Contiguous Forest Mapping in the Islands Trust Area

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1.0 Executive Summary

Cabin Resource Management was hired by the Islands Trust to map contiguous forest patches in consultation with the Islands Trust Conservancy (ITC). The goal of the mapping exercise was to identify contiguous forest patches within the Islands Trust Area in order to provide the Islands Trust with information to underpin policy, regulatory and legal conservation tools that protect Coastal Douglas-fir forests and their associated ecosystems. This mapping was identified as an essential step in the Islands Trust's report titled "Protecting the Coastal Douglas-fir Zone & Associated Ecosystems: An Islands Trust Toolkit."

After the initial proposal of using overlays of Terrestrial Ecosystem Mapping (TEM) and disturbance layers in a Geographic Information System (GIS), various subsequent analyses were evaluated by the project team and members of the ITC staff. Consultation with ITC staff was focused on the identification of ecological values and careful consideration of the geographic scale of the planning activities that would be informed by the resulting product. Following the identification of the ecological parameters, Islands Trust staff provided input on the draft mapping products and these products were adjusted to reflect planning needs. The resulting maps and data sets show the distribution of forested ecosystems in the Islands Trust Area, differentiating between established forests and forested ecosystems in earlier structural stages; a stand quality rating was calculated considering low or high intensity of effects based on road density and structure locations.

2.0 Background Information

The Islands Trust and the Coastal Douglas-fir and Associated Ecosystems Conservation Partnership have emphasized the protection of Coastal Douglas-fir (CDF) and associated ecosystems in order to maintain their unique ecological value and the numerous ecosystem services they provide. Mapping of the CDF and associated ecosystems is essential to the establishment of conservation priorities and the administration of regulatory tools such as zoning and Development Permit Areas (DPAs) which can serve to protect these values.

3.0 Approach and Rationale

Through consultation with the ITC, a constraints mapping and inventory approach[1] was taken to identify and map contiguous forest patches. The patches were subsequently ranked by the presence and the type of disturbance within the forested area. The consultation

[1] Constraints mapping is used in land use planning to minimize negative effects to a landscape and to identify areas of high or low sensitivity. Areas of constraint are present when there is higher potential for environmental impact or where there are high value natural resources (e.g. older forest).

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process focused strongly on accurate problem definition and avoiding the incorporation of implicit biases in the model design.

TEM polygons were chosen as the basic spatial unit of the analysis. Each TEM polygon has a defined spatial boundary and unique attributes. The individual polygons provide spatially explicit information that describes the distribution of ecological features on the landscape. These TEM polygons can be aggregated to larger patch sizes composed of sets of polygons which share common attributes. Where these attributes define a forested ecosystem, the aggregated set of adjacent units may form a contiguous area where boundaries are shared. At the landscape level, defined by islands, the aggregated patch size is an informative metric. For instance, this can tell us how much recruitment stage forest is present versus established forest for an island. While large aggregated polygons may store a quantitative summary of their individual TEM components, any variation within the patch cannot be shown on the maps. The value of maintaining TEM polygons as intact spatial units is that their boundaries and attributes are defined by a standard process and the attributes can be queried to provide more information than is symbolized in map layouts.

In ranking contiguous forest patches, proposed approaches included evaluation of patch size, and defining interior versus edge affected patches. Much of the relevant literature regarding contiguity and continuity of forested ecosystems focuses on large fauna, most of which are absent from the Islands Trust study area. The chosen approach did not use contiguity criteria from any specific animal species to limit the spatial distribution of forested ecosystems as the use of such criteria risked de-valuing or excluding patches that did not meet the criteria for that particular species. For instance, it was recognized during modelling parameter discussions that if a minimum patch size criterion was set, it would discount small patches that otherwise provide important refuge for many wildlife species. Likewise, a similar result would be realized if only "interior forest" patches set back from the forest edge were considered high-quality or included in the final data set.

The following analyses were undertaken to describe the forested components of the Islands Trust land base:

1. <u>Use of Terrestrial Ecosystem Mapping:</u> TEM was acquired by the ITC between 2007 and 2011 and was updated in 2017. The TEM formed the basis of both the disturbance layers generated in this analysis and the classification of contiguous forest patches. TEM polygons are based on air-photo interpretation at 1:10,000 to 1:20,000 scale and field sampling. Each polygon has attributes that indicate the ecosystems types (site units) within the polygons, their relative representation and attributes such as structural stage. Anthropogenic features are also attributed as unique Map Codes in the TEM (*Standard for Terrestrial Ecosystem Mapping in British Columbia,* 1998).

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2. Incorporation of disturbances into analyses: Provincial road and structure location data sets were used to augment the information contained in the TEM. Because of the significant investment in TEM mapping made by the Islands Trust and the ecological merits of the data, it was intended that the integrity of that data set be preserved in any data products resulting from the subsequent analysis. As such, information was added to the polygon framework of the TEM without modifying the TEM polygons spatially. The approach was first subtractive, removing anthropogenically modified sites on the landscape. The threshold for anthropogenic disturbance was set at 20%. The assumption was made that above this threshold the value of ecological communities would decrease in response to losses of habitat availability. This threshold is consistent with the low-risk target for maintaining habitat representation across a Coastal Douglas-fir landscape described in *Conservation Planning in the Coastal Douglas-fir Ecosystem* (Holt, 2007). Natural non-forest ecosystems were then removed from the data set, and impacts on the remaining forested area were identified.

   Road presence was determined to be a negative impact on the score of patch quality where it occurred above a linear density threshold. Unless they were greater than 20% of a polygon in the original TEM, roads were not considered to break contiguity of forest patches. The presence of roads is generally considered to affect both plant and animal communities. The impacts may include the avoidance of roads by certain species, direct mortality of species, as well as negative effects associated with the use of roads by humans and the increased colonization of habitat by invasive plant species. The general effects of roads on large vertebrate population at the landscape scale is well supported, however site-level effects on specific species may be more difficult to generalize (USFS, 2001). The threshold at which road density affects animal populations varies widely by species, with estimates ranging from 0.36 - 1.9 km/km^2 for large mammals and avoidance distances ranging from 35 m for salamanders and 300 m for deer (Robinson et al, 2010). These effects may be due to either presence of the infrastructure or motor vehicle traffic. Road features that were considered infrequently used by the public, or that were designated for non-motorized use only, were excluded from the analysis. Polygons with road densities greater than 1 km/km^2 were considered high road density polygons, and this layer was included in patch quality analysis.

   Structure location point density was classified using the Jenks natural breaks classification method. Where structure location points occurred at high densities in TEM polygons, the TEM polygons were classified as anthropogenic non-forest sites. At low structure densities, the forest ecological quality of TEM polygons was reduced. This procedure attempted to fill gaps in the disturbance mapping present in the TEM.

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The potential edge effects created by structures location points were not quantified because they did not bisect polygons and were not always visible in aerial photos. The low-density structures were not considered to have equivalent effects to road edges but may still cause lesser edge effects which are not accounted for in the analysis.

3. "Naturalness" was classified: Forest patches were described using a three-class system representing their relative "naturalness". All forest ecosystems were retained in the analysis.

4. Identification of areas with restoration potential: The final forest polygon layer was divided into early and late structural stage classes. The purpose of this was to identify polygons that have not matured into the "young forest" stage but have the potential to increase in structural complexity as they age.

4.0 Analysis Procedure

1. TEM Disturbance Mapping
   a) Non-forest polygons were identified in the TEM. Non-forest attributes are indicated by a '00' code in the Site Series field. Polygons which represented 20% or greater non-forest area were identified.
   b) Non-forest polygons with 20% or greater anthropogenic disturbance were identified. Polygons with Map Codes corresponding to the following definitions were flagged: 'Cultivated Field', 'Cultivated Orchard', 'Cultivated Vineyard', 'Exposed Soil', 'Golf Course', 'Gravel Pit', 'Industrial', 'Pasture', “Reservoir”, 'Road Surface'', 'Rural Development', 'Transmission Line', 'Urban/Suburban'.
2. Additional Disturbance Calculation
   a) The Structure Point data set from the BC Wildfire Service was used to identify structures which were not present in the TEM data used above.
      i. The structure density per TEM polygon was calculated as the number of structures within each polygon boundary divided by the polygon area in hectares. The resulting data were classified using Jenks breaks, rounded to the nearest whole number.

Range	Class	Non-Forest Polygon
<=1	1	NO
>1, <=4	2	NO

>4, <=9	3	YES
>9, <=21	4	YES
>21, <=86	5	YES

ii. Polygons with a structural density of Class 3 or higher were considered to have anthropogenic modification equivalent to the anthropogenic map codes identified above and were removed from the forested area. Class 2 was considered to have a lesser influence on the forested ecosystem and were considered in the classification of forest ecosystem quality below. Class 1 was considered to have a negligible effect.

b) Roads from the Digital Road Atlas were used to identify additional linear disturbance not represented in the TEM.

i. Roads that were classified as 'driveway', 'pedestrian', 'recreation', 'restricted' and 'resource' were removed from the analysis.

ii. The linear density of roads within each polygon was calculated by dividing the total length of all road segments within each polygon by the area of the enclosing polygon.

iii. The resulting data were grouped into two classes – 'High' and 'Low' where road density was greater than 1 km / km^2 and less than or equal to 1 km / km^2. The polygons with high road density classes were considered to have an influence on forested ecosystems and were not excluded from the forested area but were used in rating forest ecosystem quality.

3. Forest Patch Classification

a) Forested polygons were divided into two classes. For each TEM polygon 'Established Forest' was identified where the Structural Stage was greater than 4 in at least 50% of the combined deciles of the polygon. The remaining forested polygons were classified as 'Recruitment Forest'.

b) The 'naturalness' of each forested polygon was rated using the following criteria ranking disturbance:

Disturbance	Modifier
No Disturbance	0
Road Class High	-1
Road Class Low	0
Structure Class 2	-1

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Structure Class 1	0

c) The cumulative disturbance scores were represented by the following patch quality classes:

Map Class	Disturbance Level	Score
3	Low	0
2	Moderate	-1
1	High	-2

5.0 Results

Forest mapping in the Islands Trust reveals highly variable spatial patterns of forest distributions between islands. Visual interpretation of the data shows corridors between larger contiguous patches, the dominance of stands in the recruitment stage of their growth, and different matrices of forest patches and disturbances. For instance, the mapping of Bowen Island shows corridors between large established forest patches with relatively undisturbed interiors (Figure 1). Whereas the mapping of northern portion of Salt Spring Island shows a more diffuse distribution of smaller patches of different quality and structural stage classes (Figure 2). Another unique pattern is observed on North Pender where Class 1 mature forest is sparsely distributed within an anthropogenically dominated landscape (Figure 3). Many islands show a combination of these patterns. Complete map layouts for the local trust areas are appended to this document and are available in digital form.

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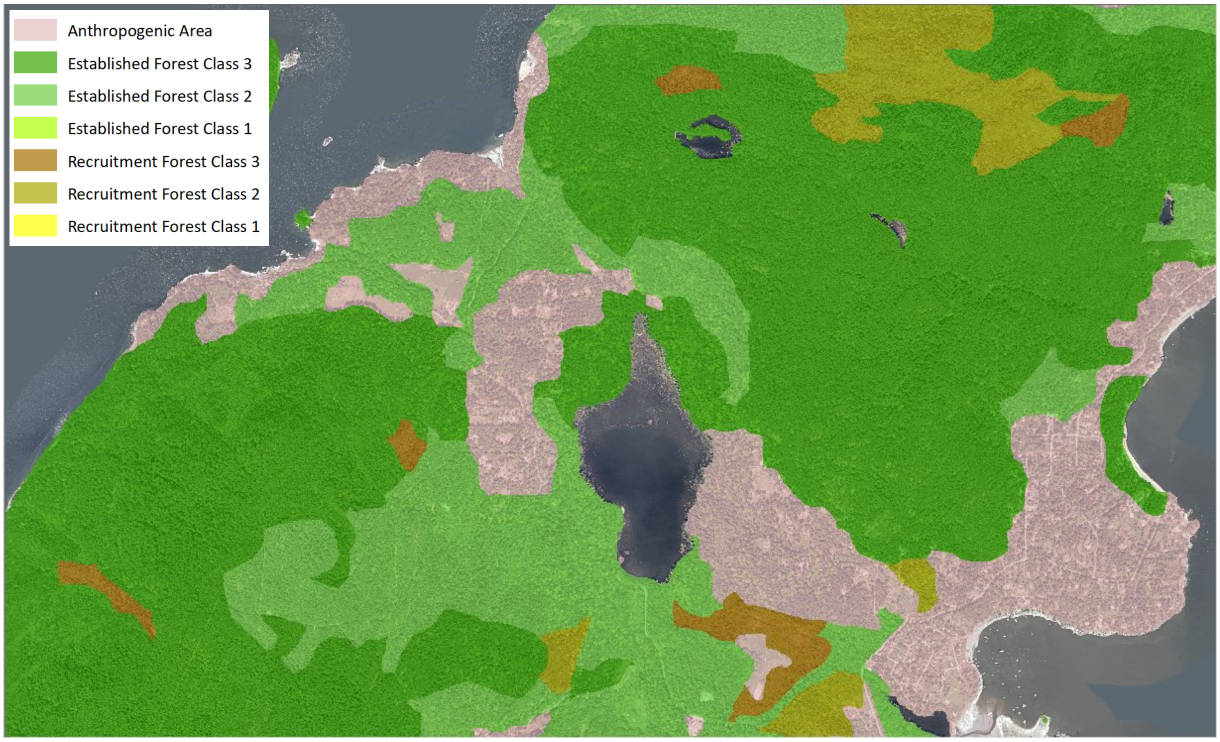

Figure 1. Corridors connecting large established forest areas on Bowen Island.

Figure 2. Diffuse patches of forested ecosystems in different structural stages on Salt Spring Island.

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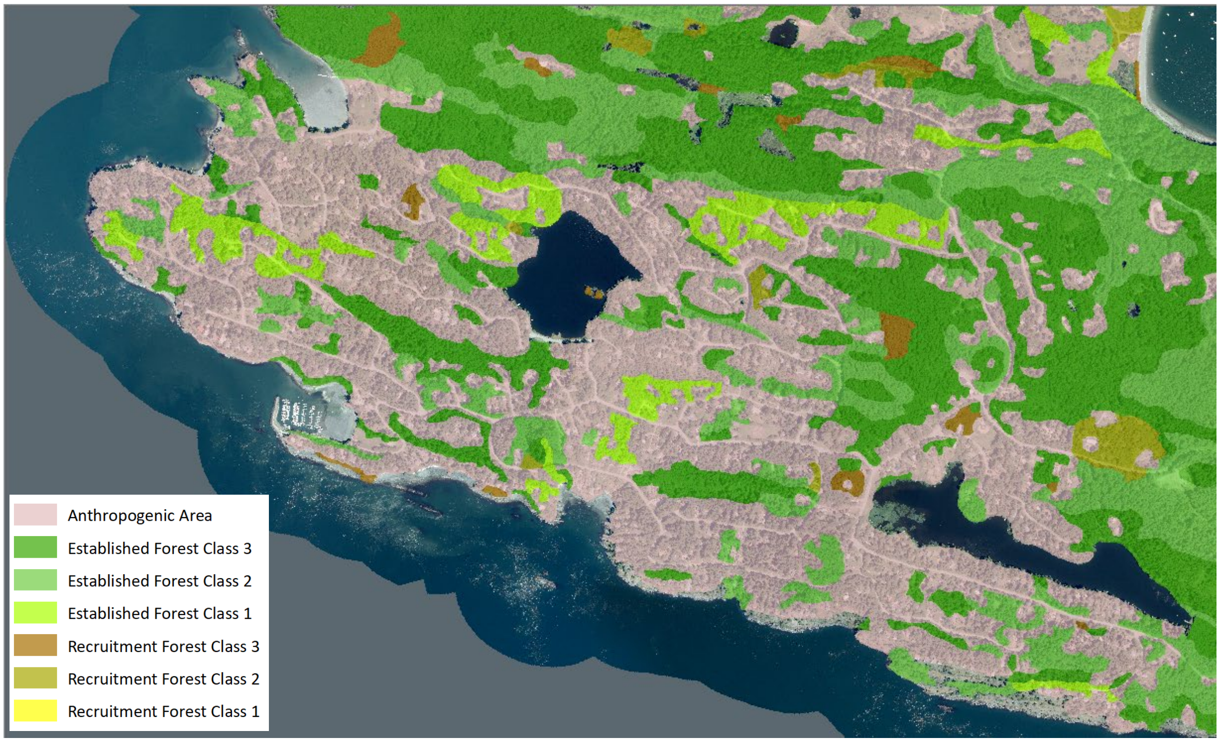

Figure 3. Small mature patches embedded in matrix of anthropogenic landscape features on North Pender.

6.0 Interpretation and Use

Using the provided mapping, management decisions can be contextualized in the forested, non-forest, and anthropogenic landscape. The data provided here can be used to inform the planning of Development Permit Areas (DPA) or recommend zoning restrictions in some areas, provided site-level ground truthing is completed. However, the key utility of this product is to help planners understand the wider spatial context in which those specific decisions are being made and to emphasize the unique patterns in each local trust area which bear on those decisions.

The variability observed in the spatial organization and size distribution of the patches between islands, as well across islands, provides an important context for site-level management decisions. However, the degree of variability described by this mapping places the weight of decision making on a case-by-case interpretation of the results.

Interpretation of these map products to define conservation goals, particular to each island or local trust area, will help inform key management decisions. For instance, restoration efforts could be focused on areas where early succession forests are dominant. Likewise, where the forested landscape is composed of small isolated patches of established forest, protection measures may be appropriate to increase connectivity between patches, to protect this scarce resource. The provided map products can be used to identify areas of connectivity between forest patches, prioritize their protection from development pressures, or identify areas of potential connectivity towards which restoration can be focused. Some combination of these strategies should be utilized in each trust area, but the balance and emphasis of management actions must rest on a detailed assessment of the needs and values of each local trust area and incorporate a variety of data, local and traditional knowledge. Local trust area specific GIS models or decision support systems may have utility, but a detailed synthesis of available knowledge and an articulation of values is critical to this process.

It is recognized that logging occurs on private land in the Islands Trust. It may be difficult to anticipate these activities as parcels change ownership and the values of the owners change over time. It may be prudent to encourage the long term, sustainable management of private forests and the incorporation of public values into this management. The mapping tools currently available to the Islands Trust can be useful in developing measures which take into consideration the existing level of fragmentation of the forested ecosystems. For instance, existing road openings and forest edges and can be used to minimize the creation of new disturbances. Alternative silviculture systems such as single tree or small patch selection could also be used to maintain canopy cover over the landscape.

7.0 Limitations

The most challenging limitation inherent in this type of analysis is the scale and accuracy of the underlying mapping. Since primary data collection was outside the scope of this project, it relied on the previously collected TEM data. This was mapped at the 1:10,000-1:20,000 scale, depending on the island. This level of precision means that decisions which require highly detailed mapping should employ a measure of "ground truthing" to verify the accuracy of TEM boundaries and attributes in the field. While considerable effort was made within the scope of this project to ensure the TEM data attributes followed conventional standards, errors and omissions may be present which would require additional field work to correct. Some of these errors may have been introduced by land use changes which occurred after the completion of this initial field work. Likewise, the identification and mapping of contiguous forest was generalized, as it was not specific to any species habitat and therefore avoided over specifying the model. Relevant ecological questions might become evident at finer scales that are not addressed here. These mapping products should be used to contextualize site-level decisions within the forested landscape but not be relied on to execute them.

8.0 Considerations for Future Work

Constraints mapping and inventory of forested ecosystems in the Islands Trust may form the basis of further analysis or provide context for other types analysis of the Trust's forest ecosystems.

Trust Area Specific Modelling and Mapping: The present model could be further developed to reflect the conservation planning goals of each trust area and the development challenges they face. This could resemble a refinement of the patch quality ratings to incorporate conservation values which have been identified per island.

LiDAR Analysis of Forest Resources: LiDAR could be used to update the present analysis with greater precision and accuracy. This will identify both recent openings and small openings in the canopy that are not presently accounted for in the TEM, and would provide a more accurate inventory of forest resources. Furthermore, the identification of veteran trees from this data set may have value for planning around natural heritage values. Additionally, LiDAR may be used in some cases to expedite the ground-truthing of DPA or zoning sites.

Resiliency and Climate Change: This inventory of forest resources in the Islands Trust could be improved by an assessment of the resiliency of stands to a changing climate and modelling compositional changes of forest ecosystems. These models can help inform long-term, multi-generational decision-making.

Carbon: Using a detailed forest inventory, the current and potential storage and sequestration rates of forest carbon can be calculated under different management scenarios. As the carbon economy matures, these models may become critical to responsible management of forest resources and provide an economic incentive for sustainable forest management.

9.0 References

Holt, R.F. (2007). *Conservation Planning and Targets for the Coastal Douglas Fir Ecosystem. A Science Review and Preliminary Approach*. Integrated Land Management Bureau, Nanaimo.

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10.0 Appendices

A. Decision criteria for constraints and forest mapping.

Map Feature	**Objective**	**Analysis**	**Decision criteria**
Anthropogenic Non-forest	Identify anthropogenically modified polygons	TEM data classification	>= 20 % non-forest polygon (Site Series = '00') and TEM Map Code represents anthropogenic landscape feature. (Holt, 2001).
Natural Non-forest	Identify natural non-forest polygons	TEM data classification	>= 20 % non-forest and TEM map code represents natural non-forest features such as rock outcrops, open water, etc.
Roads	Model disturbance caused by roads	Density analysis	Road density is over or under a threshold of 1 km / km^2. (USDA, 2001).
Structures	Model disturbance caused by structures	Density analysis	Structure density is classified by Jenks breaks. Higher classes represent disturbances not captured in TEM but observed in ortho photography.
Structural stage	Distinguish between structurally complex mature forest and early succession forests.	TEM data classification	Established Forest has TEM Structural Stage > 4 in >= 50 % of polygon. The remainder are Recruitment Forest stands in early succession.

B. Summary of forested TEM units by local trust area.

STRUCTURAL STAGE CLASS		Established Forest			Recruitment Forest			
PATCH QUALITY CLASS		1	2	3	1	2	3	**Total (ha)**
TRUST AREA	**BM**		1,162	2,543		148	93	**3,947**
	DE		729	674		1,162	421	**2,986**
	EX			29			14	**43**
	GB	17	2,094	517		821	79	**3,528**
	GL		2,594	910	3	1,456	220	**5,183**
	GM	8	1,641	6,312	18	366	460	**8,803**
	HO		568	835		2	371	**1,776**
	LA		1,392	4,551		34	151	**6,129**
	MA	15	673	869		61	92	**1,709**
	NP	34	1,184	2,171	2	174	152	**3,717**
	SA	14	1,336	1,565	2	98	163	**3,178**
	SP	2	301	387		35	17	**742**
	SS	14	3,360	5,273		1,827	2,825	**13,300**
	TH		1,205	1,947		366		**3,518**
Total (ha)		**105**	**18,239**	**28,583**	**24**	**6,549**	**5,059**	**58,559**

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"I certify that the work described herein fulfills the standards expected of a member of the Association of British Columbia Forest Professionals and that I did personally supervise the work."