Habitat Selection by Mallard Broods on Navigation Pool 7 of the Upper Mississippi River

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Abstract

Habitat use and selection was determined for radio-marked mallard broods on Pool 7 of the Upper Mississippi River for 1993 and 1994. Data were collected on a daily basis using standard telemetry techniques. Habitat use was determined using methods that consider telemetry error in estimating brood locations. Compositional analysis was used to determine habitat selection at two levels. The first level of analysis (second-order selection) compared the area composition of habitat used in the home range to the area of habitats available throughout the study area. The second level of analysis (third-order selection) evaluated the telemetry locations as habitat used and compared them to the area of habitats available in the home range. At both levels of analysis for 1993 and 1994, it was determined that use among habitats differed than what would be expected if use occurred at random. Emergent and rooted floating aquatic vegetation ranked high in the third-order selection analysis among available habitat types for 1993 and 1994. Submersed aquatic vegetation and open water ranked high among available habitat types in the second-order selection analysis for 1993 and 1994. There was a small detectable difference in selection between 1993 and 1994 in the third-order selection analysis.

In addition to analyzing habitat selection by mallard broods, several important issues concerning habitat use and selection studies are addressed. Included in this paper are discussions on the effects of triangulation error, misclassification error, definition of availability, home range estimators, and habitat use analysis methods. Results are affected by each of these issues, so each needs to be considered when planning and conducting any habitat use and selection study.

Introduction

Many ecological and management questions regarding movement, behavior, habitat use, survival, and other interests of mobile species have existed for decades. Through the development of radio-telemetry techniques, researchers have been able to gather and analyze information on mobile species (Samuel and Fuller 1994). Use of radio-telemetry data to evaluate issues such as habitat use and selection is now common practice in wildlife research and management (Samuel and Kenow 1992). Standard telemetry techniques can be used to locate an individual remotely while minimizing disturbances that can affect daily activities of that individual (Samuel and Fuller 1994). Identifying habitats selected by mallard (*Anas platyrhynchos*) broods can provide managers with information about the habitat requirements of mallard broods. This information allows researchers and managers to monitor which habitats are being used compared to habitats that are available to the animal.

Several habitat use and selection studies have been conducted using the hierarchy of selection proposed by Johnson (1980). The hierarchy contains four orders of selection. First-order is the selection of a physical or geographical range by a species. Second-order determines the home range of an individual or group. Third-order refers to the usage of habitat components within the home range. Fourth-order identifies specific resources (e.g. food) selected at a particular site. Availability of components differ between these four selection orders. To evaluate the use and availability of components on any order of selection, a ranking system was also developed by Johnson (1980). The ranking system calculates the difference between the rank of usage and the rank of availability to measure preference. From this ranking system relative statements can be made on usage and availability of components. Using this ranking system allows the results to be less subjective and less sensitive to arbitrary definitions of availability and estimated use measurements (Johnson 1980).

Many habitat use and selection studies have been conducted using Johnson's (1980) methods. Mauser *et al.* (1994) found strong habitat selection by mallards occurring at the second-order selection level, but not at the third-order selection level in northeastern California. At the second-order of selection, seasonal marshes with some type of cover component were preferred compared to open habitats or permanently flooded marshes (Mauser *et al*. 1994). Gilmer *et al.* (1975) conducted a habitat-time interaction study in Minnesota and found that mallards varied in their use of habitat types, and habitat selection differed between day and night. Overall habitat preference was for seasonal wetlands, sand bar-pond, and overhanging brush shorelines (Gilmer *et al*. 1975). Conversely, Rotella and Ratti (1992) concluded that habitat selection for certain types of wetlands was not consistent among mallard broods in southwestern Manitoba. Broods that did show selection for wetlands preferred seasonal, small semi-permanent, and large semi-permanent wetlands, while other broods did not show any selection (Rotella and Ratti 1992). Since there was a difference in selection or no selection, in that study, mallards may be considered as a generalist species.

The objective of this study was to analyze habitat use and selection of mallard broods on Pool 7 of the Upper Mississippi River (UMR) using radio-telemetry data and land cover data. Habitat selection was determined at two levels; within the home range of each animal and throughout the entire study area (Johnson 1980). Because the definition of what is available to an animal is somewhat arbitrary, evaluating habitat use at two levels provides insight into the hierarchical nature of selection by mallard broods.

Study Area

The Upper Mississippi River (UMR) is a vast system extending 1,300 miles from Lake Itasca in Minnesota to Cairo, Illinois. It supports commercial and recreational traffic while providing habitat to a diverse array of fish and wildlife species. The UMR is controlled with a lock and dam system to help support commercial and recreational traffic. A result of the lock and dam system has been the considerable amount of change in habitat composition over several years.

An important annual activity that occurs on the UMR that also affects habitat composition is flooding. Flooding can be important for many species on the UMR, but can also be detrimental to other species. In any case, flooding affects vegetation dynamics and subsequently the availability of habitats to individual species from year to year.

The Pool 7 study area encompasses approximately 12,422 hectares and extends from river mile 714 near Trempealeau, Wisconsin to river mile 697.5 near La Crosse, Wisconsin (Figure 1). The study area composition (Figure 2) mainly consisted of open water (39%), woody terrestrial (19%), and agriculture-urban-other (19%; Table 1). Much of the Pool 7 study area is contained within the Upper Mississippi River National Wildlife and Fish Refuge, which is one of the five National Wildlife Refuges that encompass 300,000 acres of land and water along the river corridor.

Methods

Mallard brood location data (provided by K. P. Kenow, USGS Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin, unpublished data) were collected as part of a larger study to document brood survival and movement on the UMR. The mallard nests were found by searching islands on Pool 7. Eggs were collected from the nests and placed in incubators until hatching. When a clutch began to hatch, individuals from the brood were randomly selected for subcutaneous implant of radio transmitters (Korschgen *et al*. 1996). The ducklings were then deployed as broods back into existing

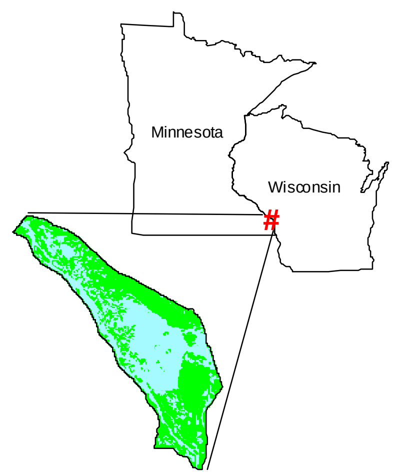

Figure 1. Pool 7 study area.

Table 1. 1994 study area land cover classes used in the analysis.

Class Abbreviation	Full Class Name	Area (Hectares)	Area (Proportion)
OW	Open Water	4874.72	0.39
S	Submersed Aquatic Vegetation	561.42	0.05
RF	Rooted Floating Aquatic Vegetation	738.92	0.06
E	Emergent Vegetation	815.18	0.07
EG	Emergents-Grasses-Forbs	151.68	0.009
GF	Grasses-Forbs	524.65	0.04
WT	Woody Terrestrial	2408.29	0.19
AUD	Agriculture-Urban-Developed-Other	2334.56	0.19
SM	Sand-Mud	12.55	0.001
Total Area		**12421.97**	**1.00**

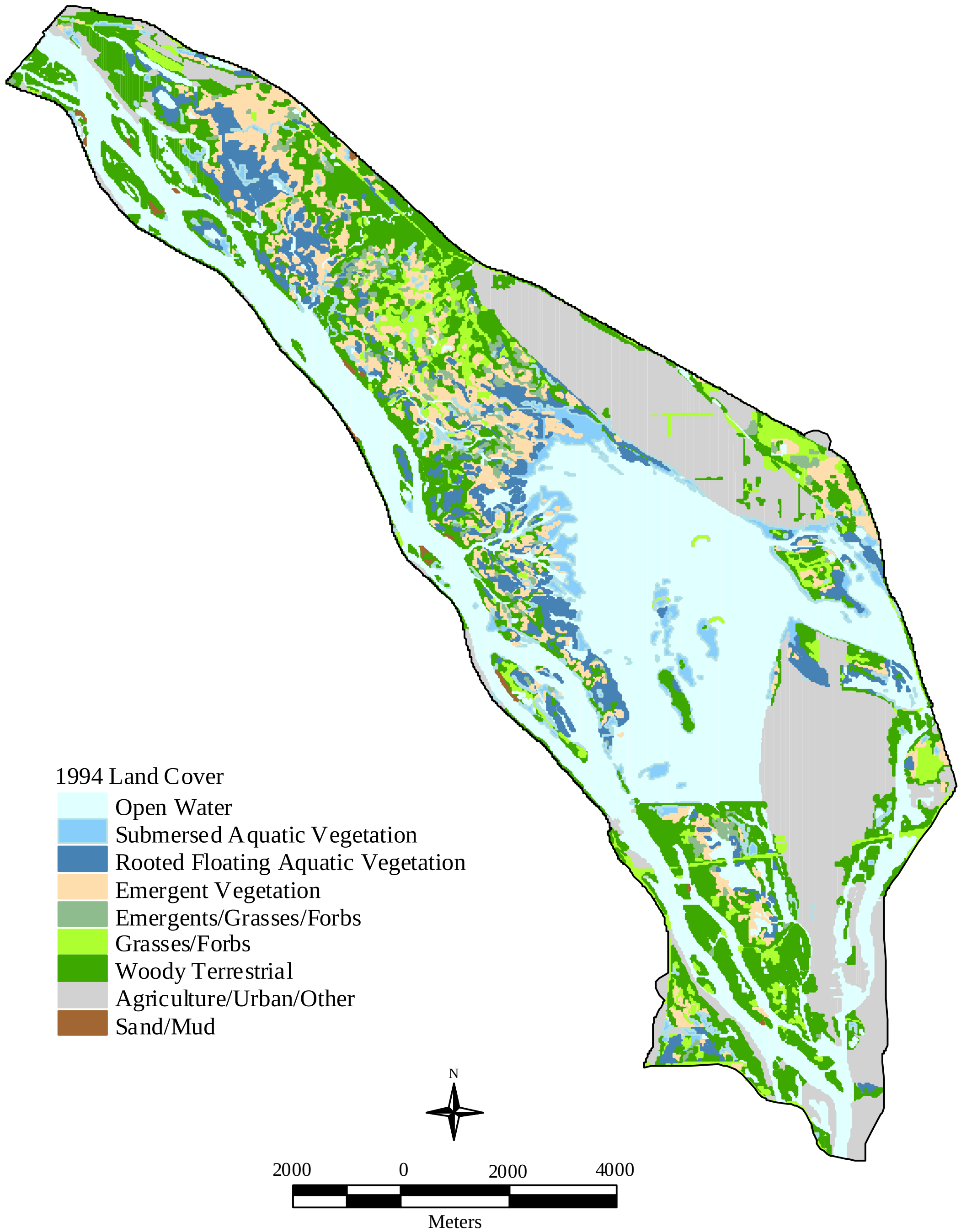

Figure 2. Study area habitat composition.

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nests on the islands of Arrowhead, Broken Gun, Cormorant, or McIlvane in Lake Onalaska of Pool 7 (Figure 3). After deployment, radio-marked ducklings were tracked from June through August in 1993 and May through August in 1994 using standard telemetry techniques. Data were recorded and processed using a modified version of the XYLOG program developed by Dodge and Steiner (1986). The location of an individual was determined using triangulation, which is the process of estimating the location of a transmitter by using two or more directional bearings obtained from known, remote locations (White and Garrott 1990). The standard deviation of directional bearings for this study was calculated to be 6.93 degrees based on methods proposed by Lee *et al.* (1985).

Once the location data were compiled, they were edited and summarized. A total of seventeen broods were monitored in 1993 and twenty-two broods were monitored in 1994. From each of the broods an individual duck was selected to represent the entire movement of the brood. For 1993, twelve of the seventeen broods were represented, and for 1994, seventeen of the twenty-two broods were represented. The data for the broods that were not represented did not contain complete information or did not contain at least two readings to generate a location solution, so they were not used in the analysis. The data records associated with each duckling included the duckling identification, date, time, receiver location, and azimuth to the duckling. In addition, the data were evaluated and records were eliminated that contained incomplete readings or non-intercepting azimuths. Also, the size of the error ellipse associated with

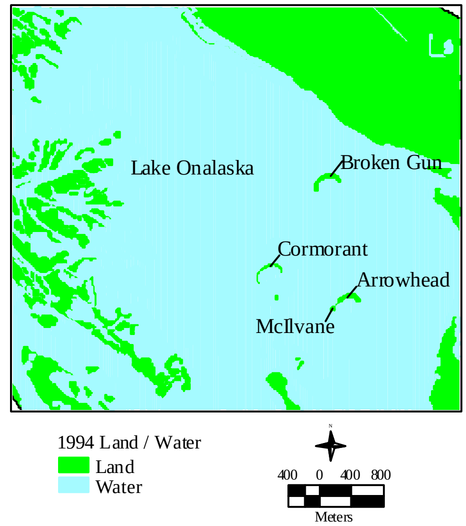

Figure 3. Islands used by nesting mallards in Lake Onalaska.

each location solution was evaluated. Larger error ellipse values may signify a decrease in the accuracy of the azimuths used in generating a particular location solution. Based on the distribution of the error ellipse sizes, location solution sets that generated a 95% error ellipse greater than 26 hectares were also eliminated from the analysis.

Land cover data were generated from 1:15,000-scale color infra-red aerial photographs, which were taken in August of 1994. From the photography, the signatures were interpreted using standard operating procedures (Owens and Hop 1995) with a minimum mapping unit of one acre. The photo interpreted transparencies were then transferred onto a 1:24,000-scale USGS topographic map (Owens and Robinson 1996) and digitized into a geographic information system (GIS) using standard operating procedures (Arndt and Olsen 1995). Using USGS topographic maps for transfer medium resulted in the accuracy of the land cover data to be within fifteen meters. Over 160 species and species combinations of aquatic and terrestrial vegetation have been identified on the UMR (L. Robinson, USGS, pers. comm.). For GIS and mapping purposes thirteen general vegetation classes were generated for the 1994 land cover data. After examining the characteristics of each class and reviewing the habitats most likely to be used by mallard broods, I combined some classes and ended up with nine classes for the analysis (Table 1).

Newly developed software (K. P. Kenow, R. B. Wright, M. D. Samuel, and P. Rasmussen, Integration of SAS and GIS software to improve habitat use estimates from radio-telemetry data, unpublished software) was used to conduct the habitat use analysis of the brood location data. The software consists of two components. A Statistical Analysis Systems (SAS) executable program, SUBSAMPL, generated 100 random points from the error distribution of each estimated duck location (Figure 4) using maximum likelihood procedures (Lenth 1981). The output from SUBSAMPL generated a

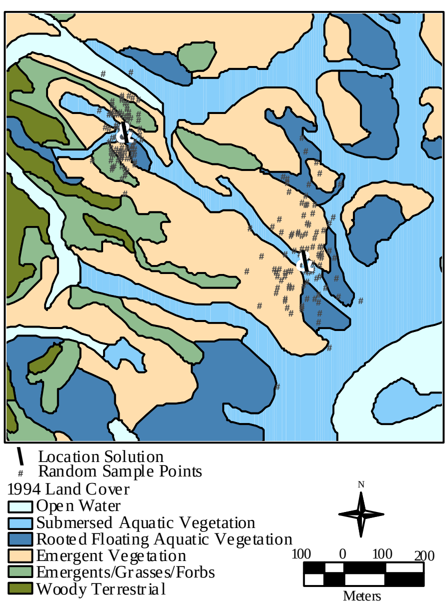

Figure 4. Example of random sampling points within the 95% error ellipse of actual location solution.

file consisting of coordinate and attribute information that can be processed in ARC/INFO. The geographic information systems (GIS) program HABUSE created a digital data set from the files containing coordinate and attribute information, determined the habitat type for each random point in the error ellipse, and summarized the habitat types for all of the points. The probability of use for each habitat type was calculated from the summarized values.

Based on the resource selection methods of Johnson (1980), second- and third- order selection were estimated from information on habitat use relative to availability. As part of these selection models, the home range was determined in ArcView (Environmental Systems Research Institute, Inc. 1998) using the minimum convex polygon (MCP) method. The MCP home range was generated by connecting each bird's outer-most point locations. There are other techniques to obtain an animal's home range, but the MCP method is the simplest and most commonly used in habitat selection studies (Samuel and Fuller 1994).

Compositional analysis (Aebischer *et al*. 1993) was used to test for habitat selection. It is one of the newer techniques used to analyze habitat selection and addresses shortcomings that might exist in other habitat selection analysis methods. To deal with these shortcomings, compositional analysis uses the animal rather than the radio location as a sample unit, performs a log-ratio transformation of the data to overcome non-independence of proportional values, tests between-group differences by referencing within-group between-animal variation, and can analyze data at different levels of availability (Aebischer *et al*. 1993).

The compositional analysis program (G. W. Pendleton, Alaska Department of Fish and Game, Douglas, Alaska, unpublished software) tested the hypothesis that habitat use was proportional to habitat availability. The difference between the log-ratio transformation of habitat used and the log-ratio transformation of habitat available was calculated for each habitat type indicating selection. These differences were then placed in a pair-wise comparison matrix to summarize the selection analysis. Matrices of the means and standard errors were generated, and the sign of each value from the mean matrix was then extracted and placed in a simplified ranking matrix (see Results). The mean value matrix and the simplified ranking matrix provided an indication of relative selection among available habitat types. The significance of relative selection was related to how much the mean value deviated from zero, which also signified how much use differed from random use. The rankings were determined from the number of positive signs generated for each habitat type compared to all other habitat types in the pair-wise comparison matrix. For nine habitat classes, the rankings ranged from 0 to 8 with 0 being the least selected and 8 being the most selected.

Results

Habitat use

Habitat use data were summarized to evaluate any use patterns that may have occurred by the mallard broods. Home range estimates that were used in the habitat use and selection analyses ranged from 2 hectares to 1,100 hectares for 1993 and 55 hectares to 1,450 hectares for 1994. Location and home range composition data for 1993 are represented in Tables 2a and 2b, respectively. Tables 3a and b represent proportion of use for 1993. On average, habitats used consisted primarily of open water (38%) and rooted floating aquatic vegetation (22%) based on the radio location data (Table 3a). When evaluating habitat composition of the home range of the broods (Table 3b), the composition consisted primarily of open water (61%) with each of the remaining vegetation classes representing less than 10 percent of the average home range composition.

Table 2a. Location data showing the proportion of habitat types used in 1993.

Brood No.	No. of Locations	OW	S	RF	E	EG	GF	WT	AUD	SM
4009	13	3.32	0.01	0.16	2.34	1.29	0.09	5.19	0.60	0
4025	23	2.92	0.25	17.53	0.94	0.14	0	1.22	0	0
4367	5	0.28	0	0	0.38	0	2.58	1.76	0	0
4422	24	7.25	0.55	6.52	4.35	1.16	0.48	3.69	0	0
4692	2	0.68	0.53	0.56	0.06	0.17	0	0	0	0
4782	9	1.08	1.22	1.25	0.51	1.08	0.82	2.26	0.78	0
4826	6	2.98	0.24	1.92	0.48	0.07	0	0.31	0	0
5759	4	2.57	0.05	1.36	0	0	0	0.02	0	0
5774	2	1.98	0.02	0	0	0	0	0	0	0
5855	12	5.37	0.68	4.21	0.89	0.46	0.04	0.35	0	0
5958	7	3.43	0	0.57	1.77	0.16	0.05	0.44	0.58	0
7243	12	4.13	1.07	0.81	0.88	0.47	2.51	2.13	0	0

Table 2b. Minimum convex polygon home range habitat composition in hectares for 1993.

Brood No.	OW	S	RF	E	EG	GF	WT	AUD	SM
4009	315.05	26.58	5.49	22.46	6.19	25.47	239.35	31.27	0.37
4025	208.80	24.70	44.59	6.08	1.49	0.08	12.19	0.14	0
4367	45.67	18.99	24.63	38.46	6.35	33.38	29.65	0.002	0
4422	108.02	25.07	28.39	19.90	4.31	1.87	16.80	0.02	0
4692	68.23	8.18	2.52	0.30	0.35	0.14	0	0.18	0
4782	512.77	166.57	124.11	107.93	38.80	10.11	80.46	62.05	0
4826	126.82	15.74	18.30	5.12	1.49	0.24	8.64	0.26	0
5759	31.22	2.13	0.99	0	0	0.48	0.34	0.19	0
5774	2.20	0.04	0	0	0	0.04	0	0.08	0
5855	218.59	30.05	63.12	16.22	3.95	2.22	11.47	0.19	0
5958	91.57	12.54	4.10	21.39	6.82	18.40	18.19	51.31	0
7243	457.74	123.53	93.07	155.49	33.15	48.72	83.42	0.18	0

Table 3a. Proportion of radio locations representing habitat use for 1993.

Brood No.	OW	S	RF	E	EG	GF	WT	AUD	SM
4009	0.255	0.001	0.012	0.180	0.099	0.007	0.399	0.046	0.000
4025	0.127	0.011	0.762	0.041	0.006	0.000	0.053	0.000	0.000
4367	0.056	0.000	0.000	0.076	0.000	0.516	0.352	0.000	0.000
4422	0.302	0.023	0.272	0.181	0.048	0.020	0.154	0.000	0.000
4692	0.340	0.265	0.280	0.030	0.085	0.000	0.000	0.000	0.000
4782	0.120	0.136	0.139	0.057	0.120	0.091	0.251	0.087	0.000
4826	0.497	0.040	0.320	0.080	0.012	0.000	0.052	0.000	0.000
5759	0.643	0.013	0.340	0.000	0.000	0.000	0.005	0.000	0.000
5774	0.990	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5855	0.448	0.057	0.351	0.074	0.038	0.003	0.029	0.000	0.000
5958	0.490	0.000	0.081	0.253	0.023	0.007	0.063	0.083	0.000
7243	0.344	0.089	0.068	0.073	0.039	0.209	0.178	0.000	0.000
Mean Value of Usage	**0.384**	**0.054**	**0.219**	**0.087**	**0.039**	**0.071**	**0.128**	**0.018**	**0.000**

Table 3b. Proportion of habitat composition within the home range of each brood for 1993.

Brood No.	OW	S	RF	E	EG	GF	WT	AUD	SM
4009	0.469	0.040	0.008	0.033	0.009	0.038	0.356	0.047	0.001
4025	0.701	0.083	0.150	0.020	0.005	0.000	0.041	0.000	0.000
4367	0.232	0.096	0.125	0.195	0.032	0.169	0.150	0.000	0.000
4422	0.529	0.123	0.139	0.097	0.021	0.009	0.082	0.000	0.000
4692	0.854	0.102	0.032	0.004	0.004	0.002	0.000	0.002	0.000
4782	0.465	0.151	0.113	0.098	0.035	0.009	0.073	0.056	0.000
4826	0.718	0.089	0.104	0.029	0.008	0.001	0.049	0.001	0.000
5759	0.883	0.060	0.028	0.000	0.000	0.014	0.010	0.005	0.000
5774	0.932	0.017	0.000	0.000	0.000	0.017	0.000	0.034	0.000
5855	0.632	0.087	0.183	0.047	0.011	0.006	0.033	0.001	0.000
5958	0.408	0.056	0.018	0.095	0.030	0.082	0.081	0.229	0.000
7243	0.460	0.124	0.094	0.156	0.033	0.049	0.084	0.000	0.000
Mean Value of Usage	**0.607**	**0.086**	**0.083**	**0.065**	**0.016**	**0.033**	**0.080**	**0.031**	**0.000**

Location and home range composition data for 1994 are represented in Tables 4a and 4b, respectively. Radio location data from 1994 indicated that on average, habitats used consisted of emergent vegetation (29%), open water (25%), and rooted floating aquatic and submersed aquatic vegetation (16%; Table 5a). Habitat composition of the home ranges for broods in 1994 indicated that open water represented the largest portion of the home range (64%; Table 5b). Submersed aquatic vegetation represented 14 percent of the composition with the remaining habitat types representing less than 10 percent of the average home range composition.

Habitat selection

Habitat selection occurred if a habitat was used more than what would be expected if use among habitats occurred at random. While *t*-tests were used for pair-wise comparisons, MANOVA was used to test for selection across all habitats. Analysis indicated that second-order selection occurred in 1993 ($p = 0.0017$). Selection was indicated by the mean values in Table 6a and the rankings in Table 6b. Comparing the signs in the ranking matrix showed that selection of submersed aquatic vegetation, which ranked highest among all habitat types, differed from all other habitats except open water and emergents-grasses-forbs. Also, the selection for open water (rank 7) differed from that of grasses-forbs, sand-mud, woody terrestrial, and agriculture-urban-developed. Agriculture-urban-developed was selected significantly less relative to all other habitat types except emergent vegetation and woody terrestrial. Other comparisons that were indicative included selection of rooted floating aquatic vegetation differing from submersed aquatic vegetation, woody terrestrial, and agriculture-urban-developed, and selection of emergent vegetation differing from submersed aquatic vegetation and emergents-grasses-forbs.

Table 4a. Location data showing the proportion of habitat types used in 1994.

Brood No.	No. of Locations	OW	S	RF	E	EG	GF	WT	AUD	SM
4208	14	6.54	0.12	3.02	1.46	0.24	0.03	2.58	0.01	0
4330	15	3.73	2.42	3.96	3.12	0.64	0.19	0.93	0.01	0
4537	6	1.05	1.16	1.20	1.81	0.71	0.02	0.05	0	0
4573	17	8.53	1.63	2.56	1.64	0.09	0.01	2.54	0	0
4689	2	1.14	0.11	0.56	0.10	0	0	0.09	0	0
4804	4	0.67	1.19	1.35	0.36	0	0	0.43	0	0
5074	24	0.06	2.57	1.33	18.51	1.53	0	0	0	0
5124	11	0.52	0.82	0.69	6.12	2.35	0	0.50	0	0
5235	7	0.50	1.12	1.33	2.95	0.44	0.09	0.57	0	0
5476	22	0.29	5.26	1.97	13.15	1.30	0.01	0.02	0	0
5494	31	9.20	2.11	7.59	9.34	1.08	0.13	1.55	0	0
5637	22	0.59	2.70	3.80	14.36	0.49	0	0.06	0	0
5816	3	1.51	1.36	0	0	0	0.13	0	0	0
5826	30	4.38	9.47	0.22	6.67	0.69	0.15	8.42	0	0
7030	10	3.86	1.44	0.78	0.46	0	0.03	3.43	0	0
7045	9	1.48	0.42	2.40	2.24	0.72	1.02	0.72	0	0
7211	10	4.28	0.99	1.79	1.86	0.15	0.03	0.90	0	0

Table 4b. Minimum convex polygon home range habitat composition in hectares for 1994.

Brood No.	OW	S	RF	E	EG	GF	WT	AUD	SM
4208	515.27	52.63	14.74	15.76	10.31	3.71	78.71	0.79	0
4330	235.51	87.16	45.01	33.47	5.88	2.29	17.10	0.06	0
4537	546.56	130.55	59.45	42.85	8.16	3.27	14.68	0.84	0
4573	536.07	78.30	30.77	21.35	3.36	2.46	14.46	0.84	0
4689	154.13	23.85	15.63	1.80	0	0.05	2.45	0.06	0
4804	193.59	19.50	68.16	8.28	1.05	0.58	14.12	0.24	0
5074	94.72	23.19	7.52	24.30	3.55	0.002	0.23	0.005	0
5124	434.58	105.85	43.80	52.86	13.49	1.12	16.49	0.06	0
5235	422.93	125.56	121.56	140.38	28.26	12.23	58.67	0.11	0
5476	160.48	56.68	28.36	53.24	12.50	0.86	8.59	0.006	0
5494	180.12	47.33	31.86	20.45	4.06	3.11	14.86	0.57	0
5637	960.58	174.09	146.56	90.02	17.89	4.80	55.46	0.84	0
5816	35.67	16.29	1.41	0	0	1.08	0	0.54	0
5826	256.99	39.34	3.83	8.73	1.42	0.33	7.10	0.03	0
7030	280.69	26.97	7.26	6.94	7.2	3.69	54.17	0.68	0
7045	87.70	20.02	32.11	13.98	3.43	1.81	8.72	0.02	0
7211	452.08	99.33	109.67	47.69	10.45	4.09	50.31	0.54	0

Table 5a. Proportion of radio locations representing habitat use for 1994.

Brood No.	OW	S	RF	E	EG	GF	WT	AUD	SM
4208	0.467	0.009	0.216	0.104	0.017	0.002	0.184	0.001	0.000
4330	0.249	0.161	0.264	0.208	0.043	0.013	0.062	0.001	0.000
4537	0.175	0.193	0.200	0.302	0.118	0.003	0.008	0.000	0.000
4573	0.502	0.096	0.151	0.096	0.005	0.001	0.149	0.000	0.000
4689	0.570	0.055	0.280	0.050	0.000	0.000	0.045	0.000	0.000
4804	0.168	0.298	0.338	0.090	0.000	0.000	0.108	0.000	0.000
5074	0.003	0.107	0.055	0.771	0.064	0.000	0.000	0.000	0.000
5124	0.047	0.075	0.063	0.556	0.214	0.000	0.045	0.000	0.000
5235	0.071	0.160	0.190	0.421	0.063	0.013	0.081	0.000	0.000
5476	0.013	0.239	0.090	0.598	0.059	0.000	0.001	0.000	0.000
5494	0.297	0.068	0.245	0.301	0.035	0.004	0.050	0.000	0.000
5637	0.027	0.123	0.173	0.653	0.022	0.000	0.003	0.000	0.000
5816	0.503	0.453	0.000	0.000	0.000	0.043	0.000	0.000	0.000
5826	0.146	0.316	0.007	0.222	0.023	0.005	0.281	0.000	0.000
7030	0.386	0.144	0.078	0.046	0.000	0.003	0.343	0.000	0.000
7045	0.164	0.047	0.267	0.249	0.080	0.113	0.080	0.000	0.000
7211	0.428	0.099	0.179	0.186	0.015	0.003	0.090	0.000	0.000
Mean Value of Usage	**0.248**	**0.155**	**0.164**	**0.286**	**0.045**	**0.012**	**0.090**	**0.000**	**0.000**

Second-order selection also occurred in 1994 ($p = 0.0001$). The mean values (Table 7a) and the habitat selection rankings (Table 7b) indicated a significant selection for submersed aquatic vegetation relative to all other habitat types. The selection of open water (rank 7) differed significantly from all habitat types except rooted floating aquatic vegetation. Another obvious comparison was woody terrestrial, grasses-forbs, and sand-mud being relatively equal in selection, but differing from all other habitats. Finally, selection of agriculture-urban-developed, which ranked lowest,

Table 5b. Proportion of habitat composition within the home range of each brood for 1994.

Brood No.	OW	S	RF	E	EG	GF	WT	AUD	SM
4208	0.745	0.076	0.021	0.023	0.015	0.005	0.114	0.001	0.000
4330	0.552	0.204	0.106	0.078	0.014	0.005	0.040	0.000	0.000
4537	0.678	0.162	0.074	0.053	0.010	0.004	0.018	0.001	0.000
4573	0.780	0.114	0.045	0.031	0.005	0.004	0.021	0.001	0.000
4689	0.779	0.120	0.079	0.009	0.000	0.000	0.012	0.000	0.000
4804	0.634	0.064	0.223	0.027	0.003	0.002	0.046	0.001	0.000
5074	0.617	0.151	0.049	0.158	0.023	0.000	0.001	0.000	0.000
5124	0.650	0.158	0.066	0.079	0.020	0.002	0.025	0.000	0.000
5235	0.465	0.138	0.134	0.154	0.031	0.013	0.064	0.000	0.000
5476	0.500	0.177	0.088	0.166	0.039	0.003	0.027	0.000	0.000
5494	0.596	0.157	0.105	0.068	0.013	0.010	0.049	0.002	0.000
5637	0.662	0.120	0.101	0.062	0.012	0.003	0.038	0.001	0.000
5816	0.649	0.296	0.026	0.000	0.000	0.020	0.000	0.010	0.000
5826	0.809	0.124	0.012	0.027	0.004	0.001	0.022	0.000	0.000
7030	0.724	0.070	0.019	0.018	0.019	0.010	0.140	0.002	0.000
7045	0.523	0.119	0.191	0.083	0.020	0.011	0.052	0.000	0.000
7211	0.584	0.128	0.142	0.062	0.013	0.005	0.065	0.001	0.000
Mean Value of Usage	**0.644**	**0.140**	**0.087**	**0.065**	**0.014**	**0.006**	**0.043**	**0.001**	**0.000**

Table 6a. Habitat matrix of the means for 1993 by comparing proportions of habitats in the home range with proportions of habitats available study area wide.

Habitat	OW	S	RF	E	EG	GF	WT	AUD	SM
OW	0.00	-0.15	0.95	1.67	0.97	1.40	2.58	4.63	2.51
S	0.15	0.00	1.10	1.82	1.12	1.55	2.73	4.78	2.66
RF	-0.95	-1.10	0.00	0.72	0.03	0.45	1.63	3.68	1.56
E	-1.67	-1.82	-0.72	0.00	-0.70	-0.27	0.90	2.96	0.84
EG	-0.97	-1.12	-0.03	0.70	0.00	0.42	1.60	3.66	1.53
GF	-1.40	-1.55	-0.45	0.28	-0.42	0.00	1.18	3.24	1.11
WT	-2.58	-2.73	-1.63	-0.90	-1.60	-1.18	0.00	2.06	-0.07
AUD	-4.63	-4.78	-3.68	-2.96	-3.66	-3.24	-2.06	0.00	-2.13
SM	-2.51	-2.66	-1.56	-0.84	-1.53	-1.11	0.07	2.13	0.00

Table 6b. Ranking matrix for habitat selection in 1993 by comparing proportions of habitats in the home range with the proportion of habitats available study area wide. A triple sign represents significant deviation from random at $P < 0.05$.

Habitat	OW	S	RF	E	EG	GF	WT	AUD	SM	Rank
OW	0	-	+	+	+	+++	+++	+++	+++	7
S	+	0	+++	+++	+	+++	+++	+++	+++	8
RF	-	---	0	+	+	+	+++	+++	+	6
E	-	---	-	0	---	-	+	+	+	3
EG	-	-	-	+++	0	+	+++	+++	+++	5
GF	---	---	-	+	-	0	+	+++	+++	4
WT	---	---	---	-	---	-	0	+	-	1
AUD	---	---	---	-	---	---	-	0	---	0
SM	---	---	-	-	---	---	+	+++	0	2

Table 7a. Habitat matrix of the means for 1994 by comparing proportions of habitats in the home range with proportions of habitats available study area wide.

Habitat	OW	S	RF	E	EG	GF	WT	AUD	SM
OW	0.00	-0.55	0.34	1.13	1.00	3.31	2.59	6.70	2.80
S	0.55	0.00	0.89	1.68	1.55	3.86	3.14	7.25	3.35
RF	-0.34	-0.89	0.00	0.79	0.66	2.97	2.25	6.36	2.46
E	-1.13	-1.68	-0.79	0.00	-0.13	2.18	1.47	5.58	1.67
EG	-1.00	-1.55	-0.66	0.13	0.00	2.31	1.60	5.71	1.80
GF	-3.31	-3.86	-2.97	-2.18	-2.31	0.00	-0.72	3.39	-0.51
WT	-2.59	-3.14	-2.25	-1.47	-1.60	0.72	0.00	4.11	0.21
AUD	-6.70	-7.25	-6.36	-5.58	-5.71	-3.39	-4.11	0.00	-3.90
SM	-2.80	-3.35	-2.46	-1.67	-1.80	0.51	-0.21	3.90	0.00

Table 7b. Ranking matrix for habitat selection in 1994 by comparing proportions of habitats in the home range with the proportion of habitats available study area wide. A triple sign represents significant deviation from random at $P < 0.05$.

Habitat	OW	S	RF	E	EG	GF	WT	AUD	SM	Rank
OW	0	---	+	+++	+++	+++	+++	+++	+++	7
S	+++	0	+++	+++	+++	+++	+++	+++	+++	8
RF	-	---	0	+++	+	+++	+++	+++	+++	6
E	---	---	---	0	-	+++	+++	+++	+++	4
EG	---	---	-	+	0	+++	+++	+++	+++	5
GF	---	---	---	---	---	0	-	+++	-	1
WT	---	---	---	---	---	+	0	+++	+	3
AUD	---	---	---	---	---	---	---	0	---	0
SM	---	---	---	---	---	+	-	+++	0	2

differed significantly from all other habitats.

Third-order selection occurred in 1993 ($p = 0.01$) with emergent vegetation ranking highest among all habitat types. The mean values (Table 8a) and the ranking matrix (Table 8b) indicated that selection for emergent vegetation differed significantly from open water, submersed aquatic vegetation, and agriculture-urban-developed. Rooted floating aquatic vegetation and emergents-grasses-forbs were equally selected relative to all other habitat types, and they both were selected significantly more than submersed aquatic vegetation. In addition, submersed aquatic vegetation, the lowest ranked habitat, was selected significantly less than rooted floating aquatic vegetation, emergent vegetation, emergents-grasses-forbs, woody terrestrial, and sand-mud.

As in 1993, third-order selection occurred in 1994 ($p = 0.0001$). The mean value matrix (Table 9a) and the habitat ranking matrix (Table 9b) both indicated that emergent vegetation was selected significantly more than all other habitat types. Rooted floating aquatic vegetation and emergents-grasses-forbs were equally selected relative to each other, and they both were selected significantly more than open water and agriculture-urban-developed habitats. Finally, the lowest ranked habitat, open water, was selected significantly less than all other habitat types except grasses-forbs and agriculture-urban-developed.

Analysis also indicated a difference in third-order habitat selection

Table 8a. Habitat matrix of the means for 1993 by comparing the proportions of radio locations of each animal in each habitat with the proportion of each habitat within the animal's home range.

Habitat	OW	S	RF	E	EG	GF	WT	AUD	SM
OW	0.00	1.33	-0.92	-1.08	-0.91	0.67	-0.88	0.84	-0.50
S	-1.33	0.00	-2.26	-2.41	-2.24	-0.67	-2.21	-0.49	-1.83
RF	0.92	2.26	0.00	-0.16	0.02	1.59	0.05	1.76	0.43
E	1.08	2.41	0.16	0.00	0.17	1.74	0.20	1.92	0.58
EG	0.91	2.24	-0.02	-0.17	0.00	1.57	0.03	1.75	0.41
GF	-0.67	0.67	-1.59	-1.74	-1.57	0.00	-1.54	0.17	-1.16
WT	0.88	2.21	-0.05	-0.20	-0.03	1.54	0.00	1.72	0.38
AUD	-0.84	0.49	-1.76	-1.92	-1.75	-0.17	-1.72	0.00	-1.34
SM	0.50	1.83	-0.43	-0.58	-0.41	1.16	-0.38	1.34	0.00

Table 8b. Ranking matrix for habitat selection in 1993 by comparing the proportions of radio locations of each animal in each habitat with the proportion of each habitat within the animal's home range. A triple sign represents significant deviation from random at P < 0.05.

Habitat	OW	S	RF	E	EG	GF	WT	AUD	SM	Rank
OW	0	+	-	---	-	+	---	+	---	3
S	-	0	---	---	---	-	---	-	---	0
RF	+	+++	0	-	+	+	+	+	+	7
E	+++	+++	+	0	+	+	+	+++	+	8
EG	+	+++	-	-	0	+	+	+	+	6
GF	-	+	-	-	-	0	---	+	-	2
WT	+++	+++	-	-	-	+++	0	+++	+	5
AUD	-	+	-	---	-	-	---	0	-	1
SM	+++	+++	-	-	-	+	-	+	0	4

Table 9a. Habitat matrix of the means for 1994 by comparing the proportions of radio locations of each animal in each habitat with the proportion of each habitat within the animal's home range.

Habitat	OW	S	RF	E	EG	GF	WT	AUD	SM
OW	0.00	-1.42	-1.84	-2.91	-1.79	-0.96	-1.58	-0.46	-1.55
S	1.42	0.00	-0.42	-1.49	-0.38	0.45	-0.16	0.95	-0.13
RF	1.84	0.42	0.00	-1.08	0.04	0.87	0.26	1.37	0.29
E	2.91	1.49	1.08	0.00	1.12	1.95	1.33	2.45	1.36
EG	1.79	0.38	-0.04	-1.12	0.00	0.83	0.21	1.33	0.25
GF	0.96	-0.45	-0.87	-1.95	-0.83	0.00	-0.62	0.50	-0.58
WT	1.58	0.16	-0.26	-1.33	-0.21	0.62	0.00	1.12	0.03
AUD	0.46	-0.95	-1.37	-2.45	-1.33	-0.50	-1.12	0.00	-1.08
SM	1.55	0.13	-0.29	-1.36	-0.25	0.58	-0.03	1.08	0.00

($p = 0.0145$) between 1993 and 1994. When the habitat ranking matrices for 1993 (Table 8b) and 1994 (Table 9b) were compared, a few differences became apparent. Selection for emergent vegetation was more significant in 1994 relative to all habitat types. In 1993, emergent vegetation significantly differed from only three habitat types, open water, submersed aquatic vegetation, and agriculture-urban-developed. Also, in 1993, woody terrestrial significantly differed from open water, submersed aquatic vegetation, grasses-forbs, and agriculture-urban-developed, but

Table 9b. Ranking matrix for habitat selection in 1994 by comparing the proportions of radio locations of each animal in each habitat with the proportion of each habitat within the animal's home range. A triple sign represents significant deviation from random at P < 0.05.

Habitat	OW	S	RF	E	EG	GF	WT	AUD	SM	Rank
OW	0	---	---	---	---	-	---	-	---	0
S	+++	0	-	---	-	+	-	+	-	3
RF	+++	+	0	---	+	+	+	+++	+	7
E	+++	+++	+++	0	+++	+++	+++	+++	+++	8
EG	+++	+	-	---	0	+	+	+++	+	6
GF	+	-	-	---	-	0	-	+	-	2
WT	+++	+	-	---	-	+	0	+	+	5
AUD	+	-	---	---	---	-	-	0	---	1
SM	+++	+	-	---	-	+	-	+++	0	4

significantly differed from only one habitat type, open water, in 1994. The stronger selection for woody terrestrial in 1993 compared to 1994 was expected because important habitats for the broods such as submersed aquatic, rooted floating aquatic, and emergent vegetation were either covered or washed out by the high water levels in 1993 (National Biological Service *et al.* 1994, Spink and Rogers 1996). One other obvious difference between 1993 and 1994 was the order of habitat rankings. Open water (rank 3 in 1993) and submersed aquatic vegetation (rank 0 in 1993) switched rankings in 1994 to rank 0 and rank 3, respectively. Second-order selection was not significant between 1993 and 1994 (p = 0.06).

Discussion

Several habitat selection studies have been conducted using radio-telemetry data without accounting for the error that can occur with triangulation and misclassification. More bias is introduced into those studies that do not account for triangulation and misclassification error (Samuel and Kenow 1992). Many sources can introduce error into triangulation including unknown receiver locations, equipment malfunction, field conditions, and misuse of equipment (Samuel and Fuller 1994). An error assessment was done for this study based on the methods proposed by Lee *et al.* (1985), and the standard deviation of bearings was calculated to be 6.93 degrees. From this standard deviation an error polygon is created and used to minimize the effects of misclassification errors. If misclassification is not accounted for, two possible outcomes can occur. There can either be an underestimation of the true proportion of habitat used or an overestimation of the true proportion of habitat used (Samuel and Kenow 1992). In this study, misclassification was addressed using methods proposed by Samuel and Kenow (1992). Taking a sub-sample from the error distribution of each telemetry location reduced bias in the habitat selection results, but this method only produces an estimate of habitat use and does not provide exact results.

Data censoring is another way to increase data quality from triangulation methods. In habitat selection and use studies, data collected by triangulation can be reviewed to eliminate poor-quality locations. As suggested by

White and Garrott (1990), one possible way to censor data is to incorporate a confidence ellipse size less than some cutoff value. Data that generated a 95% error ellipse greater than 26 hectares were eliminated in this study. In addition, all the data were censored to eliminate any erroneous or incomplete readings.

Although compositional analysis is accepted as a viable technique for habitat selection analyses, one main problem exists related to missing habitat values. Two situations can occur. Either a habitat type is not available for use or a habitat type is available but not utilized. Solutions to these situations vary. When habitat availability is equal to zero habitat types could either be combined to reduce the number of habitats analyzed, or habitat types could be eliminated entirely from the analysis (Aebischer *et al*. 1993). In the situation where a habitat is available but not used, the zero implies that use was so small it was not detected. A solution for a zero use value is to replace the zero with a small constant that is less than the smallest recorded nonzero value (Aebischer *et al*. 1993). Zeros are inadmissible in log-ratio analyses because taking the log of zero or dividing by zero produce undefined results (Pendleton *et al*. 1998). For this study, the compositional analysis program replaces all zeros with a small constant no matter what the zero represents. Other methods are available that are capable of performing habitat selection analysis. Alldredge and Ratti (1986) review four statistical methods for analysis of habitat selection based on type I and type II error rates. Alldredge and Ratti (1986) concluded from many simulations, that not all analysis methods produce the same results. The error rates and the overall results are affected by the number of habitats, the number of animals, the number of observations per animal, and the magnitude of the differences to be detected (Alldredge and Ratti 1986). It is important to review many existing techniques and to choose the one best suited for the defined study.

The definition of availability is another issue to be considered when conducting habitat selection studies. Although we can define any arbitrary area as available to an animal, the animal may not perceive all of that area to be available. Availability boundaries can be affected by territoriality of an animal, a disturbance located near an area or habitat, or the presence of a competing or predator species (White and Garrott 1990). The definition of availability is a key element in habitat selection studies and can influence the results (McClean *et al*. 1998). Therefore, how to define availability for a particular animal is an ongoing problem with habitat use and selection analyses.

Land cover data for 1993 did not exist at the time of this study to use in conjunction with the 1993 radio telemetry data. Instead, 1994 land cover data were used with both 1993 and 1994 telemetry data. This in itself introduces bias into the results for the 1993 data. To conduct a more accurate study of the 1993 data, land cover data would need to be generated for 1993. In addition, 1993 was a flood year generating some of the highest water levels recorded in the last century. It has been noted that submersed aquatic and emergent vegetation species decreased in abundance during the flood in July (National Biological Service *et al.* 1994). Some species recovered very quickly following the flood in August and September and others did not (National Biological Service *et al*. 1994). Also, the density and species richness of invertebrate communities were influenced at different stages of flooding (National Biological Service *et al*. 1994). Talent *et al.* (1982) conducted a multiple year study with varying water conditions in South Central North Dakota and found different results for the two years of their study. In 1976, more wetlands were available to the mallards than in 1977. This resulted in habitat selection occurring in 1976 with the mallards preferring seasonal ponds dominated by whitetop rivergrass (Talent *et al*. 1982). Semi-permanent wetlands were used less than expected in 1976, but were used exclusively in 1977 when seasonal wetland basins were dry (Talent *et al*. 1982). In summary, mallard broods did not use all of the wetland sizes available to them in 1976, but in 1977, they did use all sizes of semi-permanent wetlands in proportion to their availability. According to Talent *et al.* (1982), water conditions have a profound influence on wetland habitat use by mallard broods. For this study on Pool 7 of the UMR, the flood of 1993 probably had an effect on habitats selected by mallard broods due to the influence it had on aquatic vegetation and invertebrate communities, both of which are imperative for adequate brood-rearing habitat. Many studies (Spink and Rogers 1996, National Biological Service *et al*. 1994, and Bhowmik *et al*. 1993) have examined the effects of the 1993 flood on various components in the UMR. Although it is important to consider the effects that the flood had on habitat in the UMR, it is beyond the scope of this study. One assessment regarding the results from the 1993 analysis could be made. The stronger selection for woody terrestrial habitat in 1993 may reflect the brood's adjustment to the high water levels, which damaged the aquatic habitats normally used by mallard broods. Also, the 1993 flood probably altered the state of woody terrestrial habitat into an aquatic habitat state, which then became adequate brood-rearing habitat. Unfortunately, an accurate assessment of which habitats were used or selected in 1993 can not be conducted until land cover data for 1993 is generated.

Another issue to consider when performing habitat selection analysis is the method used to obtain an animal's home range. In this study I used the minimum convex polygon (MCP) method due to its simplicity and ease of calculation. In actuality, home ranges can be difficult to estimate, and depend on the purpose of the study and whether the methods used to collect the data satisfy this purpose (White and Garrott 1990). The MCP method has its drawbacks, as do other existing home range estimators. The size of the polygon generated for an MCP home range is a function of the number of locations used to determine that polygon (White and Garrott 1990). Polygons increase in size as the number of locations to create the polygon increase. This is attributed to the home range sizes ranging from 2 hectares to 1,450 hectares between 1993 and 1994. Another problem with the MCP method is that some misrepresentation of classes used by an animal or available to an animal may exist. Since the MCP method connects the outer-most points, it may include a class that is at the edge of the home range. An example would be including a small piece of agricultural or urban land within an MCP home range, when in reality, the animal does not use that habitat or consider it to be available. This problem is apparent when reviewing the results from the second-order analysis. It was determined that submersed aquatic vegetation and open water were selected in the second-order analysis. The results of the second-order analysis may be an artifact of the MCP estimator. When estimating the home range using the nesting island and the telemetry locations for each bird, the home range included large open water areas (Figure 5) and took on a triangular shape. This was due to the fact that the birds had to traverse the open water areas to reach brood-rearing habitat. It is difficult to select a home range estimator that is appropriate for habitat selection studies, especially since each estimator has strengths and weaknesses (White and Garrott 1990).

Based on the techniques presented here, it was determined that mallards did select certain habitats on the UMR. Third-order selection for 1993 and 1994 showed the top three selected vegetation types were emergent vegetation, rooted floating aquatic vegetation, and emergents-grasses-forbs. The reason for hens selecting these habitats probably has to do with two important aspects of brood-rearing habitat; cover and food. The emergent vegetation contains species such as bulrush, cattail, and arrowhead, which help protect the ducklings from predators and provide a food resource. Water-lily, lotus, and duckweed are rooted floating aquatic species that also provide food for the broods. Feeding habits of young are different than those of adult birds. Diets of young are generally protein-rich (O'Connor 1984). It has been shown that a duckling's growth rate is related to the amount of

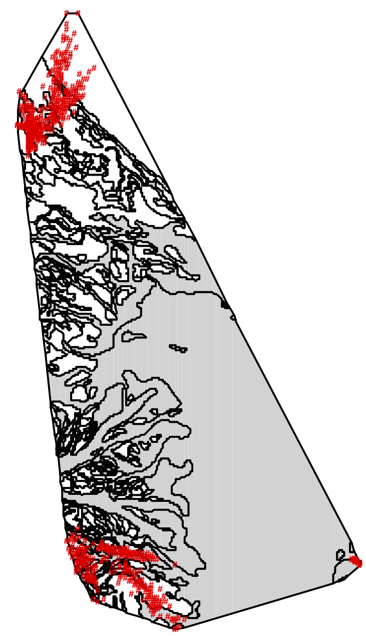

Figure 5. Example of a mallard brood home range on Pool 7, calculated using the minimum convex polygon method. Open water and submersed aquatic vegetation are shaded gray with 900 random point locations on top.

protein consumed and that invertebrates provide the major source of protein during times of peak growth (O'Connor 1984). In the emergent and rooted floating aquatic vegetation, aquatic invertebrates and insects are present for the young to feed on (Voigts 1976). Voigts (1976) also found that the abundance of invertebrates increased where submersed aquatic vegetation interspersed with emergent vegetation stands. For third-order selection, the results appear to be realistic based on the cover and food available in the selected habitat types.

As stated earlier, second-order analysis indicated selection of submersed aquatic vegetation and open water as primary habitats followed by rooted floating aquatic vegetation. In order to reach areas of brood-rearing habitat, hens had to traverse large open water and submersed aquatic vegetation areas. That is probably why these two classes appeared prominent in the second-order selection results. Submersed aquatic vegetation beds can provide a vast amount of invertebrates and insects for feeding, but may not provide enough protective cover for the broods.

Information from this study can be used by managers to assess habitat requirements for mallard broods. Brood-rearing habitat is important for the survival of mallard populations. If brood habitat is not adequately available for the ducklings, management plans such as a water level reduction, can be implemented to create or enhance required habitat. Once habitat is available, it needs to be protected from wind and wave action. There are islands that exist along the main channel of the UMR called barrier islands. These barrier islands help protect the brood-rearing habitat from wind and wave action, so they need to be created or maintained as well. These habitat areas are also important resources for other waterfowl including migratory species. The information from this study will assist managers in maintaining and protecting habitat areas that are important to many species on the UMR.

Several issues related to habitat selection studies were considered in this study. It is imperative to devise a project scope for any study addressing certain issues mentioned here before data collection begins. Data availability, error and accuracy of data, and analysis techniques should be researched and defined before beginning a project. All of these issues will ultimately affect the results obtained in a habitat use and selection study.

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