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DRAFT REPORT TO: Oregon Division of State Lands

Application of Links Wildlife Habitat Importance Index Classification and Assessment at the Astoria Airport Mitigation Bank

BY

John L. Marshall

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APPLICATION OF LINKS WILDLIFE HABITAT IMPORTANCE INDEX CLASSIFICATION AND ASSESSMENT AT ASTORIA AIRPORT MITIGATION BANK

Resource managers and planners must often make decisions on wildlife habitat management based on an assessed value of the habitat. This research provides a method to classify and assess habitat value using an importance index that appears to be verifiable by comparing relative percent use of "indexed" habitat by birds. The method provides a system to relatively rank habitat types by structure and offers a recommended compensatory mitigation credit and trade strategy.

The method is applied to a 31 acre parcel at the west shore of the mouth of the Lewis and Clark River (T.8N R.10W. W.M.) where it enters into Youngs Bay on the Columbia River. The site is in the city limits of Warrenton, Oregon and is currently owned and managed by Oregon Division of State Lands (figure 1).

In 1987 the portion of the Warrenton dike bordering the Lewis and Clark River and north of old Highway 101 was moved about 800 feet west of its historical position (the original dike was installed in the early 1900's and substantially improved by the Corps of Engineers in 1938). The old dike was then largely removed in an effort to restore tidal influence to about 31 acres of land. The restored tidelands are to be used as a mitigation bank for compensation of future anticipated wetland conversions in other areas in the general vicinity. "Credits" from the restored tidal wetland are to be sold by the state of Oregon to future developers as mitigation needs arise. Credit allocation and sale are to be administered by Oregon Division of State Lands, the current owner and manager of the site (referred to here as the Astoria Airport Mitigation Bank).

Two separate monitoring projects, vegetation (Jackson et al 1989) and bird use (Patterson and Bruner 1989), are used to obtain data for use in a modified (Larson 1976) classification strategy established by Marshall (1985). The classification method is further modified here to provide a method for habitat assessment for use by wildlife. A 1:2400 scale color infrared air photograph (Corps of Engineers 1989) is used for mapping and computing areal coverage of wetland habitat at the site.

Vegetation species composition and cover class data were obtained from eighteen samples in the 1989 Field Analysis of Estuarine Restoration at the Astoria Mitigation Bank (Jackson et al 1989). Height class data were inferred by the author based on field experience in the area and other similar areas. Bird use by habitat type was provided in unpublished data forms as part of a volunteer bird monitoring project implemented by Howard Bruner and Mike Patterson.

All data were entered and tabulated using the Marshall 1985 Importance Index method (referred to here as the Links System) on Microsoft Excel Windows Spreadsheets. An attempt was made, within the limits of the software and the knowledge of the operator, to create a semi-relational data base (Patton 1992). While this system was marginally adequate for application to the eighteen samples collected at the Astoria Mitigation Bank site, it is unsuitable for larger applications. Conversion and restructuring of the system is recommended using either Paradox, Fox Pro or other similar data base systems.

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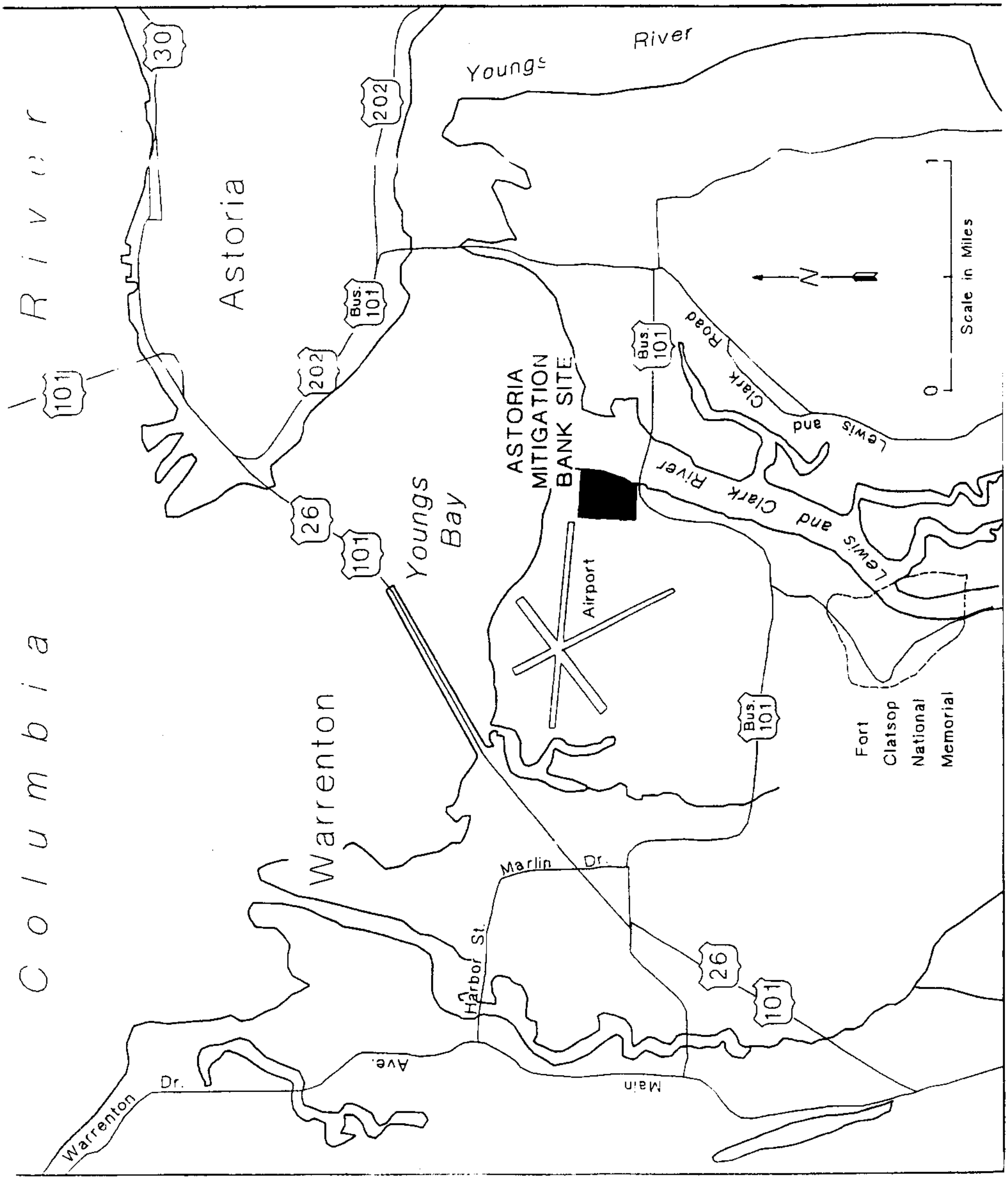

Figure 1. Astoria Airport Mitigation Site location.

SAMPLING

Ideally, sampling would progress from a stratified random sample site selection process, using a large scale air photograph, to subsequent field sampling and a plant community verification procedure. This was not possible for this research. Time constraints precluded the opportunity for field sampling. Further, bird monitoring data was for one year (1988-1989). Since the structure of the vegetation at the site has changed in the past three years due to high tree mortality, current site conditions are not suitable for comparison with bird use in 1989.

Wetland habitat type (class) stratification was done after-the-fact using existing sampling and air photo documentation. To the degree possible, vegetation samples (figure 2) were overlayed on the air photograph (Corps of Engineers 1989). Vegetation "image units" were provisionally delineated using photo signatures of tone, color, texture and shape. While vegetation data was useful in defining species composition and structure of sample sites, the position of the samples was very difficult to register on the air photo. Therefore, the actual mapping of habitat types was accomplished almost solely through air photo interpretation.

While all data was derived from existing documentation, it was organized in the Links system using parameters often applied during field data collection. Seven categories were used to organize the data:

1. Plant species moisture tolerance (Reed 1988);

2. Plant species life form and modifiers (Larson 1976);

3. Plant species cover class (Kuchler 1966);

4. Plant species height class (Kuchler 1966);

5. Hydrologic and substrate cover class (Marshall 1985);

6. Hydrologic and substrate significance coefficients (Marshall 1985); and

7. Hydrologic regime modifiers (Cowardin et al 1979).

Sample Habitat Importance Index

Data from eighteen vegetation samples (Jackson et al 1989) were used to derive a habitat classification and importance value for each habitat type at the Astoria Airport Mitigation Bank. The habitat classification and importance value were derived by computing an importance index for each sample. The importance index was derived using six steps:

1. Group plant species by life form and moisture tolerance;

2. Sum percent cover class mid-points for each life form, hydrologic trait, and substrate type;

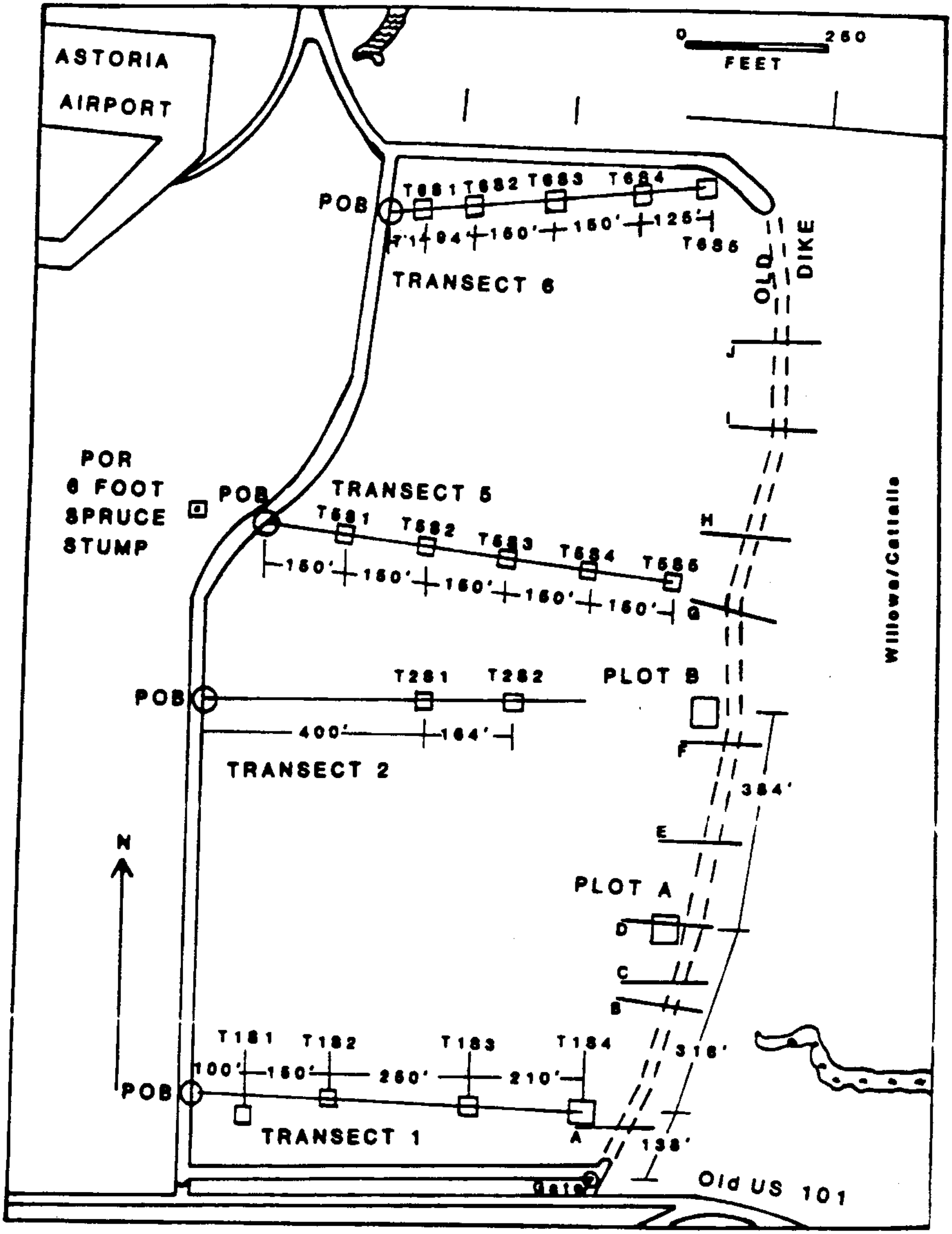

Figure 2. Astoria Airport Mitigation Bank vegetation sampling transects (Jackson et al 1989).

3. Determine the mean height class number for each life form and the significance coefficient for each hydrologic trait and substrate type. This is the height class significance coefficient;

4. Determine an importance value for each life form by multiplying the sum of the life form cover class mid-points by their respective height class significance coefficients;

5. Determine sum of importance values for all life forms, hydrologic traits and substrate types;

6. Determine a relative importance value for each life form, hydrologic trait and substrate type by dividing each respective importance value by the sum of all importance values. This is the habitat importance index number for the sample.

The process by which importance indexes are derived can be followed on figure 3. Defining the habitat importance index is the first step required for habitat classification and habitat assessment.

WILDLIFE HABITAT CLASSIFICATION

All habitat assessment systems require a classification of the habitat to be assessed. The Links system provides a method that simultaneously classifies and assesses the habitats sampled. It is a numeric interface between habitat classification and assessment.

The task of defining the relative importance of various wildlife habitat classes in each sample was accomplished using figure 4. The importance index derived for each wildlife habitat type on figure 3 is transferred to the corresponding life form, hydrologic trait and/or substrate type on figure 4. A dominance threshold was used to distinguish the dominant and subordinate habitat classes. Any life form, hydrologic trait or substrate type that obtained an importance index greater than or equal to the threshold was considered a dominant habitat class. The threshold selected for the Astoria Airport Mitigation Bank was .35. A subordinate threshold of .15 was selected to distinguish classes lower than .35 but above .15.

An upper case letter code is used to represent habitat classes. Habitat classes are organized fractionally in the code with increasing importance to the left. A slash separates the dominant classes from the subordinate and a dash separates codominant and cosubordinate classes (figure 4).

Following Larson (1976) and Cowardin et al (1979), each class is modified by descriptive components of each habitat class (e.g., short narrow leaf emergents, floating vascular, etc.). Modifiers are represented by lower case letters and are organized in order of decreasing importance to the right of the class or subclass they describe.

Physiographic Province:	Land Form:	Area Type:	Wetland System/Subsystem:
Columbia River Estuary	Tide-land	Upland nonwetland Upland wetland Bottomland nonwetland (Bottomland wetland)	Marine / Subtidal, Intertidal Estuarine / Subtidal, Intertidal Riverine / Tidal, Lower Perennial, Upper Perennial, Intermit. Lacustrine / Limnetic, Littoral (Palustrine) tidal

Location: west bank mouth of Lewis & Clark River	T1-S1	1984		

Plant Species /1	Plant Moisture Tolerance: h	h/m	m	Hydrologic Trait (H.T.)	Exposed Substrate Type (S.T.)	Trees (T)	Shrubs (S)	Herbs (H)	Open Water Wetland: Shallow (<2 m) OW(1)	Deep (>2 m) OW(2)	Exposed Substrate: St	C	G	S	Si	Cl
Hcla		3						Ø								
Glyceria sp.	1							Ø								
Popa	1							Ø								
Scmi	1							Ø								
Loco		3						100								
Gatr	2							Ø								
Spdo	2						Ø									

Site Characteristics — Cover Class and Cover Class Mid-Points (Percent); Life Form (L.F.); Hydrologic Trait (H.T.)

(Step 2)
Sum the percent cover mid-points for each site characteristic (L.F., H.T., and S.T.).

Trees	Shrubs	Herbs	Shallow OW(1)	Deep OW(2)	St	C	G	S	Si	Cl
Ø	Ø	100	Ø	Ø						

(Step 3) HEIGHT CLASS/SIG. COEFF. INDEX
Find the mean H.C. for each respective L.F. and the significance coefficient for each S.T. and H.T.

Plant Species	Hydrologic Trait	Substrate Type	Life Form Height Class: T	S	H	Hydrologic Trait Sig. Coeff. (S.C.)	Exposed Substrate Type Sig. Coeff. (S.C.): St	C	G	S	Si	Cl
Hcla					Ø							
Glyceria sp.					Ø							
Popa					Ø							
Scmi					3							
Loco					Ø							
Gatr					Ø							
Spdo				Ø								

H.C./S.C. Index /2

T	S	H	OW1	OW2	St	C	G	S	Si	Cl
Ø	Ø	3	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø

T = Trees > 2 m
S = Shrubs < 2 m
H = Herbs
OW1 = Open Water < 2 m deep
OW2 = Open Water > 2 m deep
St = Stone > 250 mm
C = Cobble 250 - 75 mm
G = Gravel 75 - 2.0 mm
S = Sand 2.0 - .05 mm
Si = Silt .05 - .002 mm
Cl = Clay < .002 mm

Hcla = Holcus lanatus
Glyceria = Glyceria spp.
Popa = Potentilla pacifica
Scmi = Scirpus microcarpus
Loco = Lotus corniculatus
Gatr = Galium trifidium
Spdo = Spirea douglassii

(Step 4) IMPORTANCE VALUE
For each L.F., H.T., and S.T., multiply the sums of cover class mid-points by their respective H.C. and S.C. indexes.

(Step 5)
Sum the importance values.

(Step 6) IMPORTANCE INDEX
Divide each importance value by the sum of importance values.

	Trees (h, h/m, m)	Shrubs (h, h/m, m)	Herbs (h, h/m, m)	Open Water: Shallow (< 2 m)	Deep (>2 m)	Exposed Substrate: St	C	G	S	Si	Cl
(Step 4)	Ø	Ø	300	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø
(Step 5)	300										
(Step 6)	Ø	Ø	1.0	Ø	Ø	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Figure 3. Importance Index procedure for sample T1-S1.

Wetland: Astoria Airport Mitigation Bank T1-S1 (1989)

Wetland System: Palustrine	Life Form Criteria				Hydrologic Trait Criteria	
	Trees (T) >2 m	Shrubs (S)	Emergents (E)		Open Water Wetland	
			>60% h/m	>60% h	Shallow <2 m	Deep >2 m
Descriptors:	a. moist decid. b. moist evergr. c. dead d. water regime (2-7)	a. moist decid. b. moist evergr. c. dead d. sapling <2 m e. short bushy <2 m f. tall bushy >2 m g. lianas h. water regime (2-7)	a. short narrow leaf <2 m b. tall narrow leaf >2 m c. robust d. persist e. nonpersistent f. water regime (3-7) g. 8	(a) short narrow leaf <2 m b. tall narrow leaf >2 m c. robust d. persist e. nonpersistent f. floating broad leaf g. water regime (1-3),7 h. 8	a. algal b. aquatic moss c. rooted vasc. d. floating broad leaf e. cobble f. gravel g. sand h. mud i. organic j. water regime (1-3,7)	a. algal b. aquatic moss c. rooted vasc. d. floating broad leaf e. cobble f. gravel g. sand h. mud i. organic j. water regime (1,7)
Dominant Import. Ind.				1.0		
Subordinate Import. Ind.						
Wetland Classification (Mod. Larson)	A Forested Wetland	B Shrub Wetland	C Infrequent Emergent Wetland	D Frequent Emergent Wetland	E Shallow Open Water Wetland	F Deep Open Water Wetland
Wetland Classification (Cowardin)	Forested Wetland Scrub Shrub Wetland	Scrub Shrub	Emergent Wetland	Emergent Wetland	Aquatic Bed	Aquatic Bed Unconsolidated Bottom

Water Regime Modifiers

1. Permanently Flooded
2. Semipermanently Flooded
3. Seasonally Flooded
4. Saturated
5. Temporarily Flooded
6. Intermittently Flooded
7. Artificially Flooded
8. tidal

Code: FEM

Figure 4a. Classification procedure for sample T1-S1.

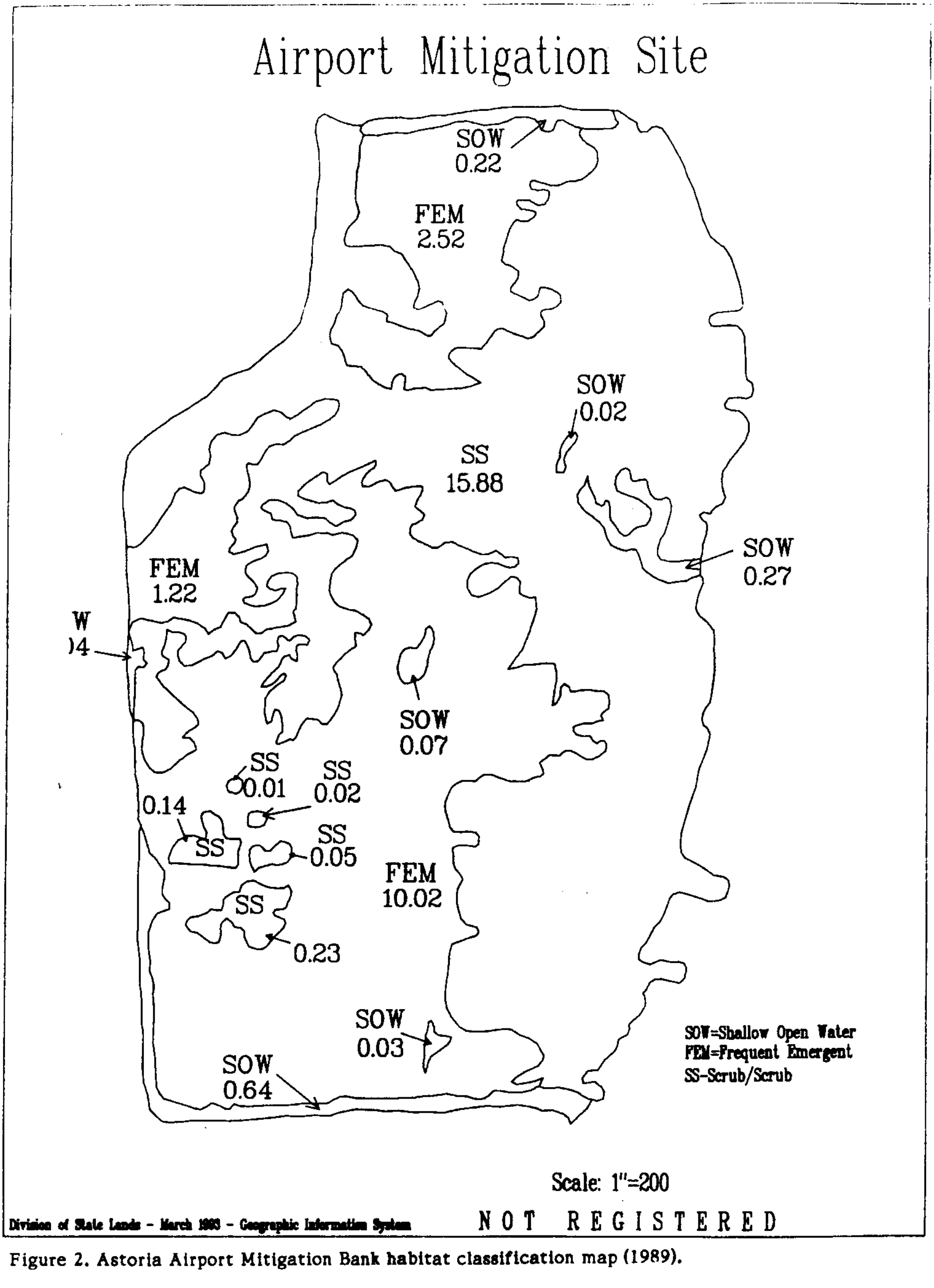

Figure 2. Astoria Airport Mitigation Bank habitat classification map (1989).

WILDLIFE HABITAT ASSESSMENT

Habitat is an anthropogenic concept used to categorize similar plant and animal assemblages. The concept of habitat is strongly tied to the concept of ecosystem and includes both the biotic and abiotic attributes of the area defined. There are physical and biological variations within and between habitat types. Habitats experience cyclic variations in environmental conditions daily, seasonally and through historic and geologic time. Habitats may also experience successional or catastrophic changes. Habitat cannot be discussed outside of the context of species and habitat distinctions are often an artifact of human scale definition. These concepts are recognized in the Links wildlife habitat classification and assessment method.

The Links system is based on the premise that habitat structure largely explains habitat use by wildlife. The Links system incorporates three structural dimensions of vegetation (canopy heights and areal coverage) and one structural attribute (diversity). It further recognizes open water and exposed substrate types as structural components of wildlife habitat. Each application of the Links system is a snapshot picture in time. Therefore, site changes can be documented through a series of time sequenced applications. Likewise, habitat composition and structural goals can be modeled using this system and subsequently tracked through monitoring to establish success or failure at predetermined target dates.

Site Level Wildlife Habitat Importance Indexes

A multi-step procedure similar to the procedure used at the sample importance value level is used to derive an importance value at the site level and to derive a subsequent set of site level habitat importance indexes (Appendix 1):

1. Average all importance values in their respective structural categories;

2. Aggregate the sample image units on the area corrected air photograph by dominant habitat type. Digitize each aggregated unit and compute areal coverage;

3. Multiply the average importance value of each respective habitat type by the area of the site covered by that habitat. These numbers represent the number of habitat units per habitat type present;

4. Sum the habitat units derived in step three to define the total number of habitat units at the site; and

5. Divide each respective importance value by the total to derive the respective habitat importance indices for the site.

The habitat values and units determined in steps three and four can be used to compare sites in the same ecologic regime and assessed using the same system. The comparisons could be used to help define mitigation trade ratios or cost per credit in a mitigation bank system. However, this method does not account for time lag and risk factors that should also be considered in compensatory mitigation technical and policy decisions.

Compared Bird Use and Site Importance Index Data

A test was needed to define how "meaningful" the importance index is for explaining wildlife habitat use of the habitats "indexed" using the above procedures. A monitoring effort was required to provide wildlife habitat use data for the test. In 1989, two volunteers, Howard Bruner and Mike Patterson, completed a one year survey of bird use at the Astoria Airport Mitigation Bank. A primary goal of this effort was to define a number for bird use by habitat type that could be compared with the "Links Habitat Index". After the monitoring was completed, the following procedure was used (Appendix 2):

1. Tabulate all habitat bird use by bird species and habitat type;

2. Convert use numbers to percent of total observations per bird species;

3. Sum total percents of use by habitat type;

4. Sum the subtotals defined in step three; and

5. Divide each of the subtotals in step three by the grand total derived in step four. The percentages derived represent the relative percent use of habitat types over a one year monitoring effort.

The relative percents of bird use by habitat type at the Astoria Airport Mitigation Bank are compared with the site's Links Habitat Importance Indexes in table 1.

Table 1. Comparison between percent use of birds of habitat typ es and habitat type importance indexes at the Astoria Airport Mitigation Bank (1989).

Habitat	Links Importance Index	Relative Percent Use by Birds
Forest	Absorbed by Scrub/Shrub	11
Scrub/Shrub	.59 - .11 = .48	48
Emergent	.36	35
Shallow Open Water	.039	04.9

CONCLUSION

The Links Wildlife Habitat Classification and Assessment method integrates two common tools employed by resource planners and managers for a large variety of resource related decisions. The first test of the method with respect to wildlife use of "indexed" habitat types appears to display a strong link between habitat structure and habitat use by birds. The numeric nature of the system allows for computer applications and subsequent potential to offer broad latitude in terms of area and scale of application. However, small scale (large area) applications should be field tested with large scale (small area) sampling to verify the accuracy differences at different scales.

The Links method should be applied to a number of sites to see if the match between importance index and relative percent bird use is consistently as close as it was in this test. Other wildlife use (e.g., mammals, reptiles, amphibians, etc.) should be monitored and compared with the index as well.

The Links system provides a method to define relative mitigation trade ratios based on site level importance values. However, these ratios do not recognize such factors as risk, time lag between habitat destruction and the achievement of compensatory mitigation goals. Nor does it explicitly recognize the impacts of ambient disturbance factors such as noise, human and ferral animal intrusion, stormwater quality, etc. There are other systems that address these considerations. As with all assessment systems, Links has strengths and weaknesses. Any conscientious application of the system should recognize this and make provisions to use complimentary tools to provide the best overall assessment possible. No assessment should be used as the final decision making effort but only as one part of the decision making information system.

Finally, if the structure/use relationship can be demonstrated consistently through the "Links Index", perhaps there are other inherent statistical relationships that can be used to examine a variety of ecological questions. For example, at this site there is a 5:1 ratio between total habitat units defined by the Links method (11,950) and total relative percent bird use over one year (2,395). Does this mean bird use accounts for 20 percent of the habitat units available? As other species are accounted for, will the ratio move closer to 1:1? Will the ratio remain the same or vary from site to site? Perhaps the ratio could be used as an index to define the relationship between habitat potential and actual habitat use. Perhaps there is no relationship at all. The point is, that if future applications demonstrate such relationships do exist, we may be able to use Links and other similar tools to numerically indicate the affects of urbanization and fragmentation on habitat health. These tools could help us with a variety of policy questions regarding habitat regulation and planning (e.g., buffer widths, corridors, mitigation ratios and site selection, etc.).

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APPENDICES FOR DRAFT REPORT:

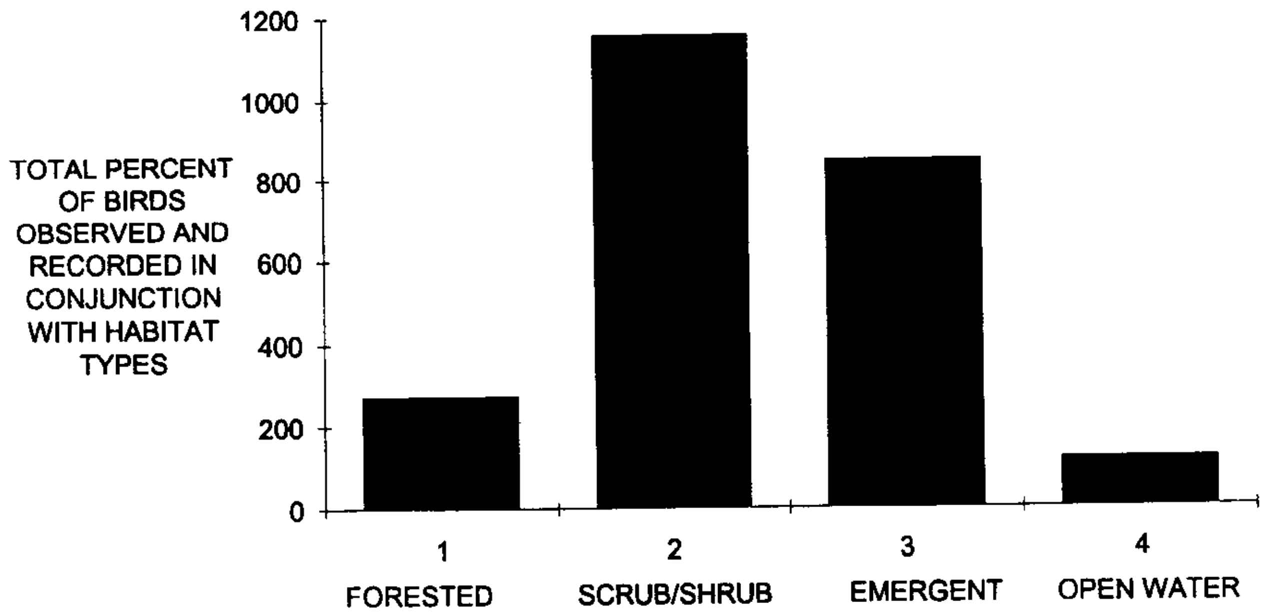
Application of Links Wildlife Habitat Importance Index Classification and Assessment at Astoria Airport Mitigation Bank.

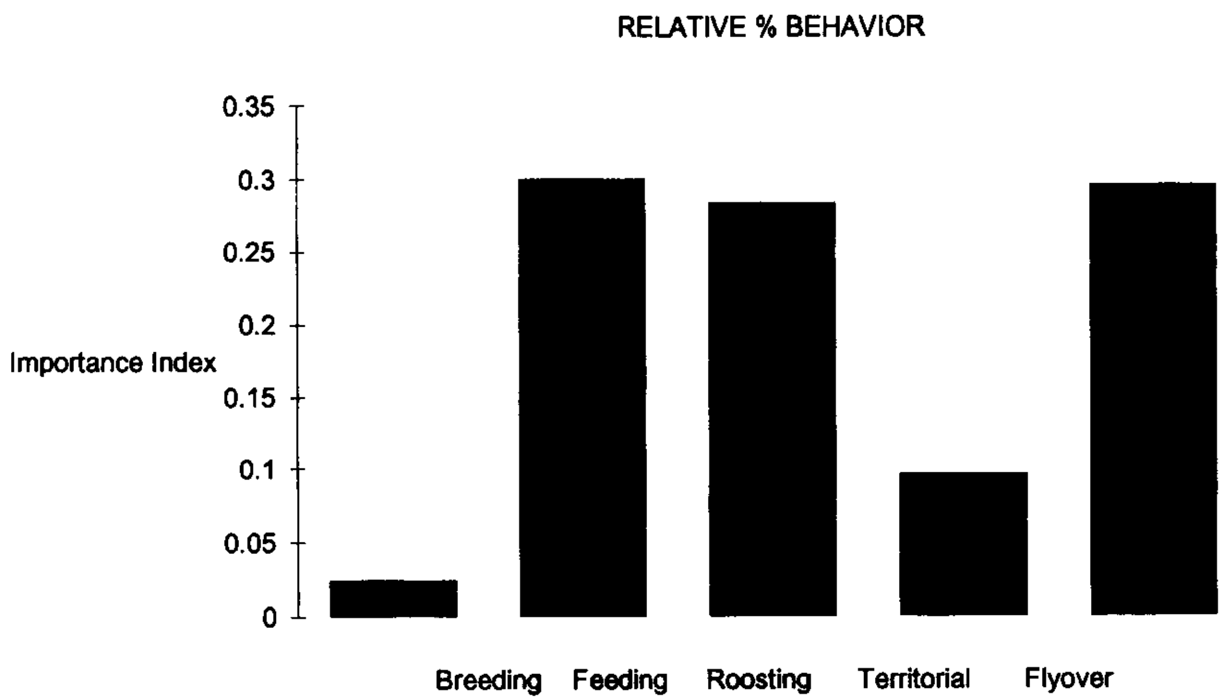
Submitted to: Oregon Division State Lands
April 2, 1993

APPENDIX 1. Links habitat classification and assessment methodology applied to the Astoria Airport Mitigation Bank.

	A	B	C	D	E
1	SITE	DATE	SAMPLE	FORESTED	SCRUB/SHRUB
2	ASTORIA AIRPORT MITIGATION BANK	1989	A	0.22	0.44
3	ASTORIA AIRPORT MITIGATION BANK	1989	B	0.16	0.41
4	ASTORIA AIRPORT MITIGATION BANK	1989	T1-S1	0	0
5	ASTORIA AIRPORT MITIGATION BANK	1989	T1-S2	0	0
6	ASTORIA AIRPORT MITIGATION BANK	1989	T1-S3	0	0
7	ASTORIA AIRPORT MITIGATION BANK	1989	T1-S4	0.25	0.32
8	ASTORIA AIRPORT MITIGATION BANK	1989	T2-S1	0	0
9	ASTORIA AIRPORT MITIGATION BANK	1989	T2-S2	0	0
10	ASTORIA AIRPORT MITIGATION BANK	1989	T5-S2	0	0
11	ASTORIA AIRPORT MITIGATION BANK	1989	T5-S3	0	0
12	ASTORIA AIRPORT MITIGATION BANK	1989	T5-S4	0	0
13	ASTORIA AIRPORT MITIGATION BANK	1989	T5-S5	0	0.12
14	ASTORIA AIRPORT MITIGATION BANK	1989	T6-S1	0	0
15	ASTORIA AIRPORT MITIGATION BANK	1989	T6-S2	0	0.13
16	ASTORIA AIRPORT MITIGATION BANK	1989	T6-S3	0	0.007
17	ASTORIA AIRPORT MITIGATION BANK	1989	T6-S4	0	0.14
18	ASTORIA AIRPORT MITIGATION BANK	1989	T6-S5	0	0.27
19	ASTORIA AIRPORT MITIGATION BANK	1989	T5-S1	0	0
20	TOTAL IMPORTANCE VALUE	11949.7679		0	7111.715
21	TOTAL IMPORTANCE INDEX	1		0	0.595134155
22	TOTAL ACRES	31.38	%ACRES	0	0.520395156

HABITAT USE BY BIRDS AT THE ASTORIA AIRPORT MITIGATION BANK SITE




RELATIVE % BEHAVIOR
0.35
0.3
0.25
0.2
Importance Index
0.15
0.1
0.05
0
Breeding
Feeding
Roosting
Territorial
Flyover

	F	G	H	I
1	FREQUENT EMERGENT	INFREQUENT EMERGENT	SHALLOW OPEN WATER	EXPOSED SUBSTRATE
2	0.04	0.01	0.27	0
3	0.36	0.07	0	0
4	1	0	0	0
5	1	0	0	0
6	1	0	0	0
7	0.41	0.02	0	0
8	0.55	0	0.45	0
9	0.04	0	0	0.96
10	1	0	0	0
11	0.98	0.02	0	0
12	0.75	0.25	0	0
13	0.87	0.01	0	0
14	0.77	0.23	0	0
15	0.53	0.34	0	0
16	0.895	0	0.098	0
17	0.78	0.09	0	0
18	0.68	0	0.05	0
19	0.17	0	0.83	0
20	4369.782857	0	468.27	0
21	0.365679309	0	0.039186535	0
22	0.438495857	0	0.041108987	0

	J	K	L
1	IMPORTANCE VALUE	CODE	IMPORTANCE INDEX FORESTED
2	459	SS/SOW-FO	0
3	412	SS-FEM/FO	
4	300	FEM	
5	300	FEM	
6	300	FEM	
7	590	FEM/SS-FO	
8	355	FEM-SOW	
9	110	EXP	
10	260	FEM	
11	300	FEM	
12	249	FEM/IFEM	
13	312	FEM/SS	
14	269	FEM/IFEM	
15	310	FEM/IFEM	
16	285	FEM	
17	317	FEM	
18	299	FEM/SS	
19	363	SOW/FEM	
20	0		0
21	0		
22	0		

	M	N	O
1	ACRES FORESTED	IMPORTANCE INDEX SCRUB/SHRUB	ACRES SCRUB SHRUB
2	0	459	16.33
3		412	
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20	0	435.5	16.33
21			
22			

	P	Q
1	IMPORTANCE INDEX FREQUENT EMERGENT	ACRES FREQUENT EMERGENT
2	300	13.76
3	300	
4	300	
5	590	
6	355	
7	260	
8	300	
9	249	
10	312	
11	269	
12	310	
13	285	
14	317	
15	299	
16		
17		
18		
19		
20	317.5714286	13.76
21		
22		

	R	S
1	IMPORTANCE INDEX INFREQUENT EMERGENT	ACRES INFREQUENT EMERGENT
2	0	0
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20	0	0
21		
22		

	T	U
1	IMPORTANCE INDEX SHALLOW OPEN WATER	ACRES SHALLOW OPEN WATER
2	363	1.29
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20	363	1.29
21		
22		

	V	W
1	IMPORTANCE INDEX DEEP OPEN WATER	ACRES DEEP OPEN WATER
2	0	0
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20	0	0
21		
22		

	X	Y	Z
1	IMPORTANCE INDEX EXPOSED SUBSTRATE	ACRES EXPOSED SUBSTRATE	FORESTED HABITAT UNITS
2	110	0	0
3			0
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20	110	0	
21			
22			

	AA	AB	AC
1	SCRUB/SHRUB HABITAT UNITS	FREQUENT EMERGENT HABITAT UNITS	INFREQUENT EMERGENT HABITAT UNITS
2	7111.715	4369.782857	0
3	0.595134155	0.365679309	0
4			
5			
6			
7			
8			
9			
10			
11			
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15			
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17			
18			
19			
20			
21			
22			

	AD	AE
1	SHALLOW OPEN WATER HABITAT UNITS	DEEP OPEN WATER HABITAT UNITS
2	468.27	0
3	0.039186535	0
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		

	AF	AG
1	EXPOSED SUBSTRATE HABITAT UNITS	TOTAL HABITAT UNITS
2	0	11949.76786
3	0	
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
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APPENDIX 2. Bird monitoring data at the Astoria Airport Mitigation Bank from 1988 to 1989 (Bruner and Patterson 1989).

	A	B	C	D	E	F	G	H	I	J	K
1	Species	7/9/88	7/20/88	8/5/88	8/20/88	9/19/88	11/2/88	1/1/89	2/5/89	2/19/89	4/5/89
2	Song sparrow	3	12	29	19	26	46	29	11	42	21
3	Marsh wren	6	3	9	7	22	53	17	2	24	23
4	American Goldfinch	2	16	3	5	6					
5	Barn swallow		10	3	8	11					
6	Cliff swallow		2								
7	Cedar waxwing	5	18	2							1
8	Common yellowthroat	2	3	9	7						1
9	Common Flicker						1		7		3
10	Bewicks wren			2	3	2	2	5	1	3	
11	Golden-crowned sparrow							11			
12	Tree swallow			1	1						54
13	Greater yellowlegs					3					11
14	Lesser yellowlegs					10	1				
15	Green-winged teal									1	17
16	Blue-winged teal					12					
17	Northern harrier					3			4	4	1
18	Ruby-crowned kinglet			1			4	6		1	4
19	Hairy woodpecker										
20	Golden-crowned kinglet					2	2	1	10	2	1
21	Thrush species									1	
22	Orange-crowned warbler					1					1
23	Rufus humingbird										29
24	Wilsons warbler										
25	American bittern			1							1
26	Blackheaded grossbeak										
27	American Robin		1	3			50		5	1	5
28	Raven							1			1
29	Sharp shinned hawk						1				
30	Black-capped chickadee			1	2	12	11	5	2	6	1
31	Meadow lark								6		
32	Starling			10			6				
33	Purple finch	3		8			3				
34	House finch				4					1	

	A	B	C	D	E	F	G	H	I	J	K
35	Swainsons thrush	2	5	6			1				
36	Flycatcher spp.										
37	Black-shouldered kite								3		
38	Rough-winged swallow										
39	Swamp sparrow							1		1	
40	Killdeer				1				11	1	
41	Red-tailed hawk					1	1	3		3	2
42	Mallard		5	3	7	6	2	2	4	7	14
43	Northern pintail									13	
44	Belted kingfisher	1		1				1			
45	Common snipe				4	2	11	1			2
46	Fox sparrow					1	3	4	1	4	1
47	Brewers blackbird										
48	Great-blue heron		4	1	1	2	1	2	2	5	2
49	Green-winged teal					1			1		
50	Green-backed heron							2			
51	Long-billed dowitcher						1				
52	American crow	2	10	4	2	44		5	11	13	9
53	Perigrine falcon						1				1
54	Downy woodpecker				2		1	4		5	1
55	Greater scaup								2		
56	Cinamon teal										
57	Red-breasted sapsucker							1			
58	Merlin					1					
59	Glaucous gull			2	2		2		4		1
60	Teal species						4		10		
61	Ring-billed gull		3						1		
62	Western gull				5				3	6	
63	Double-crested cormorant		1			11			2		1
64	Pine siskin						60				
65	Chestnut-backed chickadee			1							
66	Dunlin								7		
67	Caspian tern		3	3							
68	Swainsons hawk						1				
69	Canada goose								9	4	

	A	B	C	D	E	F	G	H	I	J	K
70	Huttons vireo										
71	Black-throated gray warbler					1					
72	Winter wren						4	2		2	
73	Sandpiper species					6					
74	Virginia rail					5	5	4	1		2
75	Short-eared owl								1		1
76	Sora rail					1	1	2			
77	Coopers hawk							1			
78	Purple martin				3						
79	Hermit thrush							2			
80	Gull species					1			6		
81	Violet-green swallow	2									7
82	Savanah sparrow										
83	Surf scotor							1			
84	Least sandpiper				1						
85	White-crowned sparrow		1								
86	Brown-headed cowbird		1								
87	Warbler species			1							
88	Swallow species		1								
89	Yellow warbler				1			1			2
90	Western sandpiper			9							
91	Red-winged blackbird			2			12				
92	TOTAL BIRDS COUNTED	28	115	115	85	193	291	114	127	150	221
93											
94											

	L	M	N	O	P	Q	R	S	T
1	4/16/89	5/28/89	6/23/89	7/30/89	TOTAL BIRDS COUNTED	AVERAGE	MINIMUM	MAXIMUM	FREQUENCY
2	10	35	24	23	330	23.5714286			14
3	34	80	27	15	322	23			14
4	1	12	4	21	70	7.77777778			9
5	1	13	11	11	68	8.5			8
6		5		3	10	3.33333333			3
7		12	8	8	54	7.71428571			7
8		12	8	8	50	6.25			8
9	1				12	3			4
10	1		3	5	27	2.7			10
11	1				12	6			2
12		20	14		90	18			5
13					14	7			2
14					11	5.5			2
15	2				20	6.66666667			3
16		2			14	7			2
17	3	1	1	1	18	2.25			8
18					16	3.2			5
19		1			1	1			1
20	1				19	2.71428571			7
21					1	1			1
22	9	2	4		17	3.4			5
23	8		3		40	13.3333333			3
24		3			3	3			1
25	2	1			5	1.25			4
26		2			2	2			1
27	1	5	5	29	105	10.5			10
28				1	3	1			3
29					1	1			1
30		1	2	2	45	4.09090909			11
31					6	6			1
32			8		24	8			3
33		13		14	41	8.2			5
34	1	2		2	10	2			5

	L	M	N	O	P	Q	R	S	T
35		29	15	36	94	13.4285714			7
36			18	3	21	10.5			2
37					3	3			1
38	1				1	1			1
39					2	1			2
40					13	4.33333333			3
41					10	2			5
42	19	12	3	8	92	7.07692308			13
43					13	13			1
44					3	1			3
45	1			2	23	3.28571429			7
46					14	2.33333333			6
47	1				1	1			1
48		5		2	27	2.45454545			11
49					2	1			2
50	1				3	1.5			2
51					1	1			1
52	4	12	2	17	135	10.3846154			13
53					2	1			2
54				1	14	2.33333333			6
55					2	2			1
56	6	1	1		8	2.66666667			3
57					1	1			1
58	1				2	1			2
59			1	1	13	1.85714286			7
60					14	7			2
61					4	2			2
62	1				15	3.75			4
63		1			16	3.2			5
64					60	60			1
65			1		2	1			2
66					7	7			1
67	1	2		3	12	2.4			5
68					1	1			1
69					13	6.5			2

	L	M	N	O	P	Q	R	S	T
70	1				1	1			1
71					1	1			1
72					8	2.66666667			3
73					6	6			1
74	2				19	3.16666667			6
75					2	1			2
76			1		5	1.25			4
77					1	1			1
78					3	3			1
79					2	2			1
80		1			8	2.66666667			3
81		2			11	3.66666667			3
82	3				3	3			1
83					1	1			1
84			1		2	1			2
85					1	1			1
86	1	1	14		17	4.25			4
87					1	1			1
88					1	1			1
89		2	2		8	1.6			5
90					9	9			1
91	1	1			16	4			4
92	120	291	181	216	2231				
93									
94									

	U	V	W	X	Y
1	WEIGHTED IMPORTANCE	RELATIVE IMPORTANCE VALUE	RECORDED OBSERVATIONS	FOREST (%)	SCRUB-SHRUB (%)
2	330	0.147915733	174	1	59
3	322	0.144329897	210	1	7
4	70	0.031376065	15	6	46
5	68	0.030479606	5	40	20
6	10	0.004482295			
7	54	0.024204393	17	17	59
8	50	0.022411475	34	3	59
9	12	0.005378754			
10	27	0.012102196	18	0	83
11	12	0.005378754			
12	90	0.040340654	6		
13	14	0.006275213			
14	11	0.004930524			
15	20	0.00896459	9	0	0
16	14	0.006275213			
17	18	0.008068131	16	5	44
18	16	0.007171672			
19	1	0.000448229			
20	19	0.00851636			
21	1	0.000448229			
22	17	0.007619901			
23	40	0.01792918	38	6	94
24	3	0.001344688			
25	5	0.002241147			
26	2	0.000896459			
27	105	0.047064097	33	30	63
28	3	0.001344688			
29	1	0.000448229			
30	45	0.020170327	29	14	79
31	6	0.002689377			
32	24	0.010757508			
33	41	0.018377409			
34	10	0.004482295			

	U	V	W	X	Y
35	94	0.042133572	1	0	100
36	21	0.009412819			
37	3	0.001344688	1	0	100
38	1	0.000448229			
39	2	0.000896459			
40	13	0.005826983			
41	10	0.004482295			
42	92	0.041237113	27	0	0
43	13	0.005826983			
44	3	0.001344688			
45	23	0.010309278	7	0	14
46	14	0.006275213			
47	1	0.000448229			
48	27	0.012102196	10	0	30
49	2	0.000896459			
50	3	0.001344688			
51	1	0.000448229			
52	135	0.060510982	10	49	50
53	2	0.000896459	1	0	100
54	14	0.006275213			
55	2	0.000896459			
56	8	0.003585836			
57	1	0.000448229			
58	2	0.000896459	1	100	0
59	13	0.005826983			
60	14	0.006275213			
61	4	0.001792918			
62	15	0.006723442			
63	16	0.007171672			
64	60	0.02689377	1	0	100
65	2	0.000896459			
66	7	0.003137606			
67	12	0.005378754			
68	1	0.000448229			
69	13	0.005826983			

	U	V	W	X	Y
70	1	0.000448229			
71	1	0.000448229			
72	8	0.003585836			
73	6	0.002689377			
74	19	0.00851636			
75	2	0.000896459	2	0	50
76	5	0.002241147			
77	1	0.000448229	1	0	0
78	3	0.001344688			
79	2	0.000896459			
80	8	0.003585836			
81	11	0.004930524			
82	3	0.001344688			
83	1	0.000448229			
84	2	0.000896459			
85	1	0.000448229			
86	17	0.007619901			
87	1	0.000448229			
88	1	0.000448229			
89	8	0.003585836			
90	9	0.004034065			
91	16	0.007171672			
92	2231	1	SUBTOTAL % HABITAT SCORE	272	1157
93			RELATIVE % USE HABITAT	0.113569937	0.48308977
94			TOTAL % HABITAT SCORE	2395	

	Z	AA	AB	AC	AD	AE
1	EMERGENT (%)	OPEN WATER (%)	RECORDED OBSERVATIONS	BREEDING (%)	FEEDING (%)	ROOSTING (%)
2	40	0	9	0	55	22
3	92	0	15	0	50	1
4	40	6	17	0	5	17
5	40	0	10	0	70	0
6						
7	24	0	8	0	12.5	62.5
8	38	0	2	0	0	0
9						
10	17	0	3	0	33	33
11						
12	83	17	9	11	55	0
13						
14						
15	78	22	1	0	0	0
16						
17	44	5	14	0	71	0
18						
19						
20						
21						
22						
23	0	0	13	0	77	0
24						
25						
26						
27	3	3	5	20	60	0
28						
29						
30	7	0	3	0	100	0
31						
32						
33						
34						

	Z	AA	AB	AC	AD	AE
35	0	0	1			100
36						
37	0	0	2	0	50	0
38						
39						
40						
41						
42	85	15	16	25	13	13
43						
44						
45	86	0	0	0	0	0
46						
47						
48	20	50	11	0	36	9
49						
50						
51						
52	1	0	17	0	0	41
53	0	0	2	0	0	50
54						
55						
56						
57						
58	0	0	1	0	0	100
59						
60						
61						
62						
63						
64	0	0	1	0	0	0
65						
66						
67						
68						
69						

	Z	AA	AB	AC	AD	AE
70						
71						
72						
73						
74						
75	50	0	2	0	0	100
76						
77	100	0	1	0	0	100
78						
79						
80						
81						
82						
83						
84						
85						
86						
87						
88						
89						
90						
91						
92	848	118	SUBTOTAL % BEHAVIOR	56	687.5	648.5
93	0.354070981	0.049269311	RELATIVE % BEHAVIOR	0.024443474	0.300087298	0.283064164
94			TOTAL % BEHAVIOR	2291		

	AF	AG
1	TERRITORIAL (%)	FLYOVER (%)
2	22	0
3	44	0
4	0	76
5	0	30
6		
7	0	25
8	50	50
9		
10	33	0
11		
12	0	33
13		
14		
15	0	100
16		
17	29	0
18		
19		
20		
21		
22		
23	23	0
24		
25		
26		
27	20	0
28		
29		
30	0	0
31		
32		
33		
34		

	AF	AG
35		
36		
37	0	50
38		
39		
40		
41		
42	0	50
43		
44		
45	0	0
46		
47		
48	0	55
49		
50		
51		
52	0	59
53	0	50
54		
55		
56		
57		
58	0	0
59		
60		
61		
62		
63		
64	0	100
65		
66		
67		
68		
69		

	AF	AG
70		
71		
72		
73		
74		
75	0	0
76		
77	0	0
78		
79		
80		
81		
82		
83		
84		
85		
86		
87		
88		
89		
90		
91		
92	221	678
93	0.096464426	0.295940637
94		

APPENDIX 3. Vegetation data for the Astoria Airport Mitigation Bank from 1987 to 1989 (Jackson et al 1989).

Observed Changes in Plant Species by Site 1987-1989

	1987 ground/canopy	1988 ground/canopy	1989 ground/canopy
T1-S1			
Holcus lanatus	--	40%	--
Glyceria	30%	10%	--
Potentilla pacifica	5%	5%	--
Scirpus microcarpus	--	30%	100%
Lotus corniculatius	T	15%	--
Ranunculus repens	--	T	--
Galium trifidum	--	T	--
Spiraea douglasii	--	T	--
T1-S2			
Juncus effusus	75%	90%	98%
Potentilla pacifica	--	1%	--
Lotus corniculatius	--	1%	--
Carex obnupta	--	8%	--
Deschampsia cespitosa	--	--	2%
Ranunculus repens	--	T	--
Galium trifidum	--	T	--
T1-S3			
Juncus effusus	50%	98%	--
Holcus lanatus	--	2%	--
Scirpus microcarpus	--	T	100%
T1-S4			
Juncus effusus	60%	3%	10%
Deschampsia cespitosa			50%
Holcus lanatus	20%	20%	
Lolium perenne	--	20%	
Agrostis alba	--	20%	
Rubus spectabilis	--	3%	T
Rosa nutkana	--	3%	1%
Ranunculus repens	T	3%	5%
Typha latifolia	--	2%	10%
Oenanthe sarmentosa	--	3%	--
Rubus ursinus	T	3%	--
Alopecurus geniculatus	--	20%	--
Galium aparine	--	T	--
Potentilla pacifica	--	--	15%

	1987 ground	1987 canopy	1988 ground	1988 canopy	1989 ground	1989 canopy
Digitalis purpurea	--		--		5%	
Galium trifidum	--		--		T	
Heracleum lanatum	--		--		T	
Rumex crispus	--		--		T	
Stachys mexicana	--		--		T	
Alnus rubra		50%		50%		50%
Salix spp.		30%		30%		30%
Pyrus fusca		20%		20%		20%

Site A 10m x 10m

	1987 ground	1987 canopy	1988 ground	1988 canopy	1989 ground	1989 canopy
Cirsium spp.	--		1%		--	
Lysichitum americanum	T		2%		2%	
Alopecurus geniculatus	--		10%		--	
Rumex conglomeratus	2%		2%		--	
Vicia gigantea	--		10%		1%	
Trifolium parryi	--		10%		--	
Lotus corniculatius	15%		10%		--	
Galium aparine	10%		10%		--	
Rosa nutkana	10%		2%		--	
Rubus ursinus	30%		2%			
Rubus laciniatus					>35%	
Rubus discolor						
Holcus lanatus	10%		20%		T	
Erechtites spp.	3%		1%		--	
Rubus spectabilis	--		T		15%	
Juncus balticus	--		T		--	
Oenanthe sarmentosa	--		--		3%	
Carex obnupta	--		--		2%	
Scirpus microcarpus	--		--		1%	
Solanum dulcamara	--		--		T	
Bareground					11%	
Water					30%	
Salix spp.		60%	10%	60%		
Sambucus racemosa		20%		20%		2%
Alnus rubra		20%		10%		3%
Pyrus fusca		--		10%		15%

T2-S1

	1987 ground	1987 canopy	1988 ground	1988 canopy	1989 ground	1989 canopy
Carex obnupta	100%		95%		50%	
Scirpus microcarpus	--		5%		--	
Juncus effusus	--		--		10%	
Water					40%	

	1987 ground	1987 canopy	1988 ground	1988 canopy	1989 ground/canopy
T2-S2					
Potentilla pacifica	5%		5%		
Juncus effusus	85%		85%		4%
Scirpus microcarpus	5%		5%		
Ranunculus repens	--		2%		
Lotus corniculatus	5%		3%		
Deschampsia cespitosa					1%
Unvegetated muck soil					95%

	1987 ground	1987 canopy	1988 ground	1988 canopy	1989 ground/canopy
Site B 10m x 10m					
Ribes divaricatum	--		2%		10%
Rubus spectabilis	T		5%		15%
Rumex conglomeratus	--		1%		T
Typha latifolia	--		1%		--
Oenanthe sarmentosa	10%		10%		20%
Scirpus microcarpus	15%		60%		8%
Lotus corniculatius	5%		2%		13%
Ranunculus repens	15%		5%		--
Alopecurus geniculatus	--		3%		--
Lonicera involucrata	--		1%		4%
Agrostis spp.	--		2%		--
Agrostis alba	--		2%		--
Hyoscyamus niger	--		1%		--
Juncus effusus	--		T		6%
Deschampsia cespitosa					15%
Epilobium spp.					1%
Potentilla pacifica					3%
Vicia gigantea					1%
Athyrium filix-femina					1%
Galium trifidum					1%
Rubus discolor			T		\
Rubus ursinus					>2%
Rubus laciniatus					/
Salix Sp.		30%	5%	50%	11%
Alnus rubra		70%	T	50%	3%
Salix Sp. dead					2%
Alnus rubra dead					8%

	1987 ground/canopy	1988 ground/canopy	1989 ground/canopy
T5-S1			
Juncus effusus	95%	88%	24%
Scirpus microcarpus	5%	12%	--
Galium trifidum	--	--	1%
Water			75%
T5-S2			
Oenanthe sarmentosa	5%	25%	4%
Ranunculus repens	90%	50%	1%
Carex obnupta	5%	25%	91%
Athyrium filix-femina	--	--	3%
Potentilla pacifica	--	--	1%
Agrostis alba	--	T	--
Holcus lanatus	--	T	--
T5-S3			
Salix spp.	20%	10%	--
Juncus effusus	40%	50%	98%
Oenanthe sarmentosa	--	35%	--
Agrostis alba	--	5%	2%
T5-S4			
Oenanthe sarmentosa	--	15%	--
Salix spp.	10%	2%	--
Juncus effusus	10%	53%	30%
Renunculus repens	10%*	10%	15%
Rubus ursinus	--	5%	--
Rubus spectabilis	5%	10%	--
Lotus corniculatius	25%	5%	15%
Lysichitum americanum	--	--	25%
Agrostis spp.	--	--	10%
Juncus effusus	--	T	
Galium aparine	--	T	
Erechtites spp.	--	T	

	1987 ground/canopy	1988 ground/canopy	1989 ground/canopy
T5-S5			
Oenanthe sarmentosa	--	75%	40%
Ranunculus repens	60%	10%	--
Carex obnupta	--	10%	50%
Ribes divaricatum	--	--	5%
Rubus spp.	--	--	4%
Athyrium filix-femina	--	--	1%
Equisetum spp.	--	--	T
Dead Rubus & Alder	--	5%	--
T6-S1			
Lotus corniculata	40%	2%	20%
Oenanthe sarmentosa	40%	50%	10%
Athyrium filix-femina	--	2%	10%
Ranunculus repens	--	2%	--
Holcus lanatus	--	35%	--
Heracleum lanatum	--	7%	--
Scirpus microcarpus	--	--	50%
Agrostis spp.	--	--	5%
Galium aparine	--	--	5%
T6-S2			
Juncus effusus	90%	75%	10%
Rubus spectabilis	--	10%	10%
Oenanthe sarmentosa	10%	5%	40%
Holcus lanatus	--	3%	
Athurium filix-femina	--	5%	5%
Agrostis spp.	--	2%	20%
Epilobium angustifolium	--	--	15%
T6-S3			
Juncus effusus	N/A	80%	85%
Carex obnupta	N/A	10%	--
Spiraea douglasii	N/A	10%	1%
Water			14%

	1987 ground/canopy	1988 ground/canopy	1989 ground/canopy
T6-S4			
Oenanthe sarmentosa	N/A	40%	80%
Galium aparine	N/A	20%	--
Rubus spectabilis	N/A	20%	9%
Ribes divaricatum	N/A	5%	1%
Scirpus microcarpus	N/A	2%	--
Holcus lanatus	N/A	10%	3%
Bidens cernua			2%
Stellaria calycantha			5%
Dead fern	N/A	1%	T
Dead spruce	N/A	2%	T
T6-S5			
Scirpus microcarpus (partly dead)			65%
Ribes divaricatum dead			20%
Oenanthe sarmentosa			10%
Grasses			1%
Water			4%

APPENDIX 4. Habitat indicator species at the Astoria Airport Mitigation Bank derived using a simple numeric threshold based on frequency and abundance.

	A	B	C
1	BIRD SPECIES	FOREST (%)	SCRUB/SHRUB (%)
2	Song sparrow	1	59
3	Marsh wren	1	7
4	American goldfinch	6	46
5	Barn swallow	40	20
6	Cedar waxwing	17	59
7	Common yellowthroat	3	59
8	Bewicks wren	0	83
9	Tree swallow	0	0
10	Green-wing teal	0	0
11	Norther harrier	5	44
12	Rufus humingbird	6	94
13	American robin	30	63
14	Black-capped chickadee	14	79
15	Swainsons thrush	0	100
16	Black-shouldered kite	0	100
17	Mallard	0	0
18	Common snipe	0	14
19	Great Blue Heron	0	30
20	American Crow	49	50
21	Perigrine falcon	0	100
22	Merlin	100	0
23	Pine siskin	0	100
24	Short-eared owl	0	50
25	Coopers hawk	0	0

	D	E
1	EMERGENT (%)	SHALLOW OPEN WATER (%)
2	40	0
3	92	0
4	40	6
5	40	0
6	24	0
7	38	0
8	17	0
9	83	17
10	78	22
11	44	5
12	0	0
13	3	3
14	7	0
15	0	0
16	0	0
17	85	15
18	86	0
19	20	50
20	1	0
21	0	0
22	0	0
23	0	0
24	50	0
25	100	0

	F	G
1	NUMBER OF OBSERVATIONS	FOREST INDICATOR SPECIES
2	174	FALSE
3	210	FALSE
4	15	FALSE
5	5	FALSE
6	17	FALSE
7	34	FALSE
8	18	FALSE
9	6	FALSE
10	9	FALSE
11	16	FALSE
12	38	FALSE
13	33	FALSE
14	29	FALSE
15	1	FALSE
16	1	FALSE
17	27	FALSE
18	7	FALSE
19	10	FALSE
20	10	TRUE
21	1	FALSE
22	1	FALSE
23	1	FALSE
24	2	FALSE
25	1	FALSE

	H	I
1	SCRUB/SHRUB INDICATOR SPECIES	EMERGENT INDICATOR SPECIES
2	TRUE	FALSE
3	FALSE	TRUE
4	FALSE	FALSE
5	FALSE	FALSE
6	FALSE	FALSE
7	TRUE	FALSE
8	FALSE	FALSE
9	FALSE	FALSE
10	FALSE	TRUE
11	FALSE	FALSE
12	TRUE	FALSE
13	TRUE	FALSE
14	FALSE	FALSE
15	FALSE	FALSE
16	FALSE	FALSE
17	FALSE	TRUE
18	FALSE	FALSE
19	FALSE	FALSE
20	FALSE	FALSE
21	FALSE	FALSE
22	FALSE	FALSE
23	FALSE	FALSE
24	FALSE	FALSE
25	FALSE	FALSE

	J
1	SHALLOW OPEN WATER INDICATOR SPECIES
2	FALSE
3	FALSE
4	FALSE
5	FALSE
6	FALSE
7	FALSE
8	FALSE
9	FALSE
10	FALSE
11	FALSE
12	FALSE
13	FALSE
14	FALSE
15	FALSE
16	FALSE
17	FALSE
18	FALSE
19	TRUE
20	FALSE
21	FALSE
22	FALSE
23	FALSE
24	FALSE
25	FALSE