

Appendix E. Cover Types for Model Building

- E.1 Introduction. This appendix contains a cover type classification system intended to provide an ecological stratification to assist in the development of habitat suitability models. We have found by experience that it is necessary to subdivide habitats into general cover types within which fish and wildlife species respond in ways that can be readily modeled. (For a discussion of cover type mapping for applying the models, see section E.2 below.)

Because of the narrow objective of this classification system, differences exist between it and the general-purpose classifications (e.g., Cowardin et al. 1979 and Bailey 1976). This does not imply that the general purpose classifications are obsolete or unnecessary. However, the constraints on a classification for model building are not adequately met by any other classification available. Constraints include: 1) exhaustiveness - all types of cover must be considered; 2) mutual exclusiveness - no site should be included in more than one category (at a given level in the hierarchy); 3) recognizability - one should be able to determine the type of site from the information typically included in research reports on fish or wildlife-habitat relationships; 4) currentness - the classification must refer to existing conditions, not the future or potential of a site; 5) simplicity - no more types should be recognized than absolutely necessary; and 6) relevance - breaks between types must correspond to the factors related directly or indirectly to the essentials driving fish or wildlife-habitat relationships.

The wetlands and deepwater habitats portion of this classification was adapted directly from Cowardin et al. (1979), to facilitate application of National Wetland Inventory maps and data bases. For model development purposes, the "class" level described by Cowardin et al. (1979) is most appropriate for wildlife, whereas the "system" level is usually better for fish. Certain classes have been combined to minimize the number of types while retaining a high degree of relevance to habitat model development.

- E.2 Cover type mapping. During a HEP application, project areas should be mapped using a surface cover type classification tailored to the area. The cover types described in this appendix may not provide the resolution required by some studies. If existing maps are available, such as National Wetland Inventory maps, they should be used if possible. In any case, habitat models developed around the broad cover types in this appendix should easily cross reference to other mapping categories. For example, one may construct a habitat model for deciduous forest and apply

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the model to a study area that has been mapped with oak-hickory, beech-maple, and cottonwood-willow cover types. In this case the model should be equally applicable to the three deciduous forest types. However, the HSI derived with the model may differ between the three forest types depending on the biological relationships included in the model.

E.3 Cover types

- A. Introduction. The Cover Type Classification (Table E-1) contains two major categories: 1) Uplands; and 2) Wetlands and Deepwater Habitats. These are subdivided into 30 types, using four levels of resolution.

Several terms used in this classification system are defined below. A particular group of plants (such as the tree stratum or layer, or the grasses) is said to be "dominant" if its canopy cover is greater than that of any other group (excluding plants that are directly underneath other plants). "Evergreen" types are those in which at least 50% of the total canopy cover of the dominant stratum (layer) consists of species that retain green foliage throughout the year. "Deciduous" types are those in which at least 50% of the total canopy cover of the dominant stratum (layer) consists of species that completely shed their foliage during part of the year. All tree-dominated and shrub-dominated types may be classified as either evergreen or deciduous. "Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. ...wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes; (2) the substrate is predominantly undrained hydric soil; and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year" (Cowardin et al. 1979, p. 3). "Emergents" are "erect, rooted, herbaceous angiosperms that may be temporarily to permanently flooded at the base but do not tolerate prolonged inundation of the entire plant; e.g., bulrushes (*Scirpus* spp.), saltmarsh cordgrass" (Cowardin et al. 1979, p. 42). "Farmed" wetlands have had the soil surface "... mechanically or physically altered for the production of crops ..." (Cowardin et al., p. 26) but the water regime is still that of a wetland.

In using this classification, note that anything in the definition of a primary division refers as well to all its subdivisions. Consider both, since the definitions of subdivisions do not repeat redundant material from the primary divisions.

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Table E-1. Summary of the cover type classification system for model building.

UPLANDS (Nonwetlands)

Agricultural and Built-up Land

Orchard

Vineyard

Cropland

Pasture and Hayland

Mining Area

Urban and Built-up Land

Undeveloped Uplands

Forest

Evergreen Forest

Deciduous Forest

Tree Savanna

Evergreen Tree Savanna

Deciduous Tree Savanna

Shrubland

Evergreen Shrubland

Deciduous Shrubland

Shrub Savanna

Evergreen Shrub Savanna

Deciduous Shrub Savanna

Grassland

Forbland

Desertic Woodland

Desertic Shrubland

Desertic Herbland

Barren Lands

WETLANDS AND DEEPWATER HABITATS

Wetlands

Forested Wetland

Evergreen Forested Wetland

Deciduous Forested Wetland

Scrub-Shrub Wetland

Evergreen Scrub-Shrub Wetland

Deciduous Scrub-Shrub Wetland

Herbaceous Wetland

Shore, Bottom Wetland

Deepwater Habitats

Riverine

Lacustrine

Estuarine

Marine

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- B. UPLANDS (Nonwetlands). Uplands are not periodically flooded with water, and have a water table that is rarely at or near the surface. They are not dominated by hydrophytes, the soils are not hydric (or if they are hydric soils, they have been drained).
- (1) Agricultural and Built-up Land. Types within this division refer to lands that are periodically plowed and planted, or mowed for hay at least once per year, or support buildings or other man made structures.
- a. Orchard. The Orchard type has trees planted and cultivated for the production of fruit or nut crops.
 - b. Vineyard. The Vineyard type has vines or shrubs planted and cultivated for the production of fruit crops.
 - c. Cropland. The Cropland type is utilized for the growth of agricultural crops that are planted and harvested annually, excluding pasture and hayland.
 - d. Pasture and Hayland. The Pasture and Hayland type is dominated by perennial grasses or forbs (usually legumes), native or introduced, that are mowed at least once per year or periodically plowed and planted primarily for livestock grazing. These areas are usually dominated by one or a few species of grasses or legumes. This type excludes native rangeland.
 - e. Mining Area. The Mining Area type is currently being mined for extraction of natural resources or recently abandoned. Reclaimed areas may be classified as other cover types depending on the extent and success of reclamation efforts.
 - f. Urban and Built-up Land. The Urban and Built-up Land type "... is comprised of areas of intensive use with much of the land covered by structures." (Anderson et al. 1976, p. 10)
- (2) Undeveloped Uplands. Types within this division refer to non-wetlands that are not converted to agriculture or built-up land.
- a. Forest. The Forest type is dominated by trees (taller than 5 m), and have a tree canopy cover of at least 25%.

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- b. Tree Savanna. The Tree Savanna type has a canopy cover of trees (taller than 5 m) between 5% and 25%, but has a total canopy cover of all vegetation of at least 25%. The area between trees is typically dominated by grasses or other herbaceous vegetation.
- c. Shrubland. The Shrubland type is dominated by shrubs (including small trees shorter than 5 m), and has a shrub canopy cover of at least 25%.
- d. Shrub Savanna. The Shrub Savanna type has a canopy cover of shrubs (including small trees shorter than 5 m) between 5% and 25%, but has a total canopy cover of all vegetation of at least 25%. The area between shrubs is typically dominated by grasses or other herbaceous vegetation.
- e. Grassland. The Grassland type has a canopy cover of all vegetation of at least 25%, and is dominated by nonwoody plants (including bryoids, e.g. lichens and mosses), of which grasses, native or introduced, are dominant. This type includes most prairies, range, and upland subalpine mountain meadows.
- f. Forbland. The Forbland type has a canopy cover of all vegetation of at least 25%, and is dominated by nonwoody plants (including bryoids, e.g. lichens and mosses), of which species other than grasses are dominant. This cover type includes many weedy fields, old fields, and other types in early successional stages.
- g. Desertic Woodland. The Desertic Woodland type has 1-25% total vegetation cover, with trees (taller than 5 m) forming the dominant vegetation stratum. It includes sparsely vegetated types in non-desert areas.
- h. Desertic Shrubland. The Desertic Shrubland type has 1-25% total vegetation cover with shrubs (and small trees shorter than 5 m) forming the dominant vegetation stratum. It includes sparsely vegetated types in non-desert areas.
- i. Desertic Herbland. The Desertic Herbland type has 1-25% total vegetation cover with nonwoody plants (including bryoids and lichens) forming the dominant vegetation stratum. It includes sparsely vegetated types in non-desert areas. Identification of Desertic Herbland in

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desert areas should be based on average conditions, rather than on conditions during peak growth of short-lived plants, when total cover may exceed 25%.

- j. Barren Land. The Barren Land type has less than 1% total vegetation cover. It includes sand dunes, rock outcrops, snow fields, etc.

- C. WETLANDS AND DEEPWATER HABITATS. Types within this division refer to wetlands (see section A above), or areas where "... surface water is permanent and often deep, so that water, rather than air, is the principal medium within which the dominant organisms live ..." (Cowardin et al. 1979, p. 3).

Modifiers exist which can be used to subdivide types more finely where that is desirable for modeling a particular species. Cowardin et al. 1979 (pp. 23-26) includes 12 modifiers for water regime (including "Artificially Flooded"), 10 modifiers for water chemistry (covering salinity and pH), two modifiers for soil ("Mineral" and "Organic") and six "special modifiers" ("Excavated", "Impounded", "Diked", "Partly Drained", "Farmed", and "Artificial"). This classification includes additional modifiers for Deepwater Habitats (size and water temperature, see Table E-2).

- (1) Wetlands. The definition of the boundary between wetland and upland is contained in section E.1. The boundary between wetland and deepwater habitats "... in the Marine and Estuarine systems coincides with the elevation of the extreme low water of spring tide; permanently flooded areas are considered deepwater habitats in these systems. The boundary between wetland and deepwater habitats in the Riverine, Lacustrine, and Palustrine systems lies at a depth of 2 m (6.6 feet) below low water; however, if emergents, shrubs or trees grow beyond this depth at any time, their deepwater edge is the boundary." (Cowardin et al., p. 4).

- a. Forested Wetland. The Forested Wetland type is dominated by woody vegetation that is 6 m (20 feet) tall or taller. It has a total vegetation cover greater than 30%.
- b. Scrub-Shrub Wetland. The Scrub-Shrub Wetland type is dominated by woody vegetation less than 6 m (20 feet) tall. It has a total vegetation cover greater than 30%.

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Table E-2. Modifiers for Deepwater Habitats.

Temperature (maximum)

cold	(< 20° C)
cool	(20-28° C)
warm	(> 28° C)

Size (Riverine)

small	(≤ 5 m mean width, or stream order 1-3)
medium	(5-30 m mean width, or stream order 2-5)
large	(> 30 m mean width, or stream order ≥ 6)

Size (Lacustrine)

small	(< 100 ha in area)
medium	(100-200 ha in area)
large	(> 200 ha in area)

- c. Herbaceous Wetland. The Herbaceous Wetland type is dominated "... by erect, rooted, herbaceous hydrophytes ...", including "... areas where mosses or lichens cover substrates other than rock ..." (Cowardin et al. 1979, p. 21) and "... plants that grow principally on or below the surface of the water for most growing seasons in most years." (Cowardin et al., p. 16) It has a total vegetation cover (excluding "... pioneer species that briefly invade wetlands when conditions are favorable ...") (Cowardin et al. 1979, p. 13) of greater than 30%. Note, this includes the "Emergent Wetland" and "Moss-Lichen Wetland" classes, and the "Aquatic Bed" class (when it occurs in wetland) of Cowardin et al. 1979.

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- d. Shore and Bottom Wetland. The Shore and Bottom Wetland type includes the following of Cowardin et al. (1979): "Unconsolidated Shore"; "Rocky Shore"; and "Streambed" in total; plus Unconsolidated Bottom, Rock Bottom and Reef classes when they occur in wetland. For practical purposes, this can be taken as characterized by wetland having less than 30% cover by vegetation (excluding "pioneers", see "Herbaceous Wetland" above).
- (2) Deepwater Habitats. The Deepwater Habitats type includes the following classes of Cowardin et al. (1979): "Reef"; "Aquatic Bed"; "Unconsolidated Bottom"; and "Rock Bottom" when they occur in Deepwater Habitats (see "(1) Wetlands", above). For practical purposes, this can be taken as deepwater having a total cover of less than 30% of emergents, trees, and shrubs.
- a. Riverine. "The Riverine [cover type] includes all wetlands and deepwater habitats contained within a channel, with two exceptions: (1) wetlands dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens, and (2) habitats with water containing ocean-derived salts in excess of 0.5 [parts per thousand]. A channel is 'an open conduit either naturally or artificially created which periodically or continuously contains moving water, or which forms a connecting link between two bodies of standing water' (Langbein and Iseri 1960:5).
- "[It] is bounded on the landward side by upland, by the channel bank (including natural and man-made levees), or by wetland dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens. In braided streams, the system is bounded by the banks forming the outer limits of the depression within which the braiding occurs.
- "The Riverine [cover type] terminates at the downstream end where the concentration of ocean-derived salts in the water exceeds 0.5 [parts per thousand] during the period of annual average low flow, or where the channel enters a lake. It terminates at the upstream end where tributary streams originate, or where the channel leaves a lake. Springs discharging into a channel are considered part of the Riverine [cover type]." (Cowardin et al. 1979, pp. 9-10).

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- b. Lacustrine. "The Lacustrine [cover type] includes wetlands and deepwater habitats with all of the following characteristics: (1) situated in a topographic depression or a dammed river channel; (2) lacking trees, shrubs, persistent emergents, emergent mosses or lichens with greater than 30% areal coverage; and (3) total area exceeds 8 ha (20 acres). Similar wetland and deepwater habitats totaling less than 8 ha are also included in the Lacustrine System if an active waveformed or bedrock shoreline feature makes up all of part of the boundary, or if the water depth in the deepest part of the basin exceeds 2 m (6.6 feet) at low water. Lacustrine waters may be tidal or nontidal, but ocean-derived salinity is always less than 0.5 [parts per thousand]." (Cowardin et al. 1979, pp. 11-12) (Note that only the "Limnetic" subsystem of Cowardin et al. is a "Deepwater Habitat". The "Littoral" subsystem is included in "Wetlands".)
- c. Estuarine. "The Estuarine [cover type] consists of deep-water tidal habitats and adjacent tidal wetlands that are usually semiencllosed by land but have open, partly obstructed, or sporadic access to the open ocean, and in which ocean water is at least occasionally diluted by freshwater runoff from the land. The salinity may be periodically increased above that of the open ocean by evaporation. Along some low-energy coastlines there is appreciable dilution of sea water. Offshore areas with typical estuarine plants and animals, such as red mangroves (*Rhizophora mangle*) and eastern oysters (*Crassostrea virginica*), are also included in the Estuarine [cover type]."

"[The Estuarine cover type] extends (1) upstream and landward to where ocean-derived salts measure less than 0.5 [parts per thousand] during the period of average annual low flow; (2) to an imaginary line closing the mouth of a river, bay, or sound; and (3) to the seaward limit of wetland emergents, shrubs, or trees where they are not included in (2). The Estuarine [cover type] also includes offshore areas of continuously diluted sea water." (Cowardin et al. 1979, pp. 4-5) (Note that only the "Subtidal" subsystem of Cowardin et al. is a "Deepwater Habitat". The "Intertidal" subsystem is included in "Wetlands".)

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- d. Marine. "The Marine [cover type] consists of the open ocean overlying the continental shelf and its associated high-energy coastline. Marine habitats are exposed to the waves and currents of the open ocean and the water regimes are determined primarily by the ebb and flow of oceanic tides. Salinities exceed 30 [parts per thousand], with little or no dilution except outside the mouths of estuaries. Shallow coastal indentations or bays without appreciable freshwater inflow, and coasts with exposed rocky islands that provide the mainland with little or no shelter from wind and waves, are also considered part of the Marine [cover type] because they generally support typical marine biota.

"The Marine [cover type] extends from the outer edge of the continental shelf shoreward to one of three lines: (1) the landward limit of tidal inundation (extreme high water of spring tides), including the splash zone from breaking waves; (2) the seaward limit of wetland emergents, trees, or shrubs; or (3) the seaward limit of the Estuarine [cover type] where this limit is determined by factors other than vegetation. Deepwater habitats lying beyond the seaward limit of the Marine [cover type] are outside the scope of this classification system." (Cowardin et al. 1979, p. 4) (Note that only the "Subtidal" subsystem of Cowardin et al. is a "Deepwater Habitat". The "Intertidal" subsystem is included in "Wetlands".)

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Appendix F. HSI Models Based on Discriminant Analysis

The process of building a mechanistic Habitat Suitability Index (HSI) model from individual "suitability index" curves can be a good approach to HSI model building when only scattered data are available on the effects of individual variables. However, a more direct approach may be taken to develop an HSI model when concurrent measures of several habitat variables and quantitative or qualitative estimates of carrying capacity (e.g., standing crop or biomass) are available for a given area. One approach to consider is discriminant analysis.

Discriminant analysis can be used to predict what suitability group (e.g., high, medium, or low) a particular habitat belongs to, based on a set of equations derived from variable measurements taken from various habitats. Discriminant analysis can be used to develop a species or species group HSI model using the steps described below.

- F.1 Step 1. Identify areas of "known" habitat suitability and assign them to a suitability group. This step requires that selected areas, such as certain lakes, or areas of forest be assigned to a specific habitat suitability group. Four or five would be the optimal number of distinct groups to use. For simplicity, the highest group number should be used to represent the best habitat. For example, if 4 groups are used, group 4 would represent the best habitat and group 1 the least suitable. The type of data used to define group membership could be anything from expert opinion to high quality, long-term population data. For example, a lake could be classified as group 4 for walleye, based on the opinion of the local fisheries biologist. If adequate standing crop data were available a lake could be placed in group 4 because the standing crop of walleyes was greater than a specified value such as 2.5 kg/ha. The method used to define group membership for "known" habitat does not influence the method used to analyze environmental data and predict group membership for "unknown" habitats. However, the more precise definitions of each group make the classification more meaningful. One of the advantages of discriminant analysis is that it can utilize qualitative "expert opinion" types of group ratings without requiring the expert to precisely define what a rating means in terms of animal numbers.
- F.2 Step 2. Measure the selected environmental variables in habitats that have been assigned to a group, and analyze the data. The Statistical Program for Social Sciences (Nie et al., 1975) contains a discriminant function subprogram that displays predicted and actual group membership for the groups entered. The classification function coefficients listed by the program are used to predict group membership for other areas of interest.

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- F.3 Step 3. Perform sensitivity analysis. If the model produced in Step 3 does an adequate job of predicting group membership, then selected habitat variables in the "known" habitats should be varied to see if predicted group membership also varies in a logical manner.
- F.4 Step 4. Apply the model to habitats with unknown group membership. After Step 4 is completed the model is ready to use in predicting group membership in habitats other than those used to develop the model. The model will provide for each group into which a habitat could be classified a series of coefficients to multiply times the value of each habitat variable measured. In order to determine group membership of a habitat, the habitat variables are measured, multiplied by the appropriate coefficient for each group, and the habitat assigned to the group which receives the highest score. A simplified example is provided below based upon the classification function coefficients given in Table F-1.

Table F-1. Classification function coefficients for an example discriminant analysis HSI model.

Variable	Classification function coefficients		
	Group 1	Group 2	Group 3
	"Unproductive"	"Moderately Productive"	"Very Productive"
A	28	23	20
B	13	14	10
C	12	10	8
Constant	-40	-30	-20

In a certain lake, variable A had a value of 1, variable B a value of 1, and variable C a value of 1. The following scores would be developed for each group

$$\text{Group 1} = (1)(28) + (1)(13) + (1)(12) - 40 = 13$$

$$\text{Group 2} = (1)(23) + (1)(14) + (1)(10) - 30 = 17$$

$$\text{Group 3} = (1)(20) + (1)(10) + (1)(8) - 20 = 18$$

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The lake would be assigned to group 3 because it received the highest classification score for group 3.

A lake where variable A had a value of 1, variable B a value of 1, and variable C a value of 2 would be classified as follow:

$$\text{Group 1} = (1)(28) + (1)(13) + (2)(12) - 40 = 25$$

$$\text{Group 2} = (1)(23) + (1)(14) + (2)(10) - 30 = 27$$

$$\text{Group 3} = (1)(20) + (1)(10) + (2)(8) - 20 = 26$$

This lake would be assigned to group 2.

Group values may be converted to HSI by the formula

$$\text{HSI} = \frac{\text{Predicted Group Value}}{\text{Higest Group Value}} = 2/3 = 0.67$$

The classification coefficients will have 6 to 8 significant figures in actual practice and application of the model to a larger number of habitats will be tedious unless a simple computer program is developed to do the multiplications.

F.5 References cited

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Appendix G. Glossary

Aquatic cover types - A classification of riverine and lacustrine environments based on average temperature (cold, cool, warm) and water body size (small, medium, large).

Assessment - An activity designed to identify, predict, and quantify information about the impact of an action. Such assessments should address all physical, biological, economic, and social parameters relevant to the change expected to result from the action.

Available habitat - An area of land or water, or both, composed of one or more cover types, capable of providing direct support for an evaluation species.

Carrying capacity - The units of biomass/unit area or units of biomass production/unit area that can be supported by an area over a long, but defined, period of time (see Giles 1978 for more discussion).

Cover type - An area of land or water with similar physical, chemical, and biological characteristics that meet a specified standard of homogeneity.

Evaluation - Value judgements made following examination of information from an assessment.

Evaluation species - Individual animal species, a group of species, life stage of a species, or life requisite of a species.

Guild - A group of species that share a common habitat resource.

Habitat suitability - The potential of a specific area to support a selected evaluation species.

Habitat Suitability Index (HSI) - A unitless number bounded by 0.0 and 1.0 where 0.0 represents unsuitable habitat and 1.0 represents optimal habitat.

Habitat Suitability Index model - The rules, in either written or mathematical form, by which a Habitat Suitability Index is determined for a particular evaluation species at a particular location. The HSI model consists of two parts: a value of interest (numerator) and a standard of comparison (denominator). The denominator is a description of optimal habitat; the numerator is a description of habitat in the area of interest.

Habitat Units (HU) - A value derived by multiplying the Habitat Suitability Index for an evaluation species by the size of the area for which the HSI was calculated. The HU provides a standardized basis for comparing habitat changes over time and space.

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Habitat variable - A measurable characteristic of an evaluation species' habitat used in the determination of a Habitat Suitability Index.

Interspersion - The spatial relationship of habitat resources to one another. Interspersion is considered for species that typically utilize more than one cover type to meet all of its life requisites.

Life requisite - Food, water, cover, reproductive, or special requirements supplied by the habitat.

Life stage - Embryo, fry, juvenile, or adult stage of a species.

Terrestrial cover type - Relatively homogeneous units based primarily on structural categories such as vegetation height or density, and leaf persistence.

Variable - A characteristic of habitat which can be directly measured and around which a habitat model is constructed.

Weighted Useable Area (WUA) - The product of the total surface area of the sampled unit of a stream (i.e., representative reach) and a composite weighting factor which represents the combination of hydraulic conditions present.

Wildlife - Wildlife includes all nondomesticated aquatic and terrestrial animal species.

Word model - A word description of habitat requirements that can be used to determine the Habitat Suitability Index for an evaluation species.