for the conservation of species and systems. One approach suggests that protecting the land necessary to maintain the largest and widest-ranging species in an ecosystem provides adequate area for the survival of all species. A minimum of 500 individuals is frequently recommended for long-term fitness (Newmark 1985; Soulé 1987). Another approach is to preserve entire functioning ecosystems (Noss 1987): maintaining a full suite of natural processes at a variety of scales will hypothetically conserve the component species. A third, widely used method employs the species-area curve that states, in general, that the more land is set aside, the more species will be represented (Williams 1943). Numerous authors, however, have shown that area alone is not a good indicator of species diversity, and factors such as species extinction rates and habitat heterogeneity must be incorporated (Watson 1964; Power 1972; Western & Ssemakula 1981).

For the coarse level of analysis that was necessary for this study, we chose to use a direct percentage (12%) of each evaluated category (cover-type, ecoregion, and rare vascular plant species) as an evaluation of adequate area of protection. We based this percentage on the Brundtland Commission's recommendation for Arctic countries that 12% be set aside (Conservation of Arctic Flora and Fauna 1994).

To identify biotic and abiotic gaps in the existing Alaskan preserve network, we compared the existing network to three biotic-abiotic geographic information system (GIS) layers: advanced very high resolution radiometer (AVHRR) landcover maps (Fleming 1997), ecoregions of Alaska (Bailey et al. 1994), and locations of globally rare vascular plant species that occur in Alaska (Alaska Natural Heritage Program, Biological Conservation Database).

We developed a spatial data set of conservation lands to assess protection. Land-management units were assigned to one of four categories of management status adapted from Scott et al. (1993; Table 1; Fig. 1a & 1b). Status 1 is represented by an area with an active management plan in operation to maintain a natural state, within which natural disturbance events are allowed to proceed without interference or are mimicked through management. Status 2 is represented by an area generally managed for natural values but which may receive use that degrades the quality of existing natural communities. Status 3 is represented by public lands not designated for protection or management of natural values. Legal mandates prevent the permanent conversion of natural habitat types to anthropogenic habitat types and confer protection to federally listed endangered and threatened species. Status 4 is represented by private or public lands without an existing easement or management agreement to maintain native species and natural communities and which are managed for intensive human use.

Management units of status 1 (Table 2) are typically owned by conservation groups such as The Nature Conservancy (Edwards et al. 1995) or are federally managed research natural areas. Management units of status 2 include national parks, national monuments, national preserves, and federal wilderness areas (Table 2). Many of the national parks and wilderness areas in Alaska also allow subsistence activities, such as hunting, fishing, and trapping by local residents.

Status 3 lands include federal areas managed under multiple use designations and most State of Alaska lands (Table 2). Examples of uses are oil and gas exploration and leasing on U. S. Fish and Wildlife refuges, and timber harvesting on state and national forest lands. The lowest management category, status 4, includes Alaskan Native regional corporations and other private lands, where land use is largely unrestricted.

Table 1. Definitions of conservation status for Alaska lands.

Management status	*Land designation*
1	Federal reserve natural area
2	State of Alaska preserve
	State of Alaska state game sanctuary
	U.S. National Forest Service national monument
	U.S. National Forest Service wilderness area
	U.S. National Park Service land
	U.S. Fish and Wildlife Service wilderness area
3	State of Alaska critical habitat area
	State of Alaska multiple use area
	State of Alaska recreation area
	State of Alaska state forest
	State of Alaska state historic park
	State of Alaska state park
	State of Alaska selected undesignated land
	U.S. Bureau of Land Management national conservation area
	U.S. Bureau of Land Management national petroleum reserve
	U.S. Bureau of Land Management national recreation area
	U.S. National Forest Service nonwilderness area
	University of Alaska land
	U.S. Fish and Wildlife Service refuge
4	Private land
	U.S. Bureau of Land Management utility corridor planning area
	Native regional corporation
	Native selected land
	Military installation
	U.S. Department of Defense land

Electronic GIS layers for Alaska land status, conservation unit boundaries, and legislatively designated areas (State of Alaska 1995) were combined into a single coverage of the major land-management units of the state. The four land-protection status classes were then applied to this layer. For the discussion, we combined status 1 and status 2 lands.

We used the Alaskan map of Bailey's system of ecoregions (ECOMAP 1993; Bailey et al. 1994) to evaluate gaps in ecosystem representativeness. The system includes an eight-level hierarchical land classification of ecological units, ranging from continental to site scales. The section level (fourth level) is the finest level currently available for the entire state, so we used it for our evaluation. Sections are defined as broad areas of similar geomorphic process, stratigraphy, geologic origin, drainage networks, topography, and regional climate. Such

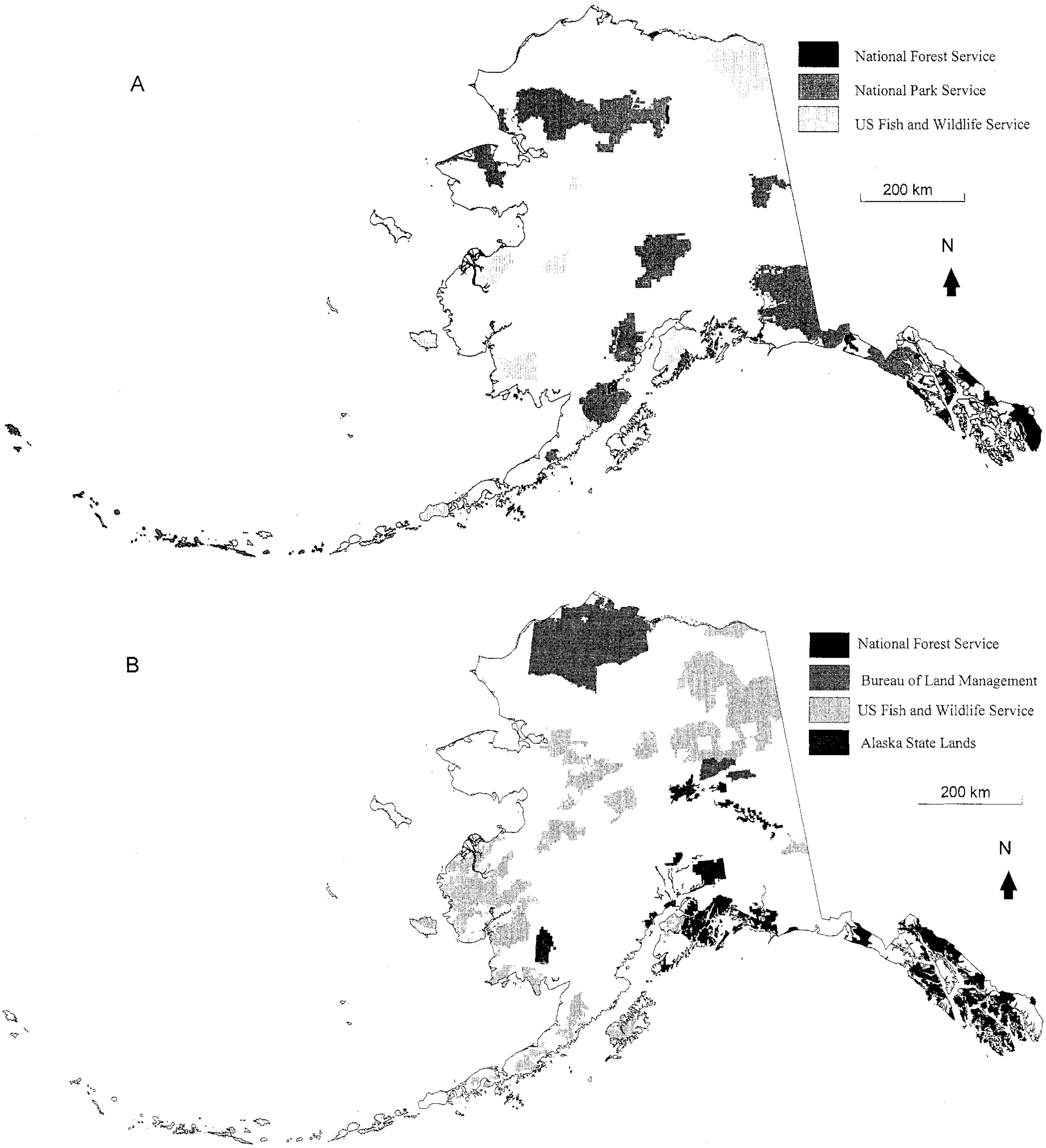

Figure 1. Ownership status of Alaskan lands of (a) status 1 and 2 and (b) status 3. Status 4 lands are not included. Status designations defined in Table 1.

areas are often inferred by relating geological maps to potential natural vegetation "series" groupings, as mapped by Kuchler (1964).

The AVHRR cover-type map provided coverage of Alaska at a coarse spatial and compositional resolution (Fleming 1997). The AVHRR has been used to evaluate vegetation spatial patterns in the conterminous United States (Loveland et al. 1991). The map covers the area extending over lat 51-71°N and long 130-172°W, excluding the central and western Aleutian chain. Methods

Table 2. Area (km²) and percentage of Alaska's 28 ecoregion sections (ECOMAP 1993) found within the biodiversity protection categories.

		Protected (status 1-2)		*Moderately protected (status 3)*		*Unprotected (status 4)*		*Total state*	
Section number	*Section name*	*km²*	*%*	*km²*	*%*	*km²*	*%*	*km²*	*%*
1	Coastal Plain	0	0.0	36,154	72.7	13,599	27.0	49,753	3.3
16	West Kodiak Island	0	0.0	3,814	43.4	4,975	56.6	8,790	0.6
4	Upper Yukon Flats	0	0.0	16,916	50.2	16,750	49.8	33,666	2.2
10	Kuskokwim Mountains	1,327	1.9	5,473	8.0	61,694	90.1	68,493	4.5
11	Yukon-Kuskokwim Delta	1,824	2.0	40,963	45.2	47,929	52.8	90,716	6.0
14	Nushagak-Lime Hills	829	3.4	0	0.0	23,384	96.6	24,213	1.6
24	Northern Gulf	829	4.1	6,634	33.1	12,604	62.8	20,067	1.3
21	Cooper River Basin	829	5.3	1,824	11.6	13,102	83.2	15,755	1.0
18	Upper Yukon Highlands	11,443	6.4	57,879	32.6	108,130	60.9	177,452	11.7
5	Upper Kobuk Valley	3,317	7.5	10,116	23.0	30,515	69.4	43,948	2.9
7	Seward Mountains	4,809	8.9	166	0.3	49,090	90.8	54,065	3.6
2	Foothills	11,443	9.4	47,597	39.0	63,020	51.6	122,060	8.0
9	Yukon-Kuskokwim Bottoms	11,277	10.9	25,208	24.4	66,669	64.6	103,154	6.8
20	Cook Inlet Lowlands	2,819	11.5	4,644	18.9	17,082	69.6	24,545	1.6
17	Aleutian Islands	1,327	11.6	498	4.3	9,619	84.1	11,443	0.8
8	Nulato Hills	6,634	12.9	4,146	8.1	40,466	79.0	51,245	3.4
13	Bristol Bay Lowlands	7,960	12.9	9,287	15.0	44,612	72.1	61,859	4.1
27	Southern Alexander Archipelago	6,136	21.9	12,107	43.2	9,785	34.9	28,027	1.8
12	Ahklun Mountains	10,116	23.4	16,584	38.3	16,584	38.3	43,285	2.8
19	Alaska Mountains	29,852	23.9	9,121	7.3	86,073	68.8	125,046	8.2
6	Kotzbue Sound Lowlands	7,629	24.0	2,985	9.4	21,228	66.7	31,842	2.1
26	Northern Alexander Archipelago	4,312	29.2	6,302	42.7	4,146	28.1	14,760	1.0
28	Boundary Range	6,468	33.9	10,614	55.7	1,990	10.4	19,072	1.3
23	Chugach-St. Elias Mountains	26,037	36.5	20,067	28.1	25,208	35.3	71,312	4.7
15	Alaska Peninsula	16,584	44.4	4,809	12.9	15,921	42.7	37,315	2.5
3	Mountains	72,142	50.9	30,349	21.4	39,139	27.6	141,630	9.3
25	Lynn Canal	8,126	51.6	3,317	21.1	4,312	27.4	15,755	1.0
22	Wrangell Mountains	27,862	84.0	1,161	3.5	4,146	12.5	33,169	2.2

used to develop this map are described by Fleming (1997). Twenty vegetation classes and two nonvegetation classes were derived from the NOAA-II AVHRR data. We excluded two categories from the discussion ("1990 fires" and "1991 fires, aufies [areas of river ice flow], and rivers") because they are transitory habitats or insufficiently recorded at our level of resolution.

The two rarest categories of vascular plants in Alaska were also included in the analysis. For plants, a G1 species is "critically imperiled globally," with five or fewer occurrences, very few individuals, or "because of some factor in its biology making it especially vulnerable to extinction." A G2 species is "imperiled globally," with either 6-20 occurrences or "because of other factors demonstrably making it very vulnerable to extinction throughout its range" (Lipkin & Murray 1998). Locations were compiled from data of the Biological Conservation Database of the Alaska Natural Heritage Program, University of Alaska Anchorage (unpublished data). Herbaria collections, principally from the Museum of the University of Alaska Fairbanks, form the basis for many of the locations. Plant collection points were used to create a spatial data layer by means of Arc/Info software. Each data point was buffered to represent the precision and accuracy of the source data, then the final polygon coverage was used for the overlay analysis with the land-status coverage.

Results

Of Alaska's 1,487,122 km² (Fig. 1a & 1b), <1% is status 1, strictly protected; 18.7% is status 2, protected; 26.3% is status 3, multiple use, moderately protected; and 55.0% is status 4, unprotected. At the state level, the 18.7% of lands in status 1 and 2 exceeds the suggested minimum level of 12% (Conservation of Arctic Flora and Fauna 1994); but, the distribution of this coverage is uneven when examined at a finer scale.

Of Alaska's 28 ecoregions, 15, representing 63.4% of the state's area, still lack sufficient protection (12% of their area) in status 1 and 2 protected areas (Table 2; Fig. 2a & 2b). These include the Arctic Coastal Plain (3.3% of the state; 0% of the ecoregion protected as status 1 and 2 lands), Copper River Basin (1.0% of the state; 5.3% protected), Upper Yukon Highlands (11.7% of state; 6.4% protected), and Cook Inlet Lowlands (1.6% of state; 11.5 % protected). In contrast, the two main ecoregions of the

Figure 2. Ecoregions and (a) status 1 and 2 and (b) status 3 lands in Alaska. Numbers refer to ecoregions in Table 2. Status 4 lands are not included. Status designations defined in Table 1.

Tongass National Forest, the Northern Alexander Archipelago (1.0% of the state; 29.2% of the ecoregion protected), and Southern Alexander Archipelago (1.8% of the state; 21.9% of the ecoregion protected), are well above the 12% level.

For land cover, 8 of 21 Alaskan vegetation-cover types, representing 33% of the state, are insufficiently represented (<12% protected) in status 1 and 2 lands (Table 3; Fig. 3a & 3b). The two most ecologically severe environments, "permanent ice and snow" (6.9% of the state;

Table 3. Area (km^2) and percentage of 21 vegetation–land cover classes (Fleming 1997) found within the biodiversity protection categories.*

Vegetation class names	Protected (status 1-2)		Moderately protected (status 3)		Unprotected (status 4)		Total state	
	km^2	%	km^2	%	km^2	%	km^2	%
Low shrub/lichen tundra	836	2.2	21,831	58.2	14,873	39.6	37,540	2.5
Closed broadleaf forest	722	5.7	1,929	15.3	9,976	79.0	12,627	0.8
Spruce and broadleaf forest	4,870	6.3	16,275	21.1	55,951	72.6	77,096	5.2
Open and closed spruce forest	4,302	6.4	21,207	31.5	41,854	62.1	67,363	4.5
Open spruce & closed mixed forest mosaic	3,355	6.4	23,934	45.5	25,369	48.2	52,658	3.5
Low shrub tussock tundra	5,167	6.7	18,030	23.3	54,039	70.0	77,236	5.2
1991 fires	422	8.0	1,865	35.2	3,016	56.9	5,303	0.4
Open spruce forest/shrub/bog mosaic	17,323	10.7	37,160	23.0	107,070	66.3	161,553	10.9
Moist herbaceous/shrub tundra	15,358	12.2	50,775	40.3	59,806	47.5	125,939	8.5
Closed spruce forest	1,111	13.5	2,009	24.5	5,090	62.0	8,210	0.6
Water	3,223	13.6	8,138	34.4	12,320	52.0	23,681	1.6
Low and tall shrub	6,030	15.8	7,610	20.0	24,490	64.2	38,130	2.6
Closed mixed forest	820	15.8	1,362	26.2	3,010	58.0	5,192	0.3
Spruce woodland/shrub	25,463	15.8	19,762	12.3	115,652	71.9	160,877	10.8
1990 fires and aufies and river	3,376	17.3	5,529	28.4	10,576	54.3	19,481	1.3
Tall shrub	25,959	17.4	28,067	18.9	94,789	63.7	148,815	10.0
Tussock sedge/dwarf shrub tundra	25,692	18.8	43,038	31.5	68,047	49.8	136,777	9.2
Closed spruce and hemlock forest	11,786	21.6	25,187	46.1	17,709	32.4	54,682	3.7
Dwarf shrub and tundra	14,838	36.6	8,610	21.3	17,063	42.1	40,511	2.7
Alpine tundra and barrens	55,003	41.9	28,372	21.6	47,915	36.5	131,290	8.8
Permanent ice and snow	52,554	51.4	20,249	19.8	29,358	28.7	102,161	6.9

**The Aleutian Islands were not included in this analysis. Status designations defined in Table 1.*

51.4% protected) and "alpine tundra and barrens" (8.8% of the state; 41.9% protected), enjoy the highest percent protection. In contrast, 5 of the 8 forest-cover types (24.9% of the state) have <12% protection in status 1 and 2 areas. Only 3 forest types, "closed mixed forest" (0.3% of the state; 15.8% protected), "closed spruce and hemlock" (3.7% of the state; 21.6% protected), and "closed spruce forest" (0.06% of the state; 13.5% protected) are adequately represented on status 1 and 2 lands.

For the 28 rare plant species, on average only 27% of occurrences fell within status 1 and 2 lands (Table 4), 17% on status 3 lands, and 44% on unprotected status 4 lands (Table 4, Fig. 4a & 4b). Two species occurred only on status 1 and 2 lands; 5 occurred only on unprotected status 4 lands. Only 7 of the 28 species had 50% or more of their occurrences on status 1 and 2 lands.

Discussion

Several factors may affect the results of this study. First, our categories of protection are relatively coarse. There is a spectrum of protection even within the ranks we assigned. We chose to rank status by restrictions to future development. An analysis of current land use would show a different picture in that more than 99% of Alaska is still undeveloped. Second, ecoregions, cover type, and rare plant species may not be adequate surrogates for biodiversity. Further analysis would require consideration of biotic-abiotic interactions (Mills et al. 1993; Bourgeron et al. 1994), modeling of the distribution and population dynamics of animal species (Edwards et al. 1995), and information on the scale of ecological processes and the historical range of ecosystem variability (Morgan et al. 1994). In addition, except for rare mammals and vascular plants, as well as a few small groups like butterflies (Lepidoptera), we know too little of Alaska's biodiversity to include most species groups in this analysis. This also limits the scale at which analyses can be performed. Third, ecoregions are relatively crude designations. Although a large percentage of an individual ecoregion may be protected, this does not ensure that the biologically most important sites are included. Much of the diversity or the critical ecological processes may be present on the remaining land with no protection. In addition, although protected areas may cumulatively represent more than 12%, they may individually be too small to be effective at conserving species. Fourth, coarse-scale vegetation maps are simplistic and can misguide research and management if ecological events or species actually operate at finer scales (Davis et al. 1994). Fifth, the plant data are based on known occurrences, but many of the species have been little studied and may yet be discovered in additional localities. The analysis thus may suffer from small sample sizes. Protected areas such as parks, however, are often better sur-

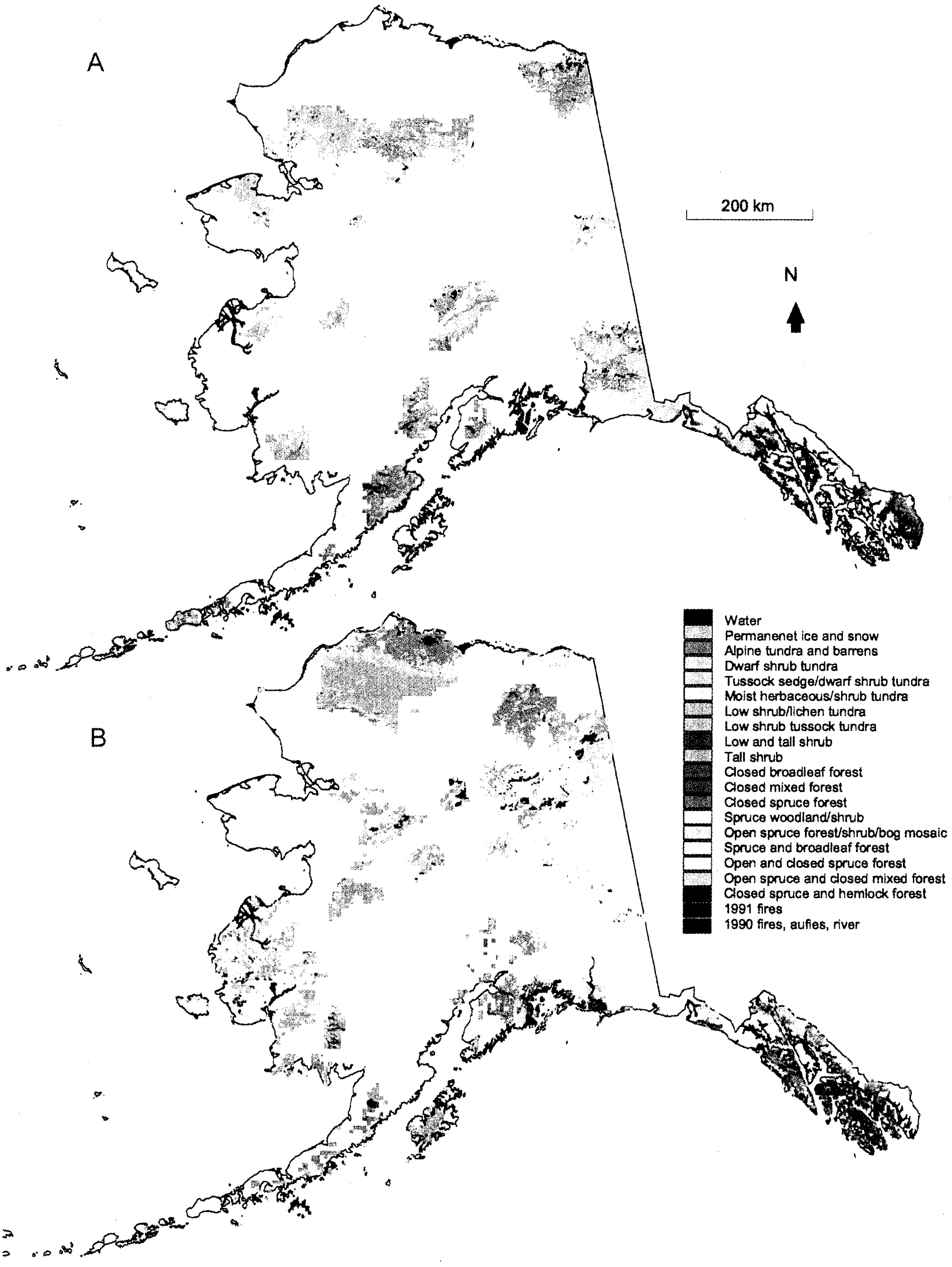

Figure 3. Cover types and (a) status 1 and 2 and (b) status 3 lands in Alaska. Status designations defined in Table 1.

Table 4. Percent of G1[a] and G2[a] species locations found within the biodiversity protection categories.

Scientific name	*Protected areas status 1–2 (%)*	*Moderately protected status 3 (%)*	*Unprotected status 4 (%)*	*Number of occurences*	*Global rank[a]*	*State rank[b]*
Arnica lessingii ssp. *norbergii*	9	36	55	11	G5T2Q	S2
Artemisia globularia var *lutea*	43	0	57	7	G4T1T2	S1S2
Artemisia aleutica	100	0	0	4	G1	S1
Beckwithia glacialis ssp. *alaskensis*	0	0	100	7	G2	S2
Botrychium sp.	0	0	100	4	G1	S1
Cochlearia sessilifolia	0	0	100	2	G1G2Q	S1S2
Cryptantha shackletteana	25	0	75	4	G1Q	S1
Douglasia alaskana	22	14	63	27	G2G3	S2S3
Douglasia beringensis	50	0	50	8	G1	S1
Draba aleutica	80	0	20	5	G2	S2
Draba murrayi	75	0	25	12	G2	S2
Draba ogilviensis	100	0	0	1	G2	S1
Draba kancanaskis	0	100	0	1	G1Q	S1
Erigeron sp.	0	100	0	1	G1G2	S1S2
Erigeron muirii	10	10	80	10	G2	S2
Eriogonum flavum var *aquilinum*	45	18	36	11	G4T2	S2
Erysimum asperum var *angustatum*	50	8	42	12	G5T2	S1S2
Lesquerella calderi	17	0	83	6	G2G3	S1S2
Mertensia drummondii	0	82	18	11	G2Q	S2
Oxytropis arctica var *barnebyana*	0	0	100	8	G4T2	S2
Oxytropis kobukensis	83	0	17	6	G2	S2
Poa hartzii ssp. *alaskana*	20	60	20	5	G4T1	S1
Podistera yukonensis	44	0	56	9	G2	S1
Polystichum aleuticum	0	80	20	5	G1	S1
Rumex krausei	0	13	88	8	G2	S2
Salix reticulata ssp. *glabellicarpa*	0	0	100	1	G5T2	S1
Saxifraga aleutica	60	10	30	10	G2G3	S2S3
Smelowskia pyriformis	17	17	67	12	G2	S2
Average for each category	27	17	44	7		

[a] *G1, critically imperiled globally; G2, imperiled globally; G3, very rare and local; G4, apparently secure globally; G5, secure globally; Tx, global rank of subspecies or variety; GxGx, rank range; GxQ, uncertain taxonomy.*
[b] *S1, critically imperiled in state; S2, imperiled in state; S3, rare or uncommon in state.*

veyed than unprotected areas, so the protected status of some plant species may actually be overrepresented in this analysis. Sixth, not all ecosystems are equal; some may have much more biodiversity (e.g., Schoen et al. 1981; Stokland 1997), so preserving 12% by area may yield differing efficiencies between ecoregions. Finally, the arbitrary 12% value may be too low to effectively conserve biodiversity at the scale of centuries.

Given these caveats, this is a "first-cut" analysis of the degree of protection of Alaska's biodiversity. The results, whether measured by ecoregion, cover type, or rare plants, show that a large proportion of Alaska's biodiversity remains unprotected at present, even at a modest 12% level. Ecoregions representing over 60% of Alaska are underrepresented in status 1 and 2 lands. Four of the ecoregions facing the most immediate prospects of development, the Arctic Coastal Plain, the Copper River Basin, the Upper Yukon Highlands, and Cook Inlet Lowlands, have <12% of their areas in highly protected status. Vegetation-cover types representing over 40% of the state's area are also underrepresented. Forested areas outside southeast Alaska are underrepresented in status 1 and 2 areas. Over 75% of Alaska's rare plant species have <50% of their known locations on status 1 and 2 lands. Except for Yukon Charley National Park and Preserve, highly protected areas and rare plant locations show little overlap.

This analysis does not involve federally listed endangered species and it generates no immediate regulatory or legal concerns. Instead it is perhaps best seen as an early warning that significant biodiversity issues, such as endangered species, are likely to emerge in the future, especially in those areas undergoing development, but with low protection levels.

There are two ways these data could be incorporated into planning for Alaska's future. They could be ignored, and future conflicts over biodiversity could be fought out in the political sphere. Given the recent political battles over logging levels in the Tongass National Forest and oil exploration in the Arctic National Wildlife Refuge and National Petroleum Reserve of Alaska, such political solutions appear to have a high potential for economic and social harm to humans, in addition to damage to biodiversity.

In contrast, a science-based initiative to preserve biodiversity in Alaska could be developed now by refining

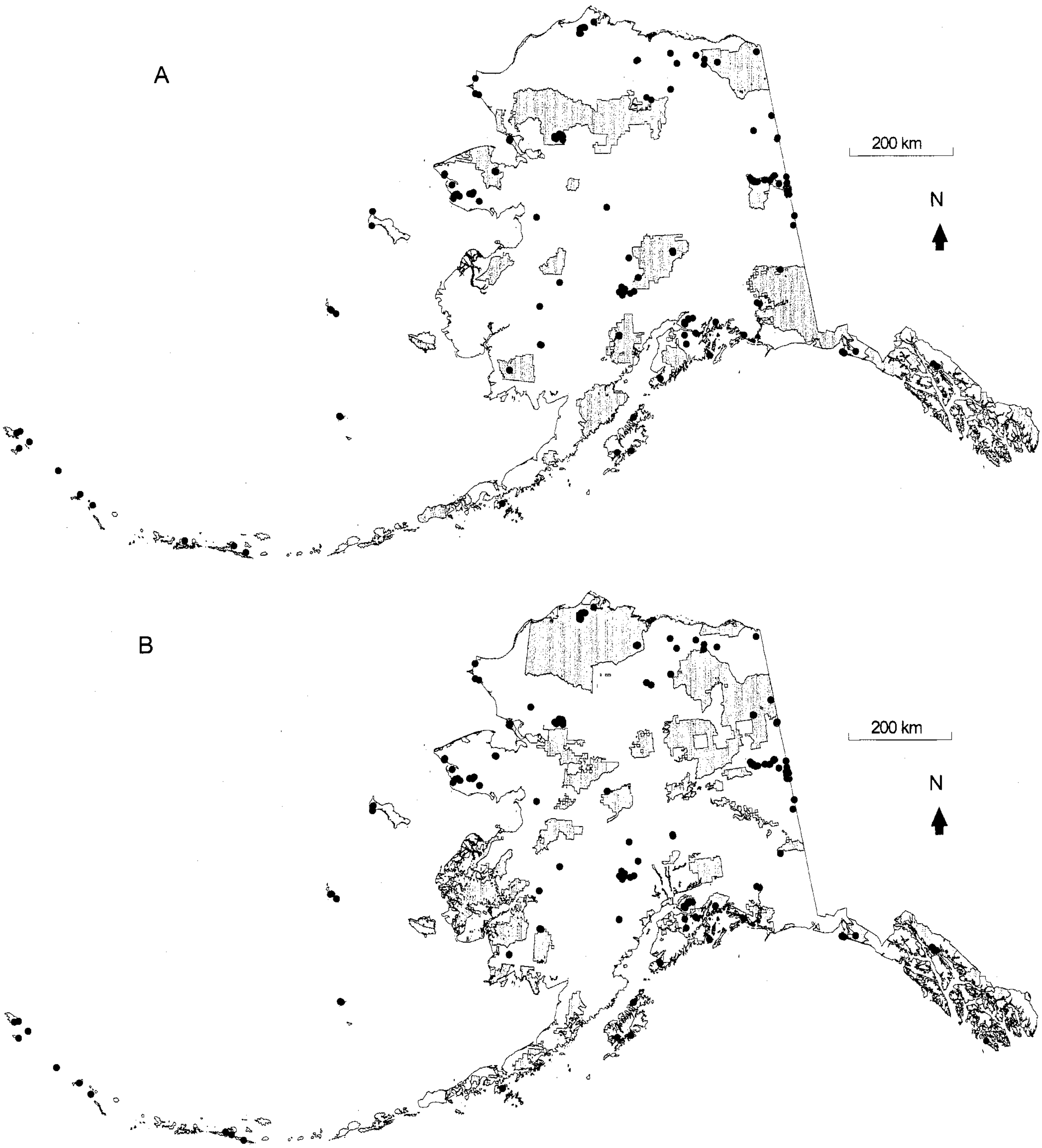

Figure 4. Rare plant species and (a) status 1 and 2 and (b) status 3 lands in Alaska. Status designations defined in Table 1.

the present analysis, addressing the short-comings mentioned above, incorporating other plant and animal species and significant natural features, and utilizing representative reserve techniques (e.g., Bedward et al. 1992; Davis et al. 1996). The representativeness methods not only identify the presence of deficiencies in reserve networks but provide tools for identifying potential modifications to networks to make them representative. Davis et al. (1996) also explore methods to identify "biodiversity management areas" where different levels of protection are considered across a gradient of land-use allocations. Such methods might be applied first, and at finer scales than here, to areas facing development, such as the National Petroleum Reserve of Alaska, the Kenai Peninsula, and the Denali National Park-Anchorage corridor.

The science-based initiative could also take human needs into account, such as Native subsistence areas, mineral deposits, timber reserves, and tourist attractions, optimizing protection of biodiversity while minimizing lost economic opportunities. From the resulting analysis, at the overall state level, land exchanges might ensure better representation of rare species and plant communities in highly protected areas. At a local level, ecologically valuable areas within status 3 lands might be identified and set aside during development through finer-scale versions of the present analysis. Management efforts should focus on status 3 lands, seeking ways to reduce the impact of development. For status 4 lands, working with and educating landowners might extend a lesser but still significant degree of protection to biodiversity, without compromising primary land uses. A state plan for such management of lands of different ownership, then known as cooperative management areas, was turned down by state lawmakers in 1980 (Hammond 1994), but we hope reconsideration of the concept will prove that it was only slightly ahead of its time.

Alaska remains relatively undeveloped. Our analysis suggests, however, that without additional effort the state may not have the right lands protected to maintain its biodiversity during future development. Fortunately we still have time to use a science-based approach to protect biodiversity during development.

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