Bear Habitat Mapping
In the Central Western Cascade Mountains of Washington State

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December 2001

Introduction

The goal of this project was to create a map and GIS data layer of bear habitat in the central western Cascade Mountains of Washington State for use in bear research conducted by the US Forest Service. Pacific Biodiversity Institute (PBI) used a combination of existing information and a sequence of satellite imagery and aerial photography to create this habitat map.

The study area boundary was defined as the crest of the Cascade Mountain range down to the interface with urban and residential areas in the Puget Sound lowlands. It extends north from Interstate 90 to US Highway 2. The study area consists of 245,916 ha (607, 671 ac) of public and private land.

Methods

Overview

A combination of existing GIS data and new interpretation of a sequence of satellite imagery was used to develop this vegetation map. This project expanded on vegetation data developed for the North Cascades Grizzly Bear Habitat Assessment (Almack el al 1993). The data from this previous effort covered the National Forest lands within the study area, but did not cover areas west of the National Forest boundary. The grizzly bear habitat data was based partially on 1986 satellite imagery; therefore it did not reflect vegetation disturbances. It also did not have some of the vegetation classes that were desired in this current study.

The existing data from the North Cascades Grizzly Bear Habitat Assessment was enhanced and the spatial gaps in the study area were filled through an analysis of a variety of other available GIS data, satellite imagery and digital aerial orthophotography. Created forest openings were delineated by identification of openings in satellite imagery and aerial photography.

Other GIS data that was used to map and model habitat types includes:

- King County parcel layer (1998)
- Snohomish County parcel layer (2001)
- 30-meter resolution digital elevation data from the US Geological Survey
- National Wetland Inventory GIS data
- Stand origin date GIS data from the US Forest Service, Mount Baker-Snoqualmie National Forest (2000)
- Water body GIS layer from Washington Department of Natural Resources

Created forest openings
Created forest openings were identified by visually examining the following historical chronosequence of imagery:

- 1972 Landsat 1 Multi-Spectral Scanner satellite image
- 1973 Landsat 1 Multi-Spectral Scanner satellite image
- 1985 Landsat 3 Multi-Spectral Scanner satellite image
- 1992 Landsat 4 Multi-Spectral Scanner satellite image
- 1998 Landsat 5 Thematic Mapper satellite image
- 1999 Landsat 7 Enhanced Thematic Mapper satellite image
- 1990 and 1994 Digital aerial photos

Image interpreters noted when forested areas changed dramatically in spectral reflectance from one image to the next in the sequence. Interpreters noted the spectral reflectance typical of mature forests and compared that to the spectral reflectance of recently cut areas. Development of successional vegetation was also noted in subsequent images for these created forest openings. Once the openings were identified, they were manually digitized using the best available georeferenced imagery. The activity date for the opening was obtained by bracketing the opening occurrence with the pre-cut image date and the post-cut image date.

Stand origin date GIS data from the US Forest Service, Mount Baker-Snoqualmie National Forest was used to date created openings on National Forest land. Recent created openings were coded to match the same categories used above and merged with that data set to create a composite created opening data set that covered all ownerships.

Mapping of other vegetation types
Other natural vegetation habitat types were mapped using a combination of the North Cascades Grizzly Bear Habitat Assessment vegetation data and a new classification of a 1999 Landsat Enhanced Thematic Mapper satellite image. The grizzly bear project vegetation data was used in all areas that were covered by this data set (primarily the federal lands in the eastern portion of the study area). The original vegetation types for this data set were cross-walked and condensed for the purpose of this current study (Table 1).

Table 1. Crosswalk between North Cascades Grizzly Bear Habitat Assessment vegetation data and habitat categories used in this study.

Habitat Type Number	Habitat Type Mapped in Current Study	Grizzly Bear Habitat Assessment Vegetation Category
1	Low elevation conifer forest	Douglas-fir – mixed conifer
1	Low elevation conifer forest	Western hemlock
1	Low elevation conifer forest	Westside second growth Douglas-fir
2	Mid elevation conifer forest	Pacific silver fir
3	High elevation conifer forest	Mountain hemlock
3	High elevation conifer forest	Subalpine larch
4	Upland deciduous forest	Upland deciduous forest
5	Riparian forests and shrubs	Riparian deciduous forests
6	Alpine and subalpine meadows	Lush subalpine meadow
6	Alpine and subalpine meadows	Subalpine heather-blueberry meadow
6	Alpine and subalpine meadows	Subalpine meadow
6	Alpine and subalpine meadows	Subalpine mosaic
6	Alpine and subalpine meadows	Alpine meadow
7	Montane herbaceous and shrubs	Montane shrub
7	Montane herbaceous and shrubs	Montane herbaceous
7	Montane herbaceous and shrubs	Montane mosaic
8	Slide alder and lush shrubs	Slide alder and lush shrubs
9	Water	Water
10	Snow and ice	Snow and ice
11	Bare, rock, roads, etc.	Bare and rock
13	Shadow and clouds	Shadow
17	Agricultural lands	Orchards and crops
18	Low elevation shrubs and herbs	Low elevation herbaceous

Mapping vegetation in areas not covered by the grizzly bear habitat assessment data
The 1999 Landsat 7 Enhanced Thematic Mapper satellite image was georeferenced and classified using ERDAS Imaging 8.5 into 20 spectral classes using an unsupervised classification procedure. These classes were then analyzed and coniferous forest classes were identified and grouped into one category. The coniferous forest category was then split into three elevation ranges to coincide with the collapsed categories from the grizzly bear habitat assessment vegetation data:

1. Low: below 600 meters
2. Middle: 600 to 1100 meters
3. High: above 1100 meters.

Nearly all of the area not covered by the grizzly bear habitat assessment vegetation data was in the lower elevation category and nearly all the non-forested areas present in the area were in lower elevation areas. The areas not mapped as coniferous forest were classified as either deciduous forests and shrubs or bare ground, rock and other non-forested areas.

Riparian Areas
Riparian forests and shrubs were mapped based on the original grizzly bear habitat assessment vegetation data plus incorporation of National Wetlands Inventory data. All forest and shrub areas that were within a 60-meter buffer of all open water (rivers, lakes and ponds) were classified as riparian forests and shrubs. Also all natural forested and shrub covered wetlands were classified as riparian forests and shrubs as well as a 30-meter buffer surrounding such features.

Urban and residential developed areas
Urban and residential developed areas were mapped using parcel data from King and Snohomish counties. These areas typically are represented by a diverse mix of land uses and vegetation and are difficult to separate using satellite imagery. Parcel size was used to separate these two developed area classes. Parcels less than 5000 square meters in size were classified as higher density urban/residential. Parcels between 5000 square meters and 50000 square meters in size were classified as low density residential. These classes were restricted to private lands within the generally recognized area where development is known to occur.

Water bodies
A water body GIS layer from Washington Department of Natural Resources was used to map the open water category in this study in conjunction with the water category that had been previously mapped in the original grizzly bear habitat assessment vegetation data.

Combining the data layers
The map information developed in each of the above steps was combined into a final habitat type grid using an Arc/INFO GRID MERGE function. In this merge function the open water layer took the highest precedence, followed in order by the following sequence: created openings, riparian forests and shrubs, urban and residential development, bare areas and snow, the regrouped original grizzly bear habitat assessment vegetation data, the classified 1999 Landsat 7 Enhanced Thematic Mapper satellite data.

Results

Twenty bear habitat types were mapped (Figure 1 and Table 2).

Table 2. Bear habitat types mapped in study area (note: class 12 not used).

Habitat Type	Area (hectares)	Area (acres)	Map Grid Code
Low elevation conifer forest	34775.28	85931.59	1
Mid elevation conifer forest	42530.40	105094.92	2
High elevation conifer forest	37236.96	92014.54	3
Upland deciduous forest	21664.98	53535.34	4
Riparian forests and shrubs	8110.62	20041.78	5
Alpine and subalpine meadows	10512.90	25977.94	6
Montane herbaceous and shrubs	11041.11	27283.18	7
Slide alder and lush shrubs	958.05	2367.39	8
Water	3783.69	9349.70	9
Snow and ice	3431.88	8480.36	10
Bare, rock, roads, etc.	19556.37	48324.85	11
Shadow and clouds	1103.58	2727.01	13
Young forest 1973-1985	10894.95	26922.01	14
Young forest 1985-1992	9863.28	24372.70	15
Young forest 1992-1998	7765.65	19189.34	16
Agricultural lands	17.64	43.59	17
Low elevation shrubs and herbs	64.89	160.35	18
Young forest 1998-1999	994.95	2458.58	19
Residential/Urban - less dense	18526.86	45780.87	20
Urban/Residential - dense	3081.60	7614.80	21

Coniferous forests dominate the study area with mid-elevation forests the dominant type. High-elevation coniferous forests are the second most dominant type followed by low-elevation coniferous forests. Upland deciduous forests (also a low elevation type) are the fourth most common habitat type in the area.

The low-elevation coniferous forest type would be the dominant type if all the young forest in created openings was included in the coniferous forest type. Young (predominantly low elevation) coniferous forests of all ages (from 1973 to 1999) comprise over 29,500 hectares in the study area and collectively are more common that upland deciduous forests. It should be noted that most upland deciduous forests in the study area are a successional phenomenon and occur in areas where coniferous forests were cut in the past 100 years.

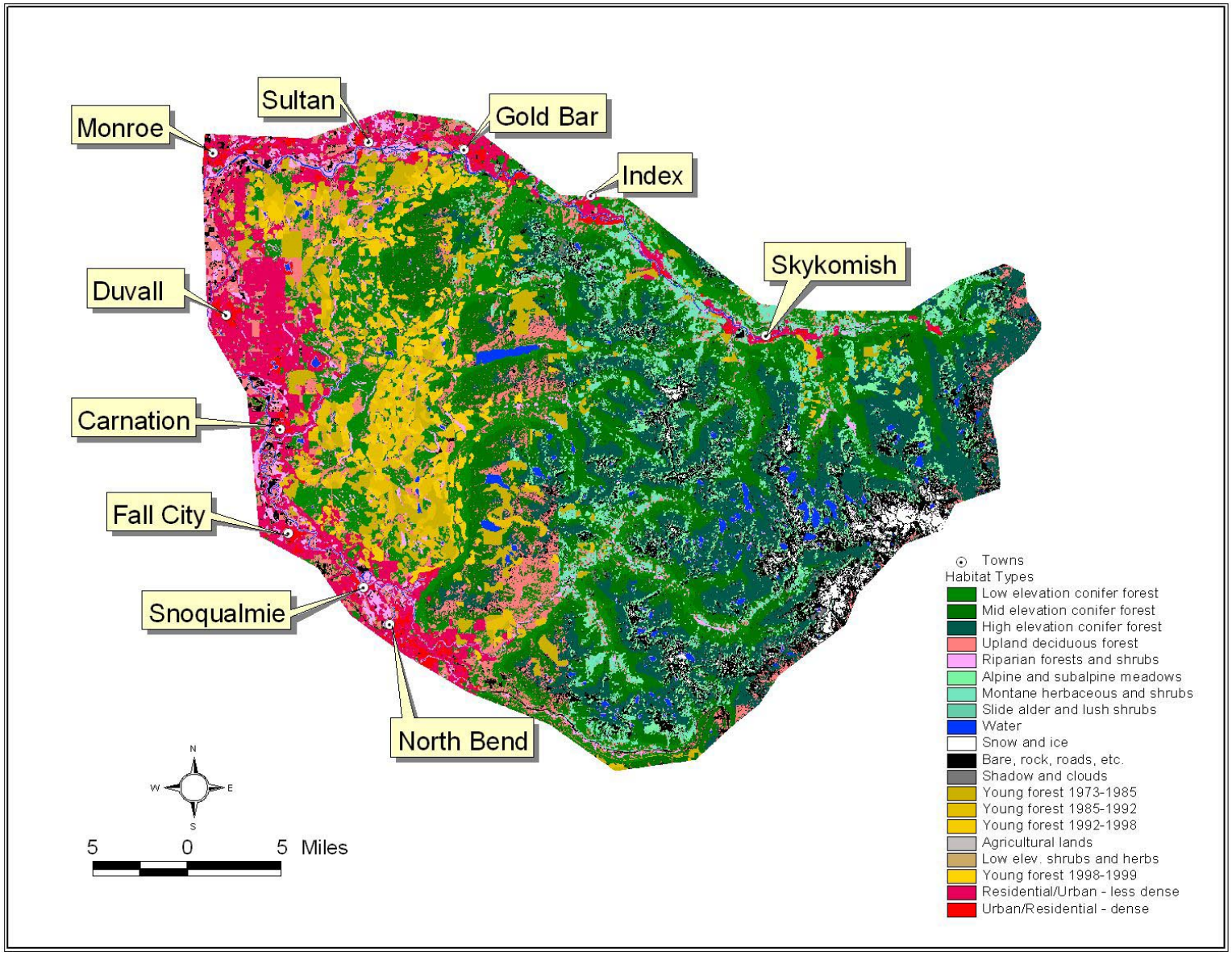

Figure 1. Habitat types mapped in study area.

Discussion
Riparian areas along third and higher order (Strahler ordering) stream segments were not mapped based on 1:24,000 hydrography data as originally planned. No IS data with reliable Strahler stream ordering was readily available for this area at this time.

Many areas that were mapped in the original grizzly bear habitat assessment vegetation data as "montane shrub and herb" in this area appear to now to be upland deciduous forest. It was beyond the scope of this project to re-map and reclassify the vegetation types from this previous study. But it was noted that most of this category within the study area might be more appropriately classified as upland deciduous forest. The new areas that were mapped in this current study area with a similar spectral reflectance of those mapped as montane shrub and herb, which are located to the west of the grizzly bear habitat mapping, are classified as upland deciduous forest, rather than montane shrub and herb.

Agricultural lands were not distinguished in the area west of the original grizzly bear habitat assessment area and are probably underreported in this study. It was beyond the scope of this project to map all the agricultural lands on private land within the study area. Agricultural lands were also inadequately addressed in the original grizzly bear habitat assessment vegetation data. Likewise, the low elevation herb/shrub category may have been underreported in the original grizzly bear habitat assessment and again in this study. Most of the vegetation that would normally be found in this category is found in recently created openings – and mapped as that in this study.

Conclusion
This project builds on the vegetation data developed in the North Cascades Grizzly Bear Habitat Assessment extending that data to the west and adding new information on created openings that have resulted from logging over the last thirty years. It has also regrouped the original grizzly bear habitat assessment vegetation data and reinterpreted in several instances.

The data developed in this study was developed quickly with a limited budget. While the accuracy of the mapping was not assessed, it should approach the accuracy of the grizzly bear habitat assessment vegetation data. It is more current than this original data in that it incorporates logging activity that has occurred since the earlier data was produced.

This data was developed for a particular use in analyzing the habitat types used by black bears in the study area. It may not be adequate for other uses.

References
Almack, J.A., W.L. Gaines, P.H. Morrison, J.R. Eby, G.F. Wooten, M.C. Snyder, S.H. Fitkin, and E.R. Garcia. 1993. North Cascades Grizzly Bear Ecosystem Evaluation - Final Report. Interagency Grizzly Bear Committee. Denver, Colorado. 156 pp.