Assessing Protection of Alaska's Terrestrial Biodiversity

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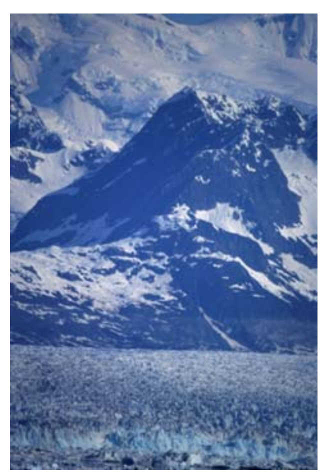
Abstract

Because 89% of Alaska is owned by the state and federal governments, one could assume that conservation there is mostly about how these lands are managed as opposed to the need for protecting new lands through acquisition, legislation or private preserves. However, several researchers have shown that protected areas (e.g. parks and refuges) in other parts of the world are often the least productive and least desirable lands and that huge gaps in biodiversity conservation can exist in spite of a large network of protected areas. Here we examine the distribution of land management across Alaska and assess how well the protected areas capture the terrestrial biodiversity of Alaska at a statewide scale and across the environmental gradients of ecoregions and elevation. First we looked at different land management types in Alaska, using the framework of the USGS Gap Analysis Program, and developed conservation management status categories appropriate to the level of development and human use in the state. Then we re-examined an earlier study of how well the protected areas represent vegetation classes, a surrogate for terrestrial biodiversity, at a statewide scale and added analyses for representation across ecoregions and elevation.

We found that while 43.6% of Alaska is managed for high and medium levels of conservation, a disproportionate amount (41.3 %) of those lands occur at high elevations (above 510 m), which are typically less biologically diverse than low-lying areas. Across the state, 5 of 19 vegetation classes are insufficiently represented in the existing protected areas, and when examining vegetation classes within ecoregions, 16 of 19 are found to be insufficiently represented in at least one of the ecoregions in which they occur. We also assessed the potential contribution of Native-owned lands, which are the majority of private lands, to conservation of terrestrial biodiversity. If we assume that the largely undeveloped lands owned by Native entities are being managed for conservation, the representation of terrestrial ecosystems improves. We conclude that the conservation of Alaska's biodiversity is not as sufficient as numbers about land management alone would indicate; some vegetation classes at low elevations require additional protection to ensure broad and widespread conservation across environmental gradients and to guard against changes in biodiversity related to climate change. Conservation management of Native-owned lands may provide some of the solution to adequately protect terrestrial ecosystems in Alaska.

Introduction



In 2005, Alaska celebrated the 25th anniversary of the Alaska National Interest Lands Conservation Act (ANILCA), which protected over 100 million acres of federal land in Alaska for conservation purposes. The Act doubled the total acreage in the U.S. national park system and created or expanded national wildlife refuges and national forests across Alaska. The Act arguably made Alaska one of the most protected places in the U.S. Its network of protected areas includes 15 national parks, 2 national forests, 16 national wildlife refuges, and over 14.7 million acres (5.9 million hectares) of state-owned lands managed for conservation.

Because 90% of Alaska is owned by the state and federal governments, one might assume that conservation in Alaska is mostly about how these lands are managed as opposed to the need for protecting new lands through acquisition, legislation or private preserves. However, several studies elsewhere have shown that protected areas are often the least productive and least desirable lands (Nilsson and Gottmark 1992; Scott et al. 2001), and that huge gaps in biodiversity protection can exist in the face of what might seem to be a sufficient network of protected areas (Caicco 1995; Rodrigues et al. 2004). We examined the distribution of land management and ownership across Alaska and assessed how well the protected areas capture and protect the terrestrial biodiversity of Alaska.

In the United States, much emphasis has been placed on federal public lands for their role in conserving national biodiversity (Crumpacker et al. 1988; Grumbine et al. 1990; Brussard et al. 1992). In the absence of written management plans and legal restrictions on development, private lands are assumed not to provide lasting protection of natural features. Gap analysis assesses current levels of protection and identifies ecosystems and species that are underrepresented in protected areas (GAP 1998; Jennings 2000). The U.S. Geological Survey's Gap Analysis Program (GAP) provides a framework for assigning conservation management status to different land management types (Scott et al. 1993; Crist 1994; Jennings 2000). Conservation management status (CMS) describes the degree to which land, particularly public land, is legally designated and explicitly managed for biodiversity conservation. Agencies and conservation scientists have used gap analyses to assess biodiversity conservation in the U.S. and other countries (e.g. Caicco et al. 1995; Crumpacker et al. 1988; Nilsson and Gottmark 1992; David et al. 1998). A consistent conclusion from gap analyses in the U.S. and other countries is that the distribution of protected lands is skewed toward higher elevations (Nilsson and Gottmark 1992; Caicco et al. 1995; Scott et al. 2001).

A complete gap analysis has not yet been conducted for Alaska. More than a decade ago, Schoen and West (1994) called for a gap analysis of Alaska to help agencies set conservation strategies across the state. Duffy et al. (1999) began that analysis by using the GAP framework to assess the degree of protection of Alaska's terrestrial biodiversity at a statewide scale. Using a minimum requirement of 12% for sufficient representation, they found that 8 of 21 vegetation classes were underrepresented across the state and that 15 of 28 ecoregions had insufficient protection. A gap analysis of Alaska is an important first step in determining an efficient approach to conservation in the state (Groves 2003).

We expand upon the assessment by Duffy et al. (1999) by examining the distribution of Alaska's protected lands across the environmental gradients of ecoregions and elevation. Because Alaska is already seeing ecological changes due to climate change and is predicted to be a region of major impact due to global warming (ACIA 2004), it is essential that vegetation classes are not protected in just one location, but across a wide variety of ecoregions and along elevational gradients. The best insurance against climate change in an uncertain world is protection of biodiversity across major environmental gradients (Parmesan and Galbraith 2004). Our study thus re-examines how well protected lands represent terrestrial vegetation classes at a statewide scale, as well as across the environmental gradients of ecoregions and elevation. We also assess the potential contribution of the majority of private lands, owned mostly by Native individuals and corporations, to conservation of terrestrial biodiversity.

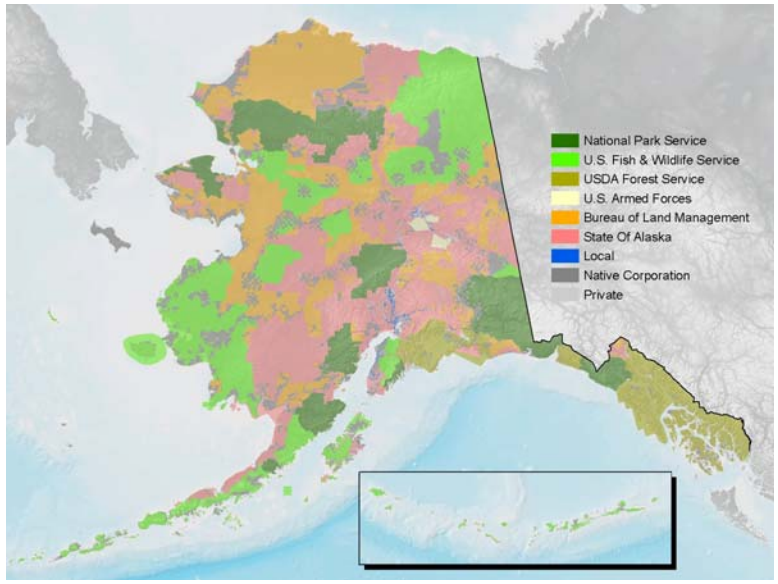
Methods

Study Area

As the largest U.S. state, Alaska encompasses approximately 148 million hectares, spanning from 51 to 71 degrees latitude and 130 west to 172 east degrees longitude, with 70,800 km of coastline (ADNR 2006), more than the rest of the U.S. combined. Elevations range from sea level to the highest mountain in North America, Denali, at 20,320 feet (6194 meters). This variety of geographical extent is reflected in a great diversity of precipitation, temperature, and vegetation in the state, from the temperate rainforest in the southeast panhandle to the arid tundra of the Arctic coastal plain.

Most of Alaska remains in federal ownership (67%), with the state owning 23%, and local governments and private entities owning 10%. Less than 1 percent of the landscape has been altered by agricultural, industrial, or urban development (Schoen and West 1994), so large-scale ecological processes continue with little human interference. For example, over 6 million acres of taiga burned in the summer of 2004 (NIFC 2004), and caribou migrate hundreds of miles annually (Paulson and Beletsky 2001). The existence of Alaska's pristine waters, unfragmented landscapes, and unmanipulated ecological processes provide ecosystem services that benefit not only the state, but the entire country (Colt 2001).

Figure 1. Land ownership in Alaska



Assigning conservation management status

The GAP framework assigns land management types to 4 CMS categories according to the degree to which the land is explicitly managed for conservation (GAP 1998; Jennings 2000). Criteria for CMS categories include size of area, what is protected, and how overall management intent. In general, CMS 1 and 2 have a strong emphasis on conservation protections and have legal designations that are challenging to change. CMS 3 and 4 have no mandated conservation management or are used primarily for human activity. CMS 1 and 2 are assumed to provide high and medium protection, respectively, of species and landscape. In the lower 48 states, national parks, wilderness areas, and national wildlife refuges are typically classified as CMS 1 or 2.

The Nature Conservancy in Alaska and other conservation practitioners (Duffy et al. 1999) have found that the GAP CMS categories cannot be applied directly to management of Alaska lands in the same way as in the lower 48 states for several reasons. First, ANILCA allows uses of federal protected areas that are typically banned in the rest of the country. For example in Alaska (but nowhere else), motorized vehicles are permitted in wilderness areas for traditional activities, such as subsistence hunting and gathering; thus we needed to determine whether these wilderness areas should be assigned a CMS 1 as in the lower 48. Second, the management of state protected areas (e.g. forests, sanctuaries, preserves) varies from state to state. Third, national parks and preserves and wildlife refuges in Alaska tend to be managed more similarly to each other than the same units are in the lower 48 states and most have minimal levels of development. Therefore these federal management types may be assigned different conservation management status than in the lower 48 in a gap analysis.

To determine how to assign CMS to Alaska lands, we reviewed the ANILCA legislation and state laws and regulations for state protected areas and interviewed federal and state land managers to help us understand how those laws and regulations are applied to Alaska protected areas. We also reviewed GAP's criteria (GAP 1998) and developed a dichotomous key to assist us in assigning CMS (Table 1). We focused on the following factors to determine CMS for Alaska land management types:

- *Permanence of protection from conversion of natural land cover to unnatural cover*. We assumed that protected areas created through legislative action will be more difficult to dissolve than those created through administrative action (e.g. National Monuments created by Executive Order) and thus offer longer-lasting protection.

- *Relative amount of land maintained in a natural state.* We looked not only at how much of the protected area has been developed but also how much of the unit is intensely utilized for human activities such as recreation or timber harvest. Most protected areas in Alaska have limited development and most federal units are very large. Thus we used the 5% limit suggested by GAP (1998) as a threshold for development and intense human utilization.
- *Ecosystem management versus single species or feature management.* We assumed that lands managed for all species will protect overall biodiversity better than those managed for particular elements of biodiversity.
- *Management of natural disturbances.* Management that allows natural processes such as fire to occur with no or minimal interference received a higher CMS than lands where natural processes are suppressed.
- *Motorized access.* Most public lands in Alaska are open to some types of motorized access. We gave the most protective CMS 1 to lands where motorized access is very restricted or prohibited.

Table 1. Dichotomous key with CMS definitions

A-1:	Can the management intent be determined through agency or institutional documentation? YES = Go to A-2. NO= Go to A-4.
A-2:	Is the land unit subject to laws or regulations that protect it from conversion of ALL or SELECTED features (e.g. state or federal legislation, deed restrictions, conservation easements). YES = Go to B-1. NO = Go to A-3.
A-3:	Is there a management plan that provides legally enforceable protection of SOME or ALL ecological features? YES = B-4. NO = A-4
A-4:	Is the land publicly owned? YES = A-6. NO = A-5.
A-5:	**CMS 4 Private** = Privately owned and either management intent is unknown or management intent doesn't protect for ecological features.
A-6	**CMS 4 Public** = Publicly owned, but not subject to a management plan or regulation that includes protection of ecological features.
B-1:	Is the total land system conserved for natural ecological function (no more than 5% of land is developed or intensely utilized)? YES = B-4. NO = B-2.
B-2:	Does management allow or mimic natural ecological disturbance events (e.g. fire, flooding) and allows only low anthropogenic use (e.g. renewable resource use or human visitation) on more than 5 % of land? YES = B-6. NO= B-3.
B-3:	**CMS 3** = Management includes protection of select ecological features; intensive anthropogenic use (e.g. resource extraction, military exercises, developed/motorized recreation) occurs on more than 5% of the land.
B-4:	Was the unit created through executive or administrative actions with the management intent very similar to legislatively created units with Status 1 or 2 (e.g. Wilderness Study Area, National Monument, RNA)? YES = Go to B-6; NO Go to B-5
B-5:	Does management allow or mimic natural ecological disturbance events? YES = B-7. NO = B-6.
B-6:	**CMS 2 =** A management plan protects the total land system but some/all natural disturbance events are suppressed and human use occurs on more than 5% of land.
B-7:	**CMS 1 =** A management plan permanently protects the total land system, allowing natural disturbance events; motorized access is limited.

Following the GAP framework, we defined 4 CMS categories for Alaska (Table 1; Table 2). The most protected areas, CMS 1, are managed for the entire ecosystem and have minimal development. Some CMS 1 lands (i.e. national parks and wilderness areas) have restrictions on motorized access and sport hunting; national preserves and wildlife refuges allow motorized access and sport hunting yet see limited use. On CMS 2 lands, all or selected natural features are protected by law or a management plan, but low intensity human use occurs on more than 5% of the land. CMS 2 includes state parks and refuges, portions of national forests not used for timber harvest, wild and scenic rivers, and Bureau of Land Management (BLM) conservation areas. CMS 3 may protect selected natural features or have minimal development, but the intent of the management is for intensive human activities like resource extraction or motorized recreation on more than 5% of the land. Recreation areas, military bases, and national forests fall into this category. We separated CMS 4 lands into public and private ownership. CMS 4 public lands are developed or the management intent is primarily for human uses, such as mining. Determining the management intent for CMS 4 private lands, including Native corporations' holdings and Native allotments, was beyond the scope of this project, so we have conservatively assumed that all private lands are primarily managed for human use.

Developing a conservation management status spatial dataset

Once we determined CMS for the different land management types in Alaska, we mapped land management types and conservation management status across the state. To develop a land management dataset for Alaska, we collected GIS datasets from the Alaska Department of Natural Resources (ADNR), BLM, National Park Service (NPS), Chugach National Forest, Tongass National Forest, and U.S. Fish and Wildlife Service (USFWS). The ADNR dataset identifies land ownership at the section level (640 acres) but does not differentiate among the various land designations managed by each agency. The boundaries of state and federal protected areas were delineated with GIS datasets from each agency. The BLM maintains a GIS dataset of Alaska Native allotments, which range in size from 40 to 160 acres. In total, we joined 36 GIS datasets to develop a statewide land management dataset. Boundary precedence was assigned in the following priority: Native Allotments, NPS, USFWS, BLM, and ADNR. We then mapped the CMS of each land management type represented in the spatial dataset.

Representation Assessment

We assessed representation of major vegetation classes by CMS, evaluated the distribution of CMS 1 and 2 lands across the environmental gradients of ecoregions and elevation, and examined the contribution of Native-owned lands to conservation statewide and by ecoregion.

An ecoregion is a geographic area that shares common geology, soils, climate, and vegetation. While Duffy et al. (1999) used the 28 ecoregions described by Bailey et al. (1994), we used a more recent ecoregion map developed by Nowacki et al. (2001). Nowacki et al. (2001) delineated 32 ecoregions in Alaska; these ecoregions are either wholly in Alaska or extend from Alaska into western Canada or the Russian portion of the Bering Sea (Figure 2).

Like Duffy et al. (1999), we employed the Advanced Very High Resolution Radiometer (AVHRR) landcover map for Alaska (Fleming 1997) for a vegetation map for the state. AVHRR covers the area from latitudes 51 – 71 degrees north and longitudes 131 to 179 degrees west, excluding the central and western Aleutian Chain. We used the 19 vegetation classes in the dataset for our assessment (Appendix 2), excluding cells coded for adjacent countries, water, and fires.   For the elevation analysis, we used a 90 meter digital elevation model from the U.S. Geological Survey. We grouped elevation into 6 classes based on equal area: 0-52 m, 53 -154 m, 155-298 m, 299- 510m, 511-887 m, and 888-6193 m.

Table 2. CMS assignments to Alaska land management

CMS	AGENCY	AGENCY LAND MANAGEMENT DESIGNATION
1	National Park Service	National Park, Wilderness Area, National Preserve
	U.S. Fish & Wildlife Service	Wilderness Area, National Wildlife Refuge
	USDA Forest Service	Wilderness, Wilderness Monument, Wilderness Monument Research Natural Area, Wilderness Monument Special Area, Wilderness Special Area, Wilderness Monument Wild River, Wilderness Wild River
2	Bureau of Land Management	National Conservation Area, Area of Critical Environmental Concern, National Conservation Area, Wild & Scenic River, Wild River, Research Natural Area, National Recreation Area
	State of Alaska	State Game Sanctuary, State Park, State Marine Park, State Wilderness Park, State Wildlife Sanctuary, State Critical Habitat Area, State Game Refuge, State Preserve, State Range Area, State Special Use Area, State Wildlife Refuge
	U.S. Fish & Wildlife Service	Research Natural Area
	USDA Forest Service	LUD II, Research Natural Area, Backcountry Prescription, Municipal Watershed, National Monument, Old Growth Habitat, Primitive Prescription, Research Natural Area, Proposed RNA, Recommended Wilderness, Brown Bear Core Area, Fish & Wildlife Conservation Area; Fish, Wildlife & Recreation Prescription; Forest Restoration, Remote Recreation, Scenic River, Semi-Remote Recreation, all Wild River designations, Recreation River
	National Park Service	National Monument, National Historical Park
3	Bureau of Land Management	National Petroleum Reserve
	State of Alaska	State Forest, State Multiple Use Area, State Public Use Area, State Recreation Area, State Recreation River, State Resource Management Area, State Restricted Area, State Special Management Area
	U.S. Armed Forces	Military Reservation
	USDA Forest Service	Experimental Forest, LUD III, LUD IV, Modified Landscape, National Forest, Scenic Viewshed, Timber Production
	Bureau of Land Management	Undesignated BLM lands
4 Public	Local	Municipal
	State of Alaska	State Recreational Mining Area, State Undesignated Lands
	USDA Forest Service	Mining Claim with Approved Operations Plan, Transportation/Utility Corridor
4 Private	Private	Native Allotment, Native Corporation, Private

Our analysis, like many before (Duffy et al. 1999; Engelking et al. 1994; Scott et al. 1993), used vegetation as a surrogate for terrestrial biodiversity in the representation assessment. The question of what constitutes sufficient representation has been approached in very different ways, from not determining a threshold (DeVelice et al. 1988), to setting one minimum for a large region (CAFF 1994), to quantifying relationships between number of species and land area (Dobson 1996; MacArthur and Wilson 1967). Based on recommendations for Arctic countries (CAFF 1994), Duffy et al. (1999) used 12% as an acceptable minimum for all vegetation classes but noted that it may be an inadequate level of protection for some classes and "to effectively conserve biodiversity at the scale of centuries." In lieu of a widely accepted theory that suggests how much area is enough, we chose a 30% minimum benchmark because it is in accord with current recommendations for conservation plans (Groves et al. 2003). Our more cautious approach in Alaska follows recommendations for large reserves (Poiani et al. 2000; Groves et al. 2002) and is based on the large habitat needs of wide-ranging and migratory mammals like brown bear and caribou, as well as the homogeneity of the landscape and ecological processes that still occur across large areas without human interference.

Explicit in the GAP approach to assigning conservation management status is the assumption that only publicly-owned lands with management plans that emphasize conservation or private lands with legal restrictions on development (e.g. conservation easements) will protect biodiversity over a long time period. In Alaska, some private lands may likely provide the same protections without those particular legal constraints. Native corporations and individuals comprise the largest class of private landholders, owning 10% of the total land in the state. Most of this land is undeveloped and maintained for the subsistence lifestyles of the shareholders or individual owners. An additional incentive to not develop land was included in the Alaska Natives Claims Settlement Act, the law that conveyed land to the Native corporations. Under that law, lands not under active development or utilization (e.g. logging) are not assessed property taxes. We examined how management of these lands could increase protection of Alaska's biodiversity by calculating the amount of Native-owned land in each ecoregion and comparing that to the amount of CMS 1 and 2 lands.

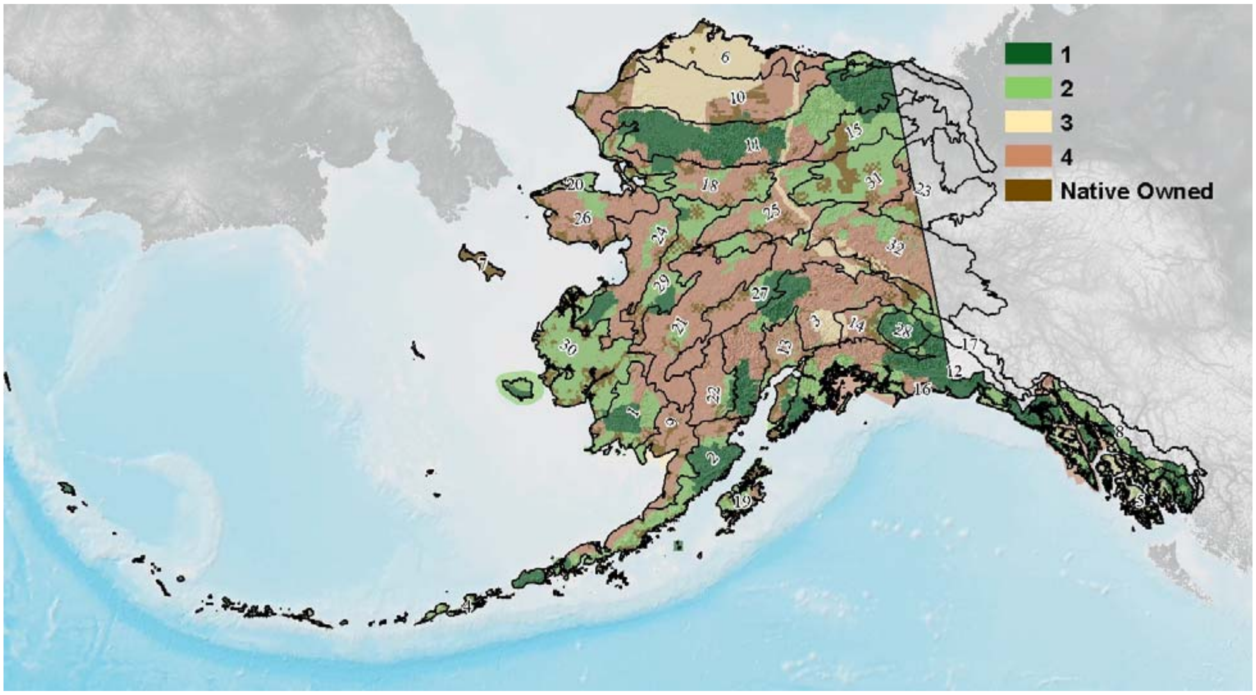
Results

Assessment of Conservation Management Status

Revisions to how lands were classified as CMS 1 and 2 improved the picture of conservation at the statewide scale from the Duffy et al (1999) study. Our inclusion of national wildlife refuges and some forest service lands in CMS 1 and 2 increased the amount of protected lands from less than 19% to 43.6% statewide. Of Alaska's 365 million acres, 36.7% come under CMS 1, 6.9% under CMS 2, 9.2% under CMS 3, and 47.2% CMS 4 public and private lands (Figure 2). We found that despite the overwhelming majority ownership (90%) by federal and state government, less than half of all public lands (43.6% CMS 1 and 2) are managed for high or medium conservation (CMS 1 and 2).

At the ecoregion level, the amount of land in CMS 1 and 2 ranges from 6.9% in the Beaufort Coastal Plain to 100% in the Kluane Range (Figure 2; Table 3). Eleven of 32 ecoregions in the state have less than 30% of their lands in CMS 1 and 2. Collectively, these ecoregions comprise 40.6% of the area of the state, and thus a significant proportion of the environmental gradients represented by ecoregional differences are not captured in CMS 1 and 2 lands.

Figure 2. Conservation management status and ecoregions in Alaska. (Ecoregion numbers correspond to Appendix 1)

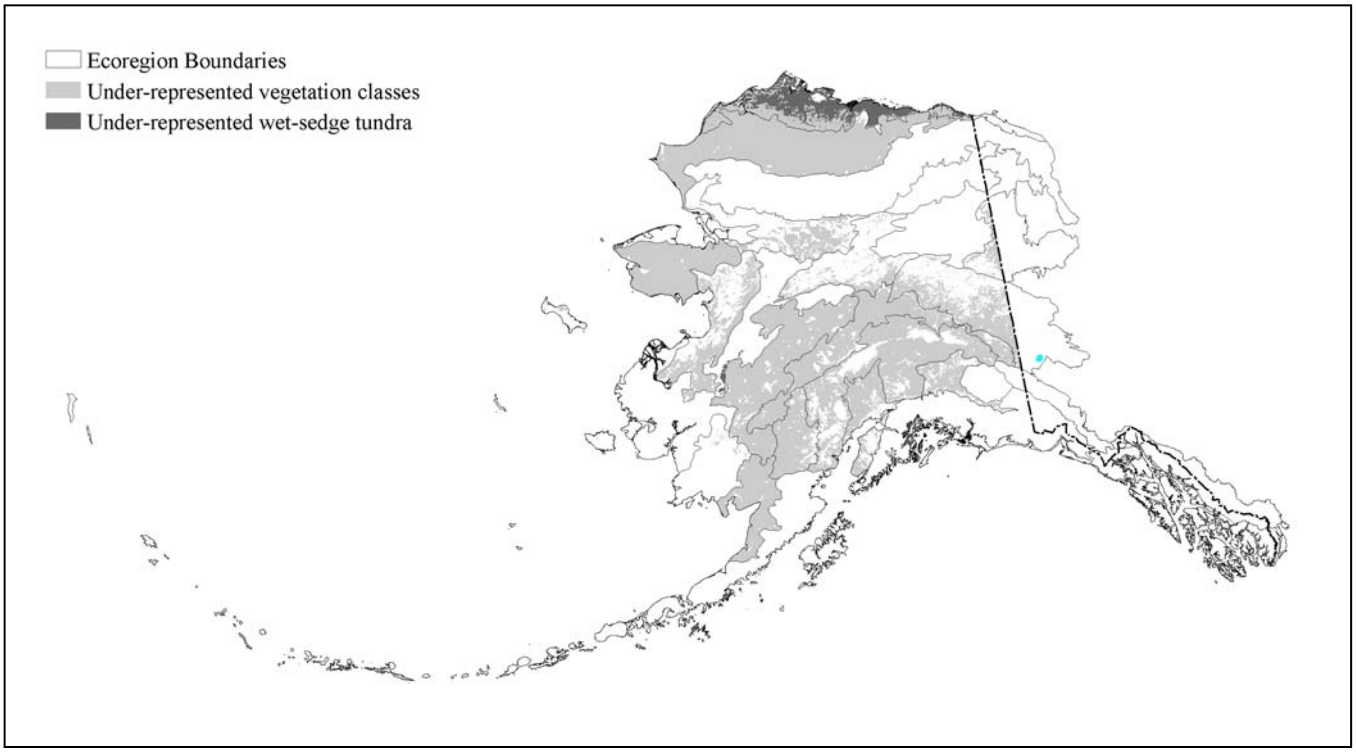


Representation of Terrestrial Ecosystems

Across the state of Alaska, 5 of 19 (26.3%) vegetation classes have less than 30% of their total area in CMS 1 or 2 (Appendix 2). The least represented vegetation class - wet sedge tundra - has only 10.6% of its distribution in CMS 1 and 2. Corresponding with the findings of Duffy et al. (1999), the best represented classes are also the least biologically diverse -- “glaciers and snow” (76.4% CMS 1 and 2) and “alpine tundra and barrens” (64.0% CMS 1 and 2).

Across the state, most of the terrestrial biodiversity of Alaska is protected by the current network of protected areas, but ecoregional differences in vegetation classes may not be. At the ecoregion level, 16 of 19 (84%) vegetation classes are found to be under-represented in one or more of the ecoregions in which they occur (Appendix 2). We considered vegetation classes to be peripheral in ecoregions containing less than 1% of the class’s total area in the state and did not assess their representation in those ecoregions. Upon examining the distribution of under-represented vegetation classes, a pattern emerges that shows a lack of protection of northern, low elevation coastal ecoregions and interior forested ecoregions (Figure 2). Nineteen of 32 ecoregions (59%) contain under-represented vegetation classes. The vegetation class that consistently shows lack of protection in both ours and the Duffy et al. (1999) analysis is ‘wet sedge tundra’ (Appendix 2, Figure 3). Statewide, 10.6% of its total area is included in CMS 1 and 2 lands, but in the Beaufort Coastal Plan ecoregion, where 53% of its distribution occurs, only 4% of ‘wet sedge tundra’ is in CMS 1 and 2 lands.

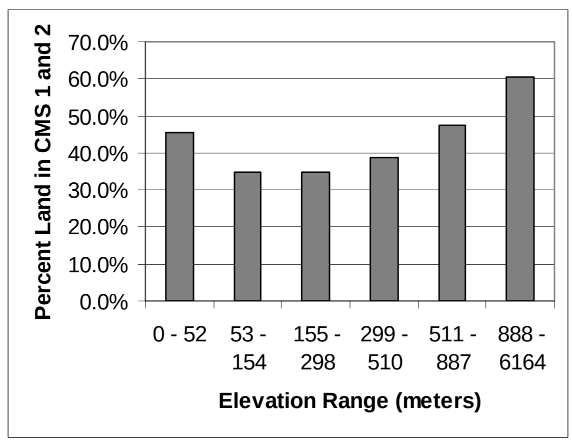
Figure 3. Under-represented vegetation classes in Alaska ecoregions.



Assessment of Conservation Management Status by Elevation

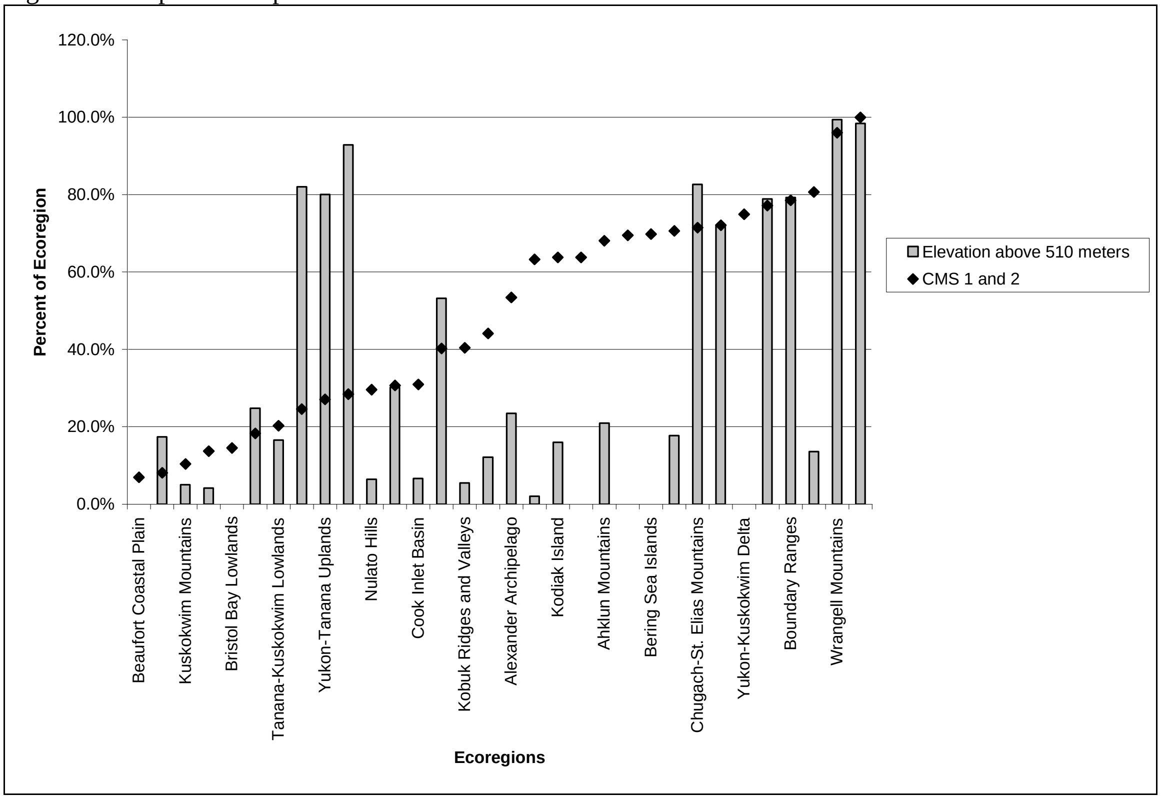
Of all Alaska lands in CMS 1 and 2, 41.3% occur above 510 meters. The most protected elevations are those above 887 meters, with 60.4% of land in this highest elevation class occurring in CMS 1 and 2 (Figure 4). The other five elevation classes have between 34.6% and 47.3% of land in CMS 1 and 2.

Figure 4. Percent of Land in CMS 1 and 2 in 6 Equal-area Elevation Ranges



When we examined ecoregions, we found that the seven least protected ecoregions have a majority (>75%) of their land below 511 meters, and of the eight most protected ecoregions, six have the majority (>72%) of their land above 510 meters (Figure 5).

Figure 5. Comparison of percent of land above 510 meters and in CMS 1 and 2



Conservation on Native-owned lands

Assuming that Native-owned lands are managed similarly to national wildlife refuges or primitive areas of national forests increases the amount of lands in CMS 1 and 2 in all ecoregions (Appendix 1). This assumption puts 5 ecoregions (16%) almost entirely in CMS 1 and 2 (>97%). The change is large in another 13 ecoregions, where increases range from a 36% to 164% increase. Despite the inclusion of Native-owned lands, 5 ecoregions in the state still have less than 30% of their lands in CMS 1 or 2.

Protection of vegetation classes also increases with this assumption, with an additional 4 vegetation classes being adequately represented statewide on either CMS 1 or 2 or Native-owned lands (Appendix 2). Three of these classes are forest types. One of these -- Closed Broadleaf & Closed Mixed Forest – is underrepresented statewide (20.5%) on CMS 1 and 2 lands but is adequately represented (41.1%) statewide when Native-owned lands are included.

Discussion

Conservation of Alaska's terrestrial biodiversity is not as secure as one might guess from simply noting the total acreage under protection. If one considers the state as a whole, 43.6% resides in CMS 1 and 2 lands, and even though 5 of 19 vegetation classes (26.3%) are under-represented at the 30% level, only one has less than 20% in CMS 1 and 2. Compared to the contiguous United States, where only 5.1% is in CMS 1 and 2 (DellaSala et al. 2001), Alaska may be viewed as an excellent conservation achievement. But Alaska today is an area of rapid climatic change and there is a need to provide options for resilience and future evolutionary response (ACIA 2004). In practical terms this means that we should protect all vegetation classes in as many different ecoregions as possible. Given this concern, it is noteworthy that most vegetation classes are under-represented in at least one of the ecoregions in which they occur. Lack of protection across the major environmental gradients of ecoregions and elevation increases the vulnerability of Alaska's plants and wildlife to the long-term effects of global warming.

In regard to elevation, our results echo those found in previous studies in other geographic areas – less productive and diverse higher elevations are better protected than more productive, more diverse lower elevations (Nilsson and Gottmark 1992; Caicco et al. 1995; Scott et al. 2001). Whereas 43.6% of Alaska is managed for high and medium levels of conservation, a disproportionate amount (41.3%) of those lands occurs at high elevations (above 510 meters). This unequal distribution of Alaska's protected areas across elevation gradients leaves the most biologically diverse areas, those at low elevations, the most vulnerable to future anthropogenic impacts. Climate change models predict that Alaska's lowest elevations may see the least amount of change (Saxon et al. 2005), thus these areas may provide refugia for species dependent upon low elevations and those that are adaptable to a wide range of habitats, such as brown bears and wolves. Conversely, the higher elevations may see the greatest change. The current disproportionate allocation of protected areas to higher elevations may increase the loss of species due to long-term climate change.

Our analysis also highlights areas of particular concern due to development. Coastal wetlands from the Beaufort Coastal Plain to the Yukon Delta lack adequate protection and are under pressure for oil and gas development. These lowland habitats not only include most of the wet sedge tundra of Alaska, but also 30% of the coastal wetlands of the entire Arctic region (CAVM Team 2003). When protection of the wet sedge tundra is examined in more depth, the need for a spatial dimension to gap analysis becomes clear. Much of the wet sedge tundra that is protected occurs in small fragments, whereas conservation theory suggests there is a great value to preserving habitats in large contiguous blocks (Meffe et al.1997). Loss of these ecosystems, measured both by area and connectivity, could have global consequences for not only species diversity but also ecosystem services and resiliency to climate change.

Our analyses not only point out the gaps in protection of Alaska's biodiversity but also attempt to find new approaches to how we think about conservation. Conservation plans and debates in Alaska tend to focus on federal and state lands. However, we found that the representation of vegetation classes improved when we included Native lands with CMS 1 and 2 lands. In a state like Alaska, where so much land has already been designated as parks, refuges, and forests, emphasizing conservation in the management of undeveloped Native-owned lands may provide an important part of the solution to protecting biodiversity.

Another caveat for conserving Alaska's biodiversity is not to confuse total amount of protected areas with total effective conservation. While vast protected areas are a tremendous boon to biodiversity and wilderness in Alaska, species and ecological systems may still fall through the cracks. There is a growing tendency when establishing global priorities for conservation to focus on coarse scale analyses of threats, such as regional deforestation (e.g. Global Forest Watch), endemic species at risk (e.g. Conservation International hotspots), or habitat conversion and protection (Hoekstra et al. 2005). These coarse scale threat analyses inevitably make Alaska look secure and thus a low priority for conservation attention. Other studies have shown, however, that regions with comparatively low human impacts and mammals with high sensitivities to disturbance may face a high potential risk of extinction of those species (Cardillo et al. 2006). Our analyses show that protection cannot be measured in acres alone, and that the biodiversity of places like Alaska, with large protected wilderness areas, cannot be assumed to be conserved. This is especially true in high latitude regions, where global warming may have the greatest impact on habitats and the species that need them to survive.

Acknowledgements

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Appendix 1. Area and percentage of Conservation Management Status (CMS) within Alaska's ecoregions

Number	Ecoregion Name	Total Area in Alaska (acre)	CMS 1 and 2 (%)	CMS 3 (%)	CMS 4 (%)	Native-owned Lands (%)	CMS 1 and 2 and Native-owned Lands (%)	Increase with Native-owned Lands (%)
1	Ahklun Mountains	9,565,730	68.1%	0.3%	23.6%	8.0%	76.1%	11.8%
2	Alaska Peninsula	15,745,320	70.7%	0.1%	18.1%	11.2%	81.8%	15.8%
3	Alaska Range	25,533,884	28.4%	7.9%	58.1%	5.5%	34.0%	19.4%
4	Aleutian Islands	3,302,471	80.7%	0.0%	0.0%	19.3%	100.0%	23.9%
5	Alexander Archipelago	13,022,755	53.4%	19.4%	22.9%	4.3%	57.8%	8.1%
6	Beaufort Coastal Plain	14,588,080	6.9%	68.2%	16.4%	8.4%	15.3%	121.0%
7	Bering Sea Islands	2,353,983	69.8%	0.0%	0.0%	30.2%	100.0%	43.2%
8	Boundary Ranges	5,001,553	78.5%	9.0%	11.8%	0.6%	79.1%	0.7%
9	Bristol Bay Lowlands	7,903,765	14.5%	12.0%	56.0%	17.4%	32.0%	119.8%
10	Brooks Foothills	28,473,856	8.1%	42.9%	35.8%	13.2%	21.3%	163.5%
11	Brooks Range	31,810,340	77.2%	4.1%	16.7%	2.0%	79.2%	2.6%
12	Chugach-St. Elias Mountains	19,559,239	71.5%	0.8%	25.0%	2.8%	74.2%	3.9%
13	Cook Inlet Basin	7,186,201	30.9%	1.3%	44.2%	23.5%	54.5%	76.1%
14	Copper River Basin	4,729,105	24.6%	9.4%	42.4%	23.6%	48.2%	96.0%
15	Davidson Mountains	7,166,881	72.1%	0.0%	9.4%	18.5%	90.6%	25.6%
16	Gulf of Alaska Coast	4,346,096	44.2%	0.7%	44.4%	10.7%	54.9%	24.3%
17	Kluane Range	1,242,278	100.0%	0.0%	0.0%	0.0%	100.0%	0.0%
18	Kobuk Ridges and Valleys	13,623,826	40.4%	0.4%	46.3%	12.9%	53.3%	31.9%
19	Kodiak Island	3,144,935	63.8%	0.0%	10.9%	25.3%	89.1%	39.7%
20	Kotzebue Sound Lowlands	3,462,872	69.5%	0.0%	10.1%	20.4%	89.9%	29.3%
21	Kuskokwim Mountains	21,092,243	10.4%	0.0%	83.4%	6.2%	16.6%	59.3%
22	Lime Hills	7,095,517	18.3%	0.1%	77.1%	4.5%	22.8%	24.6%
23	North Ogilvie Mountains	3,139,948	40.2%	0.0%	36.9%	22.9%	63.1%	56.8%
24	Nulato Hills	14,433,213	29.6%	0.0%	59.2%	11.2%	40.8%	38.0%
25	Ray Mountains	12,662,068	30.7%	9.2%	52.3%	7.8%	38.5%	25.4%
26	Seward Peninsula	11,699,290	13.7%	0.0%	70.2%	16.1%	29.8%	117.6%
27	Tanana-Kuskokwim Lowlands	15,818,173	20.3%	9.5%	55.1%	15.1%	35.4%	74.6%
28	Wrangell Mountains	3,537,087	96.0%	0.0%	0.0%	4.0%	100.0%	4.2%
29	Yukon River Lowlands	12,782,423	63.8%	0.0%	17.9%	18.4%	82.1%	28.8%
30	Yukon-Kuskokwim Delta	18,964,625	74.9%	0.0%	2.1%	23.0%	97.9%	30.7%
31	Yukon-Old Crow Basin	13,991,621	63.3%	0.0%	13.9%	22.8%	86.1%	36.1%
32	Yukon-Tanana Uplands	15,751,473	27.1%	8.5%	57.6%	6.8%	33.9%	25.0%

Appendix 2. Area and percentage of conservation management status (CMS) statewide and within ecoregions for vegetation classes

Vegetation Class	Total Area in State (acres)	Number of ecoregions where class occurs+	CMS 1 and 2 statewide(%)	Number of ecoregions under-represented*	CMS 1 and 2 and Native-owned lands(%)	Number of ecoregions under-represented**
Alpine Tundra & Barrens	32,226,782	17	64.0%	4	67.1%	3
Closed Broadleaf & Closed Mixed Forest	3,118,155	2	20.5%	1	41.1%	0
Closed Mixed Forest	1,281,461	1	41.9%	0	67.0%	0
Closed Spruce & Hemlock Forest	13,144,979	5	61.3%	0	69.0%	0
Closed Spruce Forest	2,095,161	4	33.9%	2	65.4%	0
Dwarf Shrub Tundra	10,877,589	16	54.6%	5	65.0%	2
Glaciers & Snow	25,199,752	7	76.4%	0	76.7%	0
Low & Dwarf Shrub	6,027,510	3	56.2%	1	73.5%	0
Low Shrub/Lichen Tundra	17,741,533	11	37.8%	4	53.2%	3
Moist Herbaceous/Shrub Tundra	30,947,051	16	43.1%	7	58.5%	5
Open & Closed Spruce Forest	16,610,556	13	39.6%	5	55.7%	2
Open Spruce & Closed Mixed Forest Mosaic	13,002,402	9	56.1%	1	78.8%	0
Open Spruce Forest/Shrub/Bog Mosaic	45,926,253	23	36.6%	8	49.1%	2
Spruce & Broadleaf Forest	18,915,011	11	27.0%	4	38.5%	4
Spruce Woodland/Shrub	12,419,246	19	24.7%	10	37.3%	6
Tall & Low Shrub	27,788,619	18	37.0%	7	44.2%	4
Tall Shrub	33,755,837	23	44.8%	9	57.8%	3
Tussock Sedge/Dwarf Shrub Tundra	34,552,240	11	23.0%	6	34.7%	5
Wet Sedge Tundra	9,194,591	4	10.6%	2	20.4%	1

+ Ecoregions where more than 1% of the total area consists of this vegetation class.

* Ecoregions where less than 30% of the vegetation class occurs on CMS 1 and 2 lands.

** Ecoregions where less than 30% of the vegetation class occurs on CMS 1 and 2 and Native-owned lands.