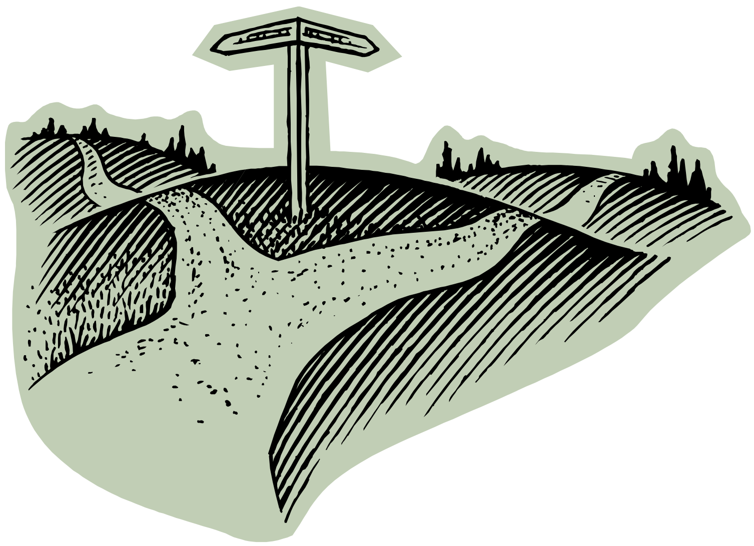
Methods for Determining High Value Biodiversity Areas and Identifying Potential Acquisition Targets within the Islands Trust Area:



A reference document for the Islands Trust Fund Spatial Decision Support System (LandscapeDST Islands Trust Version 3.0)

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Background

The Islands Trust Fund began its work on the 2011-2015 Regional Conservation Plan (RCP) in 2009 with a completion date of December 2010. Part of the RCP development process included working with the Nature Conservancy of Canada on the Salish Sea Natural Area Conservation Plan (Salish Sea NACP) which includes the entire Islands Trust Area. Through its work on the Salish Sea NACP and through work with other conservation partners, the Islands Trust Fund developed a suite of biodiversity priorities (Table 1) and biodiversity threats (Table 2) for the Islands Trust region.

Table 1. Biodiversity priorities in the Islands Trust Area

***1. Sensitive ecosystems**, including woodlands, mature and old forests, riparian areas, bodies of freshwater, wetlands, cliffs and herbaceous ecosystems*
***2. Regionally important ecosystems**, including watersheds and healthy forests of various ages*
***3. Rare and endangered species and ecosystems** as listed by the B.C. Conservation Data Centre*
***4. Areas that provide connectivity and buffers** for biodiversity priorities and existing protected areas*
***5. Shoreline areas** considered important for the function and structure of the marine environment, including the marine riparian area*
***6. Islets and small islands** that act as refuges for rare species assemblages and provide isolation from common threats to biodiversity*

Table 2. Threats to biodiversity within the Islands Trust Area

***1. Ecosystem Conversion**, from all sources including residential, commercial, industrial and agricultural conversion*
***2. Ecosystem Fragmentation**, from road infrastructure and development*
***3. Invasive Alien and Native Species**, including both plants and animals*
***4. Resource Use**, including forestry and mineral/ gravel deposit removal*
***5. Natural System Modification**, such as foreshore modification (sea walls, breakwaters) and fire suppression*
***6. Environmental Contaminants**, such as septic field contaminants, pesticides and herbicides, sediments from construction, agriculture and forestry zones and household chemical runoff*
***7. Species Disturbance and Mortality**, such as species displacement from light and noise pollution and species mortality from road kill and household pet predation (e.g. birds and rodents)*
***8. Climate Change and Variability**, including rising sea levels, changes to annual precipitation and temperature normals and severe weather*

In September 2010 we initiated the development of a spatial decision support system (SDSS) designed to aid in making the tough decisions required to conserve these biodiversity priorities amidst these diverse and growing threats. An SDSS combines spatial data (i.e. maps of information), scientific knowledge, and the Island Trust Fund institutional values to provide maps and tables that will help in making land use and management decisions (Figure 1). The primary decision that the SDSS is designed for is figuring out which lands would be the best to buy. A key assumption is that the best lands to buy are not only very important for biodiversity, but are also reasonably priced, such that many hectares can be conserved with a limited budget. The SDSS will also be able to help with other types of land use and management decisions.

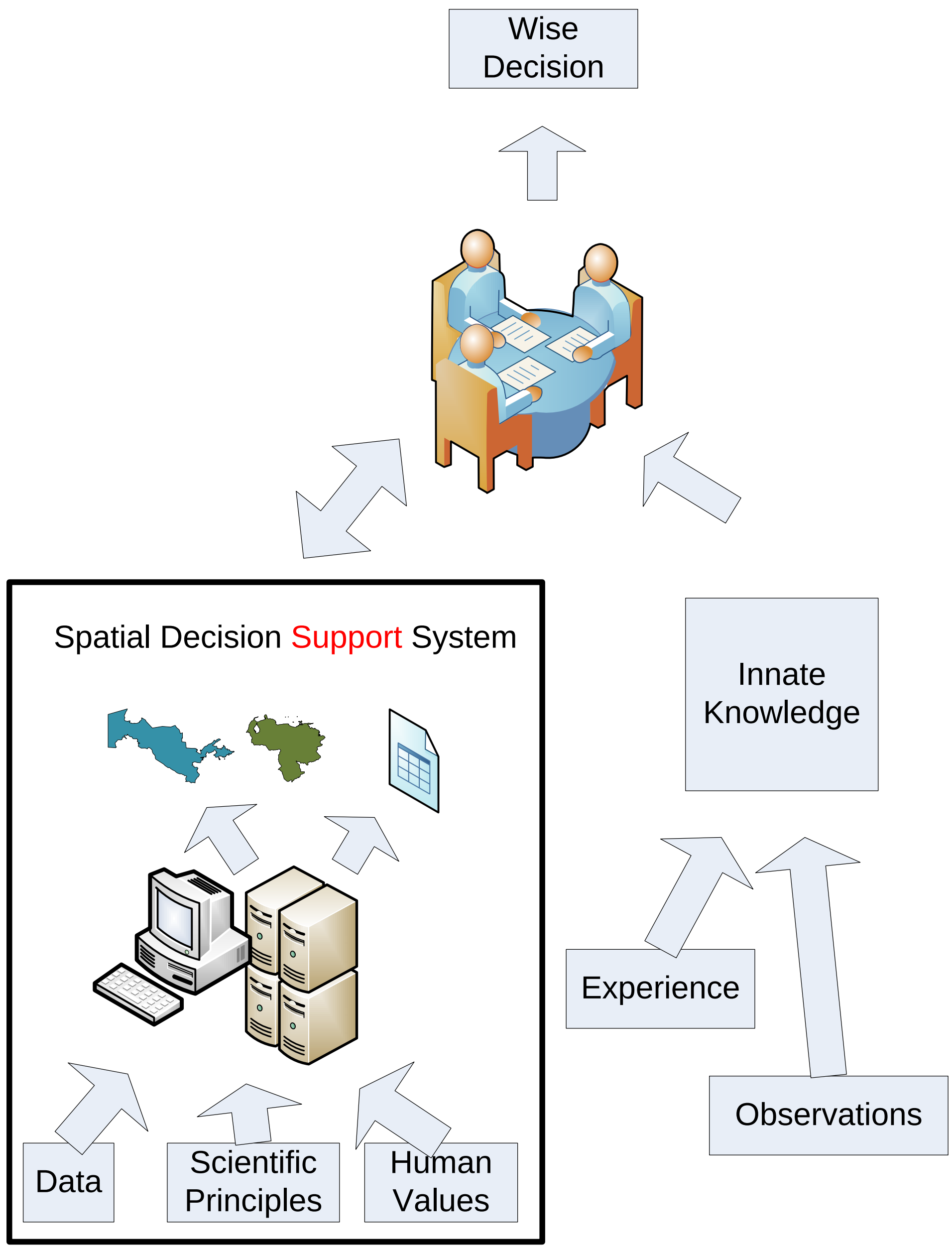

Figure 1: Simplified schematic of a spatial decision support system (SDSS)

One of the important attributes of an effective SDSS is that it is **transparent**. People should be able to "look under the hood" so to speak and see how all the analyses are performed. It is not possible to effectively model the complexity of our world in a simple and realistic way however, so it requires patience and training to understand every single detail of the SDSS. Another very important attribute is that it is "**living**." In other words, the SDSS is designed to easily grow in scope and complexity over time, and to easily recalculate everything as conditions on the landscape change, or as the institutional values of the Fund change. Our SDSS meets both of these objectives.

The first iteration of the SDSS was completed in October of 2010, and is known as LandscapeDST Islands Trust, Version 1.0. It focused on biodiversity priorities 1-4 (from Table 1) and information on existing protected areas to create Biodiversity Importance maps for the Islands Trust region. Version 2.0 was completed in April of 2011, expanding on biodiversity priorities 1-4 and incorporating priorities 5 and 6 from Table 1 as well as analyses regarding "threat" found in Table 2. These documents describing the methodology and showing some of those results are available upon request.

This document details the third iteration of the SDSS (LandscapeDST Islands Trust Version 3.0) and is intended for a technical audience. It expands upon the documentation of Iteration 1 and 2, so it is not necessary to first read those reports. This iteration of the SDSS bolsters many of the analyses of Iteration 2, and incorporates analyses regarding connectivity and the coding behind incorporating the cost data for acquisition when it becomes available. The SDSS uses a multiple-criteria decision analysis (MCDA) coupled with geographical information systems (GIS). The major criteria that are used in Iteration 3.0 of the SDSS are provided here in Figure 2. The MCDA and GIS approach is introduced in the following section, and then the detailed methodology follows. The results of each sub-analysis are indicated by maps of a subset of the region. The entire SDSS is operational and can be queried with the help of Islands Trust staff.

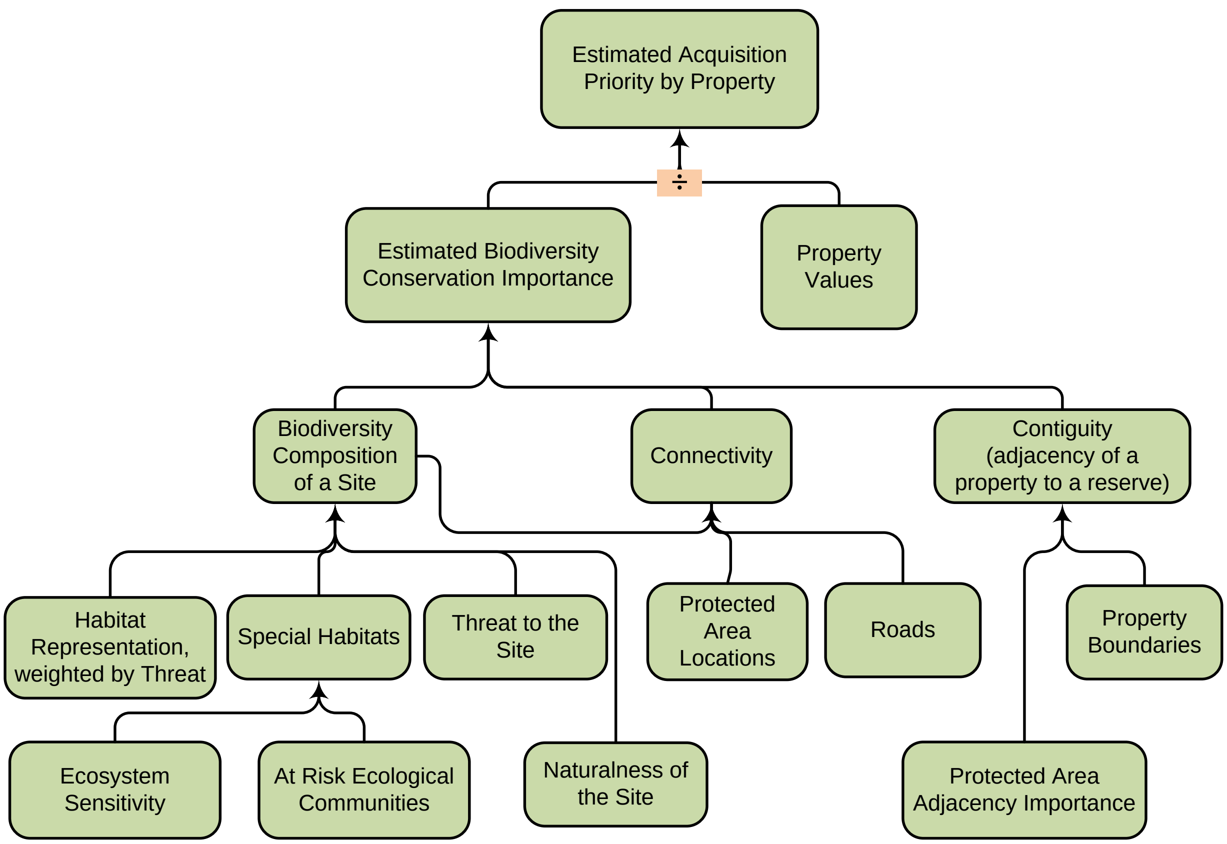

Figure 2: Summary of the major criteria used in the model

In 2012, Islands Trust staff plan to make improvements to many of the existing criteria and research the available cost data to weed out the inconsistent data and incorporate it into the analysis.

Multiple-criteria Decision Analysis (MCDA) and the Complete Model Hierarchy

Multiple-criteria decision analysis (MCDA) is a suite of methodologies that can help decision makers and analysts combine multiple factors, and it typically results in a rating or ranking of alternatives (Belton and Stewart, 2002). MCDA was developed in the context of non-spatial decisions in a variety of application areas including business, and is often used to help select among a small number of “discrete” alternatives (e.g. interviewed candidates for a senior management position, proposed advertising strategies, proposed locations for a new hospital, etc). Of the many ways in which MCDA has grown and expanded, two are particularly noteworthy for the purposes of this report. First is its use in “continuous” problems with a large or virtually unlimited number of alternatives (e.g. selection of an investment portfolio, identification of possible locations for a new waste disposal facility, etc). The second is the combination of MCDA and geographic information systems (GIS) (Malczewski, 2006). GIS-based MCDA can support discrete scenarios, such as helping estimate ambulance drive times to hospital, site selection, and continuous problems. The latter are often handled using raster datasets that cover the study area in a regular grid of cells, as in Figure 3.

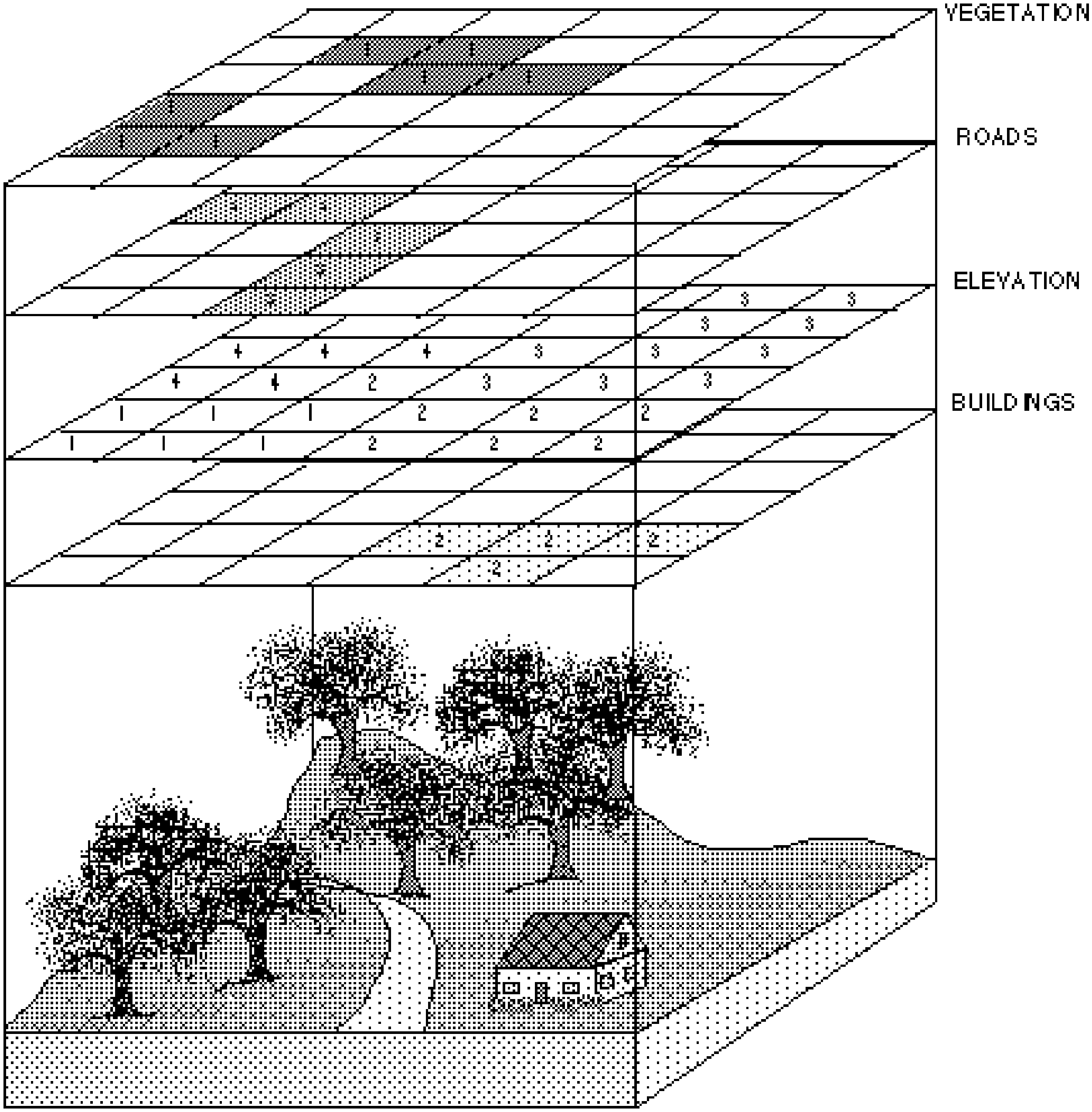

Figure 3: Illustration of how the landscape can be transformed into multiple layers of grid cells. (credit: unknown)

Typically, a single output layer is created, whereby every cell (location on the landscape) is rated or scored in relation to the problem at hand. Spatially continuous approaches to GIS-based MCDA have already been applied to conservation planning (including Possingham et al., 2000; Liu et al., 2006; Geneletti, 2007; Wood and Dragicevic, 2007) and underlie the Islands Trust Fund 2011-2015 Regional Conservation Plan (RCP). It is important to note that MCDA is intended to support and inform the decision-making process, but that people must make, and take responsibility for, the land-management decisions.

The specific GIS-based MCDA approach used in this RCP is based on the work of John Gallo and his colleagues (Gallo et al. In Revision). It has been refined in the course of a number of studies and Gallo's PhD work. One key element of the approach is use of a continuous benefit function (CBF) to describe the relative benefit of protecting different types of habitat or species, or meeting other spatial goals (Davis et al., 2006; Gallo et al., In Revision). This is in contrast to approaches that define a fixed target for a conservation goal or other objective. After such a goal is met the assumption is that there would be no value to allocating any additional land to that goal. In addition to addressing these faulty assumptions and the fact that choosing a target is a subjective exercise, another noteworthy aspect of the approach underlying this RCP is use of a weighted sum, also called simple additive weighting or weighted linear combination, method of multiple-criteria evaluation (MCE). It is widely used because of its simplicity and transparency (Belton and Stewart, 2002), and can be applied in a hierarchical fashion to successively compose or decompose the elements of a problem. The approach is flexible to incorporate additional criteria and analyses over time.

In spatially continuous problems modelled using a GIS, weighted summation begins by creating a separate GIS raster layer for each criterion (decision factor), similar to the diagram above. Because the original input data for each criterion could be measured on a different scale, the data must first be brought to a common scale in a process called normalization. This is done in our approach by finding the maximum value, then dividing each value by that maximum. Locations within the study area where the particular criterion are not present are assigned a zero for that layer, so all locations then have a value between 0 and 1 for that criterion.

Once all criteria to be combined have been normalized, they are assigned relative importance measures called weights. In our approach, all weights sum to 1, with the result that the lowest possible output value is 0 and the highest possible output value is 1. The output values (importance rating or scores) are calculated as a weighted sum for each cell (location) using the formula $V_I = \Sigma_J W_J V_{IJ},$ where V_I is the overall value or rating of the Ith location (I = 1 to M locations), W_J is the weight of the Jth criterion (J = 1 to N criteria), and V_{IJ} is the normalised value of the Jth criterion for the Ith location (Malczewski, 1999; Nyerges and Jankowski, 2010). Figure 4 provides a simplified depiction of a GIS-based weighted sum with two criteria (species and habitat) and a small study area that is divided into 4 raster cells.

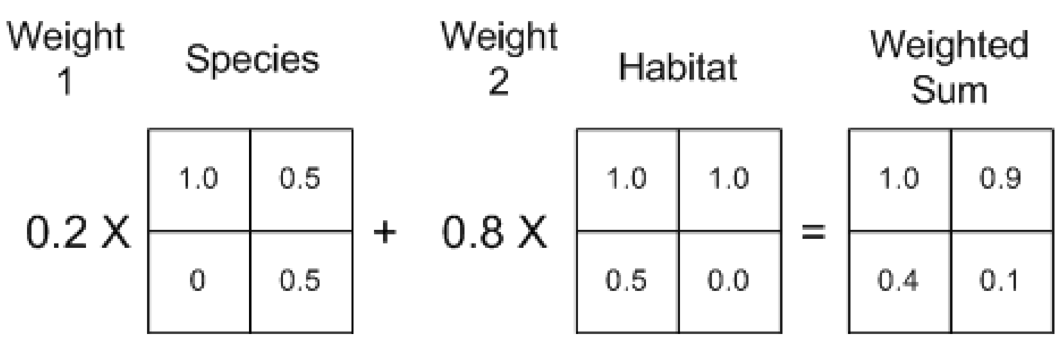

Figure 4: Simplified schematic of a spatial, weighted, multi-criteria sum

Figure 5 shows the relationships among:

- Input data (in pink), which are created by Islands Trust staff outside this RCP.
- Derived intermediate data (in light green), created by the GIS tools that implement the methodology.
- Derived output data (in dark green at the top).

Numbers in green refer to the multi-criteria weighting, where weighted sum is used as the data processing technique. Numbers in blue refer to the corresponding document section below, which describes the item, summarizes the methods of processing from an ecological perspective, summarizes the data processing from a GIS software perspective and, where appropriate, describes the resulting output for the item. The document section numbers breakdown into subsection numbers where weighted sum is used as the data processing technique. For instance, item 3 (Estimated Biodiversity Conservation Importance by Spatial Unit) is a weighted sum of item 3.1 (Composition, with a weight of 0.5), 3.2 (Connectivity, with a weight of 0.25) and 3.3 (Contiguity, with a weight of 0.25).

Abbrevations seen throughout the document are GIS variable names for the items they represent. For example, EstAcqPriority is for Estimated Acquisition Priority and BiodivImpMean is for Biodiversity Importance Mean.

Maps to demonstrate the outputs at each level have been included at the end of each section. For the purposes of this description, Gabriola Island Local Trust Area has been used as an example. The data layers used to map this island also cover all of the other islands in the region.

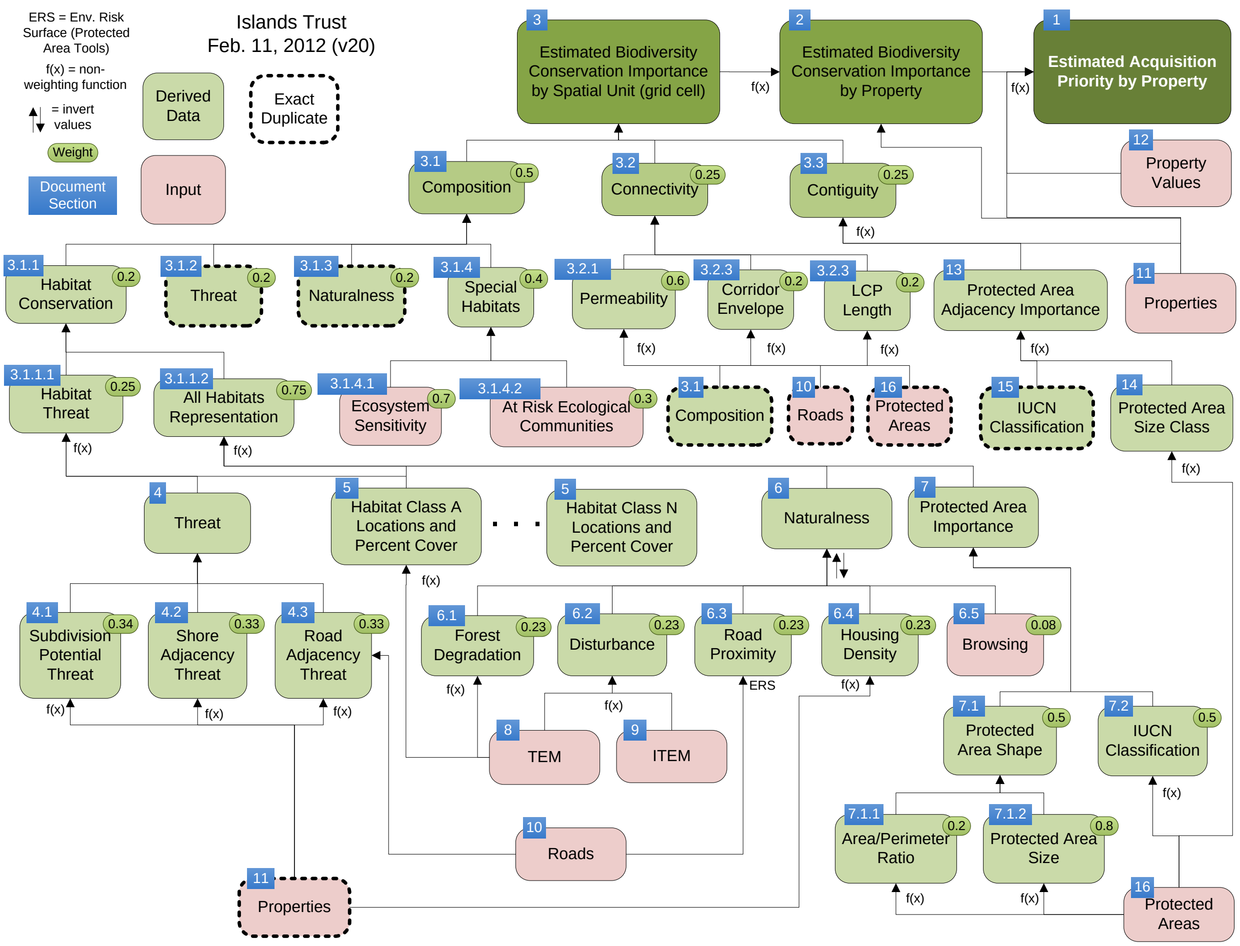

Figure 5: Diagram of entire methodology hierarchy

NOTE: For a full page version of this diagram, see Figure 7.

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How to use this Document

It helps to refer to the above diagram when looking at each new step in the methodology. You can click to it from the hotlink in the Inputs section of that step. If you are reading this in adobe, just click the back button to get back to where you were. In Word, there are two ways to get back to where you were. The first is clicking the return to table of contents link, below Figure 5, and then clicking on the section of the methodology in the table of contents. The second is to install add the back button to your toolbar, and just click that when you want to go back to where you were.

1 Estimated Acquisition Priority of Properties

Each property's estimated priority for acquisition based on its relative biodiversity importance and its cost per hectare. In other words, a prioritization intended to support cost-effective use of available conservation-oriented land acquisition funds. It is recommended that high priority properties be further investigated for possible acquisition. A cost data set has not yet been obtained that is accurate enough to enter into the model.

Methods Summary

The goal of the GIS-based MCDA component of Islands Trust Fund regional conservation planning is to prioritize properties within the Islands Trust Area for land securement either through land acquisition or conservation covenant. The approach to prioritizing lands is as follows:

1. Identify lands with the highest biodiversity values;
2. Identify areas where biodiversity is under threat;
3. Balance high biodiversity value areas with their corresponding threats to determine high priority areas for land securement; and,
4. Incorporate information on probability of land securement success (e.g. cost, willingness of landowner, etc.) to determine focus properties for land conservation.

The output for the GIS-based MCDA tool has been the identification of properties with a high relative biodiversity conservations importance and that are under the highest threat. It is anticipated that other factors affecting the probability of land securement success, such as the willingness of the landowner, and more accurate cost data from BC Assessment will be incorporated into the model at a later date. Also data is lacking to incorporate species representation at this time.

Crown lands have been kept separate from private lands so that they can be placed in priority for the Free Crown Grants program[1].

Data Processing Summary

Inputs (as per Figure 5)

- Properties– vector dataset with an assessed ActualValue for each property (see 11).
- Property Values– vector dataset of market values (see 12).
- ScenarioOutput –copy of Properties vector dataset with an Estimated Biodiversity Conservation Importance value (BiodivImpMean) for each Property (see 2).

Outputs:

- ScenarioOutput – copy of the Properties vector dataset with a new field EstAcqPriority for each property.

Geoprocessing:

- For each Property
  - Calculate ValuePerSqMetre as ActualValue / ShapeArea.

[1] Free Crown Grants allow the Islands Trust Council and the Islands Trust Fund to work together under the sponsorship of the Minister of Community, Sport and Cultural Development to acquire up to one parcel of Crown land each year. Trust Council, the relevant local trust committee, the Trust Fund Board and local First Nations must be in favour of the protection of the land by the Islands Trust Fund for the application to proceed.

- Calculate RelativeAcqPriority as BiodivImpMean / ValuePerSqMetre.
- Normalize RelativeAcqPriority to create EstAcqPriority.

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2 Estimated Biodiversity Conservation Importance of Properties

The estimated relative importance of undertaking measures to conserve each property in a natural state, thereby promoting biodiversity.

Methods Summary

These properties have been identified based on the highest biodiversity conservation importance by spatial unit (see 3). The following assumptions have been made to assess the biodiversity importance of properties:

1. It is important to maintain:
   a. Sensitive ecosystems;
   b. "At Risk" ecosystems;
   c. Representative ecosystems; and,
   d. Naturalness
2. Where biodiversity values are the same:
   a. the conservation of large properties is more important than the conservation of small properties; and
   b. the expansion of existing protected areas is more important than the creation of new protected areas.
3. It is important to incorporate the relative level of threat using available data. Available useable data for this model includes:
   a. Subdivision potential
   b. Marine shore adjacency
   c. Road adjacency

As data becomes available other threats to biodiversity such as the viewscape available from a property may be incorporated. Useable invasive species information is also missing at this time.

Data Processing Summary

Inputs (as per Figure 5):

- Properties – vector dataset of properties (see 11).
- Biodiversity – 25m raster dataset of relative Biodiversity Importance of Spatial Units (see 3).

Outputs:

- ScenarioOutput – copy of Properties vector dataset with fields added for BiodivImpMean and its breakdown .

Geoprocessing:
- For each Property, use zonal statistics to calculate the average Biodiversity Importance value of the 25m cells within the property.

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3 Biodiversity Conservation Importance of Spatial Units (grid cells)

The estimated relative importance of undertaking measures to conserve each 25m X 25m landscape cell in a natural state, thereby promoting biodiversity.

Methods Summary
The biodiversity importance of spatial units has been identified by combining information on ecological composition with information on connectivity and contiguity with existing protected areas. Methods for determining contiguity, connectivity and composition are described below. Connectivity and Contiguity are both sub-criteria of an overarching criterion that is often called 'Spatial Context.' This overarching criterion is often at the same weighting as Composition. To make this work, both Contiguity and Connectivity (which are often equal by default), should be 0.25.

Data Processing Summary
Inputs (as per Figure 5):
- Composition – 25m raster dataset of relative Composition importance (see 3.1).
- Connectivity – 25m raster dataset of relative Contiguity importance (see 3.2).
- Contiguity – 25m raster dataset of relative Contiguity importance (see 3.3).

Outputs:
- Biodiversity – 25m raster dataset.

Geoprocessing:
- For each 25m cell, calculate the relative Biodiversity Importance as (Composition X 0.5) + (Connectivity X 0.25) + (Contiguity X 0.25).

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3.1 Composition

Composition value is the relative importance of the ecological elements that are found at any particular 25mX25m landscape cell, irrespective of the spatial context of the cell. It is a function of Habitat Conservation (see 3.1.1), Threat (see 3.1.2), Naturalness (see 3.1.3) and Special Habitats (see 3.1.4). Special Habitats are given a higher weighting because of the importance of the ecosystems and ecological communities they contain, as identified by Islands Trust and its partners. Additional Composition elements, such as Species Representation will improve the model and may be included in future enhancements as funds and staff resources become available.

Methods Summary
The following assumptions have been made to assess the composition value of spatial units:

- It is important to maintain:
    a. All special ecosystems (e.g. sensitive ecosystems and "at risk" ecosystems); and,
    b. Portions of all other ecosystems to maintain their viability.
- In determining how well one of the other ecosystems has been conserved, size and shape of protected areas affect the relative quality of conservation.
- Threatened land warrants protection (As opposed to an alternate assumption in some places of the world that concedes development as inevitable, and so conserving threatened ares just displaces the threat to some other place in the region. Hence, this alternate assumption that we ar not following is that conservation priority should not be based on threat but be based solely on ecological benefit and on cost.)
- Areas of with a high naturalness value warrant protection

Special ecosystems have been weighted as more important than habitat conservation, threat and naturalness in the GIS-based model because they represent crucial conservation features on the landscape that are not as well represented in other areas of the model (e.g. wetlands and riparian areas).

Data Processing Summary

Inputs (as per Figure 5):

- HabitatCons – 25m raster dataset of relative importance from a Habitat Conservation perspective (see 3.1.1).
- Threat – 25m raster dataset of relative importance from a Threat perspective (see 3.1.2).
- Naturalness – 25m raster dataset of relative importance from a Naturalness perspective (see 3.1.3).
- SpecialHab – 25m raster dataset of relative importance from a Special Habitats perspective (see 3.1.4).

Outputs:

- Composition – 25m raster dataset.

Geoprocessing:

- For each 25m cell, calculate the relative Composition importance as (HabitatCons X 0.2) + (Threat X 0.2) + (Naturalness X 0.2) + (SpecialHab X 0.4).
- Normalize the values to ensure the maximum value is 1.

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3.1.1 Habitat Conservation

The relative importance of each 25mX25m landscape cell from the perspective of a) the threat to the habitat types within the cell, and b) the relative importance of those habitats from a representative perspective.

Methods Summary

All Habitats Representation is weighted more heavily than the Habitat Threat to signify the greater relative importance of representation.

Data Processing Summary

Inputs (as per Figure 5):

- HabThreat – 25m raster dataset of relative importance from a Habitat Threat perspective (see 3.1.1.1).
- AllHabsRepn – 25m raster dataset of relative importance from an All Habitats Representation perspective (see 3.1.1.2).

Outputs:

- HabitatCons – 25m raster dataset.

Geoprocessing:

- For each 25m cell, calculate the relative Habitat Conservation importance as (HabThreat X 0.25) + (AllHabsRepn X 0.75).
- Normalize the values to ensure the maximum value is 1.

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3.1.1.1 Habitat Threat

The relative threat to the habitat types within each 25mX25m landscape cell.

Methods Summary

This processing has a non-spatial foundation in that it first calculates for each habitat class the percent of that habitat's extent that is threatened. This value is then used to calculate the overall habitat threat for each cell based on the habitats classes (up to 3) within the cell and their percent covers.

Data Processing Summary

Inputs (as per Figure 5):

- Threat – 25m raster dataset of relative Threat (see 4).
- <HabitatClassN> – 25m raster dataset for each Habitat Class showing the locations and percent cover of that habitat class. Each location can have up to three different habitats present (see 5).

Outputs:

- HabThreat – 25m raster dataset.

Geoprocessing:

- For each habitat class:
    - Determine the percent of that habitat class that is threatened.
    - For each 25mX25m landscape cell, calculate the relative threat to habitat as:
        - (PercentCoverOfPrimaryHabitatClass X RelativeThreatToThatHabitatClass) + (PercentCoverOfSecondaryHabitatClass X RelativeThreatToThatHabitatClass) + (PercentCoverOfTertiaryHabitatClass X RelativeThreatToThatHabitatClass)

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3.1.1.2 All Habitats Representation

The relative importance of the habitat(s) within each 25mX25m landscape cell from a conservation perspective.

Methods Summary

The input used for All Habitats Representation was derived from Terrestrial Ecosystem Mapping (TEM, see 8). TEM mapcodes were used to define the different habitats found on the landscape. In some cases, where similar habitats existed, mapcodes were combined. The mapcodes represent forest vegetation associations (e.g. Douglas-fir – Salal), sparsely vegetated units (e.g. Fescue – Camas), non-vegetated units (e.g. Lake) or anthropogenic units (e.g. urban). Anthropogenic units were excluded from the model as it was assumed that biodiversity values would be minimal.

The goal of conserving representative habitats is not to protect all of these remaining habitats, but rather to protect enough of them to maintain biodiversity. One of the benefits of using continuous benefit functions is that there is no need to set arbitrary targets for what percentage of a certain habitat needs to be conserved in order to conserve biodiversity. Instead, inflection points can be defined which adjust the change in relative importance of conserving additional hectares of a habitat. Often times, it is really important to conserve the first 5% of a habitat, and after that it gets gradually less important. The rate at which it gets less important can change at different inflection points.

To set the inflection points we considered the threshold at which biodiversity begins to be lost (i.e. the amount of protected area required to maintain biodiversity).

It would have been ideal to also use the original extent of the various habitats found within the Islands Trust Area as part of the analysis. These data were not readily available, but will hopefully be generated for future iterations of the model.

Information on thresholds for the maintenance of biodiversity suggests that the relative importance of conserving additional habitat declines rapidly after about 60-70% of the habitat has been conserved (Price et al., 2007*).*

Because of the limited amount of protected area in the Islands Trust region (approximately 16.5%), setting conservation targets consistent with the thresholds described above in the model would have yielded results showing most of the landscape as having high importance for conservation in order to meet habitat representation needs. While most of the landscape may be important for conservation, it was desirable to set priorities. Consequently, the conservation inflection point for habitat representation, for the purposes of the model, was set at 5% and the value of acquiring additional habitat after 5% decreased quickly as a linear function until 40% habitat conservation was reached and then decreased at a slower rate until the habitat was completely protected (see Continuous Benefit Function graph below). It is important to note that these targets were used to obtain meaningful information from the model. As more of the landscape becomes conserved, the continuous benefit function thresholds used below will be changed to better reflect threshold science.

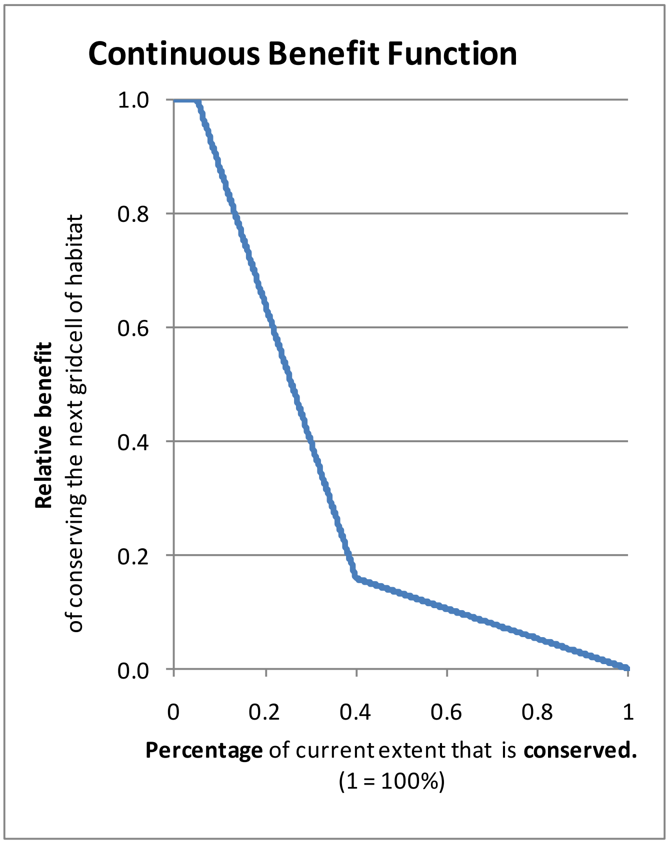

Figure 6: Continuous Benefit Function for Habitat Representation

Data Processing Summary

Inputs (as per Figure 5):

- Naturalness – 25m raster dataset of relative Naturalness (see 6).
- ProtAreaImp – 25m raster dataset of relative importance of each Protected Area (see 7).
- <HabitatClassN> – 25m raster dataset for each Habitat Class showing the locations and percent cover of that habitat class. Each location can have up to three different habitats present (see 5).

Outputs:

- AllHabsRepn – 25m raster dataset.

Geoprocessing:

- For each habitat class:
    - Determine the percent of that habitat class that is already protected, weighted by the relative importance of the protected area(s) in which it occurs (see 7) and the Naturalness of the protected area(s) (see 6).
    - Determine the relative benefit of protecting the next unit of that habitat class. This is based on the continuous benefit function (see Diagram 2 above), with parameters including:
        - Percent already protected (see previous bullet).

    - First inflection point, from a flat continuous benefit function (CBF) to a downward sloping one (0.05).
    - Slope factor of the downward slope (-1). Note, this is not the actual slope, see Gallo (In Revision) for the detailed formulas.
    - Second inflection point, where the downward sloping curve changes slope angle (0.4).
    - Slope factor of the second downward sloping CBF line segment (1).

To reiterate, the low initial inflection point (0.05) and the steepness of the CBF curve between 0.05 and 0.4 are primarily driven by the desire to differentiate between the various habitat classes. With less extreme values, such as an initial inflection point of 30 and a gently sloping curve, most every habitat class in this particular study region would be considered equally important by the model. Because the habitat data used allows up to three habitats in any given mapped polygon, a script implements the habitat representation analysis for each individual habitat to get the "RelativeBenefitOfProtectingThatHabitatClass".

- For each 25mX25m landscape cell, calculate the relative importance of habitat protection as:
    - (PercentCoverOfPrimaryHabitatClass X RelativeBenefitOfProtectingThatHabitatClass) + (PercentCoverOfSecondaryHabitatClass X RelativeBenefitOfProtectingThatHabitatClass) + (PercentCoverOfTertiaryHabitatClass X RelativeBenefitOfProtectingThatHabitatClass)

To reiterate, the habitat representation analysis was performed for the entire region, not the above island. The results shown above are just a clip of the entire result output.

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3.1.2 Threat

See 4.

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3.1.3 Naturalness

See 6.

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3.1.4 Special Habitats

The relative importance of each 25mX25m landscape cell from the perspective of a) the sensitivity of its ecosystem(s) to disturbance and, b) the relative importance of ecosystem(s) as determined by their "at risk" status in British Columbia.

Methods Summary

For the purposes of this model, special habitats include ecosystems that are considered "sensitive" under the Standards for Mapping Ecosystems at Risk in British Columbia, available at http://www.env.gov.bc.ca/sei/, and those considered to be "at risk" as determined using the recently completed Prioritization Tool from the British Columbia Conservation Framework (information available at http://www.env.gov.bc.ca/conservationframework/ and tool available through the BC Ecosystems Explorer at http://www.env.gov.bc.ca/atrisk/toolintro.html). Sensitive Ecosystems have been given a higher weight than "at risk" ecosystems because they are under-represented in other areas of the mapping and yet are deemed to be one of the most important components of the conservation landscape. Sensitive Ecosystems were derived from the Terrestrial Ecosystem Mapping (see 8) and were assigned importance values (see 3.1.4.1 below). "At risk" ecosystems were also assigned importance values (see 3.1.4.2 below).

Incorporation of species specific information may help to enhance the model at a later date, but has not been used in this analysis.

Data Processing Summary

Inputs (as per Figure 5):

- EcoSen – 25m raster dataset of Ecosystem Sensitivity (see 3.1.4.1).
- AtRisk – 25m raster dataset of At Risk Ecological Communities (see 3.1.4.2).

Outputs:

- SpecialHab – 25m raster dataset.

Geoprocessing:

- For each 25m cell, calculate the relative Special Habitats importance as (EcoSen X 0.7) + (AtRisk X 0.3).
- Normalize the values to ensure the maximum value is 1.

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3.1.4.1 Ecosystem Sensitivity

The relative sensitivity to disturbance of the ecosystem(s) within each 25mX25m landscape cell, based on the following Sensitive Ecosystem Mapping (SEM) encoding:

SEMCode	SEM label	Relative Sensitivity
HB	Herbaceous	1
CL	Cliff	1
SV	Sparsely Vegetated	1
WN	Wetland	1
WD	Woodland	1
OF	Old Forest	1
RI	Riparian	1
FW	Freshwater	1
MF	Mature Forest	0.5
YF	Young Forest	0.25
FS	Seasonally Flooded Field	0.25
NA	Not sensitive	0

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3.1.4.2 At Risk Ecological Communities

The relative likelihood of communities to become extinct or extirpated as a consequence of human activity within each 25mX25m landscape cell, based on the Habitat Class(es) present (see 8). “At risk” ecosystems were derived from the BC Conservation Framework Prioritization Tool by searching for ecosystems found in the Islands Trust region that were considered a priority under the Ecosystem Protection Action Group on October 11, 2010. Relative values for ecosystems were assigned as follows:

BC Conservation Framework Priority	Relative Value
1	1
2	0.66
3	0.33

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3.2 Connectivity

Background

Least cost corridor methodology helps indicate the important habitat linkages between pairs of core reserve areas (Beier et al. 2009; Gallo 2007; Lombard & Church 1993; Singleton et al. 2001). An enhancement of the least cost corridor methodology is applied in LandscapeDST for the Islands Trust, and is described here.

The least cost path (LCP) analysis is the foundation of the methodology (i.e. Ferreras 2001; Rouget et al. 2006). The central assumption to this method is that movement by an animal or plant, either by an individual or between generations, is easier or harder on different cells of the landscape. Cells that are harder are assumed to have a high “cost” or friction. For instance, moving across pristine habitat has low cost, and moving across a road or other paved surface has a very high cost. Least cost path analysis identifies the narrow path between any two core areas that has the least total cost for the species in question.

Least cost corridor methodology results in corridors of varying width and value, and allows for braided corridors (those that split into several distinct corridors) . The algorithm assigns a value to each cell on the landscape that is the total cost of the best path that passes through that cell and connects two particular core areas (reserves). Cells that are along the best path between two core areas will have the lowest relative value. In this way, every cell in the landscape is assigned a least cost corridor value. The best practice is to then select the high quality cells. The user defines what percentage of the best cells to keep (a Parameter). A standard approach is to choose a threshold such that the narrowest corridor on the landscape is wide enough for the species and/or ecological processes being targeted (Beier et al. 2008). This is commonly known as a Least Cost Corridor output if done for a species, and we take it a step further and call it Corridor Envelope for this iteration of the model. A growing convention is that “corridor” is the term for one species, while a “linkage” applies to many species. We will eventually call this analysis Least Cost Linkage, or Linkage Isoclines, as it is performed on habitats and condition, which are a surrogate for many species.

Method

The first step of the enhanced algorithm is to identify core reserves by identifying all the polygons that are completely comprised of cells over a minimum level (a Parameter) of stewardship quality, and then selecting those resulting polygons that are over a certain size threshold (A Parameter). Core area designation can eventually incorporate other factors such as naturalness and habitat quality (Beier et al. In Press) by utilizing the "composition" output of the model in helping define core areas.

In this analysis, the composition layer is the primary basis for the cost surface; cells that have a high composition value are assigned a low cost. This identifies linkages that connect a lot of high conservation value land together (Rouget et al. 2006). The secondary component is the roads layer. Roads that are estimated to have lots of traffic at high speeds are assigned a very high cost (less than or equal to 1). Animals either cross these roads at risk of death or avoid crossing them altogether, both of which are costly to a species. Roads with less and slower traffic are assigned a lower cost. Because crossing a 25 m road is often more risky for an animal than crossing over 25 m of poor quality habitat, the roads layer is multiplied by a constant (a Parameter) before it is combined with the composition layer to make the cost surface. (The value of the cell of the cost surface is the maximum value of that cell from either the new roads layer or the composition layer.)

For any given pair of core areas, the following three derivatives of the Least Cost Corridor are combined in a weighted sum:

- Corridor Envelope: The Least Cost Corridor output is first divided by the total cost value of the Least Cost Path. This way, all cells on the least cost path get a value of 1, and those at the edge of the corridor get a value such as 1.1 or so (depending on the value of the percentage Parameter, mentioned earlier). These values are then inverted and normalized, such that the cells along the least cost path get a value of 1, and the cells at the outer edge of the corridor get a value just above 0.
    - (max – x) / (max –min)

- Permeability: One of the problems with the Corridor Envelope is that it does not attempt to distinguish the relative value of corridors between different pairs of core areas. Some corridors may be forced to traverse much moderate and low quality habitat, while others traverse much more high quality habitat. Permeability addresses this.
    - The first step is to divide the Least Cost Corridor by the length of the Least Cost Path, not the total value. Hence, corridors that traverse a high percentage of high quality habitat will have a low relative value for this processing output known as the impermeability layer (not the permeability layer).
    - All of the impermeability cells that fall outside of the envelope created by the standardized least cost corridor are turned to a null value (which is essentially a 0 value).
    - To normalize, the pair of reserves that produces the lowest impermeability value is selected, and that lowest value becomes the benchmark value ("overall min"). The highest impermeability value of any of the corridors is defined as "overall max."
        - Here is the equation: ("overall max" – x) / ("overall max" – "overall min")
    - The output is the Permeability layer. "Overall min" becomes a 1 in this layer (as it is the most permeable point of the most permeable linkage),

and all the values for all the other linkages are less than 1 and greater than or equal to 0.

- Least Cost Path Length: A final assumption is that if two different corridors have the same maximum permeability value, but one corridor is much shorter than the other, then the cells in the shorter corridor should get a higher relative connectivity value.
    - To implement this assumption, all the cells in a given least cost corridor envelope are assigned the value of the corresponding least cost path length (measured in number of cells).
    - To normalize, the pair of reserves that have the shortest least cost path are selected, and the number of cells on that path is tallied. That value becomes the benchmark value ("overall min"). The highest least cost path length of any of the corridors is defined as "overall max."
        - Here is the equation: ("overall max" – x) / ("overall max" – "overall min")
    - "Overall min" becomes a 1 in the Least Cost Path Length layer, and all the values for all the other linkages are less than 1 and greater than or equal to 0.
    - This layer is then combined with the other two analyses in a weighted sum for the particular pair of core areas.

In order to speed up the processing time, the end-user is allowed to specify the maximum allowable distance between two core areas to be analyzed (a Parameter). The suggested approach is to visually assess the map of all the cores of the landscape, and to identify the largest distance between two cores that does not have another core within the direct or near direct path. Setting this parameter can dramatically reduce processing time by avoiding processing between core areas that are on opposite sides of the region and that have several core areas between them.

The weighted sum is performed for each pair of reserves. The outputs of all these analyses are overlaid on top of each other, and the maximum value of a cell among all the layers is selected. This way, when corridors overlap on top of each other, the best value is displayed on the final connectivity map. The final connectivity map is then normalized using the standard equation, such that the best value on the map is 1, and the lowest valued cell that is a part of the lowest valued corridor is 0.

Data Processing Summary

Inputs:

- Composition – 25m raster dataset (see 3.1)
- Roads – vector dataset, with a 0-1 Road Threat field (see 10)
- Protected Areas (see 15)

Outputs:

- Connectivity – 25m raster dataset

Geoprocessing**:**

- Generate Cost Surface from Composition and Road Threat
    - 1 - Composition
    - 20 X Road Threat
- Exclude small Protected Areas
- For each Protected Area

  - Generate separate raster
  - Calc Cost Distance with Backlinks
- Determine the Distance between each pair of Protected Areas, limiting pairs to those at least as close as the maxProtectedAreaSeparation
- For each unique pair of Protected Areas
  - Calc Corridor
  - Calc Least Cost Path (LCP)
  - Estimate LCP Length as LCP Cell Count (potential to improve this)
  - Calc Impermeability as Corridor divided by LCP Length
  - Calc Standardized Corridor as Corridor divided by LCP
  - Create Corridor Envelope by eliminating higher values from Standardized Corridor using percentageCorridorValuesToKeep
  - Set Null Impermeability cells outside Corridor Envelope
  - In the process, prepare for normalization
    Find minimum and maximum of all Impermeability rasters
    Find minimum and maximum of all LCPLengths
- For each unique pair of Protected Areas
  - Invert/Normalize Impermeability based on overall min and max (A - permeability from the wildlife perspective is desirable)
  - Invert/Normalize Corridor Envelope (B - crucial corridors between core areas need to be considered, even if they have low permeability)
  - Invert/Normalize LCP Length based on overall min and max (C - shorter corridors are better than longer corridors of the same permeability)
  - Calc Pair Connectivity as Weighted Sum of A (weight 0.6), B (weight 0.2), C (weight 0.2), then normalize

- Calc Overall Connectivity as Max of all Pair Connectivity rasters
- Normalize the output so the lowest valued cell of the lowest value corridor is 0.

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3.3 Contiguity

The relative importance of each 25mX25m landscape cell based on the adjacency of the contained property to protected areas.

Methods Summary

It is assumed that, all things being equal, lands that enlarge existing protected areas are more valuable to conservation than lands that are separated from protected areas. Further, it is more important to expand the more important protected areas. Importance is a function of size (see 14) and IUCN classification (see 15).

Data Processing Summary

Inputs (as per Figure 5):
- PAAdjImp – 25m raster dataset of Protected Area Adjacency Importance (see 13).
- Properties – 25m raster dataset of unique property identifiers (see 11).

Outputs:

- Contiguity – 25m raster dataset.

Geoprocessing:

- For each unique PAAdjImp value:
  - Get those ProtectedAreas with that PAAdjImp value.
  - Identify adjacent properties.
- Calculate Contiguity for each 25mX25m landscape cell within a Property as the maximum of the PAAdjImp value for all the protected areas that the Property is adjacent to.
- Normalize the values to ensure the maximum value is 1.

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4 Threat

The relative amount of Threat within each 25mX25m landscape cell.

Methods Summary

For this iteration of the model Threat values were assigned an importance based on Subdivision Potential Threat, Shore Adjacency Threat and Road Adjacency Threat all weighed equally. More potential threats such as proximity to views may be incorporated as data sets become available. This is a spatial component of Composition.

Data Processing Summary

Inputs (as per Figure 5):

- SubPotTht – 25m raster dataset of Subdivision Potential Threat (see 4.1).
- ShoreAdjTht – 25m raster dataset of Shore Adjacency Threat (see 4.2).
- RoadAdjTht – 25m raster dataset of Road Adjacency Threat (see 4.3).

Outputs:

- Threat – 25m raster dataset.

Geoprocessing:

- For each 25m cell, calculate the relative Threat as (SobPotThat X 0.34) + (ShoreAjdTht X 0.33) + (RoadAjdTht X 0.33).
- Normalize the values to ensure the maximum value is 1.

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4.1 Subdivision Potential Threat

The relative amount of Subdivision Potential Threat within each 25mX25m landscape cell.

Methods Summary

This threat is determined based on the size each property, the zone(s) with which it falls, and the minimum lot size for that zone. The result is a normalized measure of the relative number of lots per area that a property could be subdivided into.

Data Processing Summary

Inputs (as per Figure 5):

- CAD – vector dataset of property boundaries.
- Zoning – vector dataset of zones.
- MinLotSize – table of minimum allowed lot sizes for each zone on each island (too large to show here).

Outputs:

- SubPotThreat – 25m raster dataset.

Geoprocessing:

- Intersect Properties and Zones.
- Join to MinLotSize to determine the minimum lot size for each property/zone polygon.
- Calculate Area / MinLotSize.
  - If result is less than 2, set SubPot to 0.
  - Otherwise, set SubPot to result less 1 to account for existing property.
- Convert to raster and normalize so that maximum value is 1.
- For each 25m cell, calculate the relative Threat as (SubPotTht X 0.34) + (ShoreAjdTht X 0.33) + (RoadAjdTht X 0.33).
- Normalize the values to ensure the maximum value is 1.

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4.2 Shore Adjacency Threat

The relative amount of Shore Adjacency Threat within each 25mX25m landscape cell.

Methods Summary

This threat is based on the proximity of each property to the marine shoreline and the relative desirability of different shoreline habitat types. The result is a normalized measure of the relative threat to desirable shoreline from neighbouring properties.

Data Processing Summary

Inputs (as per Figure 5):

- ShorelineUnits – vector dataset of shoreline buffer.
- CAD – vector dataset of property boundaries.
- ShoreThreat – table of relative desirability of different shoreline habitat types, shown below.
- AdjacencyTolerance – maximum distance properties can be from shoreline to be considered for this type of threat.

REP_TYPE	REP_TYPE_N	THREAT
15	Channel	0.7
8	Gravel Flat	0.9

10	Sand Beach	1.0
13	Mud Flat	0.7
7	Gravel Beach	0.9
14	Estuary, Marsh or Lagoon	1.0
16	Man-made	0.5
6	Rock with Sand Beach	1.0
12	Sand Flat	1.0
2	Rock Platform	1.0
9	Sand and Gravel Beach	1.0
11	Sand and Gravel Flat	1.0
4	Rock with Gravel Beach	0.9
5	Rock, Sand and Gravel Beach	1.0
3	Rock Cliff	0.6
0	Unknown	0.5

Outputs:

- ShoreAdjThreat – 25m raster dataset.

Geoprocessing:

- Join ShorelineUnits to ShoreThreat to determine the relative threat for that section of shoreline.
- Add SHORE_ADJ_THT field to CAD.
- For each unique threat value:
    - Select ShorelineUnits with that threat value.
    - Select CAD properties within the AdjacencyTolerance distance of the ShorelineUnit.
    - Assign the SHORE_ADJ_THT field that threat value.
- Convert SHORE_ADJ_THT field to raster and normalize so that maximum value is 1.

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4.3 Road Adjacency Threat

The relative amount of Road Adjacency Threat within each 25mX25m landscape cell.

Methods Summary

This threat is based on the proximity of each property to roads and the class of each road segment. The result is a normalized measure of the relative threat to neighbouring properties from roads.

Data Processing Summary

Inputs (as per Figure 5):

- Roads – vector dataset of roads (see 10).
- RoadsThreat – table of relative threat by road class (based on hypothesized traffic levels), shown below
- CAD – vector dataset of property boundaries.
- AdjacencyTolerance – maximum distance properties can be from a road to be considered for this type of threat.

RD_CLASS	THREAT
other	1.00
collector	1.00
local	1.00
ramp	0.50
recreation	0.75
restricted	1.00
service	0.75
strata	1.00

Outputs:

- RoadAdjThreat – 25m raster dataset.

Geoprocessing:

- Join RoadsThreat to Roads to determine the relative threat to properties adjacent to each road segment.
- Add ROAD_ADJ_THT field to CAD and default to 0.
- For each unique threat value:
    - Select Roads with that threat value.
    - Select CAD properties within the AdjacencyTolerance distance of the Roads.
    - Assign the ROAD_ADJ_THT field that threat value.
- Convert ROAD_ADJ_THT field to raster and normalize so that maximum value is 1.

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5 Habitat Class N Locations and Percent Cover

The habitat data was classified into 61 habitat classes. The 61 habitat classes have been created from the Islands Trust Terrestrial Ecosystem Mapping (TEM) dataset based on the following table:

Map Code	Site Series	Map Class
CDFmmBE	non-veg	CDF_mm_BE
CDFmmCL	non-veg	CDF_mm_CL
CDFmmCS	14	CDF_mm_CS
CDFmmCW	9	CDF_mm_CW
CDFmmDA	2	CDF_mm_DA
CDFmmDG	4	CDF_mm_DG
CDFmmDO	3	CDF_mm_DO
CDFmmDS	1	CDF_mm_DS
CDFmmLA	non-veg	CDF_mm_FW_la
CDFmmPD	non-veg	CDF_mm_FW_pd

CDFmmFC	0	CDF_mm_HB
CDFmmLM	0	CDF_mm_HB_du
CDFmmLS	10	CDF_mm_LS
CDFmmMU	non-veg	CDF_mm_MU
CDFmmRC	11	CDF_mm_RC
CDFmmRF	6	CDF_mm_RF
CDFmmOR	0	CDF_mm_RI
CDFmmRK	5	CDF_mm_RK
CDFmmRO	non-veg	CDF_mm_RO
CDFmmRP	13	CDF_mm_RP
CDFmmRS	7	CDF_mm_RS
CDFmmRV	12	CDF_mm_RV
CDFmmGO	0	CDF_mm_WD_bd
CDFmmWf52		CDF_mm_WN_fn
CDFmmEm02	estuary	CDF_mm_WN_ms
CDFmmAS	0	CDF_mm_WN_sp
CDFmmOW	non-veg	CDF_mm_WN_sw
CDFmmEd01		CDF_mm_WN_wm
CWHvm2AB	1	CWH_AB
CWHvm2AF	5	CWH_AF
CWHvm2AS	7	CWH_AS
CWHxm1BE	non-veg	CWH_BE
CWHdmCD	9	CWH_CD
CWHxm1CL	non-veg	CWH_CL
CWHxm1CS	15	CWH_CS
CWHxm1CW	10	CWH_CW
CWHdmDC	2	CWH_DC
CWHdmDF	4	CWH_DF
CWHdmDS	3	CWH_DS
CWHdmLA	non-veg	CWH_FW_la
CWHxm1FC	0	CWH_HB
CWHdmHD	6	CWH_HD
CWHXM1HK	1	CWH_HK
CWHdmHM	1	CWH_HM
CWHvm2HS	3	CWH_HS
CWHvm2LC	2	CWH_LC
CWHdmLS	11	CWH_LS
CWHxm1MU	non-veg	CWH_MU
CWHxm1RB	13	CWH_RB
CWHdmRC	12	CWH_RC
CWHdmRF	7	CWH_RF

CWHdmRO	non-veg	CWH_RO
CWHdmRS	5	CWH_RS
CWHxm1RT	14	CWH_RT
CWHdmSC	0	CWH_SC
CWHxm1SS	8	CWH_SS
CWHxm1Wb50	wet	CWH_WN_bg
CWHxm1Wf51	wet	CWH_WN_fn
CWHxm1Ws50	wet	CWH_WN_sp
CWHdmOW	non-veg	CWH_WN_sw
CWHvm2YG	9	CWH_YG

Each location on the landscape can have up to three different habitat classes (primary, secondary, tertiary) with coverage always totalling 100%. Therefore, up to 3 of the 61 Habitat Class datasets can contain a value for a particular location/cell on the landscape. A script was written that made 61 different habitat layers. For each habitat layer, the estimated percent cover of that habitat was mapped for every location in the region.

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6 Naturalness

The relative importance of each 25mX25m landscape cell from a naturalness perspective. Naturalness is a measure of direct and indirect human impact, with more natural being less impacted.

Methods Summary

This model defines naturalness by taking into consideration Forest Degradation, Disturbance, Road Proximity, Housing Density and Browsing. Browsing is given a substantially lower weight because of the coarseness and uncertainty of this dataset. As the model moves forward more criteria, such as ATV use and invasive species, may be added. This is a spatial component of Composition.

Data Processing Summary

Inputs (as per Figure 5):

- ForestDeg – 25m raster dataset of Forest Degradation (see 6.1).
- Disturbance – 25m raster dataset of Disturbance (see 6.2).
- RoadProx – 25m raster dataset of Road Proximity (see 6.3).
- HousDensity – 25m raster dataset of Housing Density (see 6.4).
- Browsing – 25m raster dataset of vegetation Browsing (see 6.5).

Outputs:

- Naturalness – 25m raster dataset.

Geoprocessing:

- For each 25m cell, calculate the relative Naturalness as (Forest Degradation * 0.23) + (Disturbance * 0.23) + (Road Proximity * 0.23) + (Housing Density * 0.23) + (Browsing * 0.08).
- Reverse normalize the values so that more degradation/disturbance/proximity/density/browsing gets a lower Naturalness rating, and to ensure the maximum value is 1.

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6.1 Forest Degradation

The relative amount of Forest Degradation within each 25mX25m landscape cell.

Methods Summary

This is based on the structural stage of the forested habitat classes within each cell and an estimate of the degree of disturbance typically associated with those structural stages. The result is a normalized measure of the relative degradation of forested stands.

Data Processing Summary

Inputs (as per Figure 5):

- TEM – vector dataset of Terrestrial Ecosystem habitat types.
- ForestStandDegradation – table of relative degradation by structural stage, shown below.

STRCT	DISTURBANCE CLASS	DESC	DEGRADATION
0	L	None	1
1	L	Sparse/bryoid	1
2	L	Herb	1
3	L	Shrub/Herb	0.8
4		Pole/Sapling	0.6
5		Young Forest	0.4
6		Mature Forest	0
7		Old Forest	0

Outputs:

- ForestDeg – 25m raster dataset.

Geoprocessing:

- Add fields to TEM to hold the relative degradation and the percent cover for each of the primary, secondary and tertiary habitat types, and the total degradation.
- Join ForestStandDegradation to TEM to determine the relative degradation of each habitat type.
- Calculate the total degradation as:
  - (PercentCoverOfPrimaryHabitatClass X RelativeDegradationOfThatHabitatClass) + (PercentCoverOfSecondaryHabitatClass X RelativeDegradationOfThatHabitatClass) + (PercentCoverOfTertiaryHabitatClass X RelativeDegradationOfThatHabitatClass)
- Convert Total Degradation field to raster and normalize so that maximum value is 1.

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6.2 Disturbance

The relative amount of Disturbance (human impact) within each 25mX25m landscape cell.

Methods Summary

This is based on the anthropogenic land-cover types as defined by TEM and ITEM. The result is a normalized measure of the relative ecosystem disturbance.

Data Processing Summary

Inputs (as per Figure 5):

- TEM – vector dataset of Terrestrial Ecosystem habitat types.
- TEMDisturbance – table of relative disturbance of each habitat type, shown below.
- ITEM – older vector dataset of Terrestrial Ecosystem habitat types.
- ITEMDisturbance – table of relative disturbance of each habitat type, shown below.

Relative disturbance level of each TEMDisturbance habitat type.

DIST_CLASS	DESCRIPTION	DISTURBANCE
BA	N/A	1
BK	Breakwater	1
CB	Cutbank	1
CO	Cultivated orchard	0.6
CV	Cultivated Vineyard	0.6
ES	Exposed soil	1
GC	Golf course	0.6
GP	Gravel pit	1
IN	Industrial	1
RE	Reservoir	0.8
RW	Rural residential	0.6
RZ	Road surface	1
UR	Urban	1

Relative disturbance level of each ITEMDisturbance habitat type.

CLASS_DESC	SUBCLASS	SUBCLASS_D	DIST_CLASS	DISTURBANCE
Agriculture	Cf	cultivated field	AGcf	0.5
Agriculture	Co	cultivated orchard	AGco	0.5
Agriculture	Cv	cultivated vineyard	AGcv	0.5
Developed	Ca	canal	DPca	0.8

Developed	Es	exposed soils	DPes	1
Developed	Gp	gravel pit	DPgp	1
Developed	Lq	unrestored landfills and quarries	DPlq	1
Developed	Rz	road surface	DPrz	1
Developed	Sz	developed/occupied foreshore	DPsz	1
Developed	Uc	utility corridor	DPuc	0.6
Developed	Ur	urban/suburban	DPur	1
Rural	Gc	golf course	RWgc	0.6
Rural	Pk	park	RWpk	0.4
Rural	Rr	rural residence	RWrr	0.6
Rural	Se	rural residence	RWse	0.6

Outputs:

- Disturbance – 25m raster dataset.

Geoprocessing:

- For TEM:
    - Add fields to hold the relative disturbance and the percent cover for each of the primary, secondary and tertiary habitat types, and the total disturbance.
    - Join TEMDisturbance to TEM to determine the relative disturbance of each habitat type.
    - Calculate the total degradation as:
        - (PercentCoverOfPrimaryHabitatClass X RelativeDisturbanceOfThatHabitatClass) + (PercentCoverOfSecondaryHabitatClass X RelativeDisturbanceOfThatHabitatClass) + (PercentCoverOfTertiaryHabitatClass X RelativeDisturbanceOfThatHabitatClass)
    - Convert total disturbance field to raster and normalize so that maximum value is 1.
- For ITEM:
    - Add field to hold the relative disturbance.
    - Join ITEMDisturbance to ITEM to determine the relative disturbance of each habitat type.
    - Convert total disturbance field to raster and normalize so that maximum value is 1.
- Combine TEM and ITEM disturbance by using the ITEM disturbance for locations where TEM did not indicate any disturbance.

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6.3 Road Proximity

The relative proximity to roads, weighted by the level of threat associated with each road class.

Methods Summary

Road proximity is created outside the core model using the Environmental Risk Surface (ERS) module of TNC's protected area tools. It uses a convex distance decay function weighted by the threat (see 4.3 for relative threat values) associated with each road class.

Data Processing Summary

Inputs (as per Figure 5):

- TRANSPORTATION_ROADS_MOT – vector dataset of road segments (see 10).

ERS Settings
- Output Cell Size: 25 (m)
- Intensity: ROADS_THT
- Influence Distance: 1500 (m)
- Decay Type: Convex

Outputs:
- roadsprox – 25m raster dataset.

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6.4 Housing Density

The relative Housing Density within each 25mX25m landscape cell.

Methods Summary
This is calculated as the number of improved properties per hectare.

Data Processing Summary
Inputs (as per Figure 5):
- CAD – vector dataset of property boundaries.

Outputs:
- HousDensity – 25m raster dataset.

Geoprocessing:
- Select properties with an Improvement Value greater than 0.
- Convert those properties to points at the centroid of the property polygon.
- Calculate the point density per hectare.
- Convert the density value raster and normalize so that maximum value is 1.

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6.5 Browsing

The estimated relative severity of vegetation browsing by wildlife and free-range domesticated animals.

Methods Summary

Islands within the Islands Trust Area were assigned estimated importance values based on regional and island specific knowledge of vegetation browsing pressures. Although the precision of this dataset is limited, it was decided that the approximate importance values were need to represent this growing threat to biodiversity with the Trust Area.

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7 Protected Area Importance

The relative importance of each protected area, based on its shape, size and International Union for the Conservation of Nature (IUCN) classification.

Methods Summary

Terrestrial protected areas in the Islands Trust Area were classified according to the International Union for the Conservation of Nature (IUCN) protected areas classification. They were then given an importance factor based on their shape and their IUCN class. It is assumed that, all other factors being equal, protected areas are more valuable when:

a) they have a more restricted uses (e.g. more restrictive IUCN class); and,
b) they are large and have a higher area to perimeter ratio (e.g. round vs. long and skinny)

Data Processing Summary

Inputs (as per Figure 5):

- ProtAreaShape – 25m raster dataset of Protected Area Shape importance (see 7.1).
- IUCNClass – 25m raster dataset of protected area IUCN Classification importance (see 7.2).

Outputs:

- ProtAreaImp – 25m raster dataset.

Geoprocessing:

- For each 25m cell, calculate the relative Protected Area Importance as (ProtAreaShape X 0.5) + (IUCNClass X 0.5).
- Normalize the values to ensure the maximum value is 1.

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7.1 Protected Area Shape

The relative importance of each protected area, based on its area/perimeter ratio and size.

Methods Summary

Protected area shape was assigned an importance based on area to perimeter ratio and size of the protected area. Overall size was weighted at 0.8, while area to perimeter ratio was weighted at 0.2 because of the high number of small protected areas with low area to perimeter ratios within the Islands Trust Area.

Data Processing Summary

Inputs (as per Figure 5):

- ProtAreaRatio – 25m raster dataset of the relative magnitude of the Area/Perimeter Ratio of each protected area (see 7.1.1).
- ProtAreaSize – 25m raster dataset of the relative Protected Area Size (see 7.1.2).

Outputs:

- ProtAreaShape – 25m raster dataset.

Geoprocessing:

- For each 25m cell, calculate the relative Protected Area Shape importance as (ProtAreaRatio X 0.2) + (ProtAreaSize X 0.8).
- Normalize the values to ensure the maximum value is 1.

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7.1.1 Area/Perimeter Ratio

The relative magnitude of the ratios of each protected area's size to its boundary length, also known as compactness. Generally speaking, more compact areas make more efficient use of space.

Methods Summary

All factors being equal, more compact areas are less impacted by edge effect and therefore have higher biodiversity values. Consequently, protected areas with higher area to perimeter ratios were deemed to be more valuable as representative habitat than those with low ratios.

Data Processing Summary

Inputs (as per Figure 5):

- PROTECTED_AREAS_DISSOLVED – vector dataset of Protected Area polygons, dissolved to eliminate rights-of-way and other breaks that are not ecologically significant (see 15).

Outputs:

- ProtAreaRatio – 25m raster dataset.

Geoprocessing:

- For each protected area polygon calculate ShapeArea / ShapeLength.
- Normalize the values so that the maximum value is 1.
- Convert the values to raster.

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7.1.2 Protected Area Size

The relative size of each protected area.

Methods Summary

All factors being equal, larger protected areas are assumed to be more valuable than smaller protected areas for protecting representative ecosystems.

Data Processing Summary

Inputs (as per Figure 5):

- PROTECTED_AREAS_DISSOLVED – vector dataset of Protected Area polygons, dissolved to eliminate rights-of-way and other breaks that are not ecologically significant (see 15).

Outputs:

- ProtAreaSize – 25m raster dataset.

Geoprocessing:

- Determine the size of the largest protected area.
- For each protected area polygon calculate the Size / SizeOfLargestProtectedArea.
- Re-normalize the values so that the smallest protected area becomes 0.75 and the largest becomes 1.
- Convert the values to raster.

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7.2 IUCN Classification

The relative importance of each protected area, based on its IUCN Designation.

Methods Summary

The IUCN protected area classes classify protected areas according to restrictions on area usage. Science Nature Reserves and Wilderness Areas are considered to be the most highly conserved. This analysis assumes that protected areas with more restrictions have a higher conservation value over the long term. IUCN classes were assigned importance ratings as indicated in the table below.

Data Processing Summary

Inputs (as per Figure 5):

- PROTECTED_AREAS_DISSOLVED – vector dataset of Protected Area polygons, dissolved to eliminate rights-of-way and other breaks that are not ecologically significant (see 15).
- IUCNImportance Table, as follows

IUCNDesignation	Relative Importance
Science Nature Reserve	1
Wilderness Area	1
Park	0.9
Natural Monument	0.75
Habitat/Species Management Area	0.65
Protected Landscapes/Seascapes	0.6
Managed Resource Protected Areas	0.5

Outputs:

- IUCNClass – 25m raster dataset.

Geoprocessing:

- Join PROTECTED_AREAS_DISSOLVED to IUCNImportance on the IUCNDesignation field.
- Assign the RelativeImportance from the IUCNImportance table.
- Convert the values to raster.

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8 TEM

Terrestrial Ecosystem Mapping (TEM) that was completed for the Islands Trust Area in 2007-2009 (B.A. Blackwell and Associates Ltd., October 31, 2007 and Madrone Environmental Services, April 16, 2008, June 21, 2008 & 2009). TEM is a mapping methodology created by the Province of British Columbia to describe terrestrial ecosystems found in British Columbia (see http://www.env.gov.bc.ca/ecology/tem/manuals.html for TEM standards). It includes:

1. Interpretation of terrestrial ecosystems from aerial photography based on:
    a. Climate
    b. Topography and aspect
    c. Surface material
    d. Vegetation
    e. Soil
    f. Geology
2. Minimum field checking (groundtruthing) requirements; and
3. Third part quality assurance standards.

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9 ITEM

The Islands Trust Ecosystem Mapping (ITEM) classification standards were developed with assistance of BC Ministry of Environment and the BC Conservation Data Centre and the classification scheme was loosely based on the Sensitive Ecosystems Inventory (SEI) classes and Terrestrial Ecosystem Mapping (TEM) Standards. ITEM only has a vegetation component (i.e. no terrain component was mapped).

ITEM was done to a finer scale (1:5,000 to 1:16,000) than TEM resulting in more numerous and smaller polygons. ITEM is used by planners as the scale is especially important when defining home sites. It is also helpful in locating smaller habitats like wetlands and herbaceous areas.

ITEM was not groundtruthed, but on a few of the islands, namely Galiano and Salt Spring Island, site inspections have been done by the local conservancies. It also includes island-specific reports and data.

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10 Roads

The BC Digital Road Atlas (DRA) is a province wide roads vector dataset, which is administered by the Crown Registries and Geographic Base (CRGB) branch on behalf of the DRA Partnership. The DRA Partnership is comprised of public agencies, such as the Islands Trust, that require road network data. A private data provider, currently GIS Innovations (GISI), is contracted to maintain the demographic road network and its associated attributes.

The Islands Trust receives a monthly DRA update, which is maintained as TRANSPORTATION_ROADS_MOT.

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11 Properties

The vector dataset of property boundaries was developed and is maintained by the Islands Trust. Property boundaries positional accuracy and data standards are modeled after those described by the Integrated Cadastral Information Society (ICIS), with horizontal positional accuracy levels of 1 to 2 metres where possible.

Data Processing Summary

Inputs (as per Figure 5):

- CAD – vector dataset of Properties with PIDs (Property IDs).
- PropertyValues table (see 12).
- ActualValues table (see 12).

Outputs:

- ScenarioOutput – vector dataset of Properties with a new TotalValue field for each property.
- Properties – 25m raster dataset of unique ObjectIDs.

Geoprocessing:

- Join PropertyValues to CAD on the PID field.
- Assign TotalValue from the PropertyValues table.
- Join ActualValues to CAD on the PID field.
- Assign ActualValue from the ActualValues table.
- Copy CAD to ScenarioOutput.
- Convert CAD to raster on ObjectID.

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12 Property Values

A Property Values table containing a PID (Property ID), Land Value, Improvement Value and Total Value for each property as obtained from the BC Assessment Authority

An Actual Values table containing a PID (Property ID) and Actual Value for each property.

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13 Projected Area Adjacency Importance

This criterion is the relative importance of each candidate site from the perspective of adding to the pre-existing reserves. Candidate sites that are adjacent to existing reserves are more important, all else being equal, then sites that are not contiguous. Also, the relative size of the reserve is considered. With current parameter settings, sites that add to small or large reserves are more important than sites that add to medium reserves. Adding to small reserves is important because in theory, this dramatically increases the number of species that can survive on that reserve (this is because the standard species area curve is exponential). Sites that ad to the really large reserves are important because really large reserves have the highest chance of maintaining large carnivores, and hence, a complete food web.

Methods Summary

It is assumed that, all other factors being equal, lands adjacent to protected areas are more valuable if:

a) they have a more restrictive IUCN class; and,
b) they are adjacent to medium-large protected areas (as per the parameter values in the table of item 14).

Data Processing Summary

Inputs (as per Figure 5):

- IUCN_IMP field of PROTECTED_AREAS_DISSOLVED – vector dataset of Protected Area polygons, dissolved to eliminate rights-of-way and other breaks that are not ecologically significant (see 15).
- SizeClass field of PROTECTED_AREAS_DISSOLVED – vector dataset of Protected Area polygons, dissolved to eliminate rights-of-way and other breaks that are not ecologically significant (see 15).

Outputs:

- AdjImp field of PROTECTED_AREAS_DISSOLVED.

Geoprocessing:

- Add field AdjImp field to PROTECTED_AREAS_DISSOLVED.
- Calculate AdjImp = IUCN_IMP X SizeClass.
- Normalize the values so that the maximum value is 1.
- Convert the values to raster.

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14 Protected Area Size Class

As per section 5, the task at hand is to identify the relative value of conserving a property that is adjacent to one reserve size versus another, all else being equal.

Methods Summary

It is assumed that, all other factors being equal, a large protected area has more ecological value than a several small protected areas with the same total area. This “single large versus several small” reserves (SLOSS) debate raged in the conservation science in the 1990s. In general, the benefits of a larger area are less edge effects from invasives and other degrading forces, and the large areas allow larger carnivores, thereby allowing a more robust food web. That said, adding 10000 ha to a 1000 ha reserve will dramatically increase the number of species the reserve could harbour, as per the species area curve (Davis et al. 2006). The fact that the study area is comprised of islands, thereby disallowing very large reserves usable by mega-carnivores, added to the complexity. By considering these two opposing considerations, the maximum reserve size, and by looking at the species present on the islands, we arrived at the size classes and values of the following table. In short, the medium sized reserves (858 K ha – 2820 K ha) were the ones that we concluded to be of the most importance to add additional, contiguous reserves.
To capture the importance of the small sized protected areas eventually becoming medium reserves, the relative importance ranking did not go down to zero for its lowest ranking but rather 0.25.

Data Processing Summary

Inputs (as per Figure 5):

- PROTECTED_AREAS_DISSOLVED – vector dataset of Protected Area polygons, dissolved to eliminate rights-of-way and other breaks that are not ecologically significant (see 15).
- ProtAreaSizeImportance table, as follows:

SizeStart	SizeEnd	Importance
0.000000	50000.000000	0.25
50000.000001	858000.000000	0.875
858000.000001	2820000.000000	1
2820000.000001	6840000.000000	0.75
6840000.000001	999999999.000000	0.5

Outputs:

- SizeClass field of PROTECTED_AREAS_DISSOLVED.

Geoprocessing:

- Add SizeClass field to PROTECTED_AREAS_DISSOLVED.
- Assign the RelativeImportance from the ProtAreaSizeImportance table to SizeClass based on the size ranges.

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15 Protected Areas

Vector dataset of Protected Area polygons, dissolved to eliminate rights-of-way and other breaks that are not ecologically significant. (In other words, if a road goes through the middle of the reserve, it does not make two reserves, but rather, we assume that it is one reserve that has some disturbance within its boundaries. The resulting reserve is the one used for protected area size calculations, etc.)

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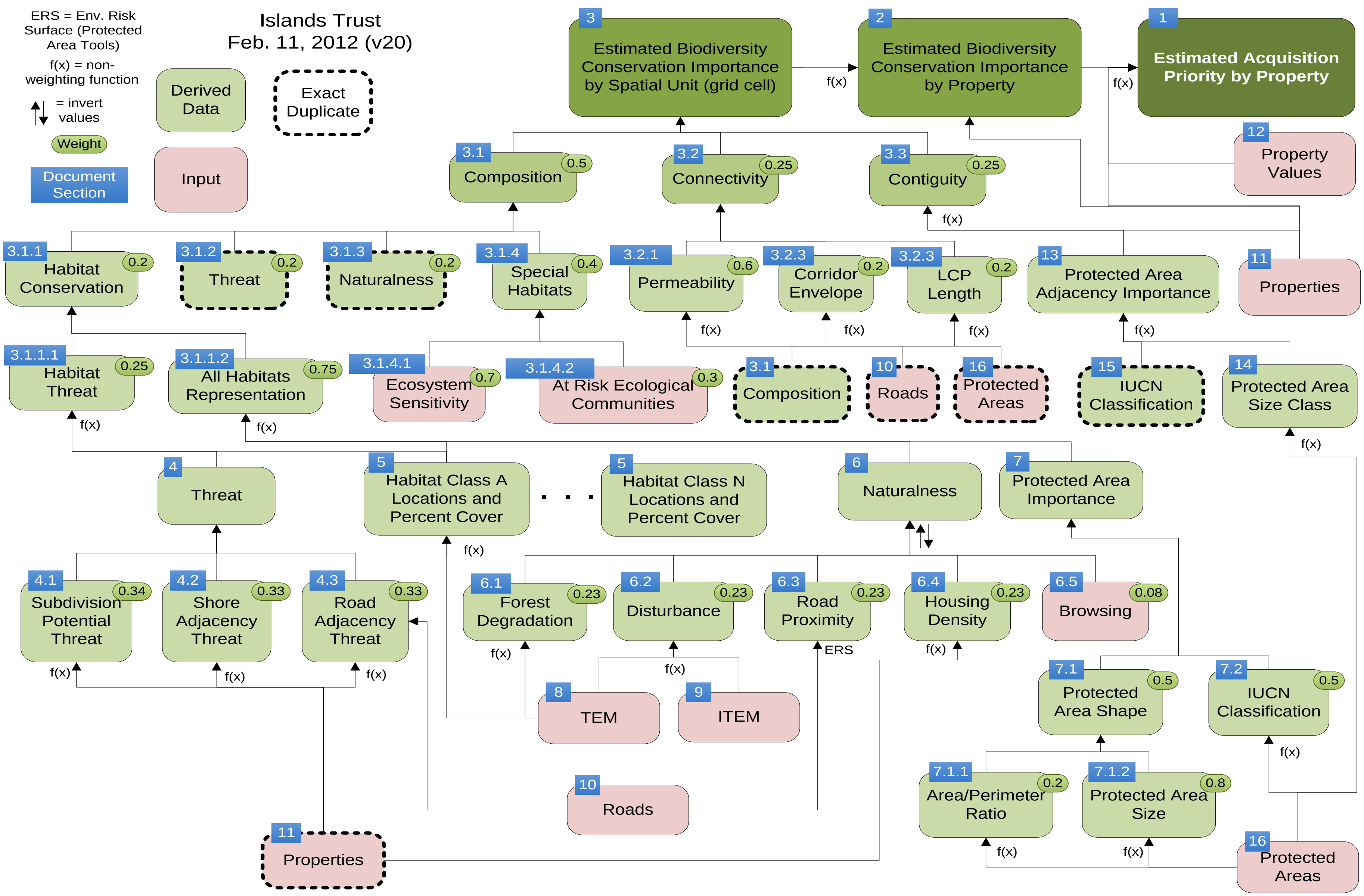

Figure 7: Full page copy of entire methodology hierarchy