Digital Data Standards for Species Distribution Modeling

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Preface

Species distribution modeling is a fundamental component of our knowledge of a species. Distribution or range maps can be used for such purposes as inventory, environmental assessments, land-use planning, scientific knowledge, and documenting First Nations traditional ecological knowledge. Such maps are crucial for assessing biodiversity throughout British Columbia because available observation data are often found along road networks and in areas of the province with high human density. Hence, there are areas of the province where species may be present that have not been adequately surveyed. If species data consist only of the available observation data, assessments will be biased toward areas that have been surveyed, and methods are required to identify the complete distribution of species.

Executive Summary

Most species distributions are presented as a range map, which is usually based on a broad polygon surrounding the known observation locations of an element, or as a dot map, which is simply a plot of the known observation points (Beauvais et al. 2004). Range maps may be somewhat subjective in how the polygon is delineated and usually cannot identify unoccupied areas within the larger range (Beauvais et al. 2004). A dot map is an assemblage of documented observations, which may represent only a fraction of the species' actual distribution (Fertig and Reiners 2002). Species distributions based solely on dot maps are usually somewhat biased in that they tend to illustrate the distribution of sampling effort (Beutel et al. 1999; Vaughan and Ormerod 2003). Furthermore, changes to an area over time can result in the exclusion of a species from a historically recorded location.

A model can be used to predict the distribution of a species. The model can reduce the oversimplification of data in range maps and increase the contribution of data from dot maps. Deductive models apply expert knowledge on species–habitat relationships and distribution barriers to spatial representations of habitat attributes such as topography, current vegetation, or ecosystems. Inductive element distribution models perform a quantitative analysis of multiple environmental factors at known observation points for a species within a study area to predict range boundaries, together with variations in species occupation within the boundaries (Beauvais et al. 2004). The term "element distribution model" is basically synonymous with predictive range model, species distribution model, climatic envelope model, ecological niche model, and predictive range model (Beauvais et al. 2004). An element can be any ecological unit such as a species, subspecies, plant variety, community, or ecosystem (Beauvais et al. 2004). This document focuses on the distribution of organisms because the distribution of communities and ecosystems are adequately handled by existing standards and data systems.

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The Government of British Columbia provides funding of the Resources Information Standards Committee work, including the preparation of this document. The Resources Information Standards Committee supports the effective, timely and integrated use of land and resource information for planning and decision making by developing and delivering focused, cost-effective, common provincial standards and procedures for information collection, management and analysis. Representatives to the Committee and its Task Forces are drawn from the ministries and agencies of the Canadian and the British Columbia governments, including academic, industry and First Nations involvement.

The Resources Information Standards Committee evolved from the Resources Inventory Committee which received funding from the Canada-British Columbia Partnership Agreement of Forest Resource Development (FRDA II), the Corporate Resource Inventory Initiative (CRII) and by Forest Renewal BC (FRBC), and addressed concerns of the 1991 Forest Resources Commission.

For further information about the Resources Information Standards Committee, please access the RISC website at: http://ilmbwww.gov.bc.ca/risc/index.htm

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The report was prepared following a workshop session held February 6 and 7, 2006. The workshop established the terms of reference, specifications, scope, and potential data sources for the standards.

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1.0 INTRODUCTION

Distribution modeling is a process that predicts the suitability of different environments within a study area for occupation by particular species. Most modeling techniques are based on deductive modeling, which is based largely on expert knowledge, or on inductive modeling, which uses the relationship between observations of species and spatial predictors, or on a combination of deductive and inductive approaches.

An example of deductive modeling is habitat capability and suitability mapping (see Wildlife Habitat Ratings, www.env.gov.bc.ca/wildlife/whr/index.html) as practiced in British Columbia. This method predicts potential distribution, but does not address the likelihood that habitats are occupied. An example of the inductive approach is NatureServe's Element Distribution Modeling (EDM) system. Element distribution models use existing observation data to empirically describe the relationship between the observations and environmental data (Beauvais et al. 2004). Both habitat capability and suitability mapping and the EDM system are static, in that there are no temporal considerations in the relationship between the species and its environment, and causal factors are not identified (Fertig and Reiners 2002; Beauvais et al. 2004). Therefore, these models are not suitable for predicting shifts in species distributions with climate or biotic variables (Fertig and Reiners 2002). Habitat supply modeling is another type of distribution model that builds on predictions of the state of past and future habitats to portray the suitability of habitats over time.

Distribution modeling involves three key components: (1) gathering and modeling species and environmental data, (2) mapping, and (3) evaluating / validating (Beauvais et al. 2004; Rushton et al. 2004). The first component involves summarizing and preparing data on the geographic pattern of element occurrence that defines suitable (with gradations if possible) versus unsuitable environments (Beauvais et al. 2004; Guisan and Thuiller 2005). The second component of species distribution modeling is to apply the model to a spatial map using a Geographic Information System (GIS). The resulting maps represent predictions with inherent uncertainty, which is revealed and documented during the modeling process. The third component involves evaluating the mapped predictions along with its uncertainty. All three components of species distribution modeling are necessary to develop a defensible model and map for resource management purposes.

See Appendix 1 for a comparison of some possible distribution models and their features. Further information on species distribution models can be found in Warman's (2006) summary paper for Ecocat: The Ecological Reports Catalogue.

1.1 Objectives

The objectives of the digital data standards for species distribution modeling are:

1. To ensure delivery of species distribution information in a standard form that allows for merging, integrating, comparing, or interpreting multiple datasets.

2. To ensure that documentation and metadata are sufficient to evaluate the reliability of the species distribution product.

3. To effectively manage changes to the standards. The standards will be subject to a change management procedure that incorporates an impact analysis of proposed changes. In keeping with this objective, this document provides background discussion, guidelines and standards, and rationales for the guidelines or standards presented.

1.2 Scope

These digital data standards for species distribution modeling using deductive and inductive approaches are applicable to all terrestrial and freshwater environments in British Columbia, but marine environments are beyond their scope. The project can be a smaller unit within the province, encompassing the distribution of a species within a given management unit, or can cover the distribution of a species within the province as a whole. If a project extends beyond British Columbia’s borders, these methods should be used as guidelines, not standards.

The standards pertain to both native and non-native species (e.g., plants, mammals, fish, insects, etc.) and populations. Entities such as ecosystems or habitat features (soil, terrain) are more appropriately mapped using other existing standards; for example, refer to Predictive Ecosystem Mapping (PEM; Terrestrial Ecosystem Mapping Alternatives Task Force 1999) or Broad Ecosystem Inventory (BEI; Ecosystems Working Group/Terrestrial Ecosystems Task Force 1998).

Relevant scales range from 1:20,000 to 1:2,000,000 (digital atlas scales). Timeframes included are historic, current, and potential (scenario-based, modeled) future.

1.3 Principles

The standards will attempt to conform to the following principles.

1.3.1 Professional Accountability

The intended audience for this document is distribution-modeling practitioners. The standards require that practitioners, or the leader of a team of practitioners, be members of a professional society who are bound by a professional code of practices that will be applied to the delivery of distribution modeling projects.

1.3.2 Software Independence

Where possible, the standards will be independent of proprietary software or proprietary software constructs. If the custodian for distribution modeling requires data in a vendor-dependent format or construct, the standards will specify either the form or a vendor-independent format that the BC Ministry of Environment system will accept.

1.3.3 Procedure Independence

The standards will be independent of procedures. However, in some cases the standards will require that a specific procedure, one of a set of specific procedures, or a procedure meeting a minimum set of criteria be followed. For example, the standards require that accuracy be estimated and documented. Rather than requiring a specific procedure, the standards require one of a number of procedures set out in an accompanying document (Meidinger 1999). In other cases, the standards require documentation of a procedure. The documentation may be a reference to an existing and publicly available document or a document appended to the species distribution map submission. Documentation must be sufficient for a qualified distribution-modeling practitioner to replicate and evaluate the procedure.

1.3.4 Conformity with Existing, Related Standards and Policies

Wherever possible, distribution modeling projects will conform to and use existing Resources Information Standards Committee (RISC) standards by reference or attachment to existing standards rather than creating new standards that require correlation or reconciliation.

The distribution-modeling practitioner should contact the Wildlife Habitat Ratings technical contact at [WHR_Mail ENV:EX] to discuss existing related data policies.

1.3.5 Development of New Standards

It is anticipated that new modeling and analysis techniques currently under development will be adopted as analysis standards. Traditional ecological knowledge standards and guidelines may be developed in collaboration with First Nations representatives.

1.4 Roles and Responsibilities

The distribution modeling process involves four main participants: the custodian, a funding agent(s), a proponent, and a practitioner. The custodian manages the standards to be applied to the project and is responsible for receiving, storing, and providing access to the data on completion. The proponent develops the project, sets the project specifications, determines the practitioner, and can either fund the project or obtain funding from another source. The proponent is ultimately responsible for delivering the data to the custodian. The funding agency allocates and audits the proponent(s). The practitioner compiles or models the species distribution data, provides qualified professional signoff, and delivers the final product to the proponent(s).

2.0 DOCUMENTATION STANDARDS

2.1 Considerations

Inductive species distribution modeling requires two types of data: (1) observation data, or the known occurrence locations of a species, and (2) georeferenced environmental data about the study area.

For deductive modeling approaches, the species account captures the expert knowledge of species–habitat relationships and the expression of those relationships in terms of available environmental data.

2.1.1 Observation Data

For the project report, document the steps taken for data preparation, the data sources, the filters, and thresholds that were applied to the datasets (e.g., observer, date, taxa, source, and accuracy), and the processing parameters. For example, if the observation dates were used as a filter, list the range of dates used.

2.1.2 Georeferenced Environmental Data

For georeferenced environmental data, including ecosystem information, list the predictor variables and associated metadata used to build the model or algorithm.

2.2 Assessment of Accuracy

The intent of these standards is to ensure that procedures are documented in enough detail that a distribution-modeling practitioner can evaluate the quality of a distribution map. The intent is also to compile sufficient data to create more rigorous quality control standards in the future. It is also important to determine the thematic and spatial accuracies for inputs and to provide measurement units with confidence intervals.

Refer to parameters of existing standards where available, for example, Vegetation Resource Inventory (VRI) [http://www.for.gov.bc.ca/hts/vridata/standards/index.html].

Quality control consists of two parts: (1) Rigorous, well-documented procedures that, if followed, will produce consistently acceptable results. (2) Assurance that the procedures have been implemented. An objective of these initial standards is to ensure that sufficient background documentation is assembled to support procedural standards for the following distribution modeling processes:

1. Assessing the quality of existing inputs.

2. Preparing and compiling the input database.

3. Validating the model logic (for deductive models).

4. Implementing the model logic against the input data (for deductive models).

To support this objective, the documentation section of the standards (Section 2.4) ensures that documentation of distribution modeling procedures is sufficient for consistent replication and monitoring of the procedure.

2.3 Modeling and Analysis Overview

2.3.1 Analysis Method

Procedures for developing the GIS component of the model:

- Choose between a raster (e.g., Hectares BC) or a vector analysis environment, depending on available resources, the desired result, and storage capabilities.

- Determine the grain/grid size or raster data resolution (if applicable).

- Determine the appropriate data resolution.

- Describe the scale for all the inputs, which affects the resulting outputs.

- Choose from a deductive or an inductive model, or a combination of both.

- Select the modeling technique(s) and software application(s).

2.3.2 Inputs

Procedures for developing the biological component of the model:

- Obtain observation and environmental data, then assemble, screen, and georeference the data to the standard scale and projection outlined in Section 3.4.

- If appropriate, link to existing products in the Land and Resource Data Warehouse (LRDW), such as the Biogeoclimatic Ecosystem Classification, the BC Watershed Atlas, Hectares BC, etc.

- Establish attributes used within a dataset (continuous, classed, or nominal). Within the attributes, define the classes (e.g., slope: low, med, high).

- For a deductive model, evaluate existing habitat capability and suitability information (optional).

- Evaluate or develop species–habitat relationships (required), such as species accounts, Bayesian belief network (BBN), etc.

2.4 Documentation and Metadata

These standards establish the minimum levels of documentation and metadata required to permit third-party evaluation of the quality of input data, predictive procedures, and output products of a distribution map. The metadata specified below meet three needs:

1. They provide sufficient information about the nature of the input entities, input data, predictive procedures, and output products for a user to understand the limitations of these items for distribution modeling applications.

2. Their compilation by the distribution-modeling practitioner ensures that the practitioner has researched the input data and adequately documented the procedures and output products.

3. A longer-term goal of the standards is the eventual integration of species distribution mapping data, information, and knowledge into a single logical data model and repository.

2.4.1 Project Details and Report

For the distribution modeling project summary, the metadata identified below are required and should be submitted as a text document.

Provide the following information in the project summary report:

[1]. **Project area –** Province, watershed, ecosection, First Nations traditional territory, etc.

[2]. **Area/size** – Provide units.

[3]. **Entity** – Population, subspecies, species, species group, and authority.

[4]. **Management objectives** – e.g., recovery planning, or ecological restoration.

[5]. **Funding sources and initiatives**

[6]. **Report** – Citation

[7]. **Personnel** – Include credentials.

[8]. **Disclaimer** – Provide a description of the limits of appropriate use for the inputs, model and outputs.

2.4.2 Model Inputs

The intent of the metadata presented below is to document distribution modeling input in enough detail for a qualified distribution-modeling practitioner to evaluate the quality of both the input data and the distribution modeling products. For a more detailed discussion of the interpretation of metadata, see *A problem analysis on data quality assessment issues* (Moon 1999).

Most of the metadata listed below require reference to a definition or procedure. If the reference is in published form, the citation is sufficient. If the reference is not in published form, the standards require appended documentation of the definition or procedure. For the completed processing and filtering, provide a description of the available data, rationale, and decisions.

For each thematic input data source used in the distribution modeling project, the metadata identified below are required and should be submitted as a text document.

Provide the following information for each of the project's <u>location</u> input data source(s):

[9]. **Input type(s)** – List the type of each location input (e.g., point location/observation data, radiotelemetry data, occurrence data, expert knowledge, existing distribution data, etc.).

[10]. **Citation of the source** – Specify reference(s) to formal, published source(s) of the data, if available, also include the version number if it was downloaded from an Internet source.

[11]. **Consultant/department** – Specify the public or private sector organization(s) responsible for collecting, compiling, and maintaining the data and an appropriate contact within the organization(s).

[12]. **Publication scale** – Specify the original scale of the input data.

[13]. **Period of compilation** – Where possible, specify the date range during which the data were compiled. This can be cross referenced with the observer to determine the reliability of the data.

[14]. **Format** – of original dataset.

[15]. **Preparation –** i.e., the steps taken to prepare each of the input data sources and filters used.

[16]. **Modified inputs** – Describe if the inputs have been modified from warehouse or archived versions and send suggested improvements back to the original custodian for potential revision of the standards.

[17]. **Assumptions**

[18]. **Scenario** – for predictions of future distributions.

Provide the following information for the <u>base map</u> or <u>predictor variables</u> input data source:

[19]. **Predictors** – List the type of each predictor. Some examples are Digital Elevation Model derivatives, other TRIM derivatives, climate surfaces, Forest Cover, Ecoregion Classification System, Biogeoclimatic Ecosystem Classification (BEC), distribution information for predators, competitors for prey or forage, etc.

[20]. **Projection –** Specify the original projection used.

[21]. **Date or version –** The publication date or version of the base map.

[22]. **NAD (North American Datum) version** – 27 or 83.

[23]. **Scale** – of all the predictor variables.

2.4.3 Models and Analysis

Provide the following information about the modeling technique and analyses performed:

[24]. **Modeling tool** – List name, version, copyright, capacity, requirements, and settings (grid size and shape, scale, origin coordinates).

[25]. **Raster or vector** – State which was used.

[26]. **Resolution**

[27]. **Modeling method** – Describe the modeling approach or reference a published account.

[28]. **Additional analysis tool** (if applicable) – Name, version, copyright, statistical test, and capacity (power).

[29]. **Confidence level**

[30]. **Assumptions**

2.4.4 Model Outputs

Provide the following information for the project's output data:

[31]. **Scale** – Include both the output and presentation scales.

[32]. **Database** – See Section 3.0 for acceptable formats.

[33]. **Season represented** – e.g., Winter range, breeding, etc.

[34]. **Timeframe** – The time that the projection represents: historical, or scenario-based future. Describe in years.

[35]. **Accuracy** – Of the model outputs.

[36]. **Legend** – Expanded.

[37]. **Storage** – Size, requirements, and source of storage.

2.4.5 Model Evaluation

Evaluation of the model involves the steps listed below. Include a description of the following procedures:

[38]. **Verification** – List the procedure(s) followed to verify the model.

[39]. **Peer review** – List how the model was reviewed and by whom.

[40]. **Accuracy assessment** – See Section 2.2.

[41]. **Qualified professional signoff** – List the names and credentials of the professional(s) signing off on the project.

[42]. **Commission and omission errors** (if applicable) – List all errors of commission and omission.

[43]. **Confusion table/matrix** – Provide a confusion matrix if applicable.

[44]. **Appropriate / intended usage**

2.5 Data Delivery

The final procedure is to deliver the resultant data product and report by submitting data to the custodian via email to the Wildlife Habitat Ratings custodian [WHR_Mail ENV:EX]. Include the format of the files and all documentation as outlined in Section 3.0.

The three components of the project to be delivered to the custodian are:

1. The final report, including the project metadata (see Section 2.4.1).
2. The source observation coverage.
3. The polygon coverage or raster product illustrating the predicted distribution.

All project data must conform to the technical data standards outlined in Sections 3.0 and 4.0.

3.0 TECHNICAL DATA STANDARDS

3.1 Purpose, Scope, and Intended Use

This section describes the specifications for species distribution data, with a focus on spatial data collected for use in Geographic Information Systems (GIS). These specifications are part of a series of related documents produced by the Resources Information Standards Committee (RISC) that are intended to ensure that BC government agencies are providing resource information that meets recognized standards for quality and consistency. The information in this document is expected to be useful to contractors or staff involved in collecting resource inventory data, managers charged with overseeing data-collection projects, custodians maintaining resource inventory datasets, and end-users seeking to apply resource inventory data to resource management and land-use issues.

Purpose of the Standards

The purpose of this document is to define the digital form and structure of species distribution digital data as managed by the BC Ministry of Environment. It defines:

- Standards for describing thematic content
- Standards for physical data specification
- Georeferencing standards, and
- Quality assurance guidelines.

These standards are introduced to achieve key provincial government objectives for digital data, by:

- making it easier to share digital spatial data between user groups using different hardware and software;
- making it easier to integrate digital spatial data by adhering to Provincial standards for georeferencing resource inventory datasets; and
- providing quantitative and qualitative measures of data quality to ensure that data-collection efforts are effective, and to ensure that the province receives good value in contracted projects.

Scope of the Standards

The digital data standards in this document will be applied to species distribution mapping as managed by the BC Ministry of Environment, a provincial agency represented on the Resources Information Standards Committee.

This document describes basic georeferencing and digital data definitions for species distribution mapping, including coordinate systems, registration, and logical and physical descriptions for attribute and spatial aspects of the datasets. The document describes, recommends, or prescribes methods for digital data capture and quality assurance, as well as metadata related to the digital capture.

The document focuses on providing those standards and guidelines required by those involved in digital data capture of species distribution data to ensure consistent delivery of digital data in the specified form or structure. The specification describes the form (or structure) in which the data are expected to be when delivered to the BC Ministry of Environment’s species distribution data custodian. The document does not attempt to describe a single process for digitally capturing the data because there might be a number of ways of getting the data into the specified form.

Intended Users of the Standards

This section is technical in nature and is intended for a specialist audience of persons compiling, managing, and using the species distribution digital dataset.

This section is intended to be used by three major groups:

- Government staff managing contracts for collecting species distribution data, or maintaining the resource inventory datasets.
- Non-government and government specialists actively involved in collecting, storing, and maintaining species distribution digital datasets.
- End-users seeking to understand the meaning and structure of species distribution datasets for use in analysis and graphic display.

Non-government and government staff involved directly with collecting species distribution data will refer to this section for specific technical guidance on the form and structure of the datasets they prepare. Managers of such data-collection projects will use this section to evaluate whether resource inventory projects have adhered to the technical data standards.

3.2 Physical Data

This section provides specifications for the physical format of the data to be delivered by the species distribution mapper to the Wildlife Habitat Ratings data custodian.

3.2.1 Attributes

Table 1. ArcInfo polygon attribute table (PAT), mandatory items

The ArcInfo polygon attribute table (PAT) must contain the following fields:

Field Type	Item Name	Item Width	Output Width	Item Type	Number of Decimals	Descriptive Name (Not to be used for naming fields/items)
System generated – DO NOT ALTER	Area	8	18	Floating Point	5	Polygon area
System generated – DO NOT ALTER	Perimeter	8	18	Floating Point	5	Polygon perimeter
System generated – DO NOT ALTER	<Cover>#	4	5	Binary Integer	0	Internal sequence number
Mandatory	<Cover>-id	4	5	Binary Integer	0	Feature identification number
Mandatory	Poly_ID	12	12	Character	N/A	User assigned unique polygon identifier
Mandatory	BAPID	5	5	Character	N/A	Business area project identifier
Mandatory	Spp_Code	9	9	Character	N/A	RISC species code
Mandatory	Fcode	10	10	Character	N/A	Feature code

Table 2. ArcInfo polygon attribute table (PAT), optional items

Only the following names, formats, and descriptions may be used to store data in the ArcInfo polygon attribute table (PAT):

Field Type	Item Name	Item Width	Output Width	Item Type	Number of Decimals	Descriptive Name (Not to be used for naming fields/items)
Optional	Ecotype	5	5	Character	N/A	Species ecotype

Optional	Src_Fcode	10	10	Character	N/A	Source feature code
Optional	HSV	1	1	Character	N/A	Habitat suitability value
Optional	R_Abund	8	18	Floating Point	5	Relative abundance
Optional	A_Abund	8	18	Floating Point	5	Absolute abundance
Optional	Pop_Unit	5	5	Character	N/A	Population unit
Optional	OccurProb	8	18	Floating Point	5	Occurrence probability
Optional	Conf_Lvl	8	18	Floating Point	5	Confidence level
Optional	D_Res	12	12	Character	N/A	Data resolution
Optional	First_Obs	7	7	Date	N/A	First observation
Optional	Last_Obs	7	7	Date	N/A	Last observation
Optional	Ref_URL	254	254	Character	N/A	Reference uniform resource locator

Table 3. ESRI Shapefile items

The ESRI Shapefile must contain the following:

Field Type	Item Name	Item Width	Output Width	Item Type	Number of Decimals	Descriptive Name (Not to be used for naming fields/items)
System generated – DO NOT ALTER	FID	4	4	Object ID	0	Feature identifier
System generated – DO NOT ALTER	Shape	Variable	Variable	Geometry	N/A	Feature geometry
System generated – DO NOT ALTER	Area	18	18	Number	5	Polygon area
System generated – DO NOT ALTER	Perimeter	18	18	Number	5	Polygon perimeter
Mandatory	Poly_ID	20	20	String	N/A	User assigned unique polygon identifier
Mandatory	BAPID	5	5	String	N/A	Business area project identifier

Mandatory	Spp_Code	9	9	String	N/A	RISC species code
Mandatory	Fcode	10	10	String	N/A	Feature code

Table 4. ArcView attribute table (DBF)

Only the following names, formats, and descriptions may be used to store data in the ArcView attribute table (DBF):

Field Type	**Item Name**	**Item Width**	**Output Width**	**Item Type**	**Number of Decimals**	**Descriptive Name** **(Not to be used for naming fields/items)**
Optional	Ecotype	5	5	String	N/A	Species ecotype
Optional	Src_Fcode	10	10	String	N/A	Source feature code
Optional	HSV	1	1	String	N/A	Habitat suitability value
Optional	R_Abund	12	12	Number	3	Relative abundance
Optional	A_Abund	12	12	Number	3	Absolute abundance
Optional	Pop_Unit	5	5	String	N/A	Population unit
Optional	OccurProb	3	3	Number	2	Occurrence probability
Optional	Conf_Lvl	3	3	Number	2	Confidence level
Optional	D_Res	12	12	String	N/A	Data resolution
Optional	First_Obs	7	7	Date	N/A	First observation
Optional	Last_Obs	7	7	Date	N/A	Last observation
Optional	Ref_URL	254	254	String	N/A	Reference uniform resource locator

Table 5. ArcInfo grid items

The ArcInfo grid must contain the following:

Field Type	Item Name	Item Width	Output Width	Item Type	Number of Decimals	Descriptive Name (Not to be used for naming fields/items)
System generated – DO NOT ALTER	Value	N/A	N/A	Long integer	0	Cell value
System generated – DO NOT ALTER	Count	N/A	N/A	Double-precision floating point number	0	Cell count
Mandatory	Rstr_Poly_ID	20	20	Character	N/A	User assigned unique raster polygon identifier
Mandatory	BAPID	5	5	Character	N/A	Business area project identifier
Mandatory	Spp_Code	9	9	Character	N/A	RISC species code
Mandatory	Fcode	10	10	Character	N/A	Feature code

Table 6. ArcInfo value attribute table (VAT)

Only the following names, formats, and descriptions may be used to store data in the ArcInfo value attribute table (VAT):

Field Type	Item Name	Item Width	Output Width	Item Type	Number of Decimals	Descriptive Name (Not to be used for naming fields/items)
Optional	Ecotype	5	5	Character	N/A	Species ecotype
Optional	Src_Fcode	10	10	Character	N/A	Source feature code
Optional	HSV	1	1	Character	N/A	Habitat suitability value
Optional	R_Abund	8	18	Floating Point	5	Relative abundance
Optional	A_Abund	8	18	Floating Point	5	Absolute abundance
Optional	Pop_Unit	5	5	Character	N/A	Population unit
Optional	OccurProb	8	18	Floating Point	5	Occurrence probability
Optional	Conf_Lvl	8	18	Floating Point	5	Confidence level
Optional	D_Res	12	12	Character	N/A	Data resolution
Optional	First_Obs	7	7	Date	N/A	First observation
Optional	Last_Obs	7	7	Date	N/A	Last observation
Optional	Ref_URL	254	254	Character	N/A	Reference uniform resource locator

3.2.2 Logical Data Description

The purpose of this section is to document a logical description of the data being collected. The intent is to provide a single integrated definition of the data that is not biased toward any single application of the data being collected and is independent of how the data are physically stored or accessed. The intent is to provide a common understanding of the data being collected.

Table 7. Logical data description

Long Field Name	Format	Description
Feature_Identifier	ArcView	The feature ID is a unique identifier assigned to each feature in a feature class by the ArcView software.
Feature_Geometry	ArcView	A GIS typically represents geographic location using rasters or vectors (feature geometry). A feature is simply an object that has a location stored as one of its properties (or fields) in the row. Typically, features are spatially represented as points, lines, polygons, or annotation, and are organized into feature classes.
Polygon_Area	ArcInfo coverage, ArcView	Area of polygon in square metres.
Polygon_Perimeter	ArcInfo coverage, ArcView	Perimeter of polygon in metres.
Internal_sequence_number	ArcInfo coverage	Unique system identification number.
User-id	ArcInfo coverage	Unique feature identification number.
Cell_Value	ArcInfo Grid	Stores the value assigned to each zone of a raster. Any two or more cells with the same value belong to the same zone.
Cell_Count	ArcInfo Grid	Stores the total number of cells in the dataset that belong to each zone.
User_Assigned_Unique_ Polygon_ Identifier	ArcInfo coverage, ArcView	The unique identifier linking the vector polygon and nonspatial attributes. It is composed of the BAPID followed by an underbar '_' and the unique polygon number: There are no leading zeros in the polygon number.
User_Assigned_Unique_Raster Polygon_Identifier	ArcInfo Grid	The unique identifier linking the raster polygon and nonspatial attributes. It is composed of the BAPID followed by an underbar '_' and the unique polygon number: There are no leading zeros in the polygon number.
Business_Area_Project_ Identifier	All formats	This field refers to a unique business area project identifier that is generated by the Species Range Mapping Data Custodian. BAPIDs can be requested by emailing WHR_Mail ENV:EX.
RISC_Species_Code	All formats	The field will contain the RISC species codes. Individual polygons may refer to a specific species or subspecies. If a coverage / shapefile represents the distribution of a

		species at the species level, a species at the species level and also subspecies, or two or more subspecies, the respective values should be entered in this field. Separate spatial coverages / shapefiles must be generated for each subspecies when subspecies ranges overlap. If a RISC species code is not defined for the species being mapped, a draft species code must be obtained by emailing WHR_Mail ENV:EX.
Feature_Code	All formats	This field will contain feature codes identifying the type of species distribution being delineated. See Table 11.
Source_Feature_Code	All formats	The feature code assigned to digitally copied arcs to identify the source feature (e.g., TRIM lake copied to species distribution coverage has source fcode attribute src_fcode GB15300000 assigned, while the fcode attribute is assigned the species distribution fcode). TRIM features codes can be accessed from: srmwww.gov.bc.ca/gis/trimfeatures.htm or the Species Range Mapping Data Custodian if the URL is inactive.
Habitat_Suitability_Value	All formats	Habitat Suitability is defined as the ability of the habitat in its current condition to provide the life requisites of a species. Suitability ratings reflect expected use of the habitat by the species of concern and are based on a measure of density (number of animals times unit of time divided by area of habitat). The animal density measures are primarily used as a conceptual framework for evaluating the value of a habitat (i.e., its potential use by animals) rather than actual numbers of animals. Three rating schemes reflect the knowledge of a given species' habitat use and the scale at which that knowledge is applied: The six-class scheme uses ratings of high (1), moderately high (2), moderate (3), low (4), very low (5), and nil (6) for defined seasons and habitat uses and is used for species for which there is a detailed knowledge level. The four-class scheme uses high (H), moderate (M), low (L), and nil (N) ratings for defined seasons and habitat uses and is used for species for which there is an intermediate knowledge level. The two-class scheme uses ratings of "habitat useable" (U) or "likely no value" (X), and is used for species for which there is a limited knowledge level. For more information on Habitat Suitability review the British Columbia Wildlife Habitat Rating Standards at ilmbwww.gov.bc.ca/risc/pubs/teecolo/whrs/assets/whrs.pdf.

Relative_Abundance	All formats	This field will contain relative abundance data to provide indices of population sizes which usually cannot be converted to an estimate of absolute abundance. However, providing survey bias is constant, the results can provide comparable estimates of abundance between localities and species, or within species over time. These indices are usually based on some measure of effort, such as a unit of time or distance travelled. For acceptable codes, see Table 8 – Relative Abundance Values.
Absolute_Abundance	All formats	The total number of organisms in an area. Absolute Abundance is usually reported as absolute density: the number of organisms per unit area or volume. For the purpose of species distribution modeling, square kilometres will be the unit of areal measurement.
Population_Unit	All formats	A population unit may be any distinct population segment of any species of vertebrate fish or wildlife that interbreeds when mature. It is required that the subgroup be separable from the remainder of and significant to the species to which it belongs. A population unit may approximate an ideal natural group of organisms with approximately equal breeding opportunities among its members, or it may refer to a loosely bounded, regionally distributed collection of organisms. In all cases, the organisms in a population are members of a single species or lesser taxon. A fish stock (i.e., Pacific salmon) may be considered a distinct population unit if it represents an evolutionarily significant unit (ESU) of a biological species. A stock must satisfy two criteria to be considered an ESU: (1) It must be substantially reproductively isolated from other conspecific population units; and (2) It must represent an important component in the evolutionary legacy of the species (adapted from the US Endangered Species Act).
Species_Ecotype	All formats	This field will contain the RISC species codes for ecotypes if they exist. If codes do not exist for specific ecotypes, new codes must be requested by emailing WHR_Mail ENV:EX. Individual polygons may refer to a specific species, subspecies, or ecotype. If a coverage / shapefile / grid represents the distribution of a species at the species level, a species at the species level and also subspecies, or two or more subspecies, the respective values should be entered in this field. Separate spatial coverages / shapefiles must be generated for each subspecies when subspecies ranges overlap. An ecotype is defined as a subdivision (e.g., a population or group of populations) within a species or subspecies that has adapted to specific landscapes or environments as expressed primarily by its movements and feeding behaviour.

Occurrence_Probability	All formats	A number between zero and one that shows how likely a certain event is. Usually, probability is expressed as a ratio: the number of experimental results that would produce the event divided by the number of experimental results considered possible. For species distribution datasets this ratio must be converted to the decimal equivalent.
Confidence_Level	All formats	Confidence Level is the normalized value assigned either at the polygon level or coverage level that indicates the likelihood that the polygon or entire coverage will represent the true range of a species. The confidence level will depend on the source data inputs and the methodology used to derive the range map. The method used to derive this confidence level should be clearly defined in the report that accompanies the species range map.
Data_Resolution	All formats	Resolution is the degree to which closely related entities can be discriminated. Since a paper map is always the same size, its data resolution is tied to its scale. Resolution also limits the minimum size of feature that can be stored. For the purposes of species distribution, the output scale ratio must be used as the indicator of data resolution, i.e., 1:20,000 or 1:250,000.
First_Observation	All formats	Earliest date of observation data used to derive species range map. It is up to the practitioner to specify if this attribute refers to each specific polygon or to the entire project area in the body of the accompanying report.
Last_Observation	All formats	Latest date of observation data used to derive species range map. It is up to the practitioner to specify if this attribute refers to each specific polygon or to the entire project area in the body of the accompanying report.
Reference_Uniform_Resource_ Locator	All formats	Link to webpage where project-specific information report(s) is stored.

Table 8. Relative abundance values

% of Provincial Best*	Substantial Knowledge of Habitat Use (6-class)	Intermediate Knowledge of Habitat Use (4-class)
	Code	Code
100–76%	1	H
75–51%	2	M
50–26%	3	M
25–6%	4	L
5–1%	5	L
0%	6	N

*"Provincial Best" is the provincial benchmark habitat for a species against which all other habitats for that species are rated.

3.2.3 Attribute Data Format

All attribute data must be in one of the following formats, depending on the GIS file format:

- ArcView Shapefile file format - dBase IV table (*.dbf).
- Info export file format (.E00 – Attribute data format of ArcInfo).

3.3 Spatial Data

3.3.1 Coordinate System

All data must be in the following coordinate system. Note that the offsets are separate from the false easting and/or false northing that may be part of the projection definition. For example, BC Albers has a false easting of 1,000,000 metres.

Table 9. ArcInfo coverage or grid – BC Albers – single precision

Horizontal Unit of Resolution	metre	Horizontal Measurement Unit	metre
Vertical Unit of Resolution	N/A	Vertical Measurement Unit	N/A
X Offset:	0	Y Offset:	0

Table 10. ESRI ArcView Shapefile – BC Albers

Horizontal Unit of Resolution	metre	Horizontal Measurement Unit	metre
Vertical Unit of Resolution	N/A	Vertical Measurement Unit	N/A
X Offset:	0	Y Offset:	0

3.3.2 Precision

Coverages should be created in single precision coordinates. This is sufficient for data used by Ministry of Environment, because Albers projection coordinates can be stored in single precision with one metre accuracy.

3.3.3 Tiles

Data must be delivered as a single dataset covering the entire project area. Data are not to be divided into geographic partitions.

If file sizes exceed the capacity of common hardware and software, then the data's creator must contact the data custodian at [WHR_Mail ENV:EX] to discuss possible tiling partitions.

3.3.4 Spatial Data Format

Spatial data must be submitted in the following format:

- ArcInfo export (E00), uncompressed (i.e., exported with NONE compression option)
- ESRI ArcView Shapefile

3.3.5 Feature Classification

Each feature must have a feature code from Table 11 in its feature attribute table, stored in the 10-character attribute called 'Fcode'.

Table 11. Feature classification

Feature Code	Custodian	Feature	Attribute	Attribute Code	Topology
FF84630000	WLD	Wildlife Range	Undifferentiated	u	Polygon
FF84630110	WLD	Wildlife Range	Annual	a	Polygon
FF84630120	WLD	Wildlife Range	Fall	f	Polygon
FF84630130	WLD	Wildlife Range	Home	h	Polygon
FF84630140	WLD	Wildlife Range	Spring	p	Polygon
FF84630150	WLD	Wildlife Range	Summer	s	Polygon
FF84630160	WLD	Wildlife Range	Winter	w	Polygon
FF84630200	WLD	Wildlife Range	Migratory	m	Polygon
FF84630300	WLD	Wildlife Range	Extirpated	e	Polygon
FF84630310	WLD	Wildlife Range	Extinct	x	Polygon
FF84630320	WLD	Wildlife Range	Introduced	i	Polygon

If a feature, or part of a feature, is copied from another dataset, then the original feature code should be stored in the 10-character attribute called Src_Fcode. For example if a polygonal wetland feature from TRIM is used to define an area where a dragonfly species is found, then the TRIM wetland feature code must be stored in the Src_Fcode field.

3.3.5.1 Naming Standards for Spatial Files

These standards apply to both ArcInfo coverages and ArcView shapefiles:

- All coverage names will be entirely in lowercase and will not exceed 13 characters.
- The first character of a coverage name refers to its map scale or spatial resolution (see Section 3.3.5.2). Do not substitute a numeric value.
- The next characters refer to the RISC species code.

- The next character is an attribute code to distinguish the multiple types of mapped wildlife ranges. Note: each ArcInfo coverage or ArcView Shapefile will represent one and only one type of wildlife range. Separate ArcInfo coverages or ArcView Shapefiles are required for each wildlife range category.

- The rest of the name refers to its geographic extent.

Typical coverage or Shapefile names, created according to this naming scheme:

- 'qbbagopbc' (1:250,000, Barrow's Goldeneye, spring range, for all of BC).

- 'baamgr_deabc' (1:2,000,000, Northwestern Salamander subspecies decorticatum, annual range, for all of BC).

- 'tmcotowsoi' (1:20,000, Townsend's Big-eared Bat, winter range, for the Southern Interior Ecoprovince).

3.3.5.2 Map Scale Characters

If a map was created at a particular scale (e.g., the NTS 1:250,000 series), that scale determines the first character in its name. A proper statement of accuracy must consider many factors, but these characters give some indication.

Table 12. Map scale characters

Character	Mnemonic	Scale	Nominal accuracy
d	Dix, French for 10	1:10,000,000	10 kilometres
i	Only character left in sIx	1:6,000,000	6 kilometres
b	Bi, like bicycle	1:2,000,000	2 kilometres
m	Million	1:1,000,000	1 kilometre
s	Six hundred thousand	1:600,000	600 metres
q	Quarter million	1:250,000	250 metres
h	Hundred thousand	1:100,000	100 metres
l (lower case L)	Roman numeral fifty	1:50,000	50 metres
t	Twenty, TRIM	1:20,000	20 metres

x	Roman numeral ten	1:10,000	10 metres
v	Roman numeral five	1:5,000	5 metres
w	Water	1:2,500	2.5 metres
a	Arbitrary	Data collected via GPS or other method with inconsistent or no data capture scale	Variable

3.3.6 Additional Attributes

Attributes in addition to those specified in Section 3.2.1 (such as biological or ecological data associated with specific polygon) may also be submitted to the Ministry. If additional data is submitted, then it must conform to Sections 3.3.6.1 and 3.3.6.2.

3.3.6.1 Linkages to Additional Attributes

Additional non-spatial attributes associated with specific polygons will be stored in a database separate from the spatial format (e.g., Info, dBase, or MS Access). The Poly_ID or RSTR_Poly_ID field must be used as a common key field in both the spatial and attribute schemas to link database records to spatial records. These fields must have the same data type, width, and name.

3.3.6.2 Data Dictionary[1]

A data dictionary must be used to define the structure and content of additional data elements.

In its simplest form, the data dictionary is a collection of data element definitions, as described below. More advanced data dictionaries contain database schema with reference keys. Still more advanced data dictionaries contain entity-relationship model diagrams of the data elements or objects. The term “data element” is sometimes referred to as “data object” or “object.”

Data Element Definitions

[1] The Data Dictionary section was adapted from *Tasks of the Database Administrator* (Mattila 2001).

- **Data element name (caption)**
  A commonly agreed on, unique data element name from the application domain. *This is the user-friendly name of this data element.*

- **Short description**
  Description of the element in the application domain.

- **Related data elements**
  List of closely related data element names when the relationship is important.

- **Field name(s)**
  Field names are the names used for this element in computer programs and database schemas. *These are the technical names, often limited by the programming languages and systems.*

- **Code format**
  Data type (character, numeric, Boolean, etc.), size, etc.

- **Default value**
  The data element may have a default value. Default value may be a variable, like current date and time of day.

- **Element coding (allowed values) or reference to other documents**
  Explanation of coding (code tables, etc.).

- **Definitions and references needed to understand the meaning of the element**
  Short application domain definitions and references to other documents needed to understand the meaning and use of the data element.

- **Source of the data in the element**
  Short description of where the data is coming from. Rules used in calculations producing the element values are usually written here.

- **Validity dates for the data element definition**
  Validity dates, start and possible end dates when the element is or was used. There may be several time periods in which the element has been used.

- **Historical references**
  Date when the element was defined in present form, references to superseded elements, etc.

- **External references**
  References to books, other documents, laws, etc.

- **Version of the data element document**
  Version number or other indicator. This may include formal version control or configuration management references, but such references may be hidden, depending on the system used.

- **Date of the data element document**
  Date of this version of the data element document.

- **Quality control references**
  Organization-specific quality control endorsements, dates, etc.

- **Data element notes**
  Short notes not included in above parts.

3.4 Georeferencing

3.4.1 Coordinate System

The position of a point on the earth's surface is defined by its coordinates. Rectangular (projection) coordinates that specify northing, easting, and elevation must be used. Northing and easting must be stated in metres. The elevation is an expression of *z*, typically in metres measured from the relevant vertical datum.

3.4.2 Horizontal Datum

The horizontal datum specifies a mathematical approximation of the earth's shape. Species distribution mappers must provide a horizontal datum. In many cases this will be a function of the Basemap Registration, for example, if the data is tied to TRIM, it is mapped to NAD83. The horizontal datum must be:

- NAD83 – North American Datum 1983, earth-centred ellipsoid derived from Geodetic Reference System 1980 (GRS80).

3.4.3 Vertical Datum

The vertical datum provides a reference for measuring elevation. This is to be specified if the data includes a value for elevation. The following vertical datum must be used if there is an elevation value:

- CVD28 – Canadian Vertical Datum 1928, a reference surface used as the basis of elevation, depth, and tide measurements. All vertical measurements are based on mean sea level as defined by this datum.

3.4.4 Projection

The BC Albers projection must be used. This projection pre-defines specific parameters for use with the Albers equal area conic projection. For British Columbia these parameters have been defined as:

- Central meridian –126° 0' 0"
- First standard parallel 50° 0' 0"
- Second standard parallel 58° 30' 0"
- Latitude of origin 45° 0' 0"

- Rectangular coordinates are metric with easting values offset by 1,000,000 metres.

3.4.5 NAD27–NAD83 Conversion

Where a dataset contains data that has been upgraded to the new datum, the method of transformation must be identified. The National Transformation Grid Version 2.0 is recommended for all datum conversions. Options are:

- National Transformation Grid Version 2.0 (recommended).
- National Transformation Grid Version 1.1 (Resources Inventory Committee 1996).

NOTE: When compared to Version 1.1, Version 2.0 of the National Transformation Grid provides greater detail in urban areas and more accurate control in pockets of the northeastern British Columbia. This difference will be significant in the northeastern areas where the required accuracy is 20 metres or less.

3.5 Registration

Species distribution mappers must identify the base mapping to which their data has been referenced. Choices are:

- Provincial Baseline Digital Atlas 1:10,000 (TRIM2)
- Provincial Baseline Digital Atlas 1:20,000 (TRIM)
- Provincial Baseline Digital Atlas 1:250,000
- Provincial Baseline Digital Atlas 1:2,000,000
- TRIM Watershed Atlas (1:20,000)
- BC Ministry of Environment Watershed Atlas (1:50,000)

3.5.1 Base Positional Accuracy

Provide the base positional accuracy definition corresponding to the choice made above.

Choices are:

- Provincial Baseline Digital Atlas 1:20,000 (TRIM) / 1:10,000 (TRIM2)
  90% of all well-defined planimetric features are coordinated to within 10 metres of their true position.
  90% of all discrete spot elevations and DEM points are accurate to within 5 metres of

their true elevation.
90% of all points interpolated from the TRIM (including contour data) are accurate to within 10 metres of their true elevation.
True position/elevation is defined as the coordinates that are obtained from positioning with high-order ground methods.

- Provincial Baseline Digital Atlas 1:250,000
  Planimetric positional data represents a structuring of digitally scanned National Topographic Series (NTS) hardcopy mapsheet layers, and therefore reflects both the accuracy of the original compilation and the errors introduced by the mylar media input to the scanning process. The published accuracy of the original input ranges from ±125 to ±500 metres horizontally and half to two contour intervals vertically. This data has also been subject to a simple *x*, *y* shift to approximate NAD83 positioning. This approximation is within 20 metres of the true NAD83 position, therefore the overall accuracy of the data remains at, ±125 to ±500 metres.

- Provincial Baseline Digital Atlas 1:2,000,000
  Planimetric positional data represents a structuring of digitally scanned constituent layers of the provincial 1J Series mapsheet and therefore reflects the accuracy of the original compilation. This digital product has been produced for a cartographic representation of thematic information at a scale of 1:2,000,000. As such, the positional accuracy is not adequate for any precise linear or areal calculations. Its intended use is for a general depiction of content information.

- TRIM Watershed Atlas 1:20,000
  Heights of land, watershed boundaries, and river segments are derived from TRIM planimetric and DEM baseline datasets. As such, the accuracy of this product is limited to that described for the Provincial Baseline Digital Atlas 1:20,000 (TRIM).

- BC Ministry of Environment Watershed Atlas 1:50,000
  The positional accuracy of water features will be slightly less than the standard accuracy of the 1:50,000 NTS source maps. The positional accuracy of the watershed polygons is interpolated from 1:50,000 contours and so reflects both the accuracy of the 1:50,000 base and the errors introduced by manual interpolation of heights of land from the contours.

3.6 Rules and Requirements for Digital Data Capture

This section is intended to apply to any data captured as part of a species distribution project, such as delineation and classification of habitat features or species observations. Most of the rules and requirements described in this section relate to the capture of polygonal and linear features.

Data capture by other methods, through Global Positioning Systems (GPS) or grid or raster modeling, are briefly described in this document. GPS rules and requirements can be found in Section 3.6.5. Grid rules and requirements can be found in Section 3.6.6.

3.6.1 Quality of Digital Data Capture

Ninety percent of all points must be positioned on NAD83 within of the appropriate distance listed in Table 13. The NAD83 datum on the ground is defined by geodetic control monuments and Active Control Points as maintained by Geographic Data BC (GDBC) [http://ilmbwww.gov.bc.ca/bmgs/products/geospatial/mascot.htm].

Table 13. Accuracy of digital data capture

Scale	Digital Data Capture Accuracy
1:10,000,000	5 kilometres
1:6,000,000	3 kilometres
1:2,000,000	1 kilometre
1:1,000,000	500 metres
1:600,000	300 metres
1:250,000	125 metres
1:100,000	50 metres
1:50,000	25 metres
1:20,000	10 metres
1:10,000	5 metres
1:5,000	2.5 metres
1:2,500	1.25 metres
Data collected via GPS or other method with inconsistent or no data capture scale	Variable

3.6.2 Interpreting Accuracy / Error

See Section 2.2.

3.6.3 Absolute (Datum-related) Positional Accuracy / Error

Point locations must be established relative to the Provincial Geo-Spatial Reference as defined by geodetic control monuments maintained by GDBC [http://ilmbwww.gov.bc.ca/bmgs/products/geospatial/mascot.htm].

When using GPS, each vertex of polygonal feature boundaries must be established by registering at least 180 readings (i.e., data collected once per second averaged over 3 minutes) of at least four satellites for 10-metre-level accuracy.

For more information on GPS standards, consult the British Columbia Standards Specifications and Guidelines for Resource Surveys Using GPS, Release 3.0 (Geographic Data BC 2001).

3.6.4 Digitizing Accuracy / Error

All features must be within 0.5 mm of the original map features when plotted on check plots at map scale. For data captured from existing hardcopy maps at 1:20,000 scale, all features must be within 10 metres of their mapped location in projection coordinates.

3.6.5 GPS Accuracy / Error

If field data are to be collected with GPS instrumentation, and these new data do not fall under existing RISC data collection standards, then the level of accuracy for these new data should follow the classification system in Section B of *British Columbia Standards, Specifications and Guidelines for Resource Surveys Using Global Positioning System (GPS) Technology - Release 3* (Geographic Data BC 2001).

3.6.6 Raster Rules and Requirements

3.6.6.1 Coordinate reference system (CRS)

The coordinate reference system (CRS) for raster data is the Albers projection of British Columbia (BC Albers) as defined below:

Datum: NAD83

Ellipsoid: GRS1980

Latitude of projection origin	45° 00' 00"
First standard parallel	50° 00' 00"
Second standard parallel	58° 30' 00"
Central meridian	–126° 00' 00"
False easting	1 000 000.0
False northing	0.0

3.6.6.2 Origin

The origin for raster data in BC Albers coordinates is:

Easting: 159 587.5

Northing: 173 787.5

3.6.6.3 Cell shape

The shape of raster cells (grids/pixels) is square (e.g., cell height equals cell width).

3.6.6.4 Cell size

The recommended size of raster cells is multiples of 5 that nest completely with the next highest cell size (e.g., 5, 25, 50, 100).

Raster cell sizes in multiples of 10 up to and including 100 may be used at the discretion of the user (e.g., if cell alignment error is insignificant to the intended use).

Raster cell sizes of 5 or less may be used as indicated in Table 14.

Table 14. Maximum raster cell sizes

Scale	Nominal accuracy	Maximum cell size
1:10,000,000	10 kilometres	100 metres by 100 metres
1:6,000,000	6 kilometres	100 metres by 100 metres
1:2,000,000	2 kilometres	100 metres by 100 metres
1:1,000,000	1 kilometre	100 metres by 100 metres
1:600,000	600 metres	100 metres by 100 metres
1:250,000	250 metres	100 metres by 100 metres
1:100,000	100 metres	100 metres by 100 metres
1:50,000	50 metres	50 metres by 50 metres
1:20,000	20 metres	25 metres by 25 metres
1:10,000	10 metres	5 metres by 5 metres
1:5,000	5 metres	5 metres by 5 metres
1:2,500	2.5 metres	2.5 metres by 2.5 metres
Data collected via GPS or other method with inconsistent or no data capture scale	Variable	5 metres by 5 metres

The maximum cell size will be 100 × 100 metres. Smaller cell size may be used as required by individual projects, but cells smaller than 100 metres may be resampled for storage within the government's data warehouse.

3.6.6.5 Rows and columns

The number of rows and columns are a limit of the data format because these figures relate to cell size and geographic extent.

3.6.6.6 X/Y coordinates

Upper left will be 0, 0. Lower left will be based on the coordinate system ground location.

3.6.6.5 Raster Metadata

The following items must be included in the metadata:

- The reference point of the cell (e.g., corner or centre point)
- The indexing scheme (e.g., lower left or upper left)
- The file format (e.g., GeoTIFF, MrSid, etc.)
- The raster creation methodology (e.g., scanning, etc.)

3.6.7 Precision

Precision of each geographic coordinate captured does not need to exceed seven decimal digits because this will maintain 1-metre accuracy for all points captured.

3.6.8 Resolution

Resolution is the degree to which closely related entities can be discriminated. This includes the minimum separation of points along the same feature, and the minimum separation between two features. For example 1:20,000 or smaller scale mapping vertices along the lines defining linear or polygon features must be at least 20 metres apart in ground coordinates. No two linear features may be less than 20 metres apart. See Table 15 for resolution at other map scales. Resolution may also refer to the amount of detail, or the smallest feature that may be captured.

Table 15. Resolution in ground coordinates

Scale	Resolution in ground coordinates
1:10,000,000	10 kilometres
1:6,000,000	6 kilometres
1:2,000,000	2 kilometres
1:1,000,000	1 kilometre
1:600,000	600 metres
1:250,000	250 metres
1:100,000	100 metres
1:50,000	50 metres
1:20,000	20 metres
1:10,000	10 metres
1:5,000	5 metres
1:2,500	2.5 metres
Data collected via GPS or other method with inconsistent or no data capture scale	Variable

3.6.9 Minimum Feature Size

There is no standard minimum size for mapped features explicitly defined in these standards. The project report must state the minimum feature size used in the project and the rationale for selecting the minimum feature size.

3.6.10 Data Capture Rules and Requirements

1. Right-hand Rule

An arc that bounds an area feature must be captured such that the feature lies to the right of the line. Equivalently, the boundary of the feature must be oriented in a clockwise direction.

2. Direction-of-flow Rule

Linear features having a defined discernible gradient or direction-of-flow must be digitized in the downward or downstream direction.

3. Pseudo-node Rule

Pseudo-nodes (i.e., 2-nodes, or nodes where only two arcs meet) should be avoided, except where necessary to meet the maximum element size constraints of a particular software product.

4. Self-intersection Rule

Arcs must not intersect (i.e., touch or cross) themselves except at their end nodes. This includes the component arcs of polygons.

5. Inter-feature Intersection Rule

Arcs in a feature class with coverage or network topology must intersect (i.e., touch or cross) each other only at mathematically exact nodes. It may be required that this rule be extended to a group of feature classes; in this case the group must be specified. For three-dimensional data this rule does not apply to the vertical coordinate (e.g., in a highway network two roads that cross each other via an overpass need not be noded together).

6. Polygon Integrity Rule

Polygonal feature classes must not contain undershoots or overshoots (i.e., 1-nodes, or nodes that touch only one arc).

7. Single Inside Point Rule

A polygonal feature must contain at most one inside point for attribute linkage.

8. Horizontal Feature Rule

Z-values on a feature with no discernible gradient (i.e., considered to be horizontal within the accuracy of the dataset) should have the same value.

9. Vertex Density Rule, Minimum Vector Length

The vertex density can be stated as the minimum vector length in coordinate system units. Vectors or arcs must not be shorter than the lengths listed in Table 16.

Table 16. Minimum vector lengths

Scale	Minimum Vector Length
1:10,000,000	5 kilometres
1:6,000,000	3 kilometres
1:2,000,000	1 kilometres
1:1,000,000	500 metres
1:600,000	300 metres
1:250,000	125 metres
1:100,000	50 metres
1:50,000	25 metres
1:20,000	10 metres
1:10,000	5 metres
1:5,000	2.5 metres
1:2,500	1.25 metres
Data collected via GPS or other method with inconsistent or no data capture scale	Variable

Table 17. Applicability of data capture rules to spatial data types

Rule	Point	Linear	Discrete Polygon	Coverage	Network
Right-Hand Rule			x		
Direction-of-flow Rule		x			
Pseudo-node Rule		x	x	x	x
Self-Intersection Rule		x	x	x	x
Inter-Feature Intersection Rule				x	x
Polygon Integrity Rule			x	x	
Single Inside Point Rule			x	x	
Horizontal Feature Rule		x	x	x	x
Vertex Density Rule		x	x	x	x

4.0 REFERENCE DATA

Any reference data submitted as a project deliverable must adhere to published data standards, i.e., species observation data submitted as part of a species distribution modeling project must adhere to RISC standards. The project leader should contact the Wildlife Habitat Ratings technical contact in the preliminary stage of the species distribution modeling project to assess what existing standards need to be followed.

5.0 METADATA

See Section 2.4 for metadata requirements.

6.0 DATA STORAGE AND ACCESS

Species distribution project data will be stored in the Land and Resource Data Warehouse (LRDW). Data will be accessible to both public and government users via LRDW-based services such as the Discovery and Distribution Services. Public and government users will be able to view data using the web-GIS application, iMapBC.

Information from peer reviews conducted after the project is completed will be added to the metadata.

7.0 CARTOGRAPHIC REPRESENTATION

Species distribution data may be plotted for presentation purposes. The desired contents of the plot will be specified on request because the contents will depend on the purpose. Presentation plots contain more cartographic information than a check plot and may be generated on request by the Ministry or client.

Presentation plots should contain the species distribution information as polygons on a grid, and should contain the source species observation points used in the modeling project.

Every presentation plot should have a legend containing the following information:

- **Title -** Short name for the data
- **Description -** What kind of data are they?
- **Source -** Where did the data come from?
- **Accuracy -** How well does the data represent the earth?

GLOSSARY

ACCURACY – The number of errors; degree of correctness; the degree by which measurements differ from their true value. (Terrestrial Ecosystems Task Force 1999)

> **POSITIONAL ACCURACY:** refers to the degree to which map coordinates correspond to the real world coordinates of features shown on the map. Positional accuracy is often stated as the probability of a map feature being represented within a specified distance. (Terrestrial Ecosystem Mapping Alternatives Task Force 1999)
>
> **SPATIAL ACCURACY:** spatial accuracy includes two components, positional accuracy and topological accuracy. (Terrestrial Ecosystem Mapping Alternatives Task Force 1999)
>
> **THEMATIC ACCURACY:** refers to the correctness of polygon labeling and is distinguished from but related to thematic precision. In simple terms, a polygon is correctly labeled if the attributes of the polygon fall within the defined attribute ranges of the map unit and its components. There is generally an inverse relationship between thematic precision and thematic accuracy in mapping projects. (Terrestrial Ecosystem Mapping Alternatives Task Force 1999)
>
> **TOPOLOGICAL ACCURACY:** topology refers to the properties of points, lines, or polygons not affected by changes in size, shape, or absolute position. For example, if a point is not located at the correct coordinates but it is located within the correct polygon it is topologically correct with reference to the polygon. Topological attributes are always with reference to two or more features. Of particular concern are the topological attributes of inside, outside, left, right, contiguous, congruent, and connected. Topological accuracy is normally much greater than positional accuracy and, because maps are frequently used as a means of locating oneself in the field by reference to topological relationships, positional inaccuracies often go unnoticed. (Terrestrial Ecosystem Mapping Alternatives Task Force 1999)

BAYESIAN BELIEF NETWORK (BBN) – a way of showing how things interact and cause specific outcomes. (Marcot 2005)

CAPABILITY – The ability of the habitat, under optimal natural conditions, to provide the life requisites of a species. (Terrestrial Ecosystems Task Force 1999)

COVER TYPE – A non-technical higher-level floristic and structural description of vegetation cover. (See also land cover classification (VRI), site series (ecosystem mapping). (Scott 2000)

DEDUCTIVE MODELING – element occurrences and element–environment relationships form out of correlative ecological studies or the field observations and experiences of qualified experts. See Inductive Modeling. (Beauvais et al. 2004)

DELINEATE – Identifying the boundaries between more or less homogenous areas on remotely sensed images as visible from differences in tone and texture. (Scott 2000)

DISTRIBUTION – The environments occupied by an element. Can be expressed at any geographic scale, and can emphasize probabilities of occurrence or presence/ absence. Methods for mapping distributions vary, but are typically spatial extrapolations of models of suitable and unsuitable habitat based on known areas of occurrence. Distribution maps, as compared to range maps, depict within-range variation in occupation rather than simply the outer limits of occupied area. (Beauvais et al. 2004)

ECOSYSTEM – Def #1. A biological community (ranging in scale from a single cave to millions of hectares), its physical environment, and the processes through which matter and energy are transferred among the components. (Scott 2000). **Def #2.** A volume of earth-space which is composed of non-living parts (climate, geologic materials, groundwater, and soils) and living or biotic parts, which is set apart from other volumes of earth-space in order to study the processes and products of production. (Terrestrial Ecosystems Task Force 1999)

ELEMENT – **Def #1.** A term introduced by state Natural Heritage programs to help organize biological information. An element is any meaningful biological unit. It is similar to a “taxon,” except an element can exist on the ecological hierarchy (e.g., ecosystem, community, guild) as well as on the standard taxonomic hierarchy (e.g., genus, species, subspecies). In practice, most zoological elements refer to species or subspecies, most botanical elements refer to species or varieties, and most ecological elements refer to vegetation communities. (Beauvais et al. 2004). **Def. #2.** – A plant community or animal species mapped by Gap Analysis. May also be referred to as “element of biodiversity.” (Scott 2000)

HABITAT – Def #1. An environment with the combination of resources and conditions that promote occupancy by individuals of a given species (or population) and allow those individuals to survive and reproduce (Morrison et al. 1992, as cited in Beauvais et al. 2004). Habitat is therefore a subset of distribution (and distribution is a subset of range), because distribution emphasizes occupancy without any direct reference to survival or reproduction (although survival and reproduction are inferred by consistent occupation). (Beauvais et al. 2004). **Def #2.** The place, including physical and biotic conditions, where a plant or an animal usually occurs. (Johnson and O’Neil 2001). More specifically, habitat is “an area with the combination of the necessary resources (for example, food, cover, water) and environmental conditions (temperature, precipitation, presence or absence of predators and competitors) that promotes occupancy by individuals of a given species (or population), and allows those individuals to survive and reproduce." (Morrison et al. 1992, as cited in Johnson and O'Neil 2001). **Def #3.** Following Definition No. 2, a habitat is always with reference to a particular species, group of species, or an expression of biodiversity. (Jones et al. 2002). **Def #4.** The physical structure, vegetational composition, and physiognomy of an area, the characteristics of which determine its suitability for particular animal or plant species. (Scott 2000)

INDUCTIVE MODELING – or statistical models, are qualitatively different from deductive models in that the EDM process is more objective and data-driven. The output is determined by how the occurrence data plots onto the environmental variables, and how that pattern is interpreted by the selected statistical function (with all of its attendant assumptions). (Beauvais et al. 2004)

INVENTORY – *verb* – The process of collecting materials, data, or information; *noun* **-** the resulting collection. (Radcliffe and Porter. 1992)

METADATA – Information about data, e.g., their source, lineage, content, structure, and availability. (Scott 2000)

OCCURRENCE – A location where a particular element has been observed. Can be expressed as a point, line, or polygon, and typically is associated with some degree of mapping error. "Occurrence data" therefore refers to a set of locations where a given element has been documented. (Beauvais et al. 2004)

POLYGON – Def #1. An area enclosed by lines in a vector-based Geographic Information System data layer or a region of contiguous homogeneous pixels in a raster system. (Scott 2000). **Def #2.** In GIS work, a stream of digitized points approximating the delineation (perimeter) of an area (e.g., ecosystem map unit) on a map. In terrestrial ecosystem mapping, a polygon consists of from one to three *ecosystem units*. (Terrestrial Ecosystems Task Force 1999)

PRECISION – **Def #1** In statistics, the variability of a series of sample estimates. The amount of agreement in a series of measurements. Generally, random deviation from the sample mean. **Def #2** The smallest unit used in taking a measurement; the smaller the unit the more precise the measurement. (Dunster and Dunster 1996)

PREPROCESSING (FILTERING) – Those operations that prepare data for subsequent analysis, usually by attempts to correct or compensate for systematic, radiometric, and geometric errors. (Scott 2000)

RANGE – The total areal extent occupied by an element. Typically expressed at coarse geographic scales (e.g., continental, regional), and typically emphasizes presence / absence rather than probabilities of occurrence. Methods for mapping ranges vary, can include substantial subjectivity, and are commonly not well documented. Most range maps are based on simple polygons that encompass the outermost points of known occurrence of an element, and thus do not show much within-range variation in occupation. Range can be represented as historical, present, or potential future. (Beauvais et al. 2004)

RANGE UNIT – A spatial, geographic unit to record and display species geographic range, e.g., polygons, herds, etc. (Scott 2000)

RASTER DATA RESOLUTION – Raster data is stored as (usually square) pixels, which form a grid or mesh over an area of the earth. The size of these pixels determines the resolution of the raster, because it is impossible to store anything that falls "between" the pixels. A GIS allows raster pixels to be any size, although they should not be smaller than the uncertainty of the data. If a raster coverage is derived from vector linework, its pixels should not be smaller than the uncertainty of the linework. If it comes from an air-photo or satellite image, its pixels should not be smaller than the resolution of the camera that recorded it. (BC Ministry of Sustainable Resource Management 1999)

RELIABILITY – **Def #1** The probability that a component part, equipment, or system will satisfactorily perform its intended function under given circumstances, such as environmental conditions, limitations as to operating time, and frequency and thoroughness of maintenance for a specified period of time. **Def #2** The amount of credence placed in a result. **Def #3** The precision of a measurement, as measured by the variance of repeated measurements of the same object. (Parker 1989)

RESOLUTION – **Def #1.** The capability of making distinguishable the individual parts of an object. Specifically, the level of detail at which ecological information is collected, which may differ from the map scale at which it is presented. (Terrestrial Ecosystems Task Force 1999). **Def #2 -** The ability of a remote sensing system to record and display fine detail in a distinguishable manner, or the smallest feature that can be distinguished or resolved on a map or image, such as a TM pixel. (Scott 2000)

SCALE – The ratio between the distance traveled between two points on a map and the equivalent true distance that this would represent on the ground. The level of detail on a map increases as the ratio decreases. Scale determines the level of *accuracy* that can be expected, specifically, the map scale at which habitat information is presented (e.g., 1:20,000, 1:50,000, or 1:250,000). (Terrestrial Ecosystems Task Force 1999)

SCALE, MAP – The ratio of distance on a map to distance in the real world, expressed as a fraction; the smaller the denominator, the larger the scale, e.g., 1:24,000 is larger scale than 1:100,000. (Scott 2000)

SPECIES ACCOUNT – A summary of geographic distribution, life requisites, seasonal use of habitats, limiting factors, and habitat attributes for an animal species within a geographic range. (Terrestrial Ecosystems Task Force 1999)

SUITABILITY – The ability of the habitat in its current condition to provide the life requisites of a species. (Terrestrial Ecosystem Mapping Alternatives Task Force 1999)

TRADITIONAL ECOLOGICAL KNOWLEDGE – A cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment. (Berkes 1999)

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Appendix 1. Comparison of species distribution modeling with other methods to determine the appropriate approach

Wildlife Habitat Ratings (WHR) – Habitat Suitability and Capability

- Ecosystem information can be put in context by using products such as the Resource Ratings Modeling tool (BC Ministry of Sustainable Resource Management 2004), for example, a clearcut adjacent to mature forest raises the value of the clearcut (forage) for some species because of proximity to security and thermal protection.
    - *e.g Step-down model for estimating Grizzly Bear populations:*

      1. Determine the habitat capability of the area.

      2. Determine the habitat suitability of the area.

      3. Determine habitat effectiveness.

      4. Determine human-caused mortality. (BC Ministry of Water, Land and Air Protection 2002)

- Depicts densities relative to the best habitat for that species in the province.
- Has been used for common plants of management concern.
- Deductive at present.

<u>Question:</u> Can BEC or BEI be overlayed with point/observation data to create an inductive model? Then cross-referenced with WHR to refine the ratings maps?

Species Distribution Models (SDM)

- Deductive or inductive.
- Presence/absence, rated, or continuous probability.
- Is there a difference between a deductive SDM and WHR?
    - Usually WHR is based on standard attributes from ecosystem mapping, but other inputs are theoretically possible.
    - Other deductive SDM approaches might include Habitat Suitability Index (HSI).
    - WHR and other approaches to habitat suitability should identify more area than SDM, unless the suitable habitat is fully occupied. Net downs could consider barriers to dispersal, displacement due to interspecific competition, proximity of critical life requisites, etc.

- Inductive SDM is spatial coverages of predictor variables overlayed with point/observation data.

Habitat Supply Models (HSM)

- Many types of models are considered HSMs, including WHR.
- The simplest difference is that HSMs include modeling over time.
- Deductive or inductive, depending on the model.

Element Distribution Models (EDM)

- Predicts entities such as communities and ecosystems that are out of scope for the BC treatment of SDM, due to the existence of already established methods and standards (Sensitive Ecosystem Inventory (SEI), TEM, PEM, etc.).
- These models typically use predictor variables such as climate, satellite imagery, and DEM because the ecosystem classification and mapping is not as well-developed as in BC.
- The EDM approach relies on high quality, well-distributed point/observation data.