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ESTIMATION OF WATERFOWL FOOD ABUNDANCE IN COASTAL FRESHWATER MARSHES OF LOUISIANA AND TEXAS

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Master of Science

in
The School of Renewable Natural Resources

by
Christian Jesse Winslow
B.S. Louisiana State University, 2001
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ABSTRACT

Food abundance might limit survival or recruitment of wintering waterfowl. Nutritional requirements of wintering waterfowl have been estimated, but there are insufficient data on the abundance of seeds and submerged aquatic vegetation (SAV) to determine if enough habitat exists to support target populations of waterfowl throughout winter. I estimated waterfowl food abundance at 14 coastal freshwater marsh sites in Texas and Louisiana from August 2001 to March 2003, and tested the hypothesis that wintering waterfowl reduce food abundance. I analyzed 210 and 360 seed and SAV samples, respectively, taken during September 2001, February 2002, September 2002, and February 2003 to estimate seed and SAV biomass and determine if biomass declined during the winter. At one site, SAV biomass was estimated from 108 samples taken at six-week intervals (August-March) to provide another means of determining if food abundance declined throughout winter. Also at that site, 108 samples were taken from waterfowl exclosures in August and January of each year to provide another means of determining if wintering waterfowl reduce food abundance. Seed and SAV biomass estimates were not significantly different among time periods; biomass estimates of 14 genera of seeds and 8 genera of SAV collected averaged 244.2 ± 23.8 kg/ha (mean ± SE) and 262.3 ± 95.0 kg/ha, respectively. No significant differences in SAV biomass were detected among time periods at the six-week site or among time, treatment, and treatment by time interactions at the exclosure site. Mean food biomass estimates were well above the 50 kg/ha threshold estimate assumed to be the “point of diminishing returns” for feeding waterfowl. These findings also indicate that waterfowl did not significantly lower food resources in my study area over the two years of my study.

INTRODUCTION

The Gulf Coast of North America, particularly coastal Texas and Louisiana, is utilized by millions of wintering waterfowl annually (Singleton 1951, Harmon et al. 1961, Michot 1996). Wintering waterfowl sustain themselves on a carbohydrate-rich diet of mostly seeds and submerged aquatic vegetation (SAV) (Chamberlain 1959, Bardwell et al. 1962, Junca et al. 1962) to provide the energy necessary to withstand the rigors of cold weather and migration (Baldassarre and Bolen 1994). The Gulf Coast Joint Venture (GCJV), one of eleven regional partnerships in the United States formed under the North American Waterfowl Management Plan (NAWMP), is charged with ensuring foraging habitat for the wintering waterfowl in this region to increase the waterfowls' chances of survival into the following breeding season (Esslinger and Wilson 2001).

Much of the Gulf Coast's wetlands have been converted to agriculture, mainly for rice production (Singleton 1951, Esslinger and Wilson 2001). To date, most Gulf Coast waterfowl food studies have focused on food availability in agricultural fields (Davis et al. 1961, Harmon et al. 1961, Rumsey 1961) or on determining duck food habits from gizzard and esophageal studies (Singleton 1951, Smith 1951, Chamberlain 1959, Junca et al. 1962, Paulus 1982). Estimates of waterfowl food biomass in these agricultural habitats allow managers to estimate energetic requirements for wintering waterfowl in those particular habitats. Estimates are based on seed biomass, true metabolizable energy (TME) of seeds, seed spoilage rates, a minimum foraging threshold of 50 kg/ha (below which foraging is assumed to become unprofitable) (Reinecke et al. 1989), food competition from geese, and an assumed proportion of foraging needs that the habitat should provide (Esslinger and Wilson 2001).

Habitat objectives for the GCJV, as with other regions important to wintering waterfowl, are built upon the estimated energetic requirements of waterfowl, allowing managers to estimate carrying capacity of these habitats (Reinecke et al. 1989, Gray et al. 1999). The lack of food biomass estimates for Gulf Coast marshes leaves waterfowl and habitat managers without the ability to objectively set habitat objectives for coastal marshes in conjunction with population objectives, or to predict forage availability in the face of marsh loss (B. Wilson, Gulf Coast Habitat Joint Venture, personal communication). As a result, valid estimates of waterfowl food biomass (seeds and SAV) are needed. Chamberlain (1959) and Chabreck et al. (1985) suggested that obtaining better knowledge of wintering waterfowl foods in southwest Louisiana could provide a basis for determining habitat quality and management to benefit wintering waterfowl. Estimates of food biomass in Gulf Coast marshes also would allow managers to avoid potentially biased comparisons of carrying capacity between agricultural and natural habitats, considering that natural seeds are generally more nutritious than agricultural grains (Fredrickson and Taylor 1982), but waterfowl spend less time feeding in agricultural habitats because of the high availability and energy associated with agricultural foods (Baldassarre and Bolen 1984, Rave and Baldassarre 1989).

The GCJV assumes that availability of winter forage likely limits survival of ducks wintering along the Gulf Coast and/or recruitment of these individuals into the following breeding population (Esslinger and Wilson 2001). The importance of wintering habitat on the breeding success of North American ducks was researched and documented in the 1980's. Heitmeyer and Fredrickson (1981) concluded that high precipitation on the wintering grounds increased the recruitment rates of Mississippi Flyway mallards the subsequent year. Kaminski and Gluesing (1987) further investigated mallard recruitment rates and also found that

Mississippi Flyway mallard recruitment rates were correlated to wintering habitat conditions, but their data suggested that breeding grounds were more important. Based on this assumption, in years of poor winter habitat conditions (i.e. little precipitation and food production), the potential for broad-scale food depletions across the GCJV wintering range could be increased.

Outside the Gulf Coast in North America, significant reductions of SAV biomass have been reported from waterfowl exclosure studies (Anderson and Low 1976, Mitchell et al. 1994). Several exclosure studies outside of North America have also attributed significant reductions in SAV biomass to waterfowl herbivory in shallow, open-water lakes, both fresh and brackish water (Sondergaard et al. 1996, Van Donk and Otte 1996, Idestam-Almquist 1998). Conversely, Bortolus et al. (1998) and Marklund et al. (2002) found that waterfowl did not significantly reduce SAV biomass in their exclosure studies outside of North America. However, the authors of these two studies concluded that high waterfowl densities and/or low SAV densities could lead to localized reductions in SAV biomass by feeding waterfowl.

To my knowledge, only two studies have been conducted along the northern Gulf Coast examining potential SAV food depletion, both in brackish marshes. Joanen and Glasgow (1965) concluded from their waterfowl exclosure study that ducks decreased SAV abundance, but their study consisted of only two exclosures sampled over one winter. Conversely, Hunter (2000) found no difference in SAV biomass between waterfowl exclosures and open areas and found no evidence of waterfowl herbivory.

Seed biomass may also be reduced by wintering waterfowl. Several studies of moist-soil and ricefield seed availability attributed general declines in seed biomass from fall to winter sampling periods to factors including consumption by ducks, small birds, and rodents, as well as loss to germination and/or deterioration (Davis et al. 1961, Harmon et al. 1961, Jemison and

Chabreck 1962). The authors considered the decreases in seed biomass negligible, but their studies took place on managed wetlands where seed production is generally greater than on natural wetlands (Fredrickson and Taylor 1982). Considering rice production has decreased in recent years and natural Gulf Coast wetlands are disappearing at an alarming rate (Esslinger and Wilson 2001), the potential for seed depletion by high numbers of waterfowl wintering on the Gulf Coast may have increased. Although the coastal marshes of the GCJV range from fresh to saline, freshwater marshes contain the most diverse vegetation and are utilized most by wintering waterfowl (Palmisano 1973). Because of this and because it was not logistically feasible to sample all four marsh types, waterfowl forage data were gathered in the freshwater zones of the GCJV coastal marshes. Table 1 summarizes common coastal fresh marsh plant species considered to be waterfowl food and their utilized parts. I should note that some of the food habits studies cited in this table focused on gizzard content, which produce a strong bias toward hard food items such as seeds and underestimate soft food items, including soft vegetation and invertebrates (Swanson and Bartonek 1970). Nonetheless, the items are utilized by waterfowl and most were determined from multiple sources.

The objectives of this two year study were to 1) estimate seed and SAV biomass in freshwater coastal marshes of Louisiana and Texas in late summer/early fall (August/September) prior to the arrival of most migratory waterfowl (Food Biomass Estimates) and 2) test the hypothesis that limited forage results in broad-scale waterfowl food depletion within freshwater marshes of the Gulf Coast (Food-Depletion Hypothesis). I attempted to test this hypothesis by: 1) comparing waterfowl food biomass between September before peak waterfowl utilization and February after peak utilization (Spatially-Intensive Sampling); 2) documenting SAV food biomass changes at one Louisiana freshwater marsh site throughout the fall and winter (August –

March) at six-week intervals (Temporally-Intensive Sampling); and, 3) comparing SAV food biomass inside and outside waterfowl exclosures (Exclosure Sampling).

These food biomass estimates, in conjunction with true metabolizable energy (TME) values (Buckley 1989, Petrie et al. 1998, Checkett et al. 2002) will be used by Gulf Coast waterfowl managers as a baseline estimate for waterfowl forage when modeling energetic requirements and allow for more accurate estimates of wintering waterfowl carrying capacity in Gulf Coast marshes. The existing models for agricultural habitats are based on seed food biomass, but knowledge of SAV food biomass will allow for the development of similar models for coastal marsh habitats and waterfowl that specialize on SAV such as the American wigeon (*Anas Americana*) and gadwall (*A. strepera*) (Chamberlain 1959, Paulus 1982).

Table 1. Food species (seeds and SAV) used by wintering waterfowl in coastal freshwater marshes of Louisiana and Texas.

Scientific Name	Common Name	Part(s) Utilized	Source[a]
Brasenia schreberi	water shield	Seeds	3, 13
Ceratophyllum demersum	coontail	Seeds, Foliage	10, 12
Cyperus spp.	flatsegde	Seeds, Foliage, Rhizomes	1, 3, 6
Echinocloa spp.	millet	Seeds	1, 5, 11, 14
Eleocharis spp.	spikerush	Seeds, Foliage, Tubers	2, 12, 13
Heliotropium spp.	heliotrope	Seeds	9
Lemna, Spirodela, Wolfia, Wolfiella spp.	duckweeds	All	9, 13, 14
Myriophyllum spicatum	water-milfoil	Seeds, Foliage	4, 13
Najas guadalupensis	southern naiad	Seeds, Foliage	12, 14
Nelumbo lutea	lotus	Seeds	13
Nitella spp.	stonewort	All	8
Nymphaea mexicana	banana water lily	Seeds, Roots	13
Nymphaea odorata	white water lily	Seeds	13
Panicum spp.	panic grasses	Seeds	7, 8
Paspalum spp.	paspalum	Seeds,Rhizomes, Foliage	3, 5, 13
Polygonum spp.	smartweed	Seeds	2, 11
Potamogeton spp.	pondweed	Seeds, Foliage, Tubers	1, 10, 14
Prosperinaca spp.	mermaid weed	Seeds	8
Rhynchospora spp.	beak rush	Seeds	3, 11
Ruppia maritima	widgeongrass	Seeds, Foliage	10, 12
Sagittaria spp.	duck potato	Seeds, Tubers	13
Scirpus spp.	bulrush	Seeds	3, 6, 12, 13
Vallisneria americana	wild celery	Foliage	4

[a] Sources: 1, Chabreck (1974); 2, Davis et al. (1960); 3, Dillon (1957); 4, Florshutz (1972); 5, Harmon et al. (1960); 6, Jemison and Chabreck (1962); 7, Jorde et al. (1983); 8, Kerwin and Webb (1971); 9, Martin and Uhler (1939); 10, Paulus (1982); 11, Singleton (1951); 12, Smith (1951); 13, Stutzenbaker (1999); 14, USDOI (1984).

STUDY AREA AND SITE SELECTION

My study was conducted from August 2001 to March 2003 on 14 randomly selected freshwater marsh sites along the Gulf Coast of Louisiana and Texas, each classified as palustrine emergent wetlands (Figure 1). Three LA sites and 1 TX site were located on state owned lands, 1 LA site and 1 TX site were located on federally owned land, and 1 LA site and 8 TX sites were located on private land. I used the same sites each year. One LA site was not sampled until the second of four sampling periods because of delays in acquiring permission from the landowner.

Initially, logistical constraints determined there would be 8 sites over the entire study area, with 3 ponds per site. The relative distribution of freshwater coastal marshes was used to calculate the number of sites to be sampled in Louisiana (LA) versus Texas (TX). Wetland data from 1990 (Louisiana Coastal Wetlands Conservation and Restoration Task Force and the Wetlands Conservation and Restoration Authority 1998) indicated coastal LA contained 3,673 km^2 of freshwater marsh and Moulton et al. (1997) classified 2,314 km^2 of coastal TX wetlands as palustrine emergent (Moulton et al. 1997). Therefore, 61% of the total fresh (palustrine emergent) marsh for this project occurred in LA. Accordingly, 5 and 3 sites were to be representative of LA and TX, respectively. Subsequent examination of aerial photographs of potential study sites in TX revealed that sites with more than 2 ponds would not always be available there, so 9 sites with 1 pond per site in TX were used instead of 3 sites with 3 ponds per site.

The five sites from LA were randomly chosen from over 6,000 fresh marsh points created in an extensive survey of LA coastal marsh vegetation (Chabreck 1998). Some initially selected sites were replaced because permission to visit the sites could not be obtained from the landowner. At sites with few ponds, the three closest to the point were chosen for study. At sites with many ponds, ponds were numbered and 3 were randomly chosen for study.

Texas site selection was performed using a combination of Texas Prairie Wetlands Project (TPWP) and National Wetlands Inventory (NWI) data. The TPWP is a private lands program initiated in 1991 by Ducks Unlimited (DU) in cooperation with the United States Fish and Wildlife Service (USFWS), United States Department of Agriculture – National Resource Conservation Service (USDA-NRCS), and Texas Parks and Wildlife Department (TPWD). The TPWP contains approximately 500 wetland units totaling over 20,000 acres. Landowners generally enter the program with a 10-year agreement to manage the wetlands.

After selecting the TPWP sites classified as fresh marsh (47), they were compared to NWI data from 1990-1992 to determine the history of the area prior to enrollment into TPWP. Only "natural" sites categorized by NWI data as "palustrine emergent" were selected to be comparable to the LA sites. Any site rectangular in shape, formerly non-wetlands, less than 30-acres, and/or not flooded seasonally was discarded because of the assumption that these characteristics were more representative of the TPWP sites than the TX coast as a whole. With these restrictions in place, 15 privately owned sites were considered. Public lands in TX, approximately 10% of which are coastal, freshwater marsh (NWI), were also included in TX site selection. In all, 9 random sites were chosen from the final list of 17 sites.

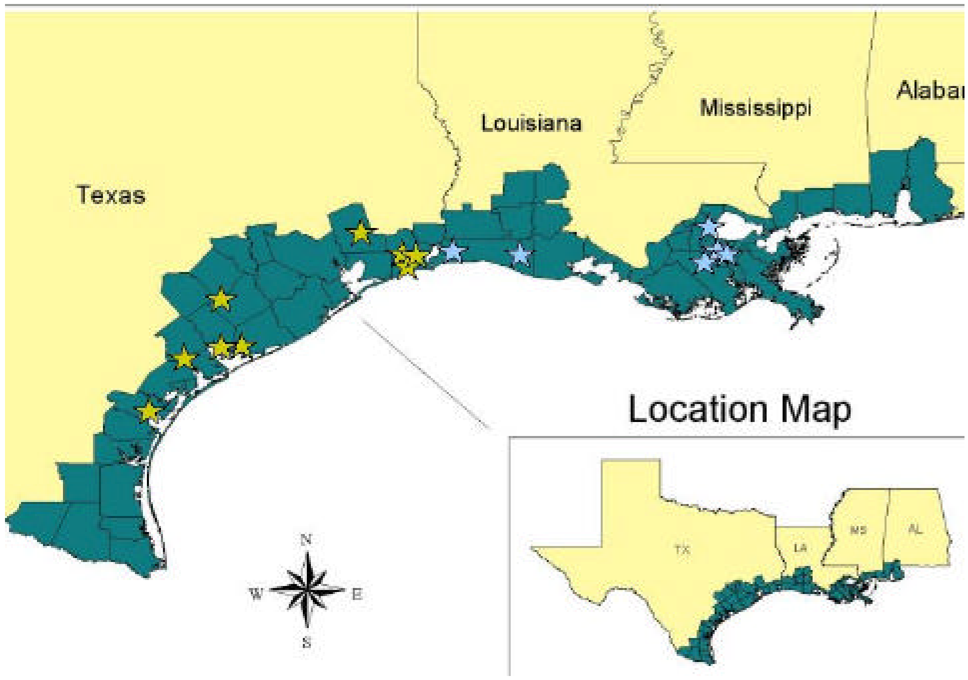

Figure 1. Map of study area (Esslinger and Wilson 2001). Texas sites are represented with yellow stars, Louisiana sites with blue stars.

METHODS

Food Biomass Estimates

Each of the 24 ponds was randomly sampled for seed and SAV biomass during September 2001 and 2002 using four transect lines along the cardinal and intermediate directions, resulting in eight line segments. Each segment contained three possible sample points (i.e., ¼, ½, or ¾ from pond center), for a total of 24 random sample points per pond (Figure 2). Random core points were re-randomized before each sampling period without replacement.

Four randomly selected cores were taken from each pond using a coring technique based on Ellison et al. (1986). The 1.5 m tall corer was constructed of 10 cm PVC-pipe. The pipe was marked every 5 cm for water level measurements, and a handle was located directly under the cap, which had a small hole for vacuum release (Figure 3). The corer was placed into the pond and upon touching bottom, pushed approximately 20 cm deep into the marsh floor, resulting in a 20 cm deep core. A rubber plug was inserted into the hole in the cap, creating a vacuum and allowing retrieval of the core. Shallower cores frequently escaped before they could be captured. Each sample was placed into a 0.50 mm mesh sieve to remove excess water before being bagged and placed on ice. All samples were maintained at 4ºC until processing.

In the laboratory, each sample was washed through 5 sieves (12.50 mm, 2.00 mm, 1.40 mm, 0.71 mm, and 0.50 mm mesh sizes) to retain all vegetation and seeds (Figure 3). Any living plant material (above- and belowground) was removed, identified to genus and/or species, and dried at 60ºC to a constant mass (± 0.01 g). Submerged aquatic vegetation was identified with the use of a dichotomous key (Godfrey and Wooten 1979, Godfrey and Wooten 1981) and help of multiple aquatic plant specialists. Any unidentifiable SAV was labeled as such and treated the same as above.

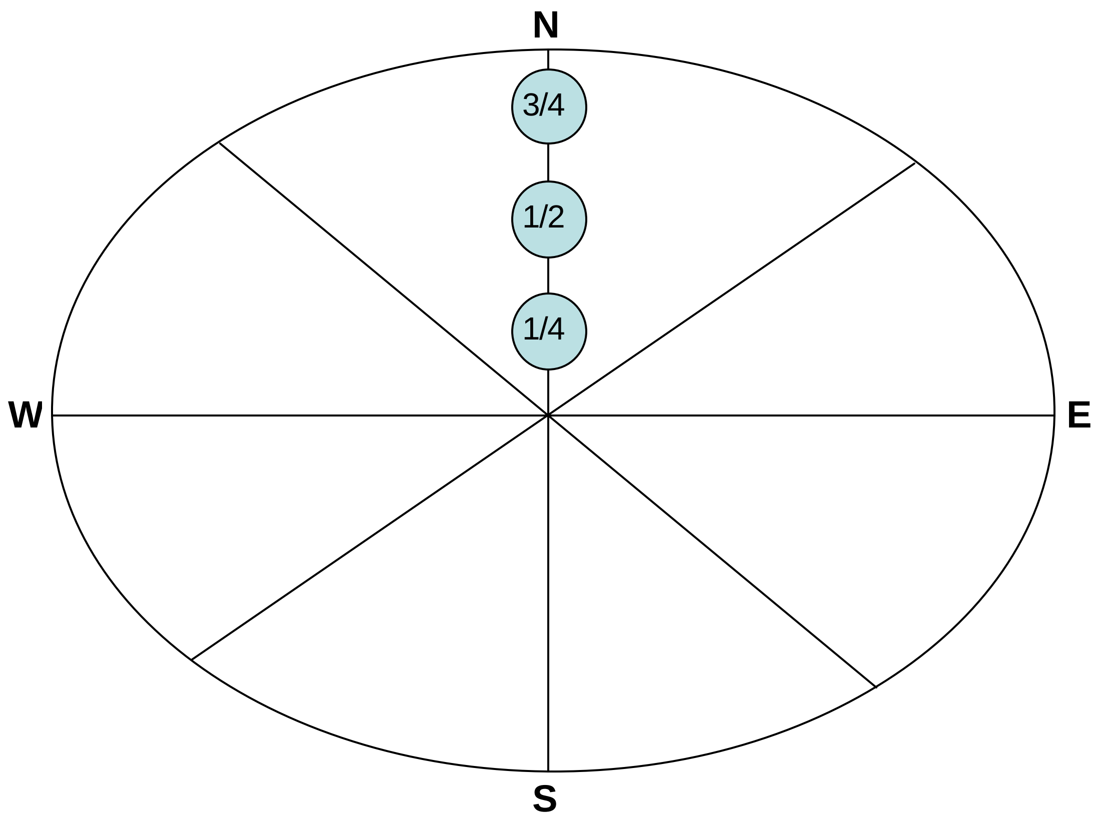

Figure 2. Diagram used to select random core locations within ponds. Eight possible directions (N, NE, E, SE, S, SW, W, and NW) with 3 points per direction (¼, ½, and ¾) yield 24 possible sample locations.

Figure 3. Corer (left) and sieves (right).

All materials from each sieve were placed into 200 ml aluminum foil pans and dried at 40ºC to a constant mass (± 0.001 g). Once dried, the compacted material was broken apart and placed into a seed blower to help separate chaff and other light material from the seeds (Jemison and Chabreck 1962). Seeds were then individually removed from the remaining material with the aid of 70X dissecting microscopes and forceps. Seed identification was possible with the help of a comprehensive seed library and multiple aquatic plant specialists. Any unidentifiable seeds were labeled as such and treated the same as above.

Some samples containing large numbers of seeds consumed a disproportionate amount of time (10-20 hours), so a subsampling technique was devised to reduce the amount of time spent on these samples. Each sample that was subsampled was weighed, individually homogenized, and placed in a square plastic dish (169 cm^2) where it was formed into a uniform line with a straight-edge. Random subsamples (between 0.02 and .25 g, depending on the substrate) were then taken (without replacement) perpendicularly from the length of the line formed by the sample and weighed. The number of subsamples necessary to produce accurate estimates of the biomass in the original sample was determined by documenting the percent change in mean seed biomass estimates. For each subsample, seed biomass was entered into a spreadsheet and a running mean was calculated. Percent change in the mean seed biomass was minimal after five subsamples, so five subsamples per sample were subsequently used.

One of the five Louisiana sites was not sampled in September 2001 because of technical difficulties. All sites from the three remaining time periods were sampled as scheduled. There were 174 seed samples and 168 SAV samples used in the analysis.

Food-Depletion Hypothesis

Spatially-Intensive Sampling. All sites, field procedures, and lab procedures were identical to that of the food biomass estimates described above. In addition to the September

samples described above, I also collected seed and SAV biomass samples during February 2002 and February 2003. All February samples were taken as scheduled, but only 36 of 96 seed samples from February 2002 and no seed samples from February 2003 were analyzed in the laboratory because of time constraints. All February SAV samples were used in the analysis. There were 210 seed samples and 360 SAV samples used in the analysis.

Temporally-Intensive Sampling. I selected one fresh marsh site (Unit 3 of Sabine NWR) from the five LA sites for this part of my study because land access and logistical support was readily available. Three randomly selected ponds, not including those sampled for food biomass estimates or spatially-intensive sampling, were randomly sampled and selected for SAV biomass at six-week intervals from August 15 to March 31 for each year of the study. These sampling periods were timed to coincide with aerial surveys of wintering waterfowl to attempt a correlation of waterfowl numbers and SAV food biomass. Both SAV collection and analyses were identical to those described above. The first two of six sample periods in the first year and the second of six sample periods in the second year were not sampled because of logistical constraints, leaving a total of 108 SAV samples for the analysis.

Exclosure Sampling. I randomly selected three additional ponds in Unit 3 of Sabine NWR where waterfowl exclosures were later constructed to create adjacent grazed and ungrazed plots in each pond. The structures were built nearly two years before sampling, allowing SAV to recolonize after the disturbance. I retrieved three core samples from each of three treatments (structured control, non-structured control, and exclosure) in each pond during August 2001 and 2002 and January 2002 and 2003 to analyze SAV biomass. Field and lab procedures were the same as described above, except each 1.4 m^2 treatment (exclosure, structured-control, and non-structured control) was broken into 16 imaginary blocks (4X4 grid) and sample locations for each

treatment were randomly selected via numbers (1-16) pulled from a hat without replacement. There were 108 SAV samples used in the analysis.

The non-structured control treatment potentially allowed waterfowl to feed freely. The exclosure treatment was completely closed to waterfowl use. The structured-control treatment was similar to that of the exclosure, but allowed for waterfowl access into the interior via two 0.4 m wide openings on opposite sides of the structure (Figure 4). The structured-control was used to test effects of the exclosure structure unrelated to waterfowl herbivory (increased shade, reduced wave action, retention of floating algal mats, etc). Each structured treatment was approximately 1.4 m^2 and 1.5 m deep located near the pond center. The structures were constructed of 2 cm diameter PVC-pipe and 4 cm mesh green safety fencing.

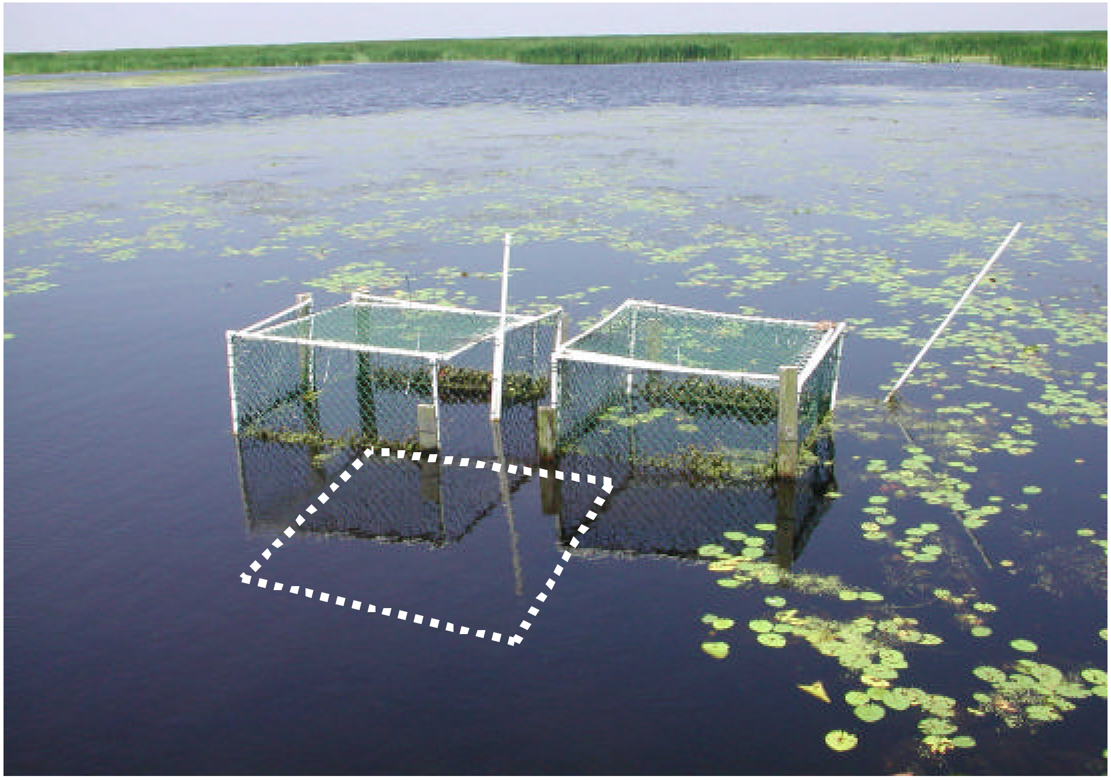

Figure 4. Picture of waterfowl exclosure treatments located in Unit 3 of Sabine NWR. (structured-control treatment, left; exclosure treatment, right; and non-structured control treatment, represented by dotted lines).

STATISTICAL ANALYSIS

Food Biomass Estimates

Both seed and SAV data were independently analyzed using two-way analysis of variance (ANOVA) with repeated measures to compare changes in biomass between September 2001 and September 2002 and test the null hypothesis that food biomass did not change between sample periods. The models I tested used total seed food biomass and total SAV food biomass as the dependent variables and site, core, pond, and time (fixed effect) as the independent variables (Proc GLM, SAS Institute Inc. 1999). The model blocked on site, with pond nested within site. All interactions were included in the model. Significant interactions were retained in the final model and all non-significant interactions were pooled into the error term.

Log transformation of the seed data was required to meet the assumptions of normality and homogeneity of variance. Because SAV data could not be transformed to meet the assumptions of normality and homogeneity of variance, they were analyzed with a random resampling (randomization) technique described by Edington (1995). Randomization tests are exceedingly accurate and are the benchmark for parametric tests when determining robustness (Edington 1995). The Type III sum-of-squares (SS) of the observed (real) time variable was chosen as our test statistic. Randomization compares the observed test statistic to the Type III SS created from randomly re-assigning the observations 4,999 times. The observed test statistic would rarely be exceeded by those created from the randomly reassigned observations if the null hypothesis of no time effect was true. I used an alpha level of 0.05 for the analyses.

Food-Depletion Hypothesis

Spatially-Intensive Sampling. Seed and SAV data were analyzed using the same techniques as the food biomass estimates described above, except the independent variable time also contained the February sample periods.

Temporally-Intensive Sampling. SAV biomass data did not meet the assumptions of normality or homogeneity of variance. Therefore, a randomization technique similar to that described for the food biomass estimates was used. The independent variable, site, was not included in the analysis because this study occurred only on one site; therefore, the model was blocked on pond with core nested within pond. The independent variable time included all sample periods taken over the two years of sampling. I was interested in any significant differences in SAV biomass among time periods.

Exclosure Sampling. SAV biomass data did not meet the assumptions of normality or homogeneity of variance. Data were analyzed by the randomization technique described in the previous section to test the null hypotheses 1) SAV biomass did not differ among treatments and 2) SAV biomass did not differ among time periods. Time, treatment, and treatment by time interaction Type III SS were generated in a two-way ANOVA with repeated measures with SAV biomass as the dependent variable and time (fixed effect), treatment, pond, and core as the independent variables.

RESULTS

Food Biomass Estimates

Seeds. Twenty-one genera of seeds accounting for 93% of total seed biomass within the samples were identified from 174 cores taken in September 2001 and September 2002 (Table 2). Eleven seed varieties encompassing 7% of total seed biomass were unidentified. Fourteen genera of seeds were considered waterfowl and total seed food biomass was used for the analysis. No difference was detected in total seed food biomass between time periods (P_{model} = 0.1610) (Table 3). Mean seed food biomass throughout the study area was 244.2 ± 23.8 kg/ha (mean ± SE) with time periods pooled. Total seed food biomass was extremely variable within and among sites (Table 4) (Appendix A). Total seed food biomass averaged 250.6 ± 49.7, 251.3 ± 38.0, and 230.6 ± 35.7 at ¼, ½, and ¾ distances from pond center, respectively.

SAV. Eleven genera of SAV, including filamentous algae, accounted for 99.9% of total SAV biomass identified from 168 cores taken in September 2001 and September 2002 (Table 5). One species of SAV accounting for <0.01% of total SAV biomass was unidentified and considered unknown. Eight genera of SAV were considered waterfowl food and total SAV food biomass was used for the analysis. No difference was detected in total SAV food biomass between time periods (P = 0.6247) (Table 6). Mean SAV food biomass was 262.3 ± 95.0 kg/ha with time periods pooled. Total SAV food biomass was extremely variable within and among sites (Table 7) (Appendix B). Total SAV food biomass averaged 142.1 ± 52.5, 595.3 ± 301.4, and 90.8 ± 34.4 at ¼, ½, and ¾ distances from pond center, respectively.

Food-Depletion Hypothesis

Spatially-Intensive Sampling. Twenty-two genera of seeds accounting for 93% of the total seed biomass were identified from 210 samples taken in September 2001 and 2002 and

Table 2. Seed biomass estimates for 174 samples from Louisiana and Texas freshwater marsh ponds taken in September 2001 and September 2002.

Species	Mean (kg/ha)	Std. Error
- - - - - - - - - - - - - - - - Food Seeds - - - - - - - - - - - - - - - -		
Brasenia schreberi	8.73	4.51
Ceratophyllum demersum	3.11	1.09
Cyperus sp.	2.50	0.99
Echinochloa sp.	3.21	0.96
Eleocharis sp. (Large)	14.10	5.02
Eleocharis sp. (Small)	1.91	0.61
Heliotropium sp.	2.52	0.98
Nymphaea odorata	1.11	0.42
Paspalum sp.	4.08	1.91
Polygonum hydropiperoides	101.77	21.85
Polygonum pensylvanicum	3.64	2.00
Potamogeton sp.	34.40	6.25
Prosperinaca sp.	0.36	0.22
Rhynchospora sp.	14.82	4.67
Ruppia maritima	0.14	0.14
Scirpus sp.	47.79	6.69
Total food	244.19	23.8
- - - - - - - - - - - - - - - Non-food Seeds - - - - - - - - - - - - - - -		
Chara sp.	0.02	0.02
Cladium jamaicense	92.64	22.66
Heteranthera dubia	0.35	0.16
Nelumbo lutea	16.57	9.58
Scleria sp.	12.52	3.59
Sesbania sp.	8.57	3.99
Zizaniopsis miliacea	0.27	0.10
Total non-food	130.94	26.3
Total known	375.13	34.05

Table 3. Mean total seed food biomass estimates for September 2001 and September 2002 (n = total number of samples from which means were calculated).

Time	N	mean (kg/ha)	Std. Error
Sep-01	84	175.4	23.7
Sep-02	90	308.4	39.3
Overall	174	244.2	23.8

Table 4. Mean total seed food biomass estimates for each site with time periods pooled (n = total number of samples from which means were calculated).

Site	n	Mean (kg/ha)	Std. Error
Appling	8	40.2	36.4
Brown	8	195.3	38.8
Couba Island	12	157.5	32.9
Hancock	8	335.2	85.2
JD Murphree	8	272.8	51.0
Jones Island	24	709.3	112.0
Levingston	8	306.0	81.9
McFaddin	8	315.0	70.1
Miami Corp.	24	164.8	36.8
Sabine NWR	18	93.8	28.0
Salvador	24	159.0	24.6
Weeden	8	23.6	10.3
Womack	8	40.3	19.0
Woodson	8	236.1	32.2
Overall	174	244.2	23.8

Table 5. SAV biomass estimates for 168 samples from Louisiana and Texas freshwater marsh ponds taken in September 2001 and September 2002.

Species	Mean (kg/ha)	Std. Error
- - - - - - - - - - Food SAV - - - - - - - - - -		
Algae (filamentous)	12.8	7.2
Ceratophyllum demersum	25.9	13.7
Eleocharis quadrangulata	3.0	1.6
Eleocharis quadrangulata (Below)	68.3	60.8
Lemna minor	1.2	0.6
Najas gaudalupensis	5.2	2.0
Nitella sp.	2.6	2.0
Nymphaea mexicana (Below)	15.3	10.8
Potamogeton pectinatus	101.0	55.7
Potamogeton pectinatus (Below)	25.9	15.1
Potamogeton sp.	1.0	0.7
Total food	262.3	95.0
- - - - - - - - - - Non-food SAV - - - - - - - - - -		
Cabomba caroliniana	34.2	28.4
Hydrilla verticillata	0.4	0.3
Utricularia vulgaris	12.0	5.0
Total non-food	46.6	28.8
Total known	308.9	98.8

Table 6. Mean total SAV food biomass estimates for September 2001 and September 2002 (n = total number of samples from which means were calculated).

Time	n	Mean (kg/ha)	Std. Error
Sep-01	72	463.6	215.7
Sep-02	96	111.4	34.0
Overall	168	262.3	95.0

Table 7. Mean total SAV food biomass estimates for each site with time periods pooled (n = total number of samples from which means were calculated).

Site	n	Mean (kg/ha)	Std. Error
Appling	8	0.0	0.0
Brown	8	0.0	0.0
Couba Island	12	250.0	141.6
Hancock	8	1496.9	1275.1
JD Murphree	8	0.0	0.0
Jones Island	24	14.6	10.5
Levingston	8	0.0	0.0
McFaddin	8	465.6	258.0
Miami Corp	24	24.6	17.1
Sabine NWR	12	37.7	20.5
Salvador WMA	24	50.6	18.8
Weeden	8	635.9	281.9
Womack	8	0.0	0.0
Woodson	8	2209.4	1335.1
Overall	168	262.3	95.0

February 2002. Twelve seed varieties encompassing 6% of the total seed biomass were considered unknown. Fourteen genera of seeds were considered waterfowl food and total seed food biomass was used for the analysis. Mean seed food biomass was not significantly different among time periods ($P_{model} = 0.1610$) (Table 8) and was 257.0 ± 22.0 kg/ha with time periods pooled.

Thirteen genera of SAV accounting for 99.9% of total SAV biomass were identified from 360 samples taken in September 2001 and 2002 and February 2002 and 2003. One species of SAV accounting for <0.01% of total SAV biomass was considered unknown. Ten genera of SAV were considered waterfowl food and total SAV food biomass was used for the analysis. Mean SAV food biomass was not significantly different among time periods ($P = 0.6247$) (Table 9) and was 248.5 ± 51.2 kg/ha with time periods pooled.

Temporally-Intensive Sampling. Six species of SAV comprising 99% of all SAV biomass were identified from 108 samples taken at six-week intervals from August to March for each year of the study. Four species (najas, coontail, duckweed, and banana waterlily) were considered waterfowl food. Total SAV food biomass was used for the analysis. Mean SAV food biomass did not differ significantly among time periods ($P = 0.6015$) (Figure 5) and was 107.6 ± 28.0 kg/ha with time periods pooled.

Exclosure Sampling. Seven species (coontail, najas, banana waterlily, muskgrass, and 3 species of duckweed), all considered waterfowl food, constituted 98% of the total SAV biomass identified from 108 samples taken during August 2001 and 2002 and January 2002 and 2003. Total SAV food biomass was used for the analysis. Mean SAV food biomass showed no significant time effect ($P = 0.2030$), treatment effect ($P = 0.2422$), or treatment by time interaction ($P < 0.6725$) (Figure 6).

Table 8. Mean total seed food biomass estimates for September 2001 and 2002 and February 2002 (n = total number of samples from which means were calculated).

Time	n	mean (kg/ha)	Std. Error
Sep-01	84	175.4	23.7
Feb-02	36	318.9	55.8
Sep-02	90	308.4	39.3
Overall	210	257.0	21.9

Table 9. Mean total SAV food biomass estimates for September 2001 and 2002 and February 2002 and 2003 (n = total number of samples from which means were calculated).

Time	n	Mean (kg/ha)	Std. Error
Sep-01	72	463.6	215.7
Feb-02	96	199.4	60.4
Sep-02	96	111.4	34.0
Feb-03	96	273.6	75.2
Overall	360	248.5	51.2

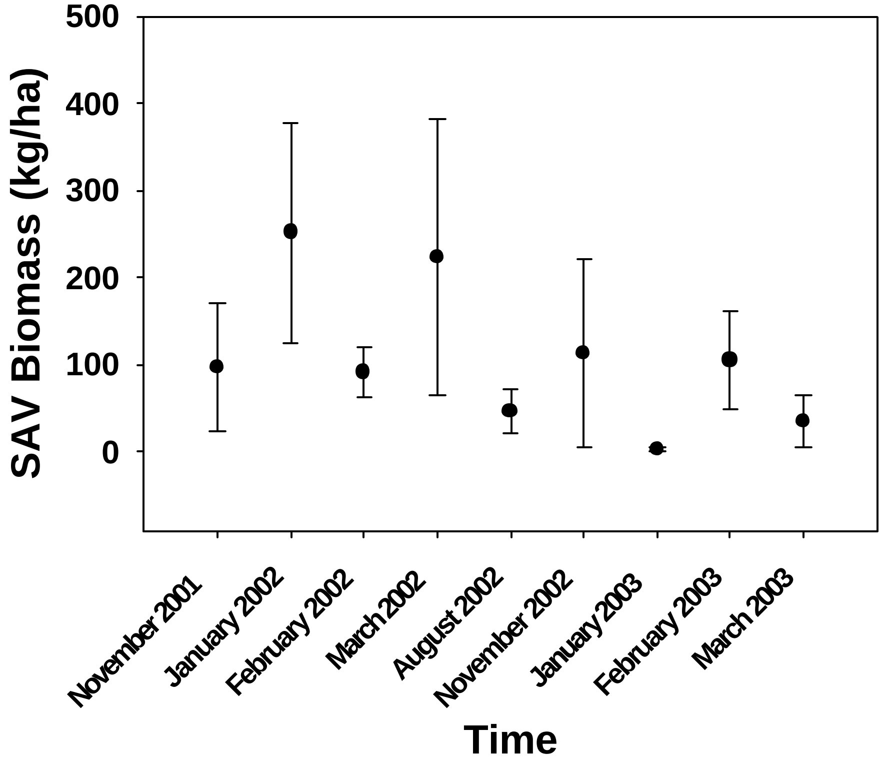

Figure 5. Mean SAV food biomass (kg/ha) observed in 3 ponds at Sabine NWR with standard error bars from November 2001 to March 2003.

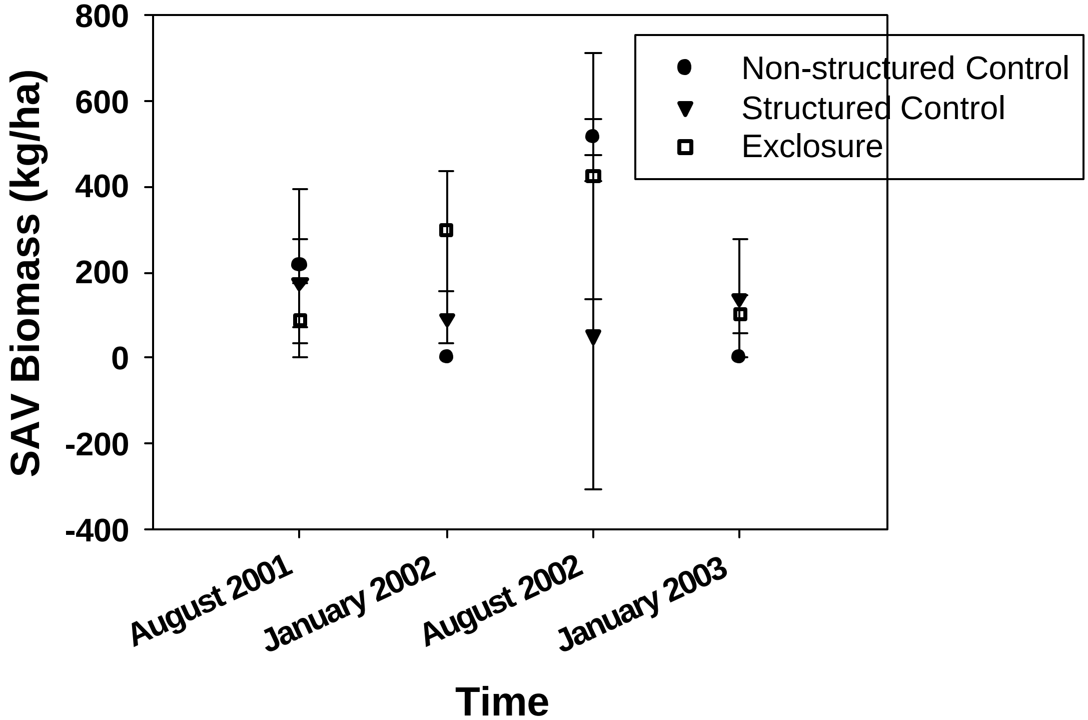

Figure 6. Mean SAV food biomass (kg/ha) observed at Sabine NWR in 3 waterfowl exclosures, 3 structured controls, and 3 non-structured controls with standard error bars from August 2001 to January 2003.

DISCUSSION AND IMPLICATIONS

Food Biomass Estimates

Seeds. Estimates of mean seed biomass for September 2001 and 2002 were not significantly different from one another, but the mean for September 2002 was nearly twice that of September 2001. There may have been a real, undetected difference.

My results provide evidence that the mean seed food biomass in freshwater coastal marshes of Louisiana and Texas is above the 50 kg/ha food-density threshold estimated by Reinecke et al. (1989) to be the minimum seed biomass necessary for successful foraging by wintering waterfowl. Jemison and Chabreck (1962) studied waterfowl food availability in a freshwater coastal marsh impoundment over one year and found a mean seed food biomass of 205 kg/ha in October 1959. I chose to exclude sawgrass biomass from their estimates as was done in my study because its value as food rather than grit has been disputed (Dillon 1957, Chabreck 1985) and mostly old, non-nutritious seeds of this once dominant species remain in the seed bank along the Gulf Coast (Valentine 1978, Caldwell 2003). Although Chabreck (1985) attributed an overall decline in biomass of most food species throughout the winter to waterfowl herbivory, the available food never fell below the threshold.

Seed food biomass has been estimated in several studies in coastal TX and LA and the Lower Mississippi Alluvial Valley (LMAV) (Table 10). Mean food biomass from this study is greater than what remains after harvest of southwest Louisiana ricefields, but lower than seed biomass in fallow ricefields, coastal freshwater impoundments, Texas coastal marshes, and moist-soil units of the LMAV.

Smartweeds, bulrushes, pondweeds, spikerushes, beakrushes, and water shield, comprised over 90% of the total seed food biomass. Smartweeds and bulrushes comprised over

Table 10. Mean seed food biomass estimates determined from other studies in the Gulf Coast region.

Habitat	Mean (kg/ha)	Location	Source
Coastal Freshwater Marshes	248	LA, TX	This Study
Coastal Freshwater Impoundment	205	LA	Jemison and Chabreck (1962)
Fallow Ricefields	298	LA	Davis et al. (1961)
Harvested Ricefields	160	LA	Harmon et al. (1961)
Coastal Marshes	413	TX	Singleton (1951)
Moist-soil Units	450	LMAV	Reinecke et al. (1989)

60% of the seed food biomass identified in this study. The observed biomass of these two genera probably reflects their ability to persist in flooded conditions because of their hard seed coats (Neely 1956, Shearer et al. 1969) better than softer-coated seeds such as those of *Cyperus*. The relative size and weight of these two seed groups is another potential explanation for their dominance in the samples, but seeds of similar and even heavier weight, spikerushes and beakrushes, respectively, occurred at much lower overall biomass. Although my seed biomass estimates are above the food-density threshold, Hoffman and Bookhout (1985) and Buckley (1989) have found that hard-coated seeds, specifically smartweeds and bulrushes, are lower in TME compared to softer-coated forage seeds. Considering that over 60% of the seeds in my study area were smartweeds and bulrushes, the wintering waterfowl carrying capacity of Gulf Coast fresh marshes could potentially be lower than anticipated.

I expected seeds of the genus *Cyperus* to occur more often than they did in the samples because of the plants' abundance in the study area (C. Bush, unpublished data). Perhaps the small, light seed readily passed through the smallest sieve (0.50 mm mesh) and/or escaped from the seed blower during analyses. Also, the seeds of this genus are soft-coated and may have broken apart beyond recognition when the samples were washed through the sieves.

Seed production for common freshwater marsh species was not estimated for this project,

so it is not known if the proportion of mean seed biomass for each species analyzed in the study is a reflection of recent plant seed production. However, Jemison and Chabreck (1962) found no relationship between the vegetative composition of their study area and the species and abundance of the seeds present in the soil, so seed production may not be a reliable indicator of what is present in the seed bank.

SAV. The mean SAV biomass of 262 kg/ha (26.2 g/m^2) for all sample periods, both aboveground and belowground, is close to the 248 kg/ha reported for mean seed biomass in this study and is well above the 50 kg/ha food-density threshold. However, it should be noted that this threshold estimate is based upon flooded agricultural habitats (ricefields) and different thresholds may exist in different habitats where food and foraging success vary (K. Reinecke, USGS Patuxent Wildlife Research Center, personal communication). Foraging costs for waterfowl feeding on SAV are unknown, but likely differ from seeds.

Little literature describing SAV biomass abundance in freshwater coastal marshes is available for comparison. Mean long-leaf pondweed (*P. nodosus*) biomass was estimated to be 219 kg/ha in a tidal freshwater wetland of coastal Louisiana (Castellanos and Rozas 2001). The authors observed other SAV species including najas, water celery (*Vallisneria americana*) and water stargrass (*Heteranthera dubia*) throughout their study, but these species occurred at relatively low densities and biomass was not estimated. Widgeongrass (*Ruppia maritima*) biomass averaged 76.0 kg/ha in a brackish marsh study conducted in coastal Louisiana (Hunter 2000), indicating that mean SAV biomass reported in this study is approximately three times that of a coastal brackish marsh. Moore et al. (2000) estimated mean biomass of SAV beds in the Chesapeake Bay to be 1,089 kg/ha compared to a mean biomass of 801 kg/ha of SAV beds for my study. Biomass estimates for SAV beds in my study were generated by removing all

observations containing no SAV from the analysis. Compared to the above estimates of mean SAV biomass, and considering that most fresh marshes are less stressed and more productive than brackish marshes (Palmisano 1973), my estimate of SAV biomass in freshwater wetlands of the Gulf Coast seems reasonable.

Sago pondweed, coontail, algae, and najas stems and leaves comprised 55.3% of the SAV food biomass in this study (95% of all aboveground biomass). Squarestem spikerush, banana waterlily, and sago pondweed roots and tubers comprised 41.7% of the SAV food biomass in the study (100% of all belowground biomass). Although spikerush is not considered SAV, I included it in the analyses because it was typically sampled in flooded conditions in my study and its foliage and tubers are valuable duck forage (Paulus 1982). Each of these species is utilized as food by a variety of waterfowl species, but little is known of their desirability. Sago pondweed has been reported as the dominant species in other freshwater wetland SAV studies (Castellanos and Rozas 2001, Moore et al. 2000), and is known as an important duck food (Martin and Uhler 1939, Anderson and Low 1976, Florshutz 1972, Paulus 1982). The fact that the mean biomass of sago pondweed alone (above- and belowground) comprised nearly 50% of the mean total SAV food biomass in this study makes it an important candidate for continued waterfowl food research. Fluctuations in biomass of this species could indicate changes in habitat quality and affect waterfowl food availability, particularly for SAV specialists, such as the gadwall and American widgeon.

Submerged aquatic vegetation is also valuable as habitat for myriad invertebrate species utilized as food by waterfowl (McIvor and Odum 1988, Castellanos and Rozas 2001), particularly invertebrate specialists such as the Northern Shoveler and Lesser Scaup (*Aythya affinis*) (Bellrose 1976, Rogers and Korschgen 1966). Unfortunately, the estimation of

invertebrate biomass was not included in the scope of this study. Assuming invertebrate biomass increases with SAV biomass (Castellanos and Rozas 2001), knowledge of SAV biomass trends over time could be used as an indicator of invertebrate abundance as food for ducks.

Food-Depletion Hypothesis

Spatially-Intensive Sampling. Estimates of mean seed biomass did not differ among time periods. In fact, the estimate for February 2002 was larger than that of either September 2001 or 2002. The small sample size for February 2002 (n=36) compared to both September 2001 (n=84) and 2002 (n=90) may have influenced the seed biomass estimates. Another explanation for the large February 2002 estimates is that many Gulf Coast marsh plant species may not drop their seeds until September, causing an underestimate of seed biomass during the September sampling periods. Jemison and Chabreck (1962) observed increases in seed biomass of some species in a freshwater impoundment from October to December and attributed these increases to some species not dropping seeds until after October. In Florida, smartweed seed production was nearly nine times greater in October than in September (Olinde et al. 1985), supporting the idea that seed production of some plant species in my study area may be greatest after September. These findings suggest that exclosures or more than two sampling periods between fall and winter should be used to track potential changes in seed biomass over times of low and high waterfowl numbers.

No difference was detected in mean SAV biomass among time periods. Mean SAV biomass in September 2001 and 2002 was the highest and lowest, respectively, of the four time periods, with both February 2002 and 2003 estimates being larger than that of September 2002. The high variation observed among sites and sampling periods probably masked any significant differences in mean SAV biomass.

There may have been a real, undetected difference between sampling periods for both seed and SAV food biomass. If winter food resources are not limiting, other factors, such as predation and/or little precipitation on the breeding grounds, little precipitation in the Mississippi Alluvial Valley, disease, or increased hunting mortality, may be limiting the nation's duck population. However, alternative reasons abound as to why I did not detect a difference if wintering waterfowl along the Gulf Coast really are depleting food resources. During the two years of this project, the Gulf Coast experienced odd weather patterns with unusually warm winters, which may have caused many wintering waterfowl to remain farther north than usual. This smaller wintering population may not have been large enough to deplete food that an average winter population would. Also, many of my sites were located on hunted WMA's and private lands, possibly causing decreased foraging opportunities on these areas. At one study site, Unit 3 of Sabine NWR, where waterfowl hunting is prohibited, water levels were exceptionally high (>0.5 m) throughout the study, making much of the forage unavailable to waterfowl. Future researchers may want to select some sites on or adjacent to waterfowl refuges where ducks are more likely to be found foraging in high numbers.

Temporally-Intensive Sampling. I expected to find a pattern of decreasing SAV biomass as waterfowl numbers increased over the six-week sampling intervals for each year. However, no seasonal patterns or trends in SAV biomass could be identified. Submerged aquatic vegetation biomass was extremely variable among samples, reducing the chance of observing a significant difference between any two time periods. Water levels at this site were exceptionally high during both years of the study (>50 cm), likely making much of the forage unavailable to dabbling ducks, which prefer water levels = 20 cm (Fredrickson and Taylor 1982). Waterfowl herbivory was not apparent from these results, so correlations of wintering duck population size

estimates and SAV biomass were not justified.

Exclosure Sampling. I expected the exclosure treatment to contain more SAV biomass than the control treatments in my January samples when waterfowl were high. The non-structured controls were devoid of SAV in both January 2002 and 2003, while the structured controls always contained SAV biomass. I observed no differences in SAV biomass among time periods, treatments, or interactions of the two and can draw no conclusions about SAV biomass related to waterfowl herbivory. I believe the structures provided protection for the SAV from wind and wave action associated with winter cold fronts. Idestam-Almquist (1998) drew similar conclusions wherein he attributed the observed differences in aboveground SAV biomass between open and exclosure plots to the exclosures sheltering SAV from destructive wave action and not to waterfowl herbivory. However, waterfowl herbivory cannot be ruled out as the cause because I was unable to conduct visual observations of the structures due to logistical complications. These observations would have allowed me to determine if waterfowl were feeding in or near the structures. Hunter (2000) found no evidence of waterfowl herbivory in her exclosure study in south Louisiana, and although Joanen and Glasgow (1965) did observe a significant decline in SAV biomass that they attributed to waterfowl herbivory, their study examined two exclosures sampled over one season.

High densities of waterfowl may cause significant reductions in SAV biomass as competition for valuable food resources increases, especially if SAV densities are lower than average due to irregular weather patterns, storm events, drought, etc. (Bortolus et al. 1998, Marklund et al. 2002). Unfortunately, predicting the following years fall flight of ducks early enough to construct exclosures and allow SAV time to recolonize after disturbance is difficult, so I am left with the data at hand to draw my conclusions.

CONCLUSIONS AND RECOMMENDATIONS

Mean seed and SAV food biomass estimates in freshwater marshes of coastal Texas and Louisiana are 244.8 and 262.3 kg/ha, respectively, both of which are well above the 50 kg/ha food-density threshold assumed to be the "point of diminishing returns" for waterfowl feeding with tactile cues in flooded agricultural habitats. Gulf Coast waterfowl managers will use these estimates to better model energetic requirements of waterfowl wintering on the Gulf Coast. The results of the food-depletion hypothesis test indicate that waterfowl did not deplete or significantly lower seed and SAV biomass over the two years of my study. However, extremely high variation was observed within and among all sites in the study area, with variation in SAV biomass being the most problematic.

Future research on waterfowl food abundance should utilize different methods of sampling seeds and SAV from marsh ponds to reduce the high variability associated with such sampling. Instead of collecting only four samples from each pond, investigators may attempt to retrieve more (25-50, depending on pond size) cores from each pond, homogenizing those cores, and subsampling the homogenized cores. By doing so, much of the variability within ponds could be eliminated and more sites could be selected. Depending on the geographic location of the study area, researchers should also consider when most of the seed food producing plants set their seeds and plan sampling dates accordingly.

I also recommend researching different methods of determining SAV biomass besides my coring method. I realize that high variability is usually inherent when estimating SAV biomass, but alternative methods may yield less variation and allow more confident statistical analyses. Caldwell (2003) sampled SAV biomass at Sabine NWR using m^2-plots, and noticed less variability in SAV biomass compared to a coring technique identical to the one used in my

study. Many studies involving the estimation of SAV biomass use sampling equipment similar to m^2-plots, but in order to sample seeds and SAV concomitantly, I elected to use the coring technique.

When estimating seed and/or SAV biomass, future investigators should increase the number of samples taken at each site as well the overall number of sites in the study area as much as logistically feasible. Along those lines, researchers should contemplate grouping geographic regions within a study area as another means of reducing variability (i.e. deltaic plain and chenier plain). Finally, researchers using waterfowl exclosures should incorporate a greater number of larger, less conspicuous exclosures into the study design and should conduct visual observations when waterfowl are abundant to document whether or not waterfowl are feeding in or near the structures.

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APPENDIX A
SEED FOOD BIOMASS ESTIMATES FOR EACH SPECIES BY SITE

Mean seed food biomass estimates for each seed food species at each site with time periods (September 2001 and September 2002) pooled.

Appling

Species	Mean (kg/ha)	Std. Error
………………………..Food Seeds………………………..		
Brasenia schreberi	0.00	0.00
Ceratophyllum demersum	0.00	0.00
Cyperus sp.	0.63	0.47
Echinochloa sp.	0.00	0.00
Eleocharis sp. (Large)	1.41	1.24
Eleocharis sp. (Small)	1.25	1.08
Heliotropium sp.	0.47	0.33
Nymphaea odorata	0.00	0.00
Paspalum sp.	35.78	35.60
Polygonum hydropiperoides	0.63	0.47
Polygonum pensylvanicum	0.00	0.00
Potamogeton sp.	0.00	0.00
Prosperinaca sp.	0.00	0.00
Rhynchospora sp.	0.00	0.00
Ruppia maritima	0.00	0.00
Scirpus sp.	0.00	0.00
Total food	40.17	36.40

Brown

Species	Mean (kg/ha)	Std. Error
………………………..Food Seeds………………………..		
Brasenia schreberi	0.00	0.00
Ceratophyllum demersum	0.00	0.00
Cyperus sp.	2.50	2.50
Echinochloa sp.	0.00	0.00
Eleocharis sp. (Large)	0.47	0.47
Eleocharis sp. (Small)	0.48	0.33
Heliotropium sp.	0.00	0.00
Nymphaea odorata	0.00	0.00
Paspalum sp.	0.47	0.33
Polygonum hydropiperoides	178.13	39.97
Polygonum pensylvanicum	6.56	5.22
Potamogeton sp.	0.16	0.16
Prosperinaca sp.	0.00	0.00
Rhynchospora sp.	6.56	3.81
Ruppia maritima	0.00	0.00
Scirpus sp.	0.00	0.00
Total food	195.33	38.80

Couba Island

Species	Mean (kg/ha)	Std. Error
…………………………Food Seeds…………………………		
Brasenia schreberi	0.00	0.00
Ceratophyllum demersum	0.00	0.00
Cyperus sp.	1.36	0.58
Echinochloa sp.	0.00	0.00
Eleocharis sp. (Large)	3.65	2.15
Eleocharis sp. (Small)	1.26	0.60
Heliotropium sp.	0.00	0.00
Nymphaea odorata	4.90	3.35
Paspalum sp.	1.17	0.48
Polygonum hydropiperoides	5.52	1.35
Polygonum pensylvanicum	2.08	1.49
Potamogeton sp.	28.77	4.20
Prosperinaca sp.	0.00	0.00
Rhynchospora sp.	0.00	0.00
Ruppia maritima	0.00	0.00
Scirpus sp.	108.75	25.38
Total food	157.46	32.90

Hancock

Species	Mean (kg/ha)	Std. Error
…………………………Food Seeds…………………………		
Brasenia schreberi	0.00	0.00
Ceratophyllum demersum	51.56	13.61
Cyperus sp.	0.00	0.00
Echinochloa sp.	0.00	0.00
Eleocharis sp. (Large)	248.47	69.88
Eleocharis sp. (Small)	1.25	1.25
Heliotropium sp.	0.00	0.00
Nymphaea odorata	0.00	0.00
Paspalum sp.	28.14	19.38
Polygonum hydropiperoides	3.91	1.73
Polygonum pensylvanicum	0.78	0.78
Potamogeton sp.	0.00	0.00
Prosperinaca sp.	0.00	0.00
Rhynchospora sp.	1.09	0.80
Ruppia maritima	0.00	0.00
Scirpus sp.	0.00	0.00
Total food	335.20	85.20

JD Murphree

Species	Mean (kg/ha)	Std. Error
………………………..Food Seeds…………………………		
Brasenia schreberi	0.00	0.00
Ceratophyllum demersum	2.19	2.19
Cyperus sp.	2.66	1.76
Echinochloa sp.	0.00	0.00
Eleocharis sp. (Large)	4.06	3.38
Eleocharis sp. (Small)	20.47	9.92
Heliotropium sp.	0.00	0.00
Nymphaea odorata	0.00	0.00
Paspalum sp.	0.00	0.00
Polygonum hydropiperoides	15.47	4.99
Polygonum pensylvanicum	0.00	0.00
Potamogeton sp.	0.47	0.47
Prosperinaca sp.	0.00	0.00
Rhynchospora sp.	0.00	0.00
Ruppia maritima	0.00	0.00
Scirpus sp.	227.50	51.60
Total food	272.82	51.00

Jones Island

Species	Mean (kg/ha)	Std. Error
………………………..Food Seeds…………………………		
Brasenia schreberi	0.00	0.00
Ceratophyllum demersum	0.00	0.00
Cyperus sp.	1.04	0.75
Echinochloa sp.	21.82	5.65
Eleocharis sp. (Large)	3.13	2.61
Eleocharis sp. (Small)	2.05	0.85
Heliotropium sp.	0.00	0.00
Nymphaea odorata	0.00	0.00
Paspalum sp.	0.00	0.00
Polygonum hydropiperoides	637.34	103.20
Polygonum pensylvanicum	0.00	0.00
Potamogeton sp.	0.00	0.00
Prosperinaca sp.	0.00	0.00
Rhynchospora sp.	43.96	10.09
Ruppia maritima	0.00	0.00
Scirpus sp.	0.00	0.00
Total food	709.34	112.00

Levingston		
Species	Mean (kg/ha)	Std. Error
……………………….Food Seeds……………………….		
Brasenia schreberi	0.00	0.00
Ceratophyllum demersum	0.00	0.00
Cyperus sp.	0.02	0.02
Echinochloa sp.	0.00	0.00
Eleocharis sp. (Large)	4.84	3.34
Eleocharis sp. (Small)	0.00	0.00
Heliotropium sp.	0.00	0.00
Nymphaea odorata	0.00	0.00
Paspalum sp.	0.33	0.20
Polygonum hydropiperoides	75.17	51.69
Polygonum pensylvanicum	39.06	38.00
Potamogeton sp.	0.00	0.00
Prosperinaca sp.	7.81	4.26
Rhynchospora sp.	178.75	77.29
Ruppia maritima	0.00	0.00
Scirpus sp.	0.00	0.00
Total food	305.98	81.90

McFaddin		
Species	Mean (kg/ha)	Std. Error
……………………….Food Seeds……………………….		
Brasenia schreberi	189.84	77.75
Ceratophyllum demersum	0.00	0.00
Cyperus sp.	0.00	0.00
Echinochloa sp.	0.00	0.00
Eleocharis sp. (Large)	32.66	12.89
Eleocharis sp. (Small)	0.00	0.00
Heliotropium sp.	0.00	0.00
Nymphaea odorata	8.91	6.75
Paspalum sp.	1.25	0.94
Polygonum hydropiperoides	4.53	1.75
Polygonum pensylvanicum	0.00	0.00
Potamogeton sp.	8.28	3.44
Prosperinaca sp.	0.00	0.00
Rhynchospora sp.	4.06	2.10
Ruppia maritima	0.00	0.00
Scirpus sp.	65.47	16.55
Total food	315.00	70.10

Miami Corporation		
Species	Mean (kg/ha)	Std. Error
……………………….Food Seeds………………………….		
Brasenia schreberi	0.00	0.00
Ceratophyllum demersum	0.78	0.78
Cyperus sp.	2.61	1.38
Echinochloa sp.	1.36	0.63
Eleocharis sp. (Large)	0.00	0.00
Eleocharis sp. (Small)	1.52	1.21
Heliotropium sp.	0.00	0.00
Nymphaea odorata	0.00	0.00
Paspalum sp.	0.00	0.00
Polygonum hydropiperoides	0.26	0.17
Polygonum pensylvanicum	0.00	0.00
Potamogeton sp.	122.27	33.87
Prosperinaca sp.	0.00	0.00
Rhynchospora sp.	0.00	0.00
Ruppia maritima	0.00	0.00
Scirpus sp.	35.99	8.04
Total food	164.79	36.80

Sabine NWR		
Species	Mean (kg/ha)	Std. Error
……………………….Food Seeds………………………….		
Brasenia schreberi	0.00	0.00
Ceratophyllum demersum	0.00	0.00
Cyperus sp.	13.68	8.99
Echinochloa sp.	0.00	0.00
Eleocharis sp. (Large)	0.00	0.00
Eleocharis sp. (Small)	1.94	1.94
Heliotropium sp.	0.00	0.00
Nymphaea odorata	3.54	0.99
Paspalum sp.	2.86	0.80
Polygonum hydropiperoides	0.76	0.43
Polygonum pensylvanicum	1.53	1.16
Potamogeton sp.	21.26	8.31
Prosperinaca sp.	0.00	0.00
Rhynchospora sp.	0.00	0.00
Ruppia maritima	0.00	0.00
Scirpus sp.	48.19	18.23
Total food	93.76	28.00

Salvador

Species	Mean (kg/ha)	Std. Error
……………………….Food Seeds……………………….		
Brasenia schreberi	0.00	0.00
Ceratophyllum demersum	3.85	2.89
Cyperus sp.	1.58	0.55
Echinochloa sp.	0.05	0.05
Eleocharis sp. (Large)	0.00	0.00
Eleocharis sp. (Small)	0.35	0.23
Heliotropium sp.	0.57	0.27
Nymphaea odorata	0.00	0.00
Paspalum sp.	0.33	0.15
Polygonum hydropiperoides	4.06	1.65
Polygonum pensylvanicum	0.00	0.00
Potamogeton sp.	32.94	4.80
Prosperinaca sp.	0.00	0.00
Rhynchospora sp.	0.00	0.00
Ruppia maritima	0.00	0.00
Scirpus sp.	115.27	25.79
Total food	159.00	24.60

Weeden

Species	Mean (kg/ha)	Std. Error
……………………….Food Seeds……………………….		
Brasenia schreberi	0.00	0.00
Ceratophyllum demersum	0.00	0.00
Cyperus sp.	0.00	0.00
Echinochloa sp.	0.00	0.00
Eleocharis sp. (Large)	0.00	0.00
Eleocharis sp. (Small)	0.00	0.00
Heliotropium sp.	20.48	10.52
Nymphaea odorata	0.00	0.00
Paspalum sp.	0.00	0.00
Polygonum hydropiperoides	0.00	0.00
Polygonum pensylvanicum	0.00	0.00
Potamogeton sp.	0.00	0.00
Prosperinaca sp.	0.00	0.00
Rhynchospora sp.	0.00	0.00
Ruppia maritima	3.14	3.12
Scirpus sp.	0.00	0.00
Total food	23.62	10.30

Womack

Species	Mean (kg/ha)	Std. Error
……………………….Food Seeds………………………..		
Brasenia schreberi	0.00	0.00
Ceratophyllum demersum	0.00	0.00
Cyperus sp.	0.00	0.00
Echinochloa sp.	0.16	0.16
Eleocharis sp. (Large)	0.00	0.00
Eleocharis sp. (Small)	0.00	0.00
Heliotropium sp.	0.31	0.31
Nymphaea odorata	0.00	0.00
Paspalum sp.	13.59	6.22
Polygonum hydropiperoides	0.00	0.00
Polygonum pensylvanicum	26.25	19.28
Potamogeton sp.	0.00	0.00
Prosperinaca sp.	0.00	0.00
Rhynchospora sp.	0.00	0.00
Ruppia maritima	0.00	0.00
Scirpus sp.	0.00	0.00
Total food	40.31	19.00

Woodson

Species	Mean (kg/ha)	Std. Error
……………………….Food Seeds………………………..		
Brasenia schreberi	0.00	0.00
Ceratophyllum demersum	0.00	0.00
Cyperus sp.	0.03	0.02
Echinochloa sp.	0.00	0.00
Eleocharis sp. (Large)	0.00	0.00
Eleocharis sp. (Small)	0.00	0.00
Heliotropium sp.	31.73	14.69
Nymphaea odorata	0.00	0.00
Paspalum sp.	0.00	0.00
Polygonum hydropiperoides	0.63	0.63
Polygonum pensylvanicum	0.00	0.00
Potamogeton sp.	182.66	27.66
Prosperinaca sp.	0.00	0.00
Rhynchospora sp.	0.00	0.00
Ruppia maritima	0.00	0.00
Scirpus sp.	21.09	8.22
Total food	236.14	32.20

APPENDIX B
SAV FOOD BIOMASS ESTIMATES FOR EACH SPECIES BY SITE

Mean SAV food biomass estimates for each SAV food species at each site with time periods (September 2001 and September 2002) pooled.

Appling

Species	Mean (kg/ha)	Std. Error
- - - - - - - - - - - - - - - - Food SAV - - - - - - - - - - - - - - - - - -		
Algae (filamentous)	0.00	0.00
Ceratophyllum demersum	0.00	0.00
Eleocharis quadrangulata	0.00	0.00
Eleocharis quadrangulata (Below)	0.00	0.00
Lemna minor	0.00	0.00
Najas gaudalupensis	0.00	0.00
Nitella sp.	0.00	0.00
Nymphaea mexicana (Below)	0.00	0.00
Potamogeton pectinatus	0.00	0.00
Potamogeton pectinatus (Below)	0.00	0.00
Potamogeton sp.	0.00	0.00
Total food	0.00	0.00

Brown

Species	Mean (kg/ha)	Std. Error
- - - - - - - - - - - - - - - - Food SAV - - - - - - - - - - - - - - - - - -		
Algae (filamentous)	0.00	0.00
Ceratophyllum demersum	0.00	0.00
Eleocharis quadrangulata	0.00	0.00
Eleocharis quadrangulata (Below)	0.00	0.00
Lemna minor	0.00	0.00
Najas gaudalupensis	0.00	0.00
Nitella sp.	0.00	0.00
Nymphaea mexicana (Below)	0.00	0.00
Potamogeton pectinatus	0.00	0.00
Potamogeton pectinatus (Below)	0.00	0.00
Potamogeton sp.	0.00	0.00
Total food	0.00	0.00

Couba Island

Species	Mean (kg/ha)	Std. Error
- - - - - - - - - - - - - - - - - Food SAV - - - - - - - - - - - - - - - - - - -		
Algae (filamentous)	0.00	0.00
Ceratophyllum demersum	28.13	14.36
Eleocharis quadrangulata	0.00	0.00
Eleocharis quadrangulata (Below)	0.00	0.00
Lemna minor	0.00	0.00
Najas gaudalupensis	7.29	6.24
Nitella sp.	0.00	0.00
Nymphaea mexicana (Below)	214.58	144.95
Potamogeton pectinatus	0.00	0.00
Potamogeton pectinatus (Below)	0.00	0.00
Potamogeton sp.	0.00	0.00
Total food	250.00	141.60

Hancock

Species	Mean (kg/ha)	Std. Error
- - - - - - - - - - - - - - - - - Food SAV - - - - - - - - - - - - - - - - - - -		
Algae (filamentous)	0.00	0.00
Ceratophyllum demersum	0.00	0.00
Eleocharis quadrangulata	62.50	25.99
Eleocharis quadrangulata (Below)	1434.38	1252.70
Lemna minor	0.00	0.00
Najas gaudalupensis	0.00	0.00
Nitella sp.	0.00	0.00
Nymphaea mexicana (Below)	0.00	0.00
Potamogeton pectinatus	0.00	0.00
Potamogeton pectinatus (Below)	0.00	0.00
Potamogeton sp.	0.00	0.00
Total food	1496.88	1275.11

JD Murphree		
Species	Mean (kg/ha)	Std. Error
- - - - - - - - - - - - - - - - - Food SAV - - - - - - - - - - - - - - - - - - -		
Algae (filamentous)	0.00	0.00
Ceratophyllum demersum	0.00	0.00
Eleocharis quadrangulata	0.00	0.00
Eleocharis quadrangulata (Below)	0.00	0.00
Lemna minor	0.00	0.00
Najas gaudalupensis	0.00	0.00
Nitella sp.	0.00	0.00
Nymphaea mexicana (Below)	0.00	0.00
Potamogeton pectinatus	0.00	0.00
Potamogeton pectinatus (Below)	0.00	0.00
Potamogeton sp.	0.00	0.00
Total food	0.00	0.00

Jones Island		
Species	Mean (kg/ha)	Std. Error
- - - - - - - - - - - - - - - - - Food SAV - - - - - - - - - - - - - - - - - - -		
Algae (filamentous)	14.58	10.52
Ceratophyllum demersum	0.00	0.00
Eleocharis quadrangulata	0.00	0.00
Eleocharis quadrangulata (Below)	0.00	0.00
Lemna minor	0.00	0.00
Najas gaudalupensis	0.00	0.00
Nitella sp.	0.00	0.00
Nymphaea mexicana (Below)	0.00	0.00
Potamogeton pectinatus	0.00	0.00
Potamogeton pectinatus (Below)	0.00	0.00
Potamogeton sp.	0.00	0.00
Total food	14.58	10.50

Levingston

Species	Mean (kg/ha)	Std. Error
- - - - - - - - - - - - - - - - - Food SAV - - - - - - - - - - - - - - - - - - -		
Algae (filamentous)	0.00	0.00
Ceratophyllum demersum	0.00	0.00
Eleocharis quadrangulata	0.00	0.00
Eleocharis quadrangulata (Below)	0.00	0.00
Lemna minor	0.00	0.00
Najas gaudalupensis	0.00	0.00
Nitella sp.	0.00	0.00
Nymphaea mexicana (Below)	0.00	0.00
Potamogeton pectinatus	0.00	0.00
Potamogeton pectinatus (Below)	0.00	0.00
Potamogeton sp.	0.00	0.00
Total food	0.00	0.00

McFaddin

Species	Mean (kg/ha)	Std. Error
- - - - - - - - - - - - - - - - - Food SAV - - - - - - - - - - - - - - - - - - -		
Algae (filamentous)	62.50	62.50
Ceratophyllum demersum	403.13	264.29
Eleocharis quadrangulata	0.00	0.00
Eleocharis quadrangulata (Below)	0.00	0.00
Lemna minor	0.00	0.00
Najas gaudalupensis	0.00	0.00
Nitella sp.	0.00	0.00
Nymphaea mexicana (Below)	0.00	0.00
Potamogeton pectinatus	0.00	0.00
Potamogeton pectinatus (Below)	0.00	0.00
Potamogeton sp.	0.00	0.00
Total food	465.63	258.00

Miami Corporation

Species	Mean (kg/ha)	Std. Error
- - - - - - - - - - - - - - - - - Food SAV - - - - - - - - - - - - - - - - - - -		
Algae (filamentous)	0.00	0.00
Ceratophyllum demersum	2.08	2.08
Eleocharis quadrangulata	0.00	0.00
Eleocharis quadrangulata (Below)	0.00	0.00
Lemna minor	0.10	0.07
Najas gaudalupensis	1.04	0.72
Nitella sp.	18.23	13.63
Nymphaea mexicana (Below)	0.00	0.00
Potamogeton pectinatus	0.00	0.00
Potamogeton pectinatus (Below)	0.00	0.00
Potamogeton sp.	3.13	3.13
Total food	24.58	17.10

Sabine NWR

Species	Mean (kg/ha)	Std. Error
- - - - - - - - - - - - - - - - - Food SAV - - - - - - - - - - - - - - - - - - -		
Algae (filamentous)	0.00	0.00
Ceratophyllum demersum	0.00	0.00
Eleocharis quadrangulata	0.00	0.00
Eleocharis quadrangulata (Below)	0.00	0.00
Lemna minor	16.88	7.06
Najas gaudalupensis	20.83	20.83
Nitella sp.	0.00	0.00
Nymphaea mexicana (Below)	0.00	0.00
Potamogeton pectinatus	0.00	0.00
Potamogeton pectinatus (Below)	0.00	0.00
Potamogeton sp.	0.00	0.00
Total food	37.71	20.50

Salvador		
Species	Mean (kg/ha)	Std. Error
- - - - - - - - - - - - - - - - - Food SAV - - - - - - - - - - - - - - - - - - -		
Algae (filamentous)	0.00	0.00
Ceratophyllum demersum	30.78	14.13
Eleocharis quadrangulata	0.00	0.00
Eleocharis quadrangulata (Below)	0.00	0.00
Lemna minor	0.00	0.00
Najas gaudalupensis	19.79	8.67
Nitella sp.	0.00	0.00
Nymphaea mexicana (Below)	0.00	0.00
Potamogeton pectinatus	0.00	0.00
Potamogeton pectinatus (Below)	0.00	0.00
Potamogeton sp.	0.00	0.00
Total food	50.57	18.80

Weeden		
Species	Mean (kg/ha)	Std. Error
- - - - - - - - - - - - - - - - - Food SAV - - - - - - - - - - - - - - - - - - -		
Algae (filamentous)	132.81	132.81
Ceratophyllum demersum	0.00	0.00
Eleocharis quadrangulata	0.00	0.00
Eleocharis quadrangulata (Below)	0.00	0.00
Lemna minor	0.00	0.00
Najas gaudalupensis	0.00	0.00
Nitella sp.	0.00	0.00
Nymphaea mexicana (Below)	0.00	0.00
Potamogeton pectinatus	503.13	206.17
Potamogeton pectinatus (Below)	0.00	0.00
Potamogeton sp.	0.00	0.00
Total food	635.94	281.90

Womack

Species	Mean (kg/ha)	Std. Error
- - - - - - - - - - - - - - - - - Food SAV - - - - - - - - - - - - - - - - - - -		
Algae (filamentous)	0.00	0.00
Ceratophyllum demersum	0.00	0.00
Eleocharis quadrangulata	0.00	0.00
Eleocharis quadrangulata (Below)	0.00	0.00
Lemna minor	0.00	0.00
Najas gaudalupensis	0.00	0.00
Nitella sp.	0.00	0.00
Nymphaea mexicana (Below)	0.00	0.00
Potamogeton pectinatus	0.00	0.00
Potamogeton pectinatus (Below)	0.00	0.00
Potamogeton sp.	0.00	0.00
Total food	0.00	0.00

Woodson

Species	Mean (kg/ha)	Std. Error
- - - - - - - - - - - - - - - - - Food SAV - - - - - - - - - - - - - - - - - - -		
Algae (filamentous)	29.69	29.69
Ceratophyllum demersum	0.00	0.00
Eleocharis quadrangulata	0.00	0.00
Eleocharis quadrangulata (Below)	0.00	0.00
Lemna minor	0.00	0.00
Najas gaudalupensis	4.69	3.29
Nitella sp.	0.00	0.00
Nymphaea mexicana (Below)	0.00	0.00
Potamogeton pectinatus	1618.75	1063.02
Potamogeton pectinatus (Below)	543.75	273.09
Potamogeton sp.	12.50	10.83
Total food	2209.38	1335.10

VITA

Christian Jesse Winslow was born in New Orleans, Louisiana, on July 25, 1979. He began his love of hunting and fishing as a child and his passion for the outdoors has only grown since. He graduated from Andrew Jackson Fundamental Magnet High School in 1997 and began attending Louisiana State University the same year. In 2001, he graduated from Louisiana State University with a Bachelor of Science in wildlife and began Graduate School in the School of Renewable Natural Resources at Louisiana State University the same year. He will receive a Master of Science degree in wildlife in December 2003 and is currently employed by the Louisiana Department of Wildlife and Fisheries as a Biologist II.