Application of a Habitat Suitability Index Model for Wintering Black Ducks

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Abstract: The Habitat Suitability Index (HSI) model (Lewis and Garrison 1984) for wintering American black ducks (*Anas rubripes*) was applied during 1985 and 1986 at Chincoteague, Virginia. HSI values of 0.66 and 0.56 were obtained during the 2 respective years. We suggested improvements in field methods for estimating biological variables. Modification of 1 variable (V_6) and inclusion of a new variable (proportion of total land and water represented by saltmarsh, V_8) were proposed to improve model output.

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The U.S. Fish and Wildlife Service's HSI model for wintering black ducks is intended for use in impact assessment and management of winter habitat along the Atlantic coast of the United States (Lewis and Garrison 1984). The model requires that 7 variables be assessed: 3 physical variables are determined from maps and 4 biological variables are measured in the field before winter. The physical variables are the percentage of subtidal open water ≤ 1 m deep (V_1), the percentage of open water area exposed at low tide (V_2), and the percentage of emergent and forested wetland area covered by streams, ponds, and impoundments (V_5). The biological variables are the percentage of subtidal shallows occupied by rooted vascular plants (V_3), the percentage of intertidal mudflat sample plots containing ≥ 300 clams/m^2 (V_4), the percentage of bottom substrate of freshwater impoundments and ponds covered by *Ruppia* sp. and *Potamogeton* sp. (V_6), and the percentage of nonforested, emergent marsh that supports ≥ 750 snails/m^2 (V_7). Based on theoretical and, less frequently, empirical considerations of habitat use by wintering black ducks, Suitability Index (SI) values are assigned to estimates of these variables.

For sites south of Cape Code, Massachusetts, the HSI model specifies 2 equations to evaluate marine and estuarine open water (ow), and estuarine vegetated wetlands (vw):

$$\mathrm{HSI[ow]} = [((\mathrm{SI}_1 + \mathrm{SI}_2)/2)^2 \times (\mathrm{SI}_3 + \mathrm{SI}_4/2)]$$
$$\mathrm{HSI[vw]} = ((2 \times \mathrm{SI}_5) + \mathrm{SI}_6 + \mathrm{SI}_7)/4.$$

An overall HSI value can be calculated by weighting each of the previous values by the relative area of each habitat (A[ow] = proportion of site that is subtidal open water; A[vw] = proportion of site that is vegetated wetlands; A[ow] + A[vw] = 1):

$$\mathrm{HSI} = (\mathrm{A[ow]} \times \mathrm{HSI[ow]}) + \mathrm{A[vw]} \times \mathrm{HSI[vw]}).$$

A partial application of this model to 23 study sites along the Atlantic coast from Virginia to Maine indicated that physical habitat characteristics alone may account for 22% to 29% of the variation in the distribution of wintering black ducks (Lewis et al. 1984). However, the biological variables for this model were neither measured nor evaluated. As part of a larger study of energetics and habitat use of wintering black ducks, we applied the model to a 25,614-ha site on the Eastern Shore of Virginia's Delmarva peninsula. The area included the Chincoteague National Wildlife Refuge (NWR), part of the Assateague National Seashore, and adjacent tidal habitats. Our objectives were to determine the HSI value for the Chincoteague area and to evaluate field measurements of the model variables for the winters of 1985–86 and 1986–87.

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Methods

Cartographic data were measured with a Tektronix 4051 electronic planimeter. The area of subtidal water (V_1) was estimated from bathymetric contours on 1:24,000 U.S. Geological Survey (USGS) topographic maps. Areas of tidal flats (V_2) and streams, ponds, and impoundments (V_5) were determined from 1:24,000 National Wetland Inventory (NWI) maps.

Cover of rooted vascular plants (V_3) was assessed from about 100 aerial photographs, representing 27 different locations, taken on 10 December 1985 from about 400 m above ground level (AGL). These locations also were photographed in December 1986, but print quality was too poor to be considered reliable. Consequently, we assumed V_3 may be the same for both years. Photo locations were distributed nonrandomly over the study area. Locations were selected that could be identified easily on USGS topographic maps. A 50-mm lens and Kodak Ektachrome film were used; however, the slides were developed as 8×10 high-contrast black and white prints. Cover was estimated with a dot grid (64 dots/2.54 cm).

To assess the frequency of *Ruppia* sp. and *Potamogeton* sp. (V_6) in impoundments, we completed the fall vegetation survey normally conducted by Chincoteague NWR personnel. Refuge impoundments constituted only 4% of the study area, but represented 70% of the available fresh and brackish standing water. Ten transects in 7 impoundments were completed in 1985; 8 transects were completed in 1986. A 5-point sampler was placed at 10-m intervals along the transect, and vegetation at each point was recorded. Totals of 714 stations (3,570 points) and 497 stations (2,485 points) were sampled in 1985 and 1986, respectively. Pool totals were weighted by the relative area of the pool. Transects were completed during 23 October–15 November 1985 and 13–22 November 1986.

Clam densities (V_4) were estimated from 10 100-m transects perpendicular to the water's edge on 10 selected tidal flats at low tide. Transect starting points were chosen randomly for each flat. Each transect was divided into 5 20-m sections, and 2 0.1-m^2 sample plots were allocated randomly to each section within 10 m perpendicular to the transect line; therefore, 100 0.1-m^2 plots were tabulated each year (200 different plots). Sand and silt, to a depth of 10 cm, were excavated with a trowel and sifted by hand. Clams were tallied by species. Transects were completed during 19–26 November 1985 and 28 November–14 December 1986.

Snail densities (V_7) were estimated from 26 100-m transects distributed nonrandomly over the study area. The sampling design was similar to that used for estimating clam densities. Each transect was perpendicular to the water's edge, divided into 5 20-m sections, and 2 0.1-m^2 sample plots were allocated randomly to each section within 10 m of the transect line; therefore, 260 0.1-m^2 plots were tabulated each year (520 different plots). All snails on the ground (within the frame) or on vegetation that was rooted within the frame were counted. Snail species, plant species, and average height (nearest 1 cm) of *Spartina alterniflora* within the plot were recorded. In 1985, we did not record stem heights in 10 sample plots. Transects were completed during 22 October–28 November 1985 and 14 November–11 December 1986.

Results

The study area was composed of 6,562-ha upland, 5,518-ha deep (>1 m) subtidal water, 5,386-ha shallow (≤ 1 m) subtidal water, 4,743-ha saltmarsh, 1,400-ha tidal flat, 910-ha impoundment, 423-ha natural pool, 324-ha shrub wetland, 304-ha stream, and 44-ha other habitat. Other habitat included areas designated as dunes under the NWI classification and were pooled with upland for this analysis.

Variables and corresponding SI values are estimated for both years in Table 1. Shallow subtidal water (V_1), tidal flat (V_2), subtidal water supporting rooted vascular aquatic plants (V_3), and ponds, creeks, and impoundments (V_5) were assumed to be

Table 1. Estimation of the 7 variables used in the Habitat Suitability Index model for black ducks at Chincoteague, Virginia, during the winters of 1985–86 and 1986–87.

		1985–86		1986–87	
Variable	Description	%	SI[a]	%	SI
V_1	Subtidal (< 1 m) water	49.4	0.74	49.4	0.74
V_2	Tidal flat	11.4	0.52	11.4	0.52
V_3	Subtidal water with rooted plants	17.4	0.87	17.4	0.87
V_4	Plots containing ≥300 clams/m^2	0.0	0.00	0.0	0.00
V_5	Ponds, creeks, or impoundments	24.4	1.00	24.4	1.00
V_6	*Ruppia* sp. and *Potamogeton* sp.	20.7	0.23	0.2	0.00
V_7	Plots containing ≥750 snails/m^2	20.8	0.80	6.9	0.25

[a]Suitability Index; derived from model predictions (Lewis and Garrison 1984).

the same during both winters. On the Chincoteague study area, widgeon grass (*Ruppia maritima*) and eel grass (*Zostera marina*) were dominant vascular plants in estuarine waters. We assumed no change in aquatic plant cover between 1985 and 1986, which is supported by data from the Virginia Institute of Marine Science (13%–14% of subtidal water in Chincoteague Bay was covered by submerged aquatic vegetation in 1986; Robert Orth, unpubl. rep.).

In 1985, impoundment water levels were high and averaged about 0.3–0.6 m deep. *Ruppia* sp. and *Potamogeton* sp. occurred on 13.7% of transect points. After weighting this sampling by the relative areas of the pools, a value of 20.7% was estimated for V_6. In 1986, however, refuge impoundments did not fill with rainwater until mid-December. *Ruppia* sp. and *Potamogeton* sp. were negligible when sampled, and represented only 0.2% of transect points. During both years, *Eleocharis parvula* was the dominant waterfowl food in refuge impoundments.

The highest number of clams in any plot (V_4) during 2 years was 4. In fact, in 1986 only 4 clams were counted in 100 sample plots. *Mercenaria mercenaria* was the common clam; *Tellina* sp. and *Tagelus* sp. were found infrequently on transects. Ribbed mussels (*Geukensia demissa*) were found commonly in the saltmarsh, but rarely on tidal flats.

The saltmarsh snail (*Melampus bidentatus*) was the only species used to estimate V_7. Although marsh periwinkles (*Littorina irrorata*) were found in the saltmarsh and mud dog whelks (*Nassarius obsoletus*) were common on flats and channel banks of high silt composition, these gastropods were much less ubiquitous than *Melampus*. In 1985, for example, *Melampus* sp. was present in 71% (N = 260) of sample quadrats with a mean density of 37.8/0.1 m^2 (SE = 3.27). In contrast, marsh periwinkles were present in 18% of sample quadrats with a mean density of 6.4/0.1 m^2 (SE = 2.13) during the same year. Additionally, *Melampus* sp. is apparently eaten more than other snails, composing 93.4% of the dry weight of invertebrates found in black ducks (N = 40) collected on the study area during the winter of 1985–86 (Morton 1987).

More plots in 1985 than in 1986 contained ≥750 snails/m^2 (V_7) (Table 1). Similarly, mean snail densities were higher in 1985 than in 1986 (Table 2).

Table 2. Mean *Melampus bidentatus* counts (per 0.1 m^2) in 4 height classes of *Spartina alterniflora* at Chincoteague, Virginia, in the fall of 1985 and 1986.

	1985			1986		
Height (cm)	N^a	$\bar{x}$	SE	N	$\bar{x}$	SE
0–20	45	3.93	1.76	77	5.69	3.49
21–40	134	62.16	5.08	132	28.42	3.77
41–60	58	15.95	4.35	26	17.19	5.95
>60	13	2.00	1.41	25	0.24	0.15
Total	250	37.83[b]	3.36	260	17.86[b]	2.36

[a] In 1985, we did not record stem heights in 10 sample quadrats; those records deleted for analysis.
[b] $P < 0.001$; t-test, 1985 vs. 1986.

Spartina alterniflora was the dominant vegetative component in the saltmarsh (present in 93% of 250 quadrants in 1985). Mean stem height of *S. alternifora* differed ($t = 1.93$, df = 508, $P = 0.054$) between 1985 ($x = 33.5$ cm, $N = 250$, SE = 1.07) and 1986 ($x = 30.3$, $N = 260$, SE = 1.27).

Discussion

Measurement of Variables

Cartographic variables (V_1, V_2, V_5) were measured as Lewis and Garrison (1984) suggested. NWI maps were easier to use than USGS maps because wetland habitat types were designated by discrete boundaries. Consequently, measurements could be replicated.

Use of aerial photographs for estimating submerged vegetative cover in subtidal waters (V_3) was practical. Obtaining a representative sample by more conventional methods would have been prohibitively time consuming. However, we suggest use of infrared film, extensive ground-truthing, and randomization of photo locations.

Lewis and Garrison (1984) suggested using an Ekman dredge to sample for clams. We found that an Ekman dredge did not penetrate compacted sand and silt, nor did it consistently hold a uniform sample. The 0.1-m^2 plot we used was adequate, although time consuming. It would have been necessary to screen samples had clam counts approached 300 clams/m^2. Each transect (i.e., 10 plots) required 1–1.5 hours to complete. Clam counting is limited to periods of low tide; thus, we were able to complete 2–3 transects per day (2 persons).

Counting *Melampus* sp. also took 1–1.5 hours per transect and was restricted to low tide, but to a lesser extent than clam transects on tidal flats. We were able to complete 3–4 transects per day (2 persons).

We believe this method provides an accurate estimate of snail densities but only when randomized properly. We used the same transect starting points for both years in an effort to minimize geographic and vegetative variances between years. However, mean stem height of *Spartina* sp. differed between years, as did mean snail densities.

To clarify the relationship between *Spartina* sp. and *Melampus* sp., sample plots were grouped (a posteriori) within 4 height classes of *Spartina* sp. (<21 cm, 21–40 cm, 41–60 cm, >60 cm, Table 2). A 2-way ANOVA suggested that snail densities did not, in fact, differ between years ($F = 2.74$, df = 1, $P = 0.098$), but were affected by *Spartina* sp. height ($F = 33.64$, df = 3, $P < 0.0001$) and the year-height interaction ($F = 7.02$, df = 3, $P < 0.0001$). Despite not being certain whether the true or sample populations of *Spartina* sp. differed between years, it is clear that snail densities are affected by the height of *Spartina* sp., and sampling designs should account for this relationship. Any relationship between *Melampus* sp. density and *Spartina* sp. stem height is presumably tide dependent, perhaps influenced by the frequency and duration of tidal inundation.

The 5-point sampler proved to be a good method for sampling vegetative frequencies in shallow impoundments. It was simple and efficient, although randomly located stations may be more appropriate than transects. Lewis and Garrison (1984) suggested using a plant dredge, which would be appropriate for deeper water (>1 m). However, there is little value in sampling deeper than a 5-point sampler can reach. Although black ducks have been known to dive (Kutz 1940), diving is not a common foraging strategy.

On the Chincoteague study area, *Ruppia* sp. and *Potamogeton* sp. were not common forage items for wintering black ducks. Esophageal and proventriculi contents data from 40 black ducks collected on the study area during 1985–86 showed little evidence of *Potamogeton* sp. and *Ruppia* sp. ingestion. Seeds (including *Salicornia* sp., *Myrica* sp., *Echinocloa* sp., *Juncus* sp., *Scirpus* sp., *Panicum* sp., and *Eleocharis* sp.) accounted for 45.9% of total dry weight and were found in 42.5% of digestive tracts. Vegetative material represented only 10.7% of total dry weight, although fragmented vegetation was found in 60% of the carcasses. We suggest that V_6 be generalized to reflect the abundance of common waterfowl forages in local ponds and impoundments. Restricting this variable to *Ruppia* sp. and *Potamogeton* sp. tends to underestimate the value of this habitat type.

Model Output

In 1985, the overall HSI value was 0.66; values for HSI[ow] and HSI[vw] were 0.56 and 0.76, respectively. In 1986, the overall HSI value was 0.56; values for HSI[ow] and HSI[vw] were both 0.56. A[ow] and A[vw] were both 0.50 for both years.

Although we believe that model variables were well chosen by Lewis and Garrison (1984), we suggest the model fails to recognize the importance of *Spartina* sp. saltmarsh on the mid-Atlantic wintering grounds. Forty-nine percent and 61%, respectively, of radio locations of female black ducks wintering in Virginia (Morton et al. 1989) and New Jersey (Costanzo 1988) were in saltmarsh.

The original model estimates area and food value for subtidal water (V_1, V_3), intertidal zones (V_2, V_4), and creeks, ponds, and impoundments (V_5, V_6). However, it fails to specifically estimate estuarine emergent vegetation, though snail numbers are evaluated (V_7). Therefore, we suggest including a new variable (V_8), which would credit the importance of *Spartina* sp. saltmarsh to wintering black ducks. Based on telemetry data (Costanzo 1988, Morton et al. 1989), the suitability index would be maximum ($SI(V_8) = 1$) when the proportion of total land and water area represented by saltmarsh is 50–60%, and be minimum when the saltmarsh proportion was either 0% or 100%. This variable would be included in the suitability equation for estuarine vegetated wetlands (Lewis and Garrison 1984), and all variables would be equally weighted (i.e., unweight V_5):

$$(SI_5 + SI_6 + SI_7 + SI_8)/4.$$

In general, the HSI model proposed by Lewis and Garrison can be applied effectively in the field. Users of this model could improve sampling efficiency by applying variance estimates reported here or by presampling in the field to determine minimum sample sizes. This model may have more applicability to wintering areas south of Cape Cod with modification of V_6 and inclusion of a new variable, V_8.

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