APPENDIX C
FISH AND WILDLIFE HEP REPORT (2010)

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United States Department of the Interior

FISH AND WILDLIFE SERVICE
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In Reply Refer To:
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Memorandum

To: Assistant Field Supervisor, Planning/Permitting Program, Bay-Delta Fish and Wildlife Office, Sacramento, California

From: Acting Assistant Field Supervisor, Conservation, Restoration, and Contaminants Program Sacramento Fish and Wildlife Office, Sacramento, California

Subject: Habitat Evaluation Procedures Analysis for the Sacramento River Deep Water Ship Channel, Contra Costa, Sacramento, Solano, and Yolo Counties, California

Attached is a revised Habitat Evaluation Procedures (HEP) analysis for the dredged material disposal impacts resulting from the proposed deepening of the Sacramento River Deep Water Ship Channel. This document was developed by the Sacramento Fish and Wildlife Office in cooperation with the Bay-Delta Fish and Wildlife Office (BDFWO) through an inter-office agreement in Fiscal Year 2010. The revised HEP is intended to quantify impacts of the proposed project's dredged material disposal sites for use by the BDFWO to develop recommendations toward the conservation of fish and wildlife habitats developed under the authority of the Fish and Wildlife Coordination Act. Acreage numbers provided herein reflect the most recent estimates of dredged material placement impacts, as of October 14, 2010.

If you have any questions regarding this report please contact Harry Kahler at (916) 414-6612.

Attachment

REVISED

HABITAT EVALUATION PROCEDURES

SACRAMENTO RIVER DEEP WATER SHIP CHANNEL PROJECT

OCTOBER 2010

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INTRODUCTION

This application of Habitat Evaluation Procedures (HEP) is intended to quantify the anticipated impacts and benefits to fish and wildlife resources that would occur with the construction of the proposed deepening and widening of the Sacramento Deep Water Ship Channel (SRDWSC) Project in Contra Costa, Solano, Sacramento, and Yolo Counties, California. In particular, the HEP addresses the effects of the proposed project on fish and wildlife habitat within six sites identified by the Port of Sacramento for dredged material placement resulting from the deepening and widening of the ship channel.

PROJECT DESCRIPTION

The U.S. Army Corps of Engineers (Corps) has developed four alternatives for increasing the suitability of the Port of Sacramento as a terminal site for goods transportation. Other alternatives to the deepening and widening of the ship channel to handle increased traffic of goods to and from the Port of Sacramento also are under consideration. Other alternatives considered include: the lighter abroad ship (LASH) transportation system, which provides for carrying cargo aboard ship in lighters (barges); intermodal transportation, or the use of other means of transportation to carry products to and from the Port of Sacramento; and the No Action alternative. Because the increased use of LASH and increased intermodal transportation project alternatives would not affect the habitats of the dredged material placement sites, these project alternatives are not considered within the scope of the HEP analysis provided herein. Alternative 1, the deepening of the ship channel and associated widening of the channel in some areas, is the only alternative to No Action considered by this HEP Two plans to deepen the channel from 30 feet are under consideration: dredging to 33 feet; and dredging to 35 feet. However, the impact upon the dredged material placement sites is equal between the two cases.

This HEP application deals with the dredged material disposal impacts of the deepening of the SRDWSC from Suisun Bay upstream to River Mile 35 of the channel. The SRDWSC Project was initially analyzed in accordance with the National Environmental Policy Act and the Fish and Wildlife Coordination Act in 1980, and a Supplemental Environmental Impact Statement (SEIS) was prepared in 1986. Deepening the channel from 30 to 35 feet began in 1989, yet due to financial constrictions only 8 miles were deepened (from the Port of Sacramento to River Mile 35). However, mitigation efforts for the entire SRDWSC Project were initiated in 1993 in accordance with a HEP conducted in 1986, although the deepening is yet to be completed. The purpose of the current HEP is to provide information for another SEIS being prepared for the deepening of the channel.

HEP OVERVIEW

HEP is a methodology developed by the Fish and Wildlife Service (Service) and other State and Federal resource agencies which can be used to document the quality and quantity of available habitat for selected fish and wildlife species. HEP provides information for two general types of habitat comparisons: (1) the relative value of different areas at the same point in time; and (2) the relative value of the same areas at future points in time. By combining the two types of comparisons, the impacts of the proposed or anticipated land-use and or water-use changes on habitat can be quantified. Similarly, any compensation needs (in terms of acreage) for the project can also be quantified, provided a mitigation plan has been developed for specific mitigation sites.

A HEP application is based on the assumption that the value of a habitat for a selected species or the value of a community can be described in a model which produces a Habitat Suitability Index (HSI). This HSI value (from 0.0 to 1.0) is multiplied by the area of available habitat to obtain Habitat Units (HUs). The HU and Average Annual Habitat Units (AAHUs) over the life of the project are then used in the comparison described above.

The reliability of a HEP application and the significance of HUs are directly dependent on the ability of the user to assign a well-defined and accurate HSI to the selected evaluation elements or communities. In addition, a user must be able to measure the areas of each distinct habitat being utilized by fish and wildlife species within the project area. Both the HSIs and the habitat acreages must also be reasonably estimable at various future points in time. The HEP Team comprised of Corps and Service staff determined that the HEP criteria could be met, or at least reasonably approximated, for the SRDWSC Project alternatives. Thus HEP was considered an appropriate analytical tool to assess impacts of the proposed project.

GENERAL HEP ASSUMPTIONS

Some general assumptions are necessary to use HEP and HSI Models in the impact assessment.

Use of HEP:

- HEP is the preferred method to evaluate the impacts of the proposed project on fish and/or wildlife resources.
- HEP is a suitable methodology for quantifying project-induced impacts on fish and wildlife habitats.
- Quality and quantity of fish and wildlife habitat can generally be numerically described using the indices derived from the HSI models and associated habitat units.
- HEP assessment is applicable to the habitat types being evaluated.

Use of HSI Models

- HSI models are hypotheses based on available data.
- HSI models are conceptual models and may not measure all ecological factors that affect the quality of a given cover-type for the evaluation species (e.g. vulnerability to predation). In some cases, The HEP Team may make assumptions and incorporate them into the analysis to account for loss of those factors not reflected by the model.

METHODOLOGY

Habitat Workshop 2.1, a windows based HEP program, was used in this application, which was conducted in August 2010. The study design was developed jointly by Service (Erin Gleason and Harry Kahler) and Corps (Bill Brostoff, Cynthia Fowler, and Bonnie Hulkower) staff. Participants in the data collection portion of the HEP included representatives from the Service (Erin Gleason and Harry Kahler) and Corps (Bonnie Hulkower).

Sites for dredged material placement and for mitigation were identified by Corps staff with guidance from the Port of Sacramento engineers (Figure 1). Habitat mapping of the dredged material placement sites was delineated in August 2010 by Mike Ericsson of Ericsson Mapping. The habitat classification used was the California Natural Community Classification developed

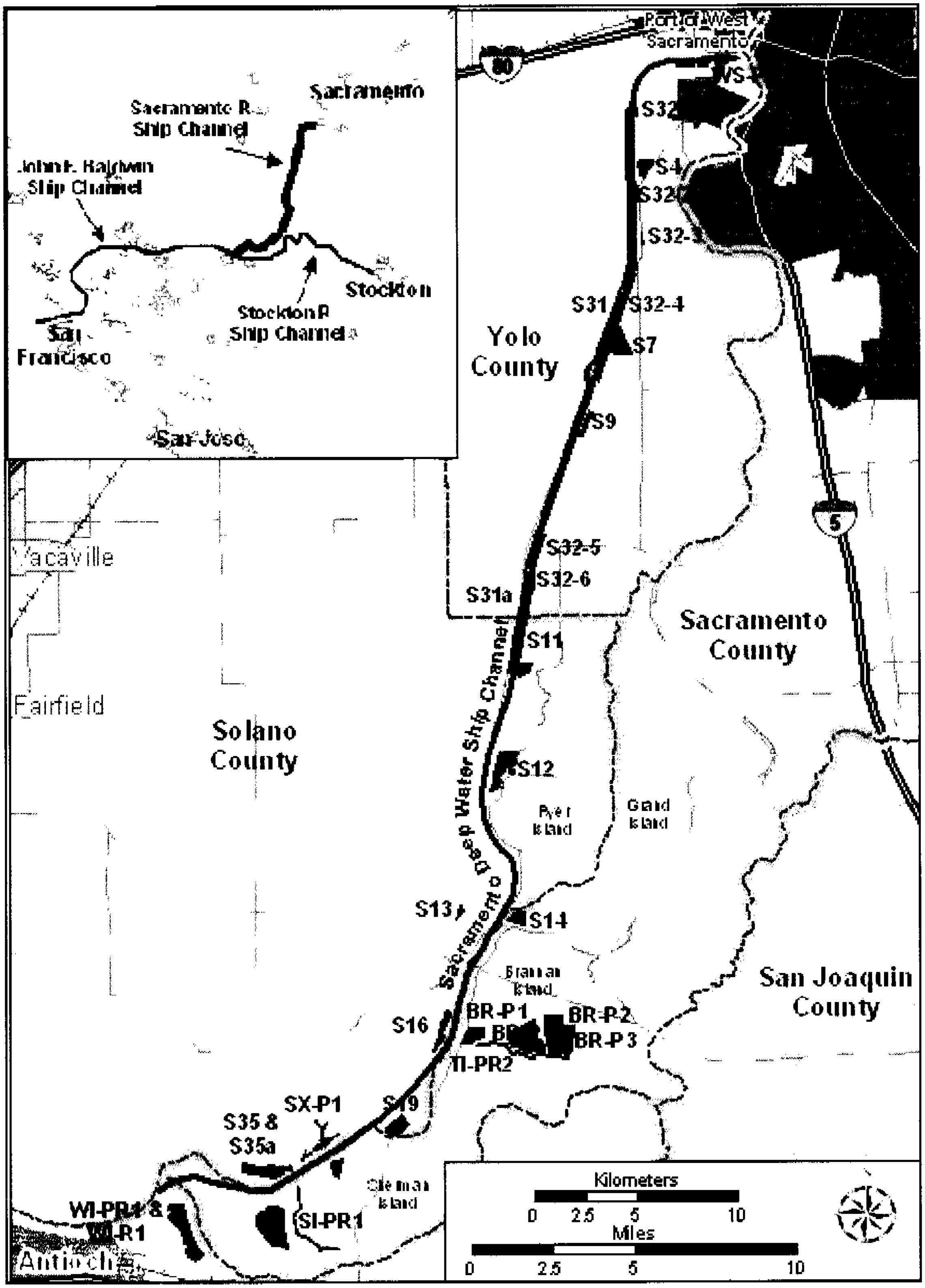

Figure 1 The Sacramento Deep Water Ship Channel and dredge material placement sites. Sites to be used are: S1, S4, S11, S14, S16, S19, S20, S31, and S35. Prospect Island (S12) is to be used for mitigation.

by Holland (1986). Marsh/swamp, non-native grassland, cultivated field, and riparian habitats would be affected by the dredge material disposal alternatives being evaluated for the proposed project. The water and river habitats will not be analyzed in this HEP because these habitats will not be affected by dredged material placement. The acreage and habitat types of areas of potential impact by the SRDWSC Alternative 1 action are summarized in Table 1.

The purpose of using HEP is to provide a quantitative basis for identifying the habitat values which would be degraded, destroyed, and/or created by the construction of the proposed project. Non-native grassland, cultivated field, and unvegetated habitats were not modeled; these areas disturbed by project activities are to be re-seeded after construction is complete. The focus of this HEP is on two habitat types that would be lost due to dredged material placement resulting from the deepening of the ship channel: marsh/swamp and riparian. The selection of HSI models was constrained in this HEP application because Corps staff stipulated that only models previously certified by the Corps be selected for use. This limited from use many available models for these habitat cover-types.

Marsh and Swamp

The marsh wren HSI model (Gutzwiller and Anderson 1987) was selected for use in the marsh/swamp habitat. Marsh wrens require dense stands of emergent herbaceous vegetation, typically cattails (*Typha* spp.) and bulrushes (*Scirpus* spp.) for nesting and cover. They prefer emergent vegetation in relatively deeper water, > 15 centimeters deep is considered optimum.

Riparian

Because the mapping followed the Holland classification system, riparian areas were broken into two separate habitat types: riparian woodland and riparian scrub. To maintain a more accurate depiction of the affected riparian habitat, the riparian woodland and riparian scrub components were measured with different models. The overall goal is to mitigate for the riparian habitat in total, regardless of the successional stage. However, mitigation acreages of both successional stages should match the requirements of each successional stage of the affected riparian wooded habitat as closely as possible.

The yellow warbler HSI model (Schroeder 1982a) was selected for use in the project's riparian scrub habitat. The yellow warbler was selected because it forages and nests in deciduous shrubs, generally 5-13 feet tall. Optimal nesting habitat for the yellow warbler is provided in wet areas with dense, moderately tall stands of hydrophytic deciduous shrubs. To better match the models to the habitat, areas mapped as riparian woodland with willow (*Salix* spp.) as the dominant component were considered riparian scrub.

The downy woodpecker HSI model (Schroeder 1982b) was selected for use in the project's riparian woodland habitats. Downy woodpeckers require open woodlands with mature trees for feeding, and five snags per acre are optimal for nesting. Optimum habitat would be woodlands with a basal area between 44 and 87 square feet of wood per acre at breast height (4.5 feet), with at least 5 snags (dead trees at least 6 inches in diameter at breast height) per acre.

HEP Analyses

When using HEP, it is necessary to determine HSI values for each evaluation species at selected

Table 1. Summary of existing habitat types and their approximate acreages within the SRDWSC potential dredge placement areas.*

LOCATION (SITE)	COVER-TYPE (HOLLAND HABITAT TYPE)	ACREAGE
S1	Non-native grassland	72.97
	Unvegetated	4.50
	Total	**77.47**
S4	Cultivated field	117.35
	Total	**117.35**
S11	Cultivated field	39.79
	Non-native grassland	0.03
	Riparian scrub	0.29
	(Total riparian)	(0.29)
	Total	**40.11**
S14	Non-native grassland	32.88
	Riparian scrub	0.37
	Riparian woodland	0.24
	(Total riparian)	(0.61)
	Total	**33.49**
S16	Developed	0.02
	Non-native grassland	32.71
	Riparian scrub	1.19
	(Total riparian)	(1.19)
	Unvegetated	32.04
	Total	**65.96**
S19	Non-native grassland	143.02
	Riparian scrub	0.61
	Riparian woodland	0.26
	(Total riparian)	(0.87)
	Unvegetated	27.62
	Total	**171.51**
S20	Non-native grassland	23.46
	Unvegetated	0.03
	Total	**23.49**
S31	Marsh and Swamp	1.33
	Non-native grassland	359.22
	Riparian scrub	0.95
	Riparian woodland	5.84
	(Total riparian)	(6.79)
	Unvegetated	13.40
	Total	**380.74**
S35	Non-native grassland	59.24
	Total	**59.24**
PROJECT TOTAL		**969.36**

* The cover types and acreages were drafted by Ericsson Mapping, May 2010. Areas mapped as riparian woodland dominated by *Salix* were considered riparian scrub in this analysis.

target years for both with-project and without-project scenarios. Proposed compensation areas must be treated similarly (with-management is substituted for with-project conditions). The capacity of each sample site to meet the needs of the evaluation elements within the project impact and compensation areas was determined by the HEP team through measurement of specific habitat variables. Baseline values for each of the model variables can be obtained by

Table 2. Summary of Habitat Suitability Index Models, variables, and how values were obtained.

HSI MODEL	HSI VARIABLE	HOW OBTAINED
Downy woodpecker	V1 – Basal area of wood at breast height per acre V2 – Number of snags per acre	Field measurement Field measurement
Yellow warbler	V1 - Percent deciduous shrub crown cover V2 - Average height of deciduous shrub canopy V3 - Percent of deciduous canopy comprised of hydrophytic shrubs	Field measurement Field measurement Field measurement
Marsh wren	V1 - Growth form of emergent hydrophytes V2 - Percent canopy cover of emergent herbaceous vegetation V3 - Mean water depth V4 - Percent canopy cover of woody vegetation	Field measurement Field measurement Field measurement Field measurement

field sampling, map interpretation, and by reviewing historic records and reports. Table 2 lists the variables in each model and indicates how data was collected.

At the completion of data collection, an HSI value was calculated for each evaluation element. A higher numerical rating is indicative of a higher suitability for the evaluated element. The HSI measurements of the same habitat in an impact area were averaged. The HSI, when multiplied by the area of the habitat, yields HUs, a measure of the quality and quantity of the habitat. The equations to calculate HSIs are contained within each model (HEP Appendix A).

Because it is not possible to calculate habitat quality and quantity for future years, future HSI values were projected. This was accomplished by increasing or decreasing specific baseline Suitability Index values for each evaluation species based on the HEP Team's best professional judgment of probable future conditions. The assumptions used to derive future HSI and acreage values for with- and without-project conditions on the impact and habitat creation areas are contained in HEP Appendix A. Habitat was created for compensation in 1993 at Prospect Island in anticipation of the channel deepening work (Figure 2), yet project work has yet to be completed.

Given these assumptions, long-term losses and gains in HUs can be estimated for each future scenario over the life of the project, and then expressed as AAHU gains or losses. Basic HEP outputs, expressed in the Habitat Workshop 2.1 Software Package are displayed in Table 3.

In order to make the comparison of future with- and without-project conditions for each alternative described above, it was necessary to first develop the future without-project scenario

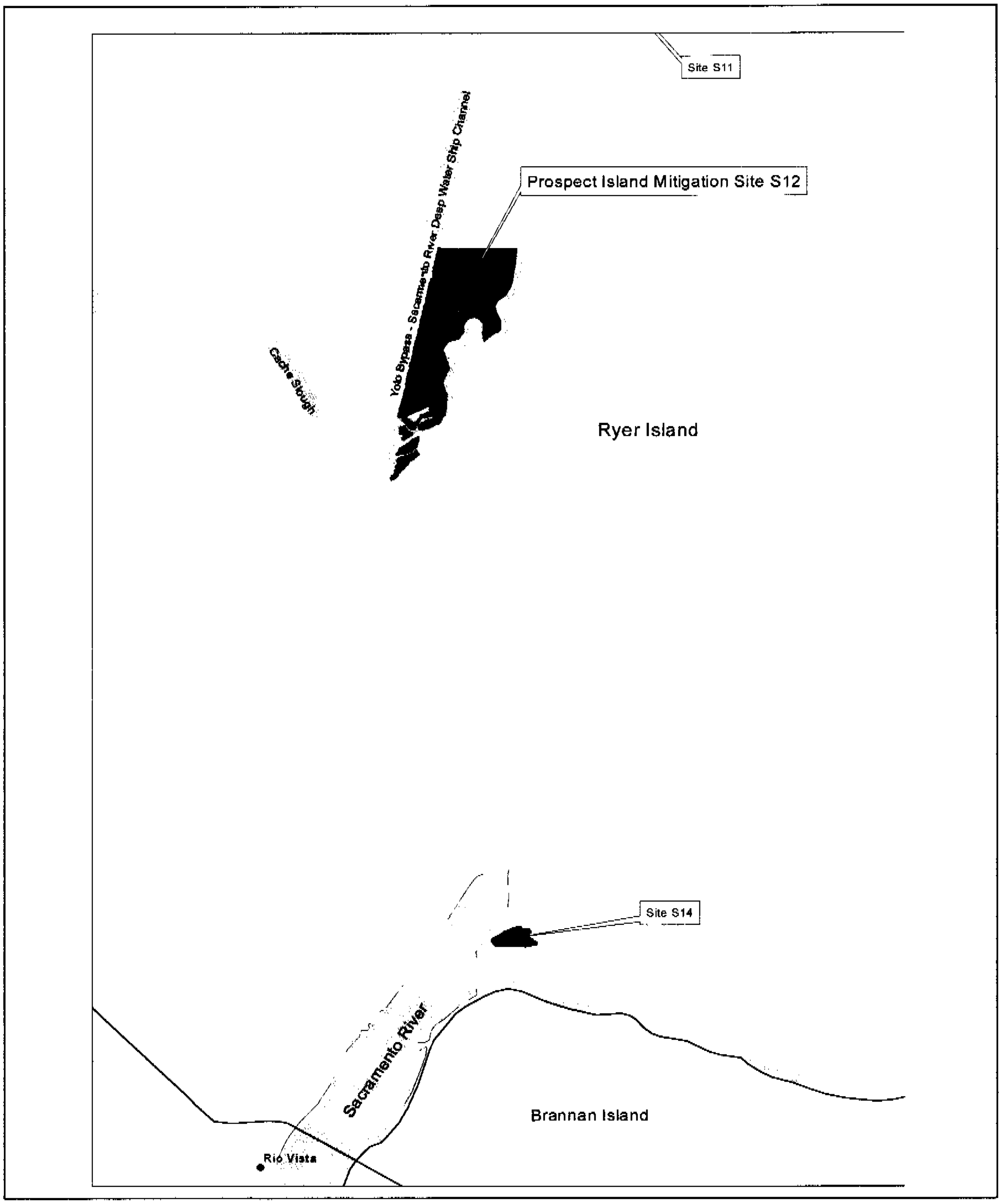

Figure 2. The Prospect Island mitigation area. Mitigation was established in 1993 although the original deepening project was never completed.

for the habitat impacted within the proposed project area. This required several key assumptions that existing land uses and maintenance activities would not change in the future without the project. Given these conditions, a future without-project scenario was developed which included: (1) no change in the existing habitat acreages, (2) riparian, marsh, and non-native

Table 3. Net change in Average Annual Habitat Units (AAHUs) and compensation need for the habitats affected by the SRDWSC Project, Alternative 1

Cover-Type (All sites)	Area Affected (acres)	AAHUs Without Project	AAHUs With Project	Net Change in AAHUs	Compensation Need (acres)
Marsh and swamp	1.33	0.00	0.000	0.00	1.33
Riparian (Total)	9.75	-0.086	-0.421	-0.335	9.98
Riparian scrub	3.41	0.00	-0.288	-0.288	3.64
Riparian woodland	6.34	-0.086	-0.133	-0.047	6.34
Cultivated field	157.14	N/A	N/A	N/A	Re-seed
Non-native grassland	782.77	N/A	N/A	N/A	Re-seed
Unvegetated	77.59	N/A	N/A	N/A	Re-seed

grassland habitat values would continue to develop, and (3) the existing hydrology would be maintained in the study area.

Similarly, a compensation site was selected which was assumed to currently be non-native grassland. Future scenarios with- and without the project were developed. The future with the project scenario reflected existing mitigation efforts established in 1993 for project plans that have yet to be implemented. These assumptions are shown in HEP Appendix A.

RESULTS AND DISCUSSION

Table 3 shows the net change in AAHUs and compensation need for each cover-type by affected area with dredged material placement resulting from Alternative 1 of the SRDWSC Project. Cultivated field, developed, non-native grassland, and unvegetated habitats were not modeled and analyzed, yet should be re-seeded with native grasses at the conclusion of the project.

Marsh and Swamp

Areas mapped as marsh/swamp within the dredged material placement action sites were found to have no standing water and no emergent herbaceous vegetation. Thus, the marsh wren HSI model produced 0.0 for an HSI value and hence no AAHU loss for the marsh/swamp habitat. The Service's general mitigation policy for wetland habitat types, however, is to recommend that no net loss of habitat value or acreage results from project activities. Therefore, 1.33 acres at the Prospect Island mitigation site would compensate for the loss of habitat resulting from dredged material placement.

Riparian

Basic assumptions predict that future dredged material placement would not result in the outright loss of all riparian habitats. However, the placement of dredged materials is likely to cause changes in riparian habitat characteristics. In total, the yellow warbler and downy woodpecker models indicate that 9.98 acres of riparian habitat are needed to compensate for the losses due to dredged material placement. To compensate for the losses due to dredged material placement 3.64 acres of riparian scrub and 6.34 acres of riparian woodland are needed.

LITERATURE CITED

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Schroeder, R.L. 1982a. Habitat suitability index models: Yellow warbler. U.S. Fish and Wildlife Service Biological Report 82(10.27). 8pp.

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HEP APPENDIX A

DATA ANALYSIS ASSUMPTIONS

DATA ANALYSIS/ASSUMPTIONS
SACRAMENTO DEEP WATER SHIP CHANNEL DEEPENING FROM RIVER MILE 35 TO SUISUN BAY, CONTRA COSTA, SACRAMENTO, SOLANO, AND YOLO COUNTIES, CALIFORNIA

MARSH/SWAMP

Alternative 1 – Future With the Project

ASSUME:

1. Existing marsh/swamp habitat area is 1.33 acres.
2. Marsh/swamp habitat will gradually be covered by dredged material and lost over a 51 year period.

TY0- Baseline (measured*)

V1- Emergent hydrophytes (Category 4)	SI = 0.00
V2- Percent canopy cover emergent herbaceous vegetation (100%)	SI = 1.00
V3- Mean water depth (0.0 in)	SI = 0.00
V4- Percent canopy cover woody vegetation (0.0%)	SI = 1.00

HSI=(SIV1*SIV2*SIV3)^1/3*SIV4

HSI=(0*1*0)^1/3*1=0.00

TY51

No emergent hydrophytes or standing water, assuming an HSI of 0.0 through year 51. Mitigate at 1:1 ratio.

* The habitat values were measured at Year 0.

MARSH/SWAMP

Alternative1 No Action – Future Without the Project

ASSUME:

1. Existing marsh/swamp habitat area is 1.33 acres.
2. Marsh/swamp habitat will experience little change over a 51 year period.

TY0- Baseline (measured*)

V1- Emergent hydrophytes (Category 4)	SI = 0.00
V2- Percent canopy cover emergent herbaceous vegetation (100%)	SI = 1.00
V3- Mean water depth (0.0 in)	SI = 0.00
V4- Percent canopy cover woody vegetation (0.0%)	SI = 1.00

HSI=(SIV1*SIV2*SIV3)^1/3*SIV4

HSI=(0*1*0)^1/3*1=0.00

TY51

No emergent hydrophytes or standing water, assuming an HSI of 0.0 through year 51. Mitigate at 1:1 ratio.

* The habitat values were measured at Year 0.

RIPARIAN SCRUB

Alternative 1 – Future With the Project

ASSUME:

1. Riparian scrub-shrub habitat area is 3.41 acres for Alternative 1.
2. Percent deciduous shrub decreases with placement of dredge material. Over 51 years, it decreases by ½ from its original percentage.
3. The average height of deciduous shrubs will be cut to about 1/3 of the original height over the course of 51 years. Blackberry will increase in percentage over time, lowering the average height of the shrubs.
4. As blackberries increase in percentage over the 51-year period, the percent of hydrophytic shrubs decreases to about 1/5 of the original canopy cover.
5. There are no foreseeable changes in the existing management practices in the future.

Yellow Warbler

TY0-	Baseline (measured)	
	V1- % deciduous scrub-shrub crown cover (58%)	SI = 0.97
	V2- Average height of deciduous scrub-shrub canopy (2.1 meters)	SI = 1.00
	V3- % deciduous scrub-shrub comprised of hydrophytic shrubs (50%)	SI = 0.55

HSI = (0.97*1.00*0.55)^1/2 = 0.70

TY1-	V1- 58%	SI = 0.97
	V2- 2.1 m	SI = 1.00
	V3- 50%	SI = 0.55

HSI = (0.97*1.00*0.55)^1/2 = 0.70 (No change from TY0)

TY25-	V1- 45%	SI = 0.75
	V2- 1.07m	SI = 0.54
	V3- 30%	SI = 0.37

HSI = (0.75*0.54*0.37)^1/2 = 0.39

TY51-	V1- 30%	SI = 0.16
	V2- 0.61m	SI = 0.31
	V3- 10%	SI = 0.19

HSI = (0.16*0.31*0.19)^1/2 = 0.17

RIPARIAN SCRUB

Alternative1 No Action -- Future Without the Project

ASSUME:

1. Riparian scrub-shrub habitat area is 3.41 acres for Alternative 1 No Action.
2. There are no foreseeable changes in the existing management practices in the future.

TY0-	Baseline (measured)	
	V1- % deciduous scrub-shrub crown cover (58%)	SI = 0.97
	V2- Average height of deciduous scrub-shrub canopy (2.0m)	SI = 1.00
	V3- % deciduous scrub-shrub comprised of hydrophytic shrubs(50%)	SI = 0.55

HSI = (0.97*1.00*0.55)^1/2 = 0.70

TY1-	V1- 58%	SI = 0.97
	V2- 2.1m	SI = 1.00
	V3- 50%	SI = 0.55

HSI = (0.97*1.00*0.55)^1/2 = 0.70

TY25-	V1- 58%	SI = 0.97
	V2- 2.1m	SI = 1.00
	V3- 50%	SI = 0.55

HSI = (0.97*1.00*0.55)^1/2 = 0.70

TY51-	V1- 58%	SI = 0.97
	V1- 2.1m	SI = 1.00
	V3- 50%	SI = 0.55

HSI = (0.97*1.00*0.55)^1/2 = 0.70

RIPARIAN SCRUB

Mitigation Site – Future With the Project

ASSUME:

1. Some shrubs/trees existed in the area at year 0 (1993) when mitigation efforts began.
2. The shrubs would be mostly blackberry, with scattered but tall hydrophytes (cottonwood).
3. For about 35 years, with the lack of farming, the deciduous shrubs fill in the canopy, overtopping the blackberry. Following that, some of the shrubs would begin dying out, leaving canopy gaps.
4. The hydrophytes prevail for the first 25 years, but then non-hydrophytic shrubs begin to enter the shrub canopy through natural succession. The hydrophytes remain prevalent throughout the 51-year period.
5. The shrub canopy height will not change much over time.

Yellow Warbler

TY0-	Year 1993, estimated	
	V1- % deciduous scrub-shrub crown cover (30%)	SI = 0.50
	V2- Average height of deciduous scrub-shrub canopy (2.1 meters)	SI = 1.00
	V3- % deciduous scrub-shrub comprised of hydrophytic shrubs (20%)	SI = 0.28

HSI = (0.5*1.00*0.28)^1/2 = 0.36

TY17-	2010, Measured	
	V1- 35%	SI = 0.58
	V2- 2.1 m	SI = 1.00
	V3- 83%	SI = 0.85

HSI = (0.58*1.00*0.85)^1/2 = 0.70

TY35-	V1- 40%	SI = 0.67
	V2- 2.1m	SI = 1.00
	V3- 72%	SI = 0.75

HSI = (0.67*1.0*0.75)^1/2 = 0.71

TY51-	V1- 35%	SI = 0.58
	V2- 2.1m	SI = 1.00
	V3- 65%	SI = 0.69

HSI = (0.58*1.0*0.69)^1/2 = 0.63

RIPARIAN SCRUB

Mitigation Site – Future Without the Project

ASSUME:

1. If farming continued, there are no indications that the original conditions of the shrubland would change much over time. However, as some of the shrubs would grow larger, it's likely that at some point, perhaps 35 or so years after Year 0, the larger shrubs would be removed for farming reasons.

TY0-	Year 1993, estimated	
	V1- % deciduous scrub-shrub crown cover (30%)	SI = 0.50
	V2- Average height of deciduous scrub-shrub canopy (2.1 meters)	SI = 1.00
	V3- % deciduous scrub-shrub comprised of hydrophytic shrubs (20%)	SI = 0.28

HSI = (0.5*1.00*0.28)^1/2 = 0.36

TY17-	2010, Measured	
	V1- 35%	SI = 0.58
	V2- 2.1 m	SI = 1.00
	V3- 83%	SI = 0.85

HSI = (0.58*1.00*0.85)^1/2 = 0.70

TY35-	V1- 30%	SI = 0.50
	V2- 1.2m	SI = 0.61
	V3- 20%	SI = 0.28

HSI = (0.5*0.61*0.28)^1/2 = 0.29

TY51-	V1- 35%	SI = 0.58
	V1- 2.1m	SI = 1.00
	V3- 20%	SI = 0.28

HSI = (0.58*1.00*0.28)^1/2 = 0.40

RIPARIAN WOODLAND

Alternative 1 – Future With the Project

ASSUME:

1. Dredge placement will not directly and immediately remove mapped woodland areas, but they will degrade and trees will die off slowly over the course of 50 years.
2. The amount of snags will remain high as trees die off, but will begin to decrease slightly after about 20 years. Snags will decrease in number per acre because old snags will fall, and as basal area decreases the number of snags will increase accordingly.
3. There are 6.34 acres of riparian woodland habitat.

TY0-	Baseline (measured)	
	V1- Basal area per acre of wood at dbh (79 sqft/acre)	SI = 1.00
	V2- Number of snags (> 6 in dbh) per acre (5 per acre)	SI = 1.00

HSI = Minimum, SI V1 or SI V2

HSI = Minimum, 1.00 or 1.00 = 1.00

TY10-	V1- 79 sqft/acre	SI = 1.00
	V2- 5 snags/acre	SI = 1.00

HSI = 1.00

TY20-	V1- 75 sqft/acre	SI = 1.00
	V2- 4.5 snags/acre	SI = 0.90

HSI = 0.90

TY35-	V1- 60 sqft/acre	SI = 1.00
	V2- 4 snags/acre	SI = 0.80

HSI = 0.80

TY51-	V1- 55 sqft/acre	SI = 1.00
	V2- 3.5 snags/acre	SI = 0.70

HSI = 0.70

RIPARIAN WOODLAND

Alternative 1 No Action – Future Without the Project

ASSUME:

1. The existing trees will die and fall, and with the current maintenance and grazing of the areas, these will probably not be replaced over the next 51 years.
2. The decrease in basal area, however, will be much less than it would if the site is used for dredge placement.
3. The snags will decrease accordingly with the decrease in basal area.
4. There are 6.34 acres of riparian woodland habitat.

TY0- Baseline (measured)
V1- Basal area per acre of wood at dbhduous tree canopy (79 sqft/acre) SI = 1.00
V2- Number of snags (> 6 in dbh) per acre (5 per acre) SI = 1.00

HSI = Minimum, SI V1 or SI V2

HSI = Minimum, 1.0 or 1.0 = 1.00

TY10- V1- 79 sqft/acre SI = 1.00
V2- 5 snags/acre SI = 1.00

HSI = 1.00

TY20- V1- 79 sqft/acre SI = 1.00
V2- 4.5 snags/acre SI = 0.90

HSI = 0.90

TY35- V1- 70 sqft/acre SI = 1.00
V2- 4.5 snags/acre SI = 0.90

HSI = 0.90

TY51- V1- 70 sqft/acre SI = 1.00
V2- 4 snags/acre SI = 0.80

HSI = 0.80

RIPARIAN WOODLAND

Mitigation Site – Future With the Project

ASSUME:

1. Mitigation began in 1993. The area had previously been a cultivated field with a few trees along the edges.
2. Dredge placement will not directly and immediately remove mapped woodland areas, but they will degrade and trees will die off slowly over the course of 50 years.
3. The amount of snags will remain high as trees die off, but will begin to decrease slightly after about 20 years. Snags will decrease in number per acre because old snags will fall, and as basal area decreases the number of snags will increase accordingly.

TY0-	1993, estimated	
	V1- Basal area per acre of wood at dbhduous tree canopy (5 sqft/acre)	SI = 0.11
	V2- Number of snags (> 6 in dbh) per acre (0 per acre)	SI = 0.00

HSI = Minimum, SI V1 or SI V2

HSI = Minimum, 0.11 or 0.0 = 0.00

TY10-	V1- 20 sqft/acre	SI = 0.45
	V2- 0 snags/acre	SI = 0.00

HSI = 0.00

TY17-	2010, measured	
	V1- 62 sqft/acre	SI = 1.00
	V2- 0 snags/acre	SI = 0.00

HSI = 0.00

TY35-	V1- 65 sqft/acre	SI = 1.00
	V2- 2 snags/acre	SI = 0.40

HSI = 0.40

TY51-	V1- 75 sqft/acre	SI = 1.00
	V2- 4 snags/acre	SI = 0.80

HSI = 0.80

RIPARIAN WOODLAND

Mitigation Site – Future Without the Project

ASSUME:

1. Without mitigation, the site basal area would increase slightly as the existing trees grow. Some new, smaller trees may come into existence as well.
2. Farming would continue, so both the basal area and amount of snags would remain low, even with the growth and decadence of the few existing trees.
3. Over the 51-year period, a few snags will gradually come into the area.

TY0-	1993, estimated	
	V1- Basal area per acre of wood at dbh (5 sqft/acre)	SI = 0.11
	V2- Number of snags (> 6 in dbh) per acre (0 per acre)	SI = 0.00

HSI = Minimum, SI V1 or SI V2

HSI = Minimum, 0.11 or 0.0 = 0.00

TY10-	V1- 5 sqft/acre	SI = 0.11
	V2- 0 snags/acre	SI = 1.00

HSI = 0.00

TY17-	2010, measured	
	V1- 8 sqft/acre	SI = 0.18
	V2- 0.5 snags/acre	SI = 0.10

HSI = 0.90

TY35-	V1- 10 sqft/acre	SI = 0.23
	V2- 1 snag/acre	SI = 0.20

HSI = 0.20

TY51-	V1- 15 sqft/acre	SI = 0.34
	V2- 2 snags/acre	SI = 0.40

HSI = 0.34

HEP APPENDIX B

HABITAT SUITABILITY INDEX MODELS

FWS/OBS-82/10.38
APRIL 1983

HABITAT SUITABILITY INDEX MODELS: DOWNY WOODPECKER

Fish and Wildlife Service

U.S. Department of the Interisr

This model is designed to be used by the Division of Ecological Services in conjunction with the Habitat Evaluation Procedures

FWS/OBS-82/10 38
April 1983

HABITAT SUITABILITY INDEX MODELS: DOWNY WOODPECKER

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PREFACE

This document is part of the Habitat Suitability Index (HSI) Model Series (FWS/OBS-82/10), which provides habitat information useful for impact assessment and habitat management. Several types of habitat information are provided. The Habitat Use Information Section is largely constrained to those data that can be used to derive quantitative relationships between key environmental variables and habitat suitability. The habitat use information provides the foundation for HSI models that ioilow. In addition, this same information may be useful in the development of other models more appropriate to specific assessment or evaluation needs.

The HSI Model Section documents a habitat model and information pertinent to its application. The model synthesizes the habitat use information into a framework appropriate for field application and is scaled to produce an index value between 0.0 (unsuitable habitat) and 1.0 (optimum habitat). The application information includes descriptions of the geographic ranges and seasonal application of the model, its current verification status, and a listing of model variables with recommended measurement techniques for each variable.

In essence, the model presented herein is a hypothesis of species-habitat relationships and not a statement of proven cause and effect relationships. Results of model performance tests, when available, are referenced. However, models that have demonstrated reliability in specific situations may prove unreliable in others. For this reason, feedback is encouraged from users of this model concerning improvements and other suggestions that may increase the utility and effectiveness of this habitat-based approach to fish and wildlife planning. Please send suggestions to:

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CONTENTS

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DOWNY WOODPECKER (Picoides pubescens)

HABITAT USE INFORMATION

General

Downy woodpeckers (Picoides pubescens) inhabit nearly all of North America where trees are found (Bent 1939) They are rare or absent in arid desert habitats and most common in open woodlands.

Food

The downy woodpecker is primarily an insectivore; 76% of the diet is animal foods, and the remainder is vegetable food (Beal 1911) Beetles, ants, and caterpillars are the major animal foods, and vegetable foods include fruits, seeds, and mast. Downy woodpeckers feed by digging into the bark with the bill, by gleaning along the bark surface, and, infrequently by flycatching (Jackson 1970)

Downy woodpeckers in Illinois foraged more in the lower height zones of trees than, in the tree canopies and foraged more often on live limbs than on dead limbs (Williams 1975) Similarly, downy woodpeckers in Virginia foraged primarily on live wood in pole age and mature forests (Conner 1980) Downy woodpeckers in New York spent 60% of their foraging time in elms (Ulmus spp.) (Kisiel 1972) They foraged most frequently on twigs 2 5 cm (1 inch) or less in diameter, and drilling was the foraging technique used most often. Downy woodpeckers are not strong excavators and do not excavate deeply to reach concentrated food sources, such as carpenter ants (Camponotus spp.) (Conner 1981)

Downy woodpeckers in Virginia foraged in the breeding season in habitats with a mean basal area of 11.3 m^2/ha (49.2 ft^2/acre) Habitats used for foraging during the postbreeding and winter seasons had significantly higher mean basal areas of 21.4 m^2/ha (93.2 ft^2/acre) and 17.2 m^2/ha (74.9 ft^2/acre), respectively Downy woodpeckers in New Hampshire fed heavily in stands of paper birch (Betula papyrifera) that were infected with a coccid (Xylococchus betulae) (Kilham 1970) The most attractive birches for foraging were those that were crooked or leaning, contained broken branches in their crown, and had defects, such as cankers, old wounds, broken branch stubs, and sapsucker drill holes. Downy woodpeckers invaded an area in Colorado in high numbers during the winter months in response to a severe outbreak of the pine bark beetle (Dendroctonus ponderosae) (Crockett and Hansley 1978) This outbreak of beetles had not resulted in increased breeding densities of the woodpeckers at the time of the study.

Downy woodpeckers foraged more on tree surfaces during summer than in winter (Conner 1979) They increased the amount of time spent in subcambial excavation in winter months, probably in response to the seasonal availability and location of insect prey Downy woodpeckers appear to broaden all aspects of their foraging behavior in the winter in order to find adequate amounts of food (Conner 1981)

Downy woodpeckers in Ontario extracted gall fly (Eurosta solidaginis) larvae from goldenrod (Solidago canadensis) galls growing near forest edges (Schlichter 1978) Corn stubble fields supported small winter populations of downy woodpeckers in Illinois (Graber et al 1977).

Water

Information on the water requirements of the downy woodpecker was not located in the literature.

Cover

The cover requirements of the downy woodpecker are similar to their reproductive requirements, which are discussed in the following section.

Reproduction

The downy woodpecker is a primary cavity nester that prefers soft snags for nest sites (Evans and Conner 1979) These woodpeckers nest in both coniferous and deciduous forest stands in the Northwest. Nests in Virginia were common in both edge situations and in dense forests far from openings (Conner and Adkisson 1977). Downy woodpeckers in Oregon occur primarily in deciduous stands of aspen (Populus tremuloides) or riparian cottonwood (Populus spp.) (Thomas et al 1979) The highest nesting and winter densities in Illinois were in virgin or old lowland forests (Graber et al 1977)

Downy woodpeckers in Virginia preferred to nest in areas with high stem density, but with lower basal area and lower canopy heights than areas used by the other woodpeckers studied (Conner and Adkisson 1977) They preferred sparsely stocked forests commonly found along ridges (Conner et al 1975) Preferred nest stands had an average basal area of 10.1 m^2/ha (44 ft^2/acre), 361.8 stems greater than 4 cm (1.6 inches) diameter/ha (894/acre), and canopy heights of 16.3 m (53.5 ft) (Conner and Adkisson 1976) Downy woodpeckers in Tennessee were frequently seen feeding in the understory and apparently selected habitats with an abundance of understory vegetation (Anderson and Shugart 1974)

Downy woodpeckers excavate their own cavity in a branch or stub 2.4 to 15.3 m (8 to 50 ft) above ground, generally in dead or dying wood (Bent 1939) There was a positive correlation between downy woodpecker densities and the number of dead trees in Illinois (Graber et al 1977) Downy woodpeckers rarely excavate in oaks (Quercus spp.) or hickories (Carya spp.) with living cambium present at the nest site (Conner 1978) They apparently require both sap rot, to soften the outer part of trees, and heart rot, to soften the interior, when hardwoods and possibly pines, are used for nesting. Downy woodpeckers in Virginia nested mainly in dead snags with advanced stages of fungal heart rot (Conner and Adkisson 1976)

Downy woodpeckers "search image" of an optimal nest site is a live tree with a broken off dead top (Kilham 1974) Suitable nest trees are in short supply in most areas and appear to be a limiting factor in New Hampshire. Downies in Montana appeared to prefer small trees, possibly to avoid the difficulty of excavating through the thick sapwood of large trees (McClelland et al 1979) The average dbh of nest trees (n = 3) in Montana was 25 cm (10 inches) All 11 nests in an Ontario study were in dead aspen, and the average dbh of four of these nest trees was 26.2 cm (10.3 inches) (Lawrence 1966) Fourteen of 19 nest trees in Virginia were dead, the average dbh of nest trees was 31.8 cm (12.4 inches), and nest trees averaged 8.3 m (27.2 ft) in height (Conner et al 1975)

Thomas et al (1979) estimated that downy woodpeckers in Oregon require 7.4 snags, 15.2 cm (6 inches) or more dbh, per ha (3 snags/acre) This estimate is based on a territory size of 4 ha (10 acres), a need for two cavities per year per pair, and the presence of 1 useable snag with a cavity for each 16 snags without a cavity. Evans and Conner (1979) estimated that downies in the Northeast require 9.9 snags, 15 to 25 cm (6 to 10 inches) dbh, per ha (4 snags/acre) Their estimate is based on a territory size of 4 ha (10 acres), a need for four cavity trees per year per pair, and a need for 10 snags for each cavity tree used in order to account for unuseable snags, a reserve of snags, feeding habitat, and a supply of snags for secondary users. Conner (pers. comm.) recommended 12.4 snags/ha (5 snags/acre) for optimal downy woodpecker habitat.

Interspersion

Downy woodpeckers occupy different size territories at different times of the year (Kilham 1974) Fall and winter territories consist of small, defined areas with favorable food supplies and the area near roost holes Breeding season territories consist of an area as large as 10 to 15 ha (24.7 to 37.1 acres) used to search out nest stubs, and a smaller area around the nest stub itself Breeding territories of downies in Illinois ranged from 0.5 to 1.2 ha (1.3 to 3.1 acres) (Calef 1953 cited by Graber et al 1977) Male and female downy woodpeckers retain about the same breeding season territory from year to year, while their larger overall range has more flexible borders (Lawrence 1966)

Downy woodpeckers occupy all portions of their North American breeding range during the winter (Plaza 1978) There is, however, a slight, local southward migration in many areas.

Special Considerations

Conner and Crawford (1974) reported that logging debris in regenerating stands' (1-year old) following clear cutting were heavily used by downy woodpeckers as foraging substrate. Timber harvest operations that leave snags and trees with heart rot standing during regeneration cuts and subsequent thinnings will help maintain maximum densities of downy woodpeckers (Conner et al 1975) Foraging habitat for the downy woodpecker in Virginia would probably be provided by timber rotations of 60 to SO years (Conner 1980)

HABITAT SUITABILITY INDEX (HSI) MODEL

Model Applicability

Geographic a This model was developed for the entire range of the downy woodpecker

Season. This model was developed to evaluate the year-round habitat needs of the downy woodpecker

Cover types. This model was developed to evaluate habitat in Deciduous Forest (DF), Evergreen Forest (EF), Deciduous Forested Wetland (DFW), and Evergreen Forested Wetland (EFW) areas (terminology follows that of U.S. Fish and wildlife Service 1981)

Minimum habitat area. Minimum habitat area is defined as the minimum amount of contiguous habitat that is required before a species will live and reproduce in an area. Specific information on minimum habitat areas for downy woodpeckers was not found in the literature However, based on reported territory and range sizes, it is assumed that a minimum of 4 ha (10 acres) of potentially useable habitat must exist or the HSI will equal zero.

Verification level. Previous drafts of this model were reviewed by Richard Conner and Lawrence Kilham and their comments were incorporated into the current draft (Conner, pers. comm , Kilham, pers. comm)

Model Description

Overview. This model considers the ability of the habitat to meet the food and reproductive needs of the downy woodpecker as an indication of overall habitat suitability Cover needs are assumed to be met by food and reproductive requirements and water is assumed not to be limiting. The food component of this model assesses food quality through measurements of vegetative conditions. The reproductive component of this model assesses the abundance of suitable snags. The relationship between habitat variables, life requisites, cover types, and the HSI for the downy woodpecker is illustrated in Figure 1

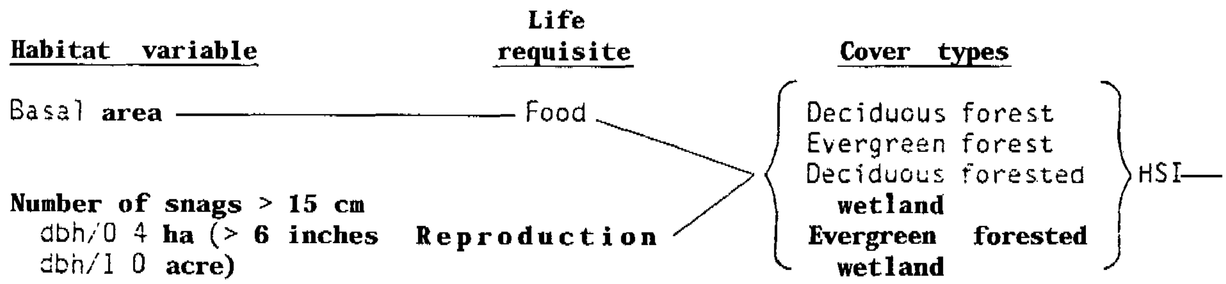


Figure 1 Relationships of habitat variables life requisites, and cover types in the downy woodpecker model

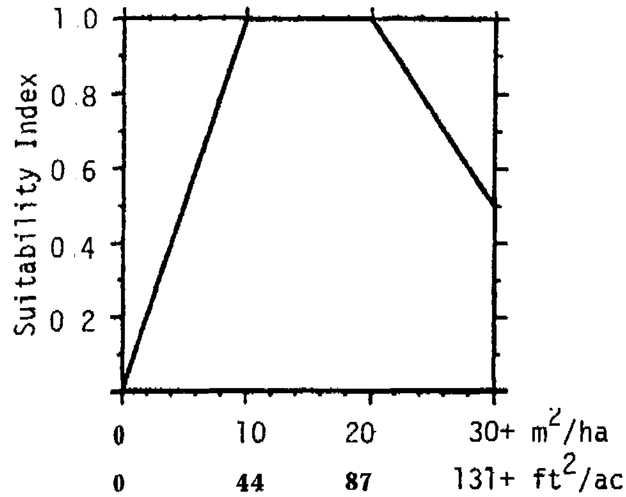
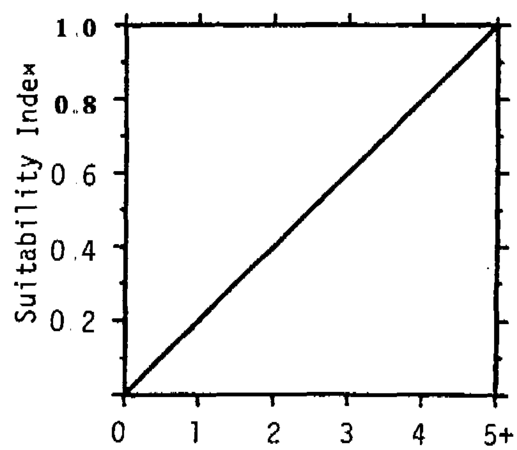
The following sections provide a written documentation of the logic and assumptions used to interpret the habitat information for the downy woodpecker in order to explain the variables and equations that are used in the HSI model Specifically, these sections cover the following: (1) identification of variables used in the model; (2) definition and justification of the suitability levels of each variable; and (3) description of the assumed relationship between variables.

Food component. Food for the downy woodpecker consists of insects found on trees in forested habitats. Downy woodpeckers occupy a wide variety of forested habitats from virgin bottomlands to sparsely stocked stands along ridges. The highest downy woodpecker densities were most often reported in the more open stands with lower basal areas, but it is assumed that all forested habitats have some food value for downies. Optimal conditions are assumed to occur in stands with basal areas between 10 and 20 m^2/ha (43.6 and 37.2 ft^2/acre), and suitabilities will decrease to zero as basal area approaches zero. Stands with basal areas greater than 30 m^2/ha (130.8 ft^2/acre) are assumed to have moderate value for downy woodpeckers.

Reproduction component. Downy woodpeckers nest in cavities in either totally or partially dead small trees. They require snags greater than 15 cm (6 inches) dbh for nest sites. Optimal habitats are assumed to contain 5 or more snags greater than 15 cm dbh/0 4 ha (6 inches dbh/1 0 acre), and habitats without such snags have no suitability.

Model Relationships

Suitability Index (SI) graphs for habitat variables. This section contains suitability index graphs that illustrate the habitat relationships described in the previous section.

Cover type	Variable		Suitability graph
EF,DF, EFW,DFW	V_1	Basal area.	
EF,DF, EFW,DFW	V_2	Number of snags > 15 cm dbh/0.4 ha (> 6 inches dbh/ 1.0 acre)	

Life requisite values. The life requisite values for the downy woodpecker are presented below.

Life requisite	Cover type	Life requisite value
Food	EF,DF,EFW,DFW	V_1
Reproduction	EF,DF,EFW,DFW	V_2

HSI determination. The HSI for the downy woodpecker is equal to the lowest life requisite value.

Application of the Model

Definitions of variables and suggested field measurement techniques (Hays et al 1981) are provided in Figure 2.

Variable (definition)		Cover types	Suggested technique
V_1	Basal area [the area of exposed stems of woody vegetation if cut horizontally at 1.4 m (4.5 ft) height, in m^2/ha (ft^2/acre)]	EF,DF,EFW,DFW	Bitterlich method
V_2	Number of snags > 15 cm (6 inches) dbh/0 4 ha (1.0 acre) [the number of standing dead trees or partly dead trees, greater than 15 cm (6 inches) diameter at breast height (1.4 m/4.5 ft), that are at least 1.8 m (6 ft) tall Trees in which at least 50% of the branches have fallen, or are present but no longer bear foliage, are to be considered snags]	EF,DF,EFW,DFW	Quadrat

Figure 2. Definitions of variables and suggested measurement tecnniques

SOURCES OF OTHER MODELS

Conner and Adkisson (1976) have developed a discriminant function model for the downy woodpecker that can be u,ed to separate habitats that possibly provide nesting habitat from those that do not provide nesting habitat. The model assesses basal area, number of stems, and canopy height of trees.

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15. Supplementary Notes

16. Abstract (Limit: 200 words)

A review and synthesis of existing information was used to develop a habitat model for the downy woodpecker (Picoides pubescens). The model is scaled to produce an index of habitat suitability between 0 (unsuitable habitat) and 1 (optimally suitable habitat) for areas of the continental United States. Habitat suitability indexes are designed for use with Habitat Evaluation Procedures previously developed by the U.S. Fish and Wildlife Service.

17. Document Analysis a. Descriptors

Mathematical models, Wildlife, Birds, Habitability

b. Identifiers/Open-Ended Terms

Downy woodpecker
Picoides pubescens
Habitat Suitability Indexes (HSI)

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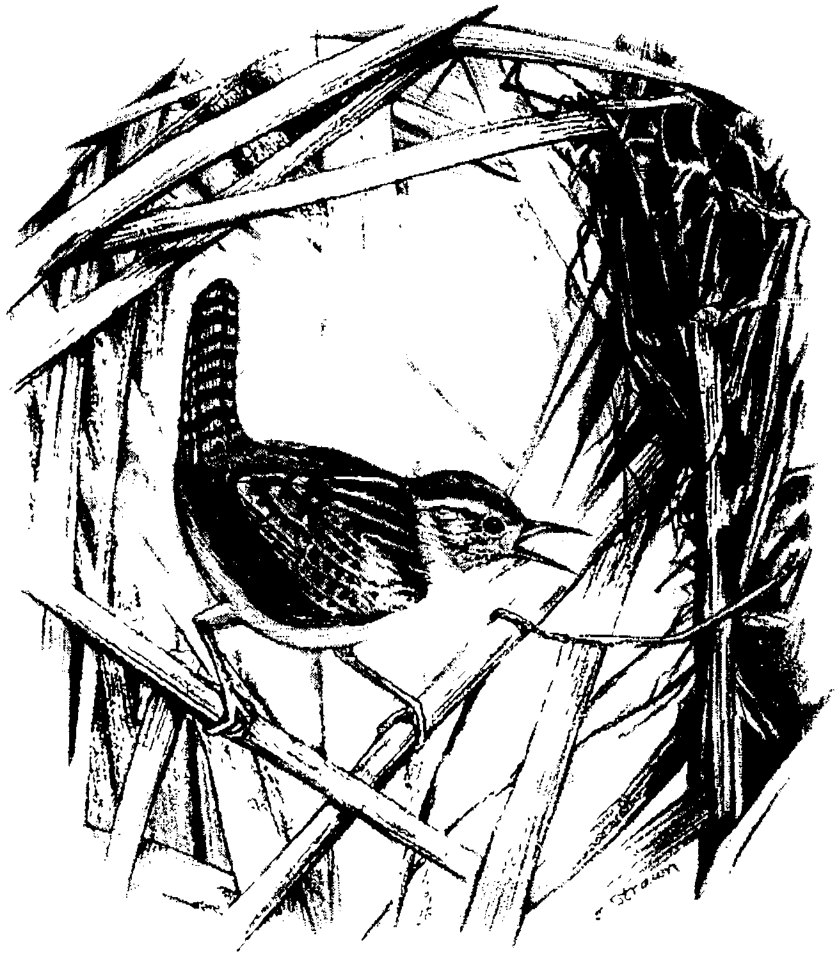
(See ANSI-Z39.18) See Instructions on Reverse OPTIONAL FORM 272 (4-77) (Formerly NTIS-35) Department of Commerce

BIOLOGICAL REPORT 82(10.139)
JUNE 1987

HABITAT SUITABILITY INDEX MODELS: MARSH WREN



Fish and Wildlife Service

S. Department of the Interior

Biological Report 82(10 139)
June 1987

HABITAT SUITABILITY INDEX MODELS MARSH WREN

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PREFACE

This document is part of the Habitat Suitability Index (HSI) model series [Biological Report 82(10)], which provides habitat information useful for impact assessment and habitat management Several types of habitat information are provided The Habitat Use Information section is largely constrained to those data that can be used to derive quantitative relationships between key environmental variables and habitat suitability This information provides the foundation for the HSI model and may be useful in the development of other models more appropriate to specific assessment or evaluation needs

The HSI Model section documents the habitat model and includes information pertinent to its application The model synthesizes the habitat use information into a framework appropriate for field application and is scaled to produce an index value between 0 0 (unsuitable habitat) and 1 0 (optimum habitat) The HSI Model section includes information about the geographic range and seasonal application of the model, its current verification status, and a list of the model variables with recommended measurement techniques for each variable

The model is a formalized synthesis of biological and habitat information published in the scientific literature and may include unpublished information reflecting the opinions of identified experts Habitat information about wildlife species frequently is represented by scattered data sets collected during different seasons and years and from different sites throughout the range of a species The model presents this broad data base in a formal, logical, and simplified manner The assumptions necessary for organizing and synthesizing the species-habitat information into the model are discussed. The model should be regarded as a hypothesis of species-habitat relationships and not as a statement of proven cause and effect relationships The model may have merit in planning wildlife habitat research studies about a species, as well as in providing an estimate of the relative suitability of habitat for that species User feedback concerning model improvements and other suggestions that may increase the utility and effectiveness of this habitat-based approach to fish and wildlife planning are encouraged. Please send suggestions to

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FIGURES

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MARSH WREN (Cistothorus palustris)

HABITAT USE INFORMATION

General

The marsh wren (Cistothorus palustris) is a locally abundant breeding bird in freshwater and saltwater marshes throughout much of the United States and southern Canada (Bent 1948; Robbins et al 1966) Marsh wrens winter in Mexico and on the gulf coast as far east as western Florida In some maritime and southern climates, where marshes do not freeze over, marsh wrens are year-round residents (Bent 1948; Verner 1965; American Ornithologists' Union 1983)

Food

Insects and spiders are taken by marsh wrens from marsh vegetation, the marsh floor, and by flycatching Insect orders commonly taken include Coleoptera, Diptera, Hemiptera, and Odonata Carabidae and Dytiscidae dominate within Coleoptera, whereas Tipulidae composes most of the Diptera in marsh wren diets (Bent 1948; Kale 1964)

Food items brought to young depend on the age of the nestlings Mosquitoes (Culicidae) and their larvae, midges (Chironomidae), larval tipulids, and other delicate stages of various insects are fed first Later, as the nestlings mature, larger forms, such as ground beetles, diving beetles, long-horned beetles (Coleoptera), caterpillars (Lepidoptera), and sawflies (Hymenoptera), are brought to the young (Welter 1935)

Water

Marsh wrens living in salt marshes are apparently able to get sufficient dietary water from succulent insects and spiders (Kale 1967) We found no discussion in the literature of dietary water needs or water procurement techniques for marsh wrens breeding in freshwater environments Marsh wrens bathe in saltwater and freshwater, but they apparently only drink freshwater (Kale 1967) Water also protects nests from predation and supports an important food source (arthropods) (Verner and Engelsen 1970)

Cover

Cover needs of the marsh wren are assumed to be the same as reproduction habitat needs and are discussed in the following section

Reproduction

Marsh wrens typically nest in cattails (*Typha* spp), bulrushes (*Scirpus* spp), or sedges (*Carex* spp) Other plants frequently present in nesting habitats include horsetails (*Equisetum* spp), bluejoint reedgrass (*Calamagrostis canadensis*), reed canarygrass (*Phalaris arundinacae*), cordgrasses (*Spartina* spp), annual wildrice (*Zizania aquatica*), spirea (*Spiraea* spp), needle rush (*Juncus roemerianus*), and American mangrove (*Rhizophora mangle*) (Welter 1935, Bent 1948, Kale 1965, Verner 1965, Clapp and Abbott 1966)

This species typically nests in marshes where water depths range from several centimeters to 61 to 91 cm (Bent 1948) Marsh wrens usually do not nest in areas without some standing water (Verner and Engelsen 1970) In intertidal areas, however, nests are built in marshes where standing water may be present only during high tides or during periods of spring tides (H W Kale, Florida Audubon Society, Maitland, FL, letter dated August 11, 1985) Further, marshes that dry out by mid to late summer have been used successfully by nesting marsh wrens (Verner 1965), but permanent water through the breeding season is generally required to supply a dependable food source and security from predation (Verner and Engelsen 1970) Marsh wrens construct various layers of their nests with water-soaked vegetation that they obtain from the marsh (Welter 1935, Verner 1965)

Nests are normally anchored at least 38 1 cm above the ground, the average above-ground height for 21 nests measured in early June was 83 8 cm (Bent 1948) Occasionally, nests are placed in mangrove (*Rhizophora* spp) trees 1 52 to 2 74 m above the ground (Bent 1948) Verner (1965) found mean nest heights varying from 76 2 to 92 7 cm above the marsh floor in cattails and bulrushes Kale (1965) recorded nest heights, from early to late in the breeding season, that ranged from 0 5 m to 2 0 m above the marsh bed Nests are typically placed 30 to 91 cm above standing water or high tide (Bent 1948) Nest height tends to increase with plant growth (Verner 1965), second nests generally yield higher mean heights than do first nests

Bigamous and monogamous males nested in cattails much more frequently than if they had simply used cattails in proportion to their availability, male marsh wrens without mates did not exhibit this preference for cattails (Verner and Engelsen 1970) Verner (1964) reported a positive trend between the fraction of a male's territory covered by emergent vegetation (including floating portions of vegetation without standing water between roots and nests) and that male's pairing success On the average, about 83 2% of the area of bachelor male territories at four marshes was covered by emergent vegetation (cattails and bulrushes), overall average percentages for these four marshes for monogamous and bigamous males were 85 1% and 87 8% Verner (1964) suggested that this trend reflects the ability of female marsh wrens to recognize the amount of available feeding habitat in a male's territory He thus implied that the proportion of a male's territory covered by emergent plants is a criterion used by female marsh wrens for mate selection Marsh wrens tend to use denser areas of cattails because their nests require several stems for attachment (Burger 1985)

Interspersion and Movements

Marshes <0 40 ha are usually not used by breeding marsh wrens (Bent 1948), although Verner (J Verner, Pacific Southwest Forest and Range Experiment Station, Forestry Sciences Lab, Fresno, CA, letter dated July 16, 1985) found nests in 0 04-ha patches of emergent, lakeside vegetation that were as much as 60 m from similar patches Welter (1935) described a monogamous male territory that was 0 12 to 0 14 ha in a preferred cattail-sedge association, in a less preferred bluejoint-reedgrass-dominated wetland, a monogamous male held a 0 28 ha territory Welter (1935) also noted that the territory of a bigamous male was almost twice that held by a monogamous male in the same vegetation type

Verner (1964) found bachelor, monogamous, and bigamous marsh wrens holding territories that were, on the average, 0 08 ha, 0 13 ha, and 0 17 ha Verner (1964) also noted one trigamous male with a territory that was 0 02 ha Verner and Engelsen (1970) reported mean territory sizes for bachelor, monogamous, and bigamous marsh wrens of 0 05 ha, 0 06 ha, and 0 07 ha There was no significant difference between these latter three means, nor was there a significant correlation between pairing success of males and their territory sizes, presumably because territory size was so variable Indeed, among five Washington sites, mean territory size for all males ranged from 0 05 to 0 17 ha (Verner 1965) Kale (1965) reported mean territory size (for all males collectively) to range from 0 01 to 0 02 ha during four breeding seasons at nine study sites in Georgia

Verner (1971) determined that the average dispersal distance between successive territory centers of 13 adult male marsh wrens during 2 consecutive years was approximately 386 m (range = 0 - 3353 m) Of these 13 males, five used the same territory in both years, and one set up a territory on a different lake during the second year Ten yearling male marsh wrens established their first breeding territories at a mean distance of 1,951 m (range = 180 - 4090 m) from their natal lake These mean dispersal distances for yearling versus adult males were significantly different (0 01 > P > 0 001) (Verner 1971)

Special Considerations

Marsh wren nestlings are occasionally consumed by common grackles (Quiscalus quiscula) (Welter 1935) Clapp and Abbott (1966) found a pilot black snake (Elaphe obsoleta obsoleta) that had preyed on marsh wren eggs Rice rats (Oryzomys palustris), raccoons (Procyon lotor), and mink (Mustella vison) are important predators of marsh wren eggs and young in Georgia (Kale 1965) Yellow-headed blackbirds (Xanthocephalus xanthocephalus) physically attack adult marsh wrens on the breeding grounds during territorial conflict (Burt 1970, cited in Picman 1980) Adult marsh wrens of both sexes destroy the eggs of other marsh wrens, presumably as a result of the evolution of intraspecific nest destruction, or perhaps because it decreases intraspecific competition for resources within a marsh (Picman 1977) Red-winged blackbirds (Agelaius phoeniceus) aggressively suppress the singing activities of marsh wrens and may, therefore, reduce marsh wren reproductive success Nesting success in marsh wrens improves with increased distance between marsh wren breeding nests and the nearest red-winged blackbird nest (Picman 1982) Thus, the density of predators, breeding marsh wrens, and red-winged and yellow-headed blackbirds in a marsh may significantly influence its suitability as marsh wren breeding habitat

HABITAT SUITABILITY INDEX (HSI) MODEL

Model Applicability

Geographic area. This model was developed for application throughout the breeding range of the marsh wren (Figure 1)

Season. This model was developed to evaluate breeding season habitat for the marsh wren

Cover type. This model was developed to assess habitat suitability in permanently and semipermanently flooded estuarine, riverine, lacustrine, and palustrine wetlands that can be classed as emergent or scrub-shrub (Cowardin et al 1979)

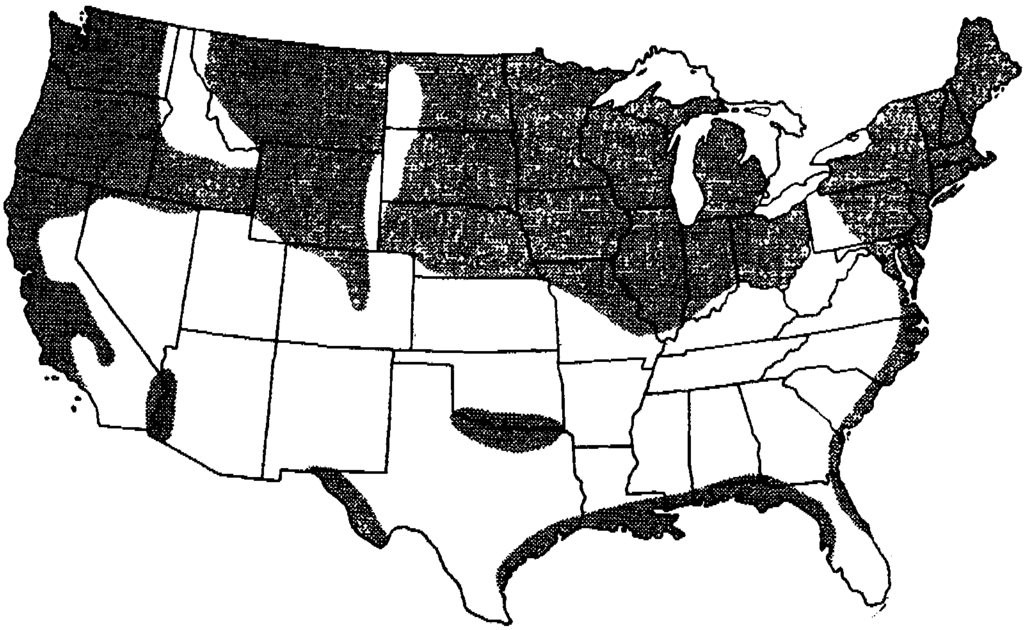


Figure 1 Approximate area of marsh wren model applicability Range estimates were adapted from several sources (including Kale, unpubl and Verner, unpubl) that combine both breeding and year-round observations

Minimum habitat area Minimum habitat area is defined as the mininum amount of contiguous habitat that is necessary before an area will be used by a species Marsh wrens do not usually nest in marshes that are <0 40 ha Accordingly, it is assumed that if less than this amount of wetland (open water plus emergent vegetation) is present, the HSI is 0

Verification level Considerable interesting work has been conducted with marsh wrens in the areas of reproductive strategy (Verner 1964), and interspecific competition between it and other marsh-dwelling passerines (Picman 1983; Leonard and Picman 1986); however, information linking the species to habitat suitability is limited For example, Verner and Engelsen (1970) were unable to exhibit statistically significant relationships between various measures of vegetation coverage within wren territories and pairing success of bachelor, monogamous, or bigamous males Where marsh wrens occur with red-winged blackbirds and yellow-headed blackbirds, redwings tend to use the drier, shallower locations, yellowheads the deeper areas bordering open water, and marsh wrens the areas in between (Weller and Spatcher 1965; Burger 1985) Measures of habitat use under these conditions apparently reflect active spatial segregation among the three species, as wrens expand their territories into areas previously occupied by redwings or yellowheads after the blackbirds leave the marshes in late summer (Leonard and Picman 1986) How these relationships relate to habitat suitability is unknown

The standard of comparison for this model focuses on male territories in wetlands as reported in the literature and interpreted by the authors The potential of a permanently or semipermanently flooded wetland to support territorial males and, we assume, nesting marsh wrens is described; the model should be useful for baseline assessments and habitat management The model is a set of hypotheses describing our interpretations of suitable marsh wren habitat conditions; however, it is not intended to serve as a predictor of numbers of wrens occupying a given wetland at any particular time The model is intended to rate the suitability of potential nesting areas as would an expert thoroughly familiar with the reproductive requirements of marsh wrens; however, we have not evaluated the model's performance under actual field conditions

Comments and suggestions from H W Kale, II, and J Verner on an earlier draft of the marsh wren model were used to formulate the present model Modifications suggested by these individuals have been incorporated into the model where possible Use of the reviewers' names, however, does not necessarily imply that they concur with each section of the model, or the model in its entirety

Model Description

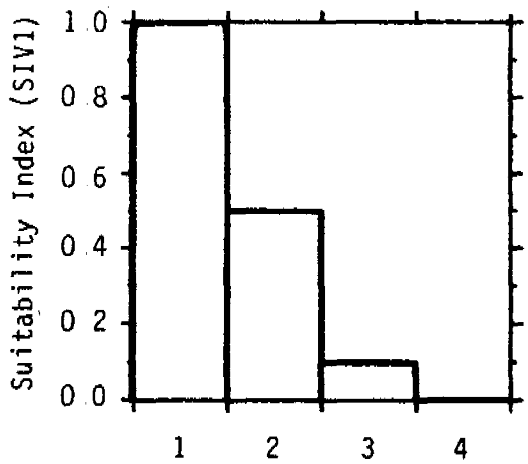
Overview Cover and reproduction requirements of the marsh wren are combined into a single habitat component because these needs are assumed to be supplied by the same habitat features It is assumed that if the cover and reproduction needs are satisfied, adequate amounts of food and water will also be available

In the sections that follow, we document the logic and assumptions used to relate marsh wren habitat information to the variables and equations used in this model Specifically, we identify variables used in the model, define and justify suitability levels for each variable, and describe the assumed relationships between variables

Cover/reproduction component It is assumed that the cover and nesting requirements for marsh wrens can be supplied by herbaceous wetlands that support hydrophytes, such as cattails, bulrushes, cordgrasses, sedges, and other species, and that contain standing water Marsh wrens tend to avoid areas of abundant woody vegetation, thus high tree or shrub densities are assumed to lower the value of a wetland for nesting marsh wrens Verner (unpubl) found marsh wrens nesting in a stand of Spiraea aquatica in Washington, isolated trees and shrubs did not preclude habitat use Instead, woody vegetation was used for singing and feeding sites

Early accounts describing the nest sites of marsh wrens identify a wide variety of emergent species used as nest support (Bent 1948) A common characteristic of nest-support vegetation is several erect and closely spaced stalks or limbs that together provide the strength and height to support a bulky nest (approximately 12 5 x 17 5 cm) at least several centimeters above the water surface Cattails and cordgrasses appear to provide a growth form commonly acceptable to nest-building marsh wrens, bulrushes are also important, especially during drier years (Verner and Engelsen 1970) Aquatic emergents exhibiting a growth form similar to cattails, cordgrass, or bulrush are assumed to provide ideal conditions for nest building and the general cover requirements for marsh wrens (SIV1, Figure 2) Species such as bluejoint reedgrass, reed canarygrass, and sedges are also used by marsh wrens, but are assumed to provide lower suitability because of their different structure, or shorter stature and assumed lower stem strength, than that exhibited by cattails and similar species Emergent species with growth forms differing significantly from those described above [e g , buttonbush (Cephalanthus occidentalis) and mangrove (Rhizophora spp)], but that are occasionally used to support nests, are assumed to have very low suitability The assignment of a suitability index to emergent vegetation not specifically identified above will require some judgement by the user

Although Verner and Engelsen (1970) were unable to exhibit statistical relationships between cover and pairing status, we feel that some consideration of relative availability of emergent vegetation for breeding marsh wrens is required to characterize cover/reproduction suitability Most studies indicate or imply that marsh wrens use areas supporting relatively dense emergent vegetation for territories and nesting The lowest mean percent coverage of emergent vegetation recorded for territorial males in Washington was 50% for bachelors using "blue" marsh (Verner 1964 257) Coverage of emergent vegetation in other territories in other marshes ranged from 57% to 100%. A diagram of marsh wren territories provided by Leonard and Picman (1986 136) also indicates the use of areas with extensive vegetation coverage, at least while yellow-headed blackbirds were present



Growth form of emergent hydrophytes

1 cattails, cordgrasses, bulrushes
2 bluejoint reedgrass, reed canary-grass, sedges
3 buttonbush, mangrove
4 other growth forms not listed

Figure 2 The assumed relationship between the growth form of emergent hydrophytes and the suitability of a wetland as cover/reproduction habitat for marsh wrens

We present the above information as increasing suitability with increasing percent canopy cover of emergent herbaceous vegetation (SIV2, Figure 3) Fifty percent canopy cover is assigned a value of 0 1, and optimum conditions are reached at 80%. These values are somewhat arbitrary, as use may equal availability after some coverage threshold is reached, especially in wetlands also used by red-winged or yellow-headed blackbirds The ultimate determination of nesting suitability may depend on female assessments of food resources within the territory, which are based on as yet unknown characteristics (Verner and Engelsen 1970)

Wetlands without standing water usually are not used for nesting by marsh wrens, although intertidal coastal marshes and other marshes that periodically lack standing water are acceptable (Verner 1965; Kale, unpubl) Information relating water depths to cover/reproduction suitability was not located; however, we have assumed a linear increase in suitability as mean depth increases (SIV3, Figure 4) Optimum conditions are assumed to occur at a minimum mean depth of 15 cm. The upper depth limit for standing water is unknown, and the graph for SIV3 indicates no limit. In reality, as water increases in depth, some threshold will be reached at which growth of emergent herbaceous vegetation will be affected, and the suitability of the wetland as represented by SIV1 and SIV2 will decrease

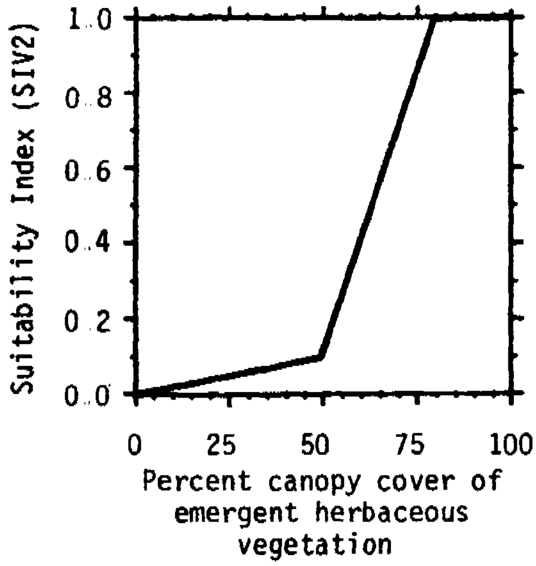


Figure 3 The assumed relationship between percent canopy cover of emergent herbaceous vegetation and cover/reproduction suitability of a wetland for marsh wrens

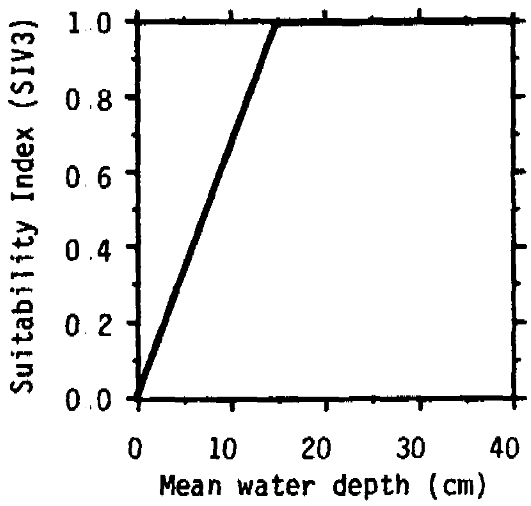


Figure 4. The assumed relationship between mean water depth and cover/reproduction suitability of a wetland for marsh wrens

The effect of woody vegetation on marsh wren habitat suitability is unclear Bent (1948) cites several early studies from the eastern United States that document nesting in woody vegetation, however, the relative importance of this activity in the overall nesting effort of the populations under study is unknown More recent studies emphasize emergent herbaceous vegetation as nesting substrate Therefore, for the purposes of this model, woody vegetation is assumed to lower the suitability of wetlands for nesting marsh wrens Forested wetlands with >30% coverage of trees >6 m in height (U S Fish and Wildlife Service 1981) are considered unsuitable Shrub-dominated wetlands (>30% coverage of woody plants <6 m tall) may have some value for nesting marsh wrens, but the value of both herbaceous and deciduous-shrub wetlands are assumed to decrease with increasing canopy closure of woody vegetation (SIV4, Figure 5) Wetlands supporting trees with <30% canopy coverage should be evaluated as either emergent or scrub-shrub wetlands

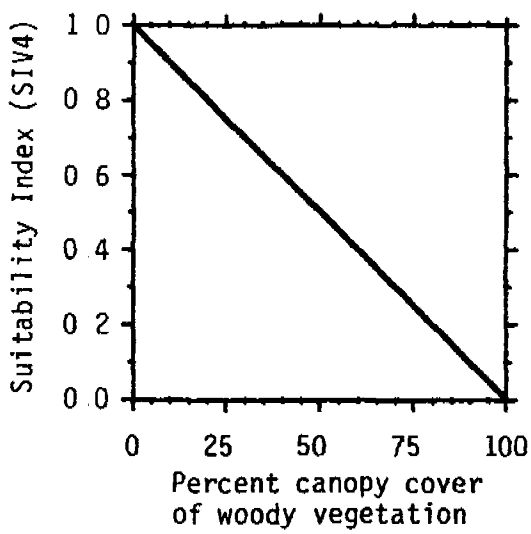


Figure 5 The assumed relationship between percent canopy cover of woody vegetation and cover/reproduction suitability of a wetland for marsh wrens

HSI determination We have assumed that habitat suitability, in terms of cover/reproduction for the marsh wren, is a reflection of the characteristics of individual permanently or semipermanently flooded estuarine, riverine, lacustrine, or palustrine wetlands classed as emergent or scrub-shrub (Cowardin et al 1979) Criteria characterizing the growth form of emergent vegetation (SIV1), the percent canopy cover of emergent herbaceous vegetation (SIV2), mean water depth (SIV3), and the percent canopy cover of woody vegetation (SIV4) can be used to assess suitability Suitability among the first three variables is compensatory, i e , a low value for one index can be compensated for by a high value in one of the other indices A zero value for any of the three variables, however, indicates a wetland that is unsuitable in terms of cover/reproduction requirements for marsh wrens The relationship between woody vegetation and habitat suitability is unclear, but we have assumed a negative affect on overall cover/reproduction suitability as the percent canopy cover of woody vegetation increases Thus, SIV4 is used to lower the value of a wetland supporting woody vegetation These relationships are described by equation 1

$$HSI = (SIV1 \times SIV2 \times SIV3)^{1/3} \times SIV4 \qquad (1)$$

Application of the Model

Summary of model variables Four habitat variables are used in this model to characterize the suitability of a wetland for supplying cover and reproductive needs of marsh wrens Relationships among these variables, the cover and reproduction component, and the HSI value are summarized in Figure 6 During application of this model, variables should be defined and measured as discussed in Figure 7

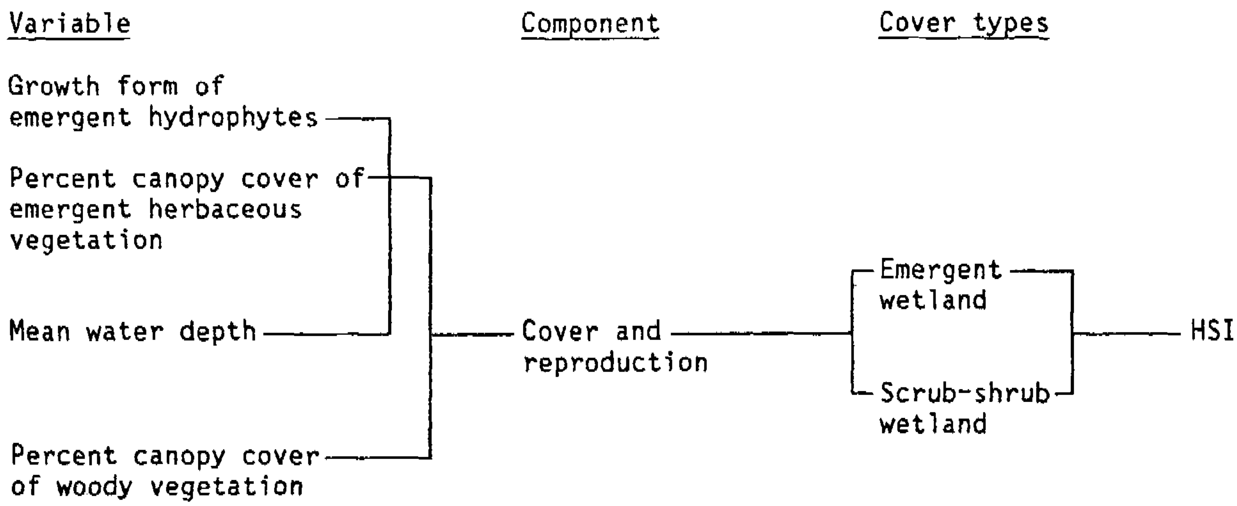


Figure 6 Relationship among habitat variables, component, cover types, and HSI for the marsh wren

Variable (definition)	Cover type	Recommended technique
Growth form of emergent hydrophytes	Emergent and scrub-shrub wetlands	Aerial photos, on-site inspection
Percent canopy cover of emergent herbaceous vegetation (the percent of the water surface shaded by a vertical projection of the canopies of emergent herbaceous vegetation, both persistent and nonpersistent)	Emergent and scrub-shrub wetlands	Line intercept
Mean water depth (cm)	Emergent and scrub-shrub wetlands	Graduated rod
Percent canopy cover of woody vegetation (the percent of the ground surface that is shaded by a vertical projection of the canopies of all woody vegetation)	Emergent and scrub-shrub wetlands	Line intercept

Figure 7 Definition of variables, applicable cover types, and recommended measurement techniques (Hays et al 1981) for the marsh wren model

Model assumptions This model was developed to assess the habitat suitability of wetlands for supplying the cover and reproductive needs of marsh wrens The model is not intended to produce outputs that reflect actual population densities at any particular time, but rather it attempts to estimate the potential of a site to supply the habitat requirements as defined above, regardless of nonhabitat variables influencing populations Model variables and relationships are based on information obtained from studies disjunct in time and space As such, the model is a collection of hypotheses and should not be interpreted as statements of proven cause and effect Users should refine the model as necessary to better represent localized conditions

Three basic assumptions characterize the model First, we assume that the growth form of herbaceous hydrophytes and percent canopy cover of emergent herbaceous vegetation in a wetland are dominant factors determining habitat suitability for marsh wrens Second, we assume that any depth of water ≥15 cm, if present during the breeding season, indicates optimum conditions Wetlands lacking such conditions would be unsuitable by definition of this variable No information was located that could be used to relate various degrees of water permanence throughout the breeding season with relative suitability Third, we assume that changes in suitability of marsh wren habitat follow a direct linear response to changes in woody vegetation canopy cover, although the influences of woody vegetation are difficult to interpret from the literature

SOURCES OF OTHER MODELS

No other habitat models for the marsh wren were found

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A review and synthesis of existing information were used to develop a Habitat Suitabiltiy Index (HSI) model for the marsh wren (*Cistothorus palustris*). The model consolidates habitat use information into a framework appropriate for field application, and is scaled to produce an index between 0.0 (unsuitable habitat) and 1.0 (optimum habitat). HSI models are designed to be used with Habitat Evaluation Procedures previously developed by U.S. Fish and Wildlife Service.

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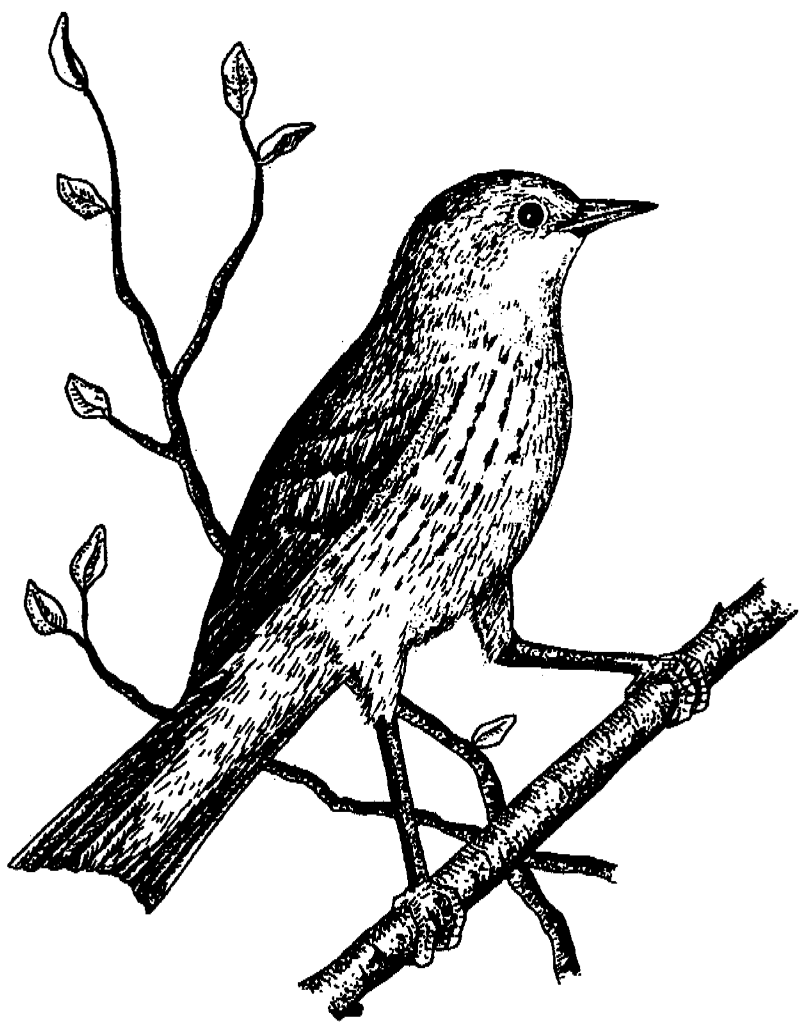
HABITAT SUITABILITY INDEX MODELS: YELLOW WARBLER



Fish and Wildlife Service

U.S. D partment of th Interior

The Biological Services Program was established within the U.S. Fish and Wildlife Service to supply scientific information and methodologies on key environmental issues that impact fish and wildlife resources and their supporting ecosystems. The mission of the program is as follows:

- To strengthen the Fish and Wildlife Service in its role as a primary source of information on national fish and wildlife resources, particularly in respect to environmental impact assessment.
- To gather, analyze, and present information that will aid decisionmakers in the identification and resolution of problems associated with major changes in land and water use.
- To provide better ecological information and evaluation for Department of the Interior development programs, such as those relating to energy development.

Information developed by the Biological Services Program is intended for use in the planning and decisionmaking process to prevent or minimize the impact of development on fish and wildlife. Research activities and technical assistance services are based on an analysis of the issues, a determination of the decisionmakers involved and their information needs, and an evaluation of the state of the art to identify information gaps and to determine priorities. This is a strategy that will ensure that the products produced and disseminated are timely and useful.

Projects have been initiated in the following areas: coal extraction and conversion; power plants; geothermal, mineral and oil shale development; water resource analysis, including stream alterations and western water allocation; coastal ecosystems and Outer Continental Shelf development; and systems inventory, including National Wetland Inventory, habitat classification and analysis, and information transfer.

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This model is designed to be used by the Division of Ecological Services in conjunction with the Habitat Evaluation Procedures

FWS/OBS-82/10.27
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HABITAT SUITABILITY INDEX MODELS: YELLOW WARBLER

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PREFACE

This document is part of the Habitat Suitability Index (HSI) Model Series (FWS/OBS-82/10), which provides habitat information useful for impact assessment and habitat management Several types of habitat information are provided The Habitat Use Information Section is largely constrained to those data that can be used to derive quantitative relationships between key environmental variables and habitat suitability The habitat use information provides the foundation for HSI models that follow In addition, this same information may be useful in the development of other models more appropriate to specific assessment or evaluation needs

The HSI Model Section documents a habitat model and information pertinent to its application The model synthesizes the habitat use information into a framework appropriate for field application and is scaled to produce an index value between 0 0 (unsuitable habitat) and 1 0 (optimum habitat) The application information includes descriptions of the geographic ranges and seasonal application of the model, its current verification status, and a listing of model variables with recommended measurement techniques for each variable

In essence, the model presented herein is a hypothesis of species-habitat relationships and not a statement of proven cause and effect relationships Results of model performance tests, when available, are referenced However, models that have demonstrated reliability in specific situations may prove unreliable in others For this reason, feedback is encouraged from users of this model concerning improvements and other suggestions that may increase the utility and effectiveness of this habitat-based approach to fish and wildlife planning Please send suggestions to

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CONTENTS

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YELLOW WARBLER (*Dendroica petechia*)

HABITAT USE INFORMATION

General

The yellow warbler (*Dendroica petechia*) is a breeding bird throughout the entire United States, with the exception of parts of the Southeast (Robbins et al 1966) Preferred habitats are wet areas with abundant shrubs or small trees (Bent 1953) Yellow warblers inhabit hedgerows, thickets, marshes, swamp edges (Starling 1978) aspen (*Populus* spp) groves, and willow (*Salix* spp) swamps (Salt 1957), as well as residential areas (Morse 1966)

Food

More than 90% of the food of yellow warblers is insects (Bent 1953), taken in proportion to their availability (Busby and Sealy 1979) Foraging in Maine occurred primarily on small limbs in deciduous foliage (Morse 1973)

Water

Dietary water requirements were not mentioned in the literature Yellow warblers prefer wet habitats (Bent 1953; Morse 1966; Stauffer and Best 1980)

Cover

Cover needs of the yellow warbler are assumed to be the same as reproduction habitat needs and are discussed in the following section

Reproduction

Preferred foraging and nesting habitats in the Northeast are wet areas, partially covered by willows and alders (*Alnus* spp), ranging in height from 1 5 to 4 m (5 to 13 3 ft) (Morse 1966) It is unusual to find yellow warblers in extensive forests (Hebard 1961) with closed canopies (Morse 1966) Yellow warblers in small islands of mixed coniferous-deciduous growth in Maine utilized deciduous foliage far more frequently than would be expected by chance alone (Morse 1973) Coniferous areas were mostly avoided and areas of low deciduous growth preferred

Nests are generally placed 0 9 to 2 4 m (3 to 8 ft) above the ground, and nest heights rarely exceed 9 1 to 12 2 m (30 to 40 ft) (Bent 1953) Plants used for nesting include willows, alders, and other hydrophytic shrubs and trees (Bent 1953), including box-elders (Acer negundo) and cottonwoods (Populus spp) (Schrantz 1943) In Iowa, dense thickets were frequently occupied by yellow warblers while open thickets with widely spaced shrubs rarely contained nests (Kendeigh 1941)

Males frequently sing from exposed song perches (Kendeigh 1941; Ficken and Ficken 1965), although yellow warblers will nest in areas without elevated perches (Morse 1966)

A number of Breeding Bird Census reports (Van Velzen 1981) were summarized to determine nesting habitat needs of the yellow warbler, and a clear pattern of habitat preferences emerged Yellow warblers nested in less than 5% of census areas comprised of extensive upland forested cover types (deciduous or coniferous) across the entire country Approximately two-thirds of all census areas with deciduous shrub-dominated cover types were utilized, while shrub wetland types received 100% use Wetlands dominated by shrubs had the highest average breeding densities of all cover types [2 04 males per ha (2 5 acre)] Approximately two-thirds of the census areas comprised of forested draws and riparian forests of the western United States were used, but average densities were low [0 5 males per ha (2 5 acre)]

Interspersion

Yellow warblers in Iowa have been reported to prefer edge habitats (Kendeigh 1941; Stauffer and Best 1980) Territory size has been reported as 0 16 ha (0 4 acre) (Kendeigh 1941) and 0 15 ha (0 37 acre) (Kammeraad 1964)

Special Considerations

The yellow warbler has been on the Audubon Society's Blue List of declining birds for 9 of the last 10 years (Tate 1981)

HABITAT SUITABILITY INDEX (HSI) MODEL

Model Applicability

Geographic area This model has been developed for application within the breeding range of the yellow warbler

Season This model was developed to evaluate the breeding season habitat needs of the yellow warbler

Cover types This model was developed to evaluate habitat in the dominant cover types used by the yellow warbler Deciduous Shrubland (DS) and Deciduous Scrub/Shrub Wetland (DSW) (terminology follows that of U S Fish and Wildlife Service 1981) Yellow warblers only occasionally utilize forested habitats and reported population densities in forests are low The habitat requirements in forested habitats are not well documented in the literature For these reasons, this model does not consider forested cover types

Minimum habitat area Minimum habitat area is defined as the minimum amount of contiguous habitat that is required before an area will be occupied by a species Information on the minimum habitat area for the yellow warbler was not located in the literature Based on reported territory sizes, it is assumed that at least 0 15 ha (0 37 acre) of suitable habitat must be available for the yellow warbler to occupy an area If less than this amount is present, the HSI is assumed to be 0 0

Verification level Previous drafts of the yellow warbler habitat model were reviewed by Douglass H Morse and specific comments were incorporated into the current model (Morse, pers comm)

Model Description

Overview This model considers the quality of the reproduction (nesting) habitat needs of the yellow warbler to determine overall habitat suitability Food, cover, and water requirements are assumed to be met by nesting needs

The relationship between habitat variables, life requisites, cover types, and the HSI for the yellow warbler is illustrated in Figure 1

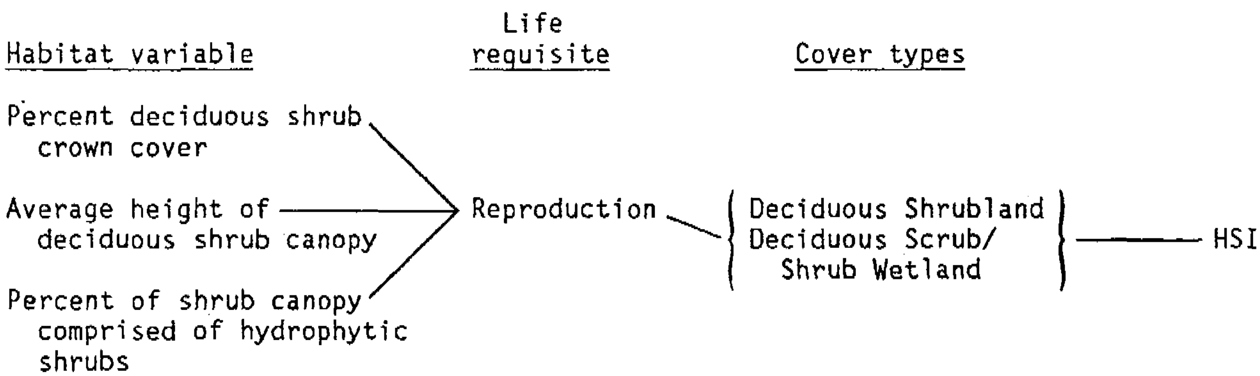


Figure 1 Relationship between habitat variables, life requisites, cover types, and the HSI for the yellow warbler

The following sections provide a written documentation of the logic and assumptions used to interpret the habitat information for the yellow warbler and to explain and justify the variables and equations that are used in the HSI model Specifically, these sections cover the following (1) identification of variables that will be used in the model, (2) definition and justification of the suitability levels of each variable, and (3) description of the assumed relationship between variables

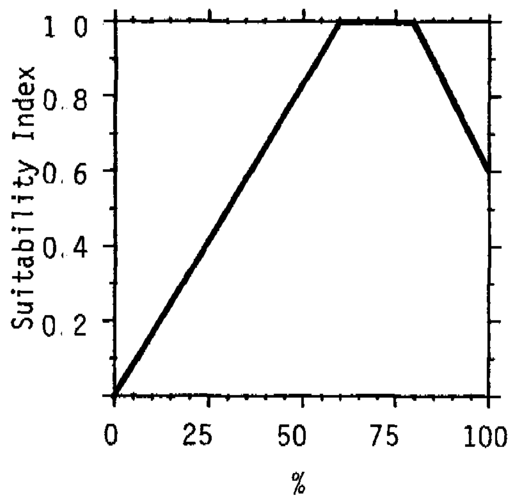
Reproduction component Optimal nesting habitat for the yellow warbler is provided in wet areas with dense, moderately tall stands of hydrophytic deciduous shrubs Upland shrub habitats on dry sites will provide only marginal suitability

It is assumed that optimal habitats contain 100% hydrophytic deciduous shrubs and that habitats with no hydrophytic shrubs will provide marginal suitability Shrub densities between 60 and 80% crown cover are assumed to be optimal As shrub densities approach zero cover, suitability also approaches zero Totally closed shrub canopies are assumed to be of only moderate suitability, due to the probable restrictions on movement of the warblers in those conditions Shrub heights of 2 m (6 6 ft) or greater are assumed to be optimal, and suitability will decrease as heights decrease to zero

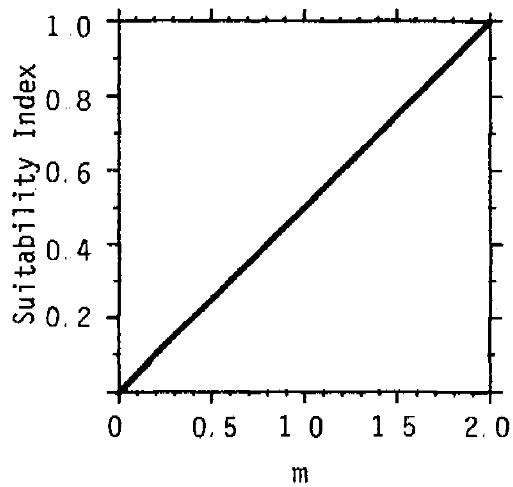
Each of these habitat variables exert a major influence in determining overall habitat quality for the yellow warbler A habitat must contain optimal levels of all variables to have maximum suitability Low values of any one variable may be partially offset by higher values of the remaining variables Habitats with low values for two or more variables will provide low overall suitability levels

Model Relationships

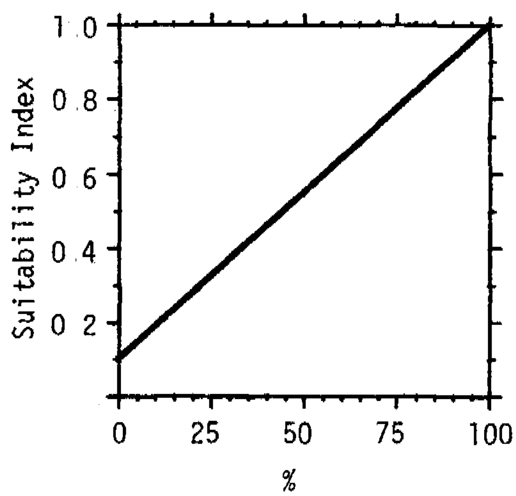
Suitability Index (SI) graphs for habitat variables This section contains suitability index graphs that illustrate the habitat relationships described in the previous section

Cover type	Variable		
DS,DSW	V_1	Percent deciduous shrub crown cover	

DS,DSW V_2 Average height of deciduous shrub canopy



DS,DSW V_3 Percent of deciduous shrub canopy comprised of hydrophytic shrubs



Equations. In order to obtain life requisite values for the yellow warbler, the SI values for appropriate variables must be combined with the use of equations. A discussion and explanation of the assumed relationship between variables was included under Model Description, and the specific equation in this model was chosen to mimic these perceived biological relationships as closely as possible. The suggested equation for obtaining a reproduction value is presented below.

Life requisite	Cover type	Equation
Reproduction	DS,DSW	$(V_1 \times V_2 \times V_3)^{1/2}$

HSI determination. The HSI value for the yellow warbler is equal to the reproduction value

Application of the Model

Definitions of variables and suggested field measurement techniques (Hays et al 1981) are provided in Figure 2

Variable (definition)		Cover types	Suggested technique
V_1	Percent deciduous shrub crown cover (the percent of the ground that is shaded by a vertical projection of the canopies of woody deciduous vegetation which are less than 5 m (16 5 ft) in height)	DS,DSW	Line intercept
V_2	Average height of deciduous shrub canopy (the average height from the ground surface to the top of those shrubs which comprise the uppermost shrub canopy)	DW,DSW	Graduated rod
V_3	Percent of deciduous shrub canopy comprised of hydrophytic shrubs (the relative percent of the amount of hydrophytic shrubs compared to all shrubs, based on canopy cover)	DS,DSW	Line intercept

Figure 2 Definitions of variables and suggested measurement techniques

SOURCES OF OTHER MODELS

No other habitat models for the yellow warbler were located.

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Habitat preferences of the yellow warbler (Dendroica petechia) are described in this publication It is one of a series of Habitat Suitability Index (HSI) models and was developed through an analysis of available information on the species-habitat requirements of the species Habitat use information is presented in a review of the literature, followed by the development of an HSI model, designed for use in impact assessment and habitat management activities

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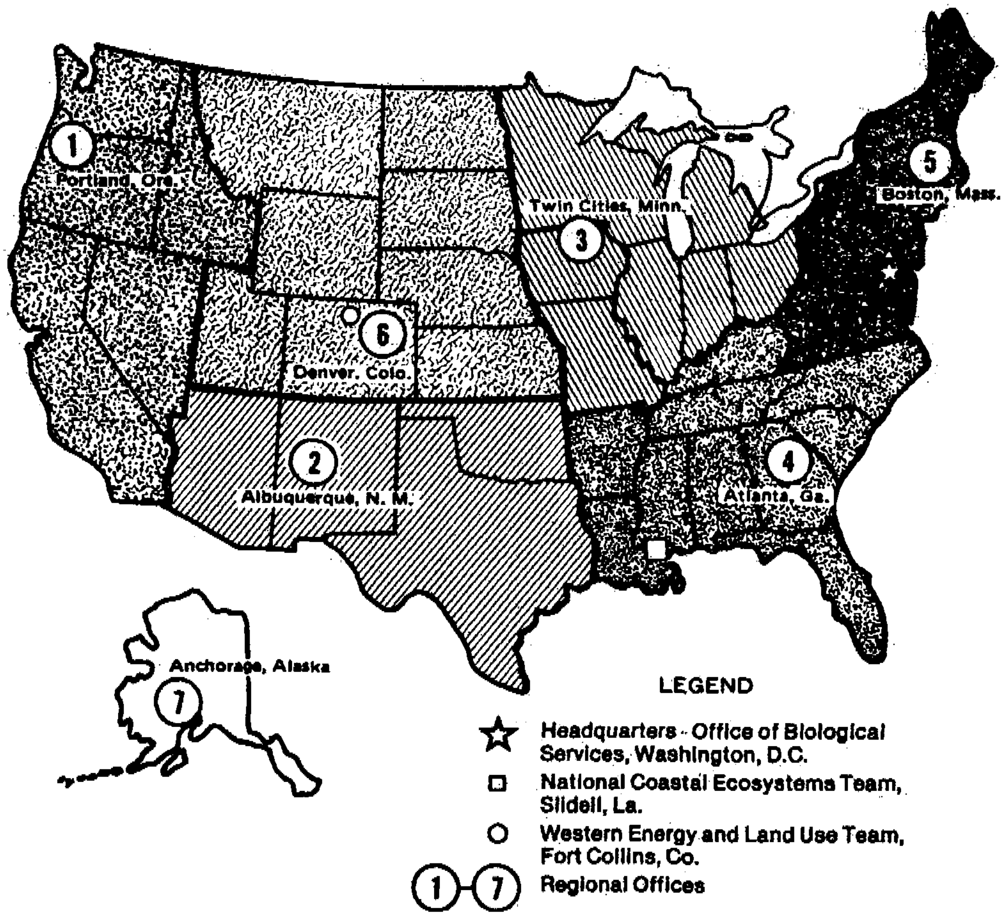

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