

**Appendix 8. Submodels of the ecosystem health submodel.**

The major ecosystem health aspects measured by Evoland for the case study are related to aquatic, riparian, and upslope habitat capacity for biodiversity and productivity. Four submodels treat (1) fish species richness and fish number, (2) floodplain habitat, (3) small stream index of biotic integrity (IBI), and (4) upslope habitat. As is the case for all landscape evaluative models, each time step a global statistic is computed (distributed uniformly on the interval from -3 to 3). Together the four models cover the entire study area. Intrinsicly (or by configuration) each model is restricted to different zones, partially overlapping, of the case study landscape. Submodel (1) is restricted to IDUs (parcels) adjacent to the main stem of the Willamette or its major tributaries. Submodel (2) is restricted to IDUs in the historical floodplain of the Willamette. Submodel (3) is restricted to IDUs adjacent to small streams of Strahler order two, three, and four. And submodel (4) is restricted to IDUs outside the floodplain and not adjacent to small streams. The landscape level statistic is computed as an area weighted mean of the submodel outputs for each IDU. If more than one submodel applies to an IDU because of overlapping zones, then the minimum statistic was used in the area weighted mean. The main text explains the method by which the raw outputs from these submodels, and the aggregate statistic, are transformed to be uniformly distributed over the interval -3 to 3. The following provides more details on the submodels.

*Fish species richness and fish number.*

The purpose of this model is to simulate species richness and fish number in the main stem of the Willamette River. This model derives from the empirical data from Gregory and Wildman (2005) who found that big wood in the Willamette River predicted species richness and fish number. The amount of big wood is simulated in Evoland using a relationship between LULC and big wood recruitment rate into the river. That relationship is based on recruitment rate output from the STREAMWOOD model (Meleason, M. A., S. V. Gregory, and J. Bolte. 2002. USDA Forest Service Gen. Tech. Rep. PSW-GTR-181. [online] [http://www.fs.fed.us/psw/publications/documents/gtr-181/036\\_Meleason.pdf](http://www.fs.fed.us/psw/publications/documents/gtr-181/036_Meleason.pdf)). The following three tables give the specifics. Table 1 shows the prediction of species number. Table 2 shows the prediction of fish number. Table 3 contains parameters used by tables 1 and 2.

**Table A8.1.** Number of Fish Species. To estimate the number of fish species in the current IDU adjacent to the main stem of the Willamette River, get the SpeciesNumberFlagV1 corresponding to the LULC of the IDU from table 3. Draw a random normal variable with mean and sd (standard deviation) corresponding to that SpeciesNumberFlagV1.

SpeciesNumberFlagV1	mean	sd
+	11.25	3.0
--	6.3	2.4

**Table A8.2.** Number of Fish (Nhat). To estimate the number of fish in the current IDU adjacent to the main stem of the Willamette River, get the ScaledVolumeV1 corresponding to the LULC of the IDU from table 3. Then substitute that into the regression equation on the first row of this table.

Nhat =	41.577(ScaledVolumeV1)+46.378
R-sqr =	0.826

**Table A8.3.** Relationship between LULC of an IDU and STREAMWOOD. The volume inputs from STREAMWOOD as fitted to the Willamette have been scaled to [0..1].

LULC_C	Description	ScaledVolumeV1	SpeciesNumberFlagV1
1	Residential 0 - 4 DU/ac	0	--
2	Residential 4 - 9 DU/ac	0	--
3	Residential 9 - 16 DU/ac	0	--
4	Residential > 16 DU/ac	0	--
6	Commercial	0	--
7	Commercial/Industrial	0	--
8	Industrial	0	--
9	TM Urban 8	0	--
10	Residential-Commercial	0	--
11	Urban non-vegetated unknown	0	--
16	Rural structures	0	--
18	Railroad	0	--
19	Primary roads	0	--
20	Secondary roads	0	--
21	Light duty roads	0	--
24	Rural non-vegetated unknown	0	--
25	TM Urban 24	0	--
49	Urban tree overstory	0.065	+
51	Forest open	0.158	+
52	Forest semi-closed mixed	0.158	+
53	Forest closed hardwood	1	+
54	Forest closed mixed	0.527	+
55	Upland forest semi-closed conifer	0.329	+
56	Forest closed conifer 1-20	0.065	+
57	Forest closed conifer 21-40	0.515	+
58	Forest closed conifer 41-60	0.808	+
59	Forest closed conifer 61-80	1.001	+
60	Forest closed conifer 81-20	1.096	+
61	Forest closed conifer >200y	1.472	+
62	Upland forest semi-closed hardwood	0.3	+
66	Hybrid poplar	0.158	+
67	Grass seed rotation	0	+
68	Irrigated annual rotation	0	--
71	Grains	0	--
72	Nursery	0	--
73	Caneberries & Vineyards	0	--
74	Double cropping	0	--
75	Hops	0	--
76	Mint	0	--
77	Radish seed	0	--
78	Sugar beet seed	0	--
79	Row crop	0	--
80	Grass	0	--
81	Burned grass	0	--
82	Field crop	0	--

83	Hay	0	--
84	Late field crops	0	--
85	Pasture	0	--
86	Natural grassland	0	--
87	Natural shrub	0	--
88	Bare/fallow	0	--
89	Flooded/marsh	0	--
90	Irrigated field crop	0	--
91	Turfgrass/park	0	--
92	Orchard	0	--
93	Christmas trees	0.065	--
95	Woodlot	0.3	--
98	Oak	0.3	--

### *Floodplain habitat*

The floodplain habitat evaluative model classifies the landscape using one or more of three indices. The first two indices, biophysical potential and social constraints, derived from a large study encompassing the case study area (Gregory et al. 2002). A third index, biophysical condition, is the same as biophysical potential, with the modification that the third index considers present forest and channel length without reference to 1850 conditions (Table A8.4). The submodel evaluates the landscape within the historical limits of the Willamette river floodplain. The sampling units are each 1 km cross-section of the floodplain perpendicular to the river channel. As published the model evaluated each sampling unit in order to rank the sampling units with respect to one another in order to calculate a restoration priority statistic that was a combination of the biophysical potential and social constraints indices. Each cross-section is evaluated for each factor, and the factors are combined in a linear combination to form each index. With respect to an index, sampling unit scores are normalized using the equation,  $norm = (current - minimum)/range$ , where the minimum and range are taken from the extreme values over all sampling units. In order to get a landscape statistic that is sensitive to changing conditions over the course of a simulation, the norm equation for each factor was parameterized once at initialization. Because conditions change during the simulation, subsequently the norm is not always in the interval [0, 1]. Thus the norm averaged over sampling units indicates conditions relative to the baseline at initialization. For the case study only the biophysical condition index was used. The factors and weights composing these indices are Table A8.4.

**Table A8.4** Floodplain habitat submodel

<i>Biophysical Potential</i>		<i>Social Constraints</i>		<i>Biophysical Condition</i>	
Component	Wt	Component	Wt	Component	Wt
length difference between 1850 and present of forest (riparian) (km)	0.4	population density (people/ km2)	0.11	length difference between 1850 and present of forest (riparian) (km)	0.4
length difference between 1850 and present of channel (km)	0.4	rural structure density (km2/ km2)	0.11	length difference between 1850 and present of channel (km)	0.4
percent of channel lacking revetment (%)	0.2	road density (km/km2)	0.22	percent of channel lacking revetment (%)	0.2
		area of private land (km2/km2)	0.22		
		percent land worth more than \$2500 / ac. (%)	0.44		

#### *Small stream index of biotic integrity (IBI)*

The small streams regression models estimate the status of fish and invertebrates in second to fourth order streams in the Willamette Valley. The predictors include proportions of agricultural and developed land with 120m buffers on both stream sides, stream flow, and other physiographic variables. These models were developed using data from 149 streams over the years 1993-1997 (Van Sickle et al. 2004; Baker et al. 2002). EPT Richness is a measure of three of the more sensitive genera of aquatic invertebrates. WINOE is a comparison of invertebrate communities at disturbed vs. undisturbed sites. Native Fish Richness is the number of native species present and reflects overall biodiversity. Fish IBI is designed to assess the alteration in composition and functional organization of the fish community relative to sites unaffected by human disturbance. Cutthroat Trout Abundance is designed to assess the alteration in composition and functional organization of the fish community. For the study area we used the same reaches, buffers, fixed variables, and LULC legends as Van Sickle et al. (2004). The version of Evoland used in the case study did not compute some of the physiographic variable, 80% exceedance flow (mean of July and August). For the case study, only IBI was calculated. IBI is a linear regression that depends on the proportions of developed and agricultural lands within the 120 m buffers surrounding stream reaches of 100 to 5000 m in length, where the proportions represent the entire upstream network. For each stream reach, The IBI prediction equation follows.

$$IBI = 67.86 - 0.45 * \text{percentUpstreamAgrc} - 0.4 * \text{rpercentUpstreamDvlp} \quad [A8.1]$$

#### *Upslope habitat*

The upslope habitat model evaluates suitability of feeding and breeding habitat for approximately 100 species (Adamus *et al.* 2000, species-habitat relationships, internal report, US EPA, Corvallis, OR). A subset of species was chosen for the case study to emphasize

protection and restoration of habitat for species not modeled by the other submodels. The model iterates over all cells in the landscape and scores each cell using a number of rules that involve LULC and physiographic characteristics of the cell and neighboring cells. Species groups with different biophysical requirements are treated differently. The landscape level score for a species group is an area weighted average. The target species included:

Great Blue Heron, Wood Duck, Osprey, Belted Kingfisher, Killdeer, Little Brown Myotis, American Beaver, Mink, Northern River Otter, Pacific Water Shrew, Northwestern Salamander, Western Terrestrial Garter Snake, Roughskin Newt, Red-Legged Frog, Western Pond Turtle.