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Effects of survey method on observer bias and detection probability of marsh birds on St. Vincent NWR

Final Report

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Wildlife Research Report #2006-04

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Executive Summary

In 2001, a national marsh bird monitoring protocol was developed for National Wildlife Refuges across North America. The protocol has been improved each year with feedback from refuges that used it to monitor secretive marsh birds. However, few participants are incorporating methods to evaluate observer bias, or evaluate the differences in vocalization probability between surveys conducted during different times of day. Between 18 May and 14 July 2006 we conducted 4 replicate marsh bird surveys on 7 routes at St. Vincent National Wildlife Refuge, an island off the northwest coast of Florida. We conducted double-blind multiple-observer surveys, paired morning and evening surveys, and paired morning and night surveys to examine the factors that influence detection probability. Observer detection probability was similar for all species detected (clapper rail, 77%; common moorhen, 69%; and least bittern, 78%). Observer detection probability was higher for clapper rails during the call-broadcast period of the survey and higher for common moorhen and least bittern during the passive period of the survey. Vocalization probability was highest in morning for all species detected. However, only common moorhen and least bittern had significantly more birds detected on morning surveys when compared to evening surveys ($P = 0.026$, and $P = 0.064$ respectively), and only clapper rail had significantly more birds detected on morning surveys when compared to night surveys ($P = 0.014$).

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Introduction

Marshlands are not surveyed sufficiently by existing national or continental monitoring programs, yet populations of many species of marsh birds are thought to be declining in North America (Tate 1986, Eddleman et al. 1988, Conway et al. 1994). In 2001, a national marsh bird monitoring protocol was developed for National Wildlife Refuges across North America. The protocol has been improved each year with feedback from refuges that used it to monitor secretive marsh birds. The protocol (Conway 2005) is suitable for use on any refuge or protected area in North America. There are currently 127 U.S. Fish and Wildlife Service (USFWS) entities participating or planning to participate in the national program (115 National Wildlife Refuges and 12 Wetland Management Districts) and the program has also attracted a large number of participants from outside USFWS (other agencies and NGOs). The program is currently generating a large amount of survey data for secretive marsh birds. However, few participants are incorporating methods to evaluate observer bias. Observer bias might affect detection probability and our ability to estimate population trends with the data produced. Also, many studies have shown that the vocalization probability of secretive marsh birds may differ depending on the time of day (Conway and Gibbs 2001). Furthermore, the differences in vocalization probability during different times of day may vary regionally and by marsh bird species (Conway et al. 2004). Few participants are evaluating the differences in vocalization probability between surveys conducted during different times of day. Such information can help other refuges and the national program identify the most effective survey times.

From May to July 2006 we conducted marsh bird surveys on St. Vincent National Wildlife Refuge (SVNWR) in northwest Florida using the national marsh bird monitoring protocol. We conducted double-blind multiple-observer surveys to estimate observer bias associated with these survey efforts. We also conducted paired morning versus evening surveys, and morning versus night surveys to evaluate differences in vocalization probability during different times of day. In addition to recording survey data for all secretive marsh bird species, we recorded management practices (e.g., history of prescribed fire, water levels, etc.) and vegetative composition at each survey point on the refuge that may have influenced abundance or detection probability of local marsh bird populations. All data collected will provide needed information for SVNWR for a group of birds that has been largely neglected, and will expand upon data collected at SVNWR in 2002. Survey data will also be pooled with similar data from refuges across the country. The estimates of observer bias will help evaluate the accuracy of population trends calculated from data being collected at refuges across the country where surveyors change from year to year. Determining the differences in vocalization probability between different times of day will help SVNWR and other surveyors in the region to select the best time of day to conduct marsh bird surveys.

Methods

Study Area

All surveys were conducted on the St. Vincent Island (SVI) portion of SVNWR (29° 40' N, -85° 05' W). SVI is a 4968 hectare forested barrier island in the northeastern Gulf of Mexico bounded by St. Vincent Sound, Apalachicola Bay, and the Gulf of Mexico. Thirty-seven percent of the island is considered marsh bird habitat, which includes: 308 hectares of managed marsh, 67 hectares of managed open water, 1090 hectares of estuarine marsh, and 383 hectares of estuarine open water. Seven marsh bird survey routes were established to survey all accessible habitat on SVI; three routes were in brackish/freshwater marshes, and four routes were in saltwater marshes (Fig. 1). Two of the seven routes were designed to replicate survey routes established in 2002 on E road and J road. However, due to the closure of J road to vehicular traffic, we were forced to shift this route south to I road. Each of the two routes included 12 points in 2006, as opposed to 10 in 2002. Points on these routes were spaced at 400 meter intervals in both years. All other routes included 10 to 14 points spaced at 200 meter intervals. We chose an interval of 200 meters on all newly established routes to increase our probability of detecting black rails; a bird with quiet, infrequent vocalizations, and a Bird of National Conservation Concern (USFWS 2002). Black rails have previously been observed on SVI (Runde et al. 1990), and reliable observers have noted black rail observations during the summer, suggesting that black rails breed on SVI. Of the seven routes established, three were surveyed by canoe, three by vehicle, and one by a combination of foot and vehicle. Survey points were marked in the field with a portable GPS receiver. Survey points along canoe routes were marked with painted rebar and surveyor tape. Stops along driving/foot routes were marked with surveyor tape around the tree nearest to the survey point along the road and then permanently marked with trap tags nailed to the tree. Marking points in this manner assured that all replicate surveys were conducted from exactly the same location. See Appendix I for a description of each survey route.

Surveys

We conducted 4 replicate surveys on all 7 survey routes between 18 May and 14 July 2006. Survey methods followed the Standardized North American Marsh Bird Survey Protocol (Conway 2005). At each point we recorded all aural and visual observations of primary marsh bird species during each minute of both a 5-minute passive listening period and a 5-minute call-broadcast period. The call-broadcast period was composed of 30 seconds of broadcasted calls, followed by 30 seconds of silence for each of the following species: black rail, least bittern, clapper rail, common moorhen, and purple gallinule. The broadcast sequence was 4 minutes shorter than the broadcast sequence used in 2002 because we excluded king rail, American coot, pied-billed grebe and American bittern. These species are not thought to breed in the region. Primary marsh bird species thought to occur in the area include: black rail, clapper rail, king rail, American coot, common moorhen, purple gallinule, pied-billed grebe, sora, American bittern, and least bittern. With the exception of night and evening surveys conducted for comparison purposes (see: Morning Versus Evening Surveys, and Morning Versus Night Surveys), all surveys were conducted in the morning from 0.5 hours before sunrise until no later than 10:00am, on days without rain and when winds were less than 10 kilometers per hour. All calls were broadcast using a Memorex CD player (Model #MD6443SIL) and Sony SRS-A27 Active Speaker System placed on the ground or bow of the canoe pointed perpendicular to the edge of the marsh. All broadcasts were approximately 90 dB measured 1 meter from the speaker. We used a Kestrel 3000 weather anemometer to record the temperature and wind speed at the beginning and end of each survey route. We also estimated the percent cloud cover at the beginning and end of each route.

After consulting SVNWR biologist Thom Lewis, we summarized the date of the most recent prescribed fire, and measurements of water quality taken at particular locations on various dates throughout the survey period. We also quantified the percent cover of dominant wetland plant species in a 50-meter radius surrounding each survey point. When possible, we used a 100-meter measuring tape to provide a reference of 50 meters on each side of the survey point parallel to the upland-wetland interface. We drew a map of the vegetative structure within a 50-meter radius and estimated the percent cover of each dominant plant species.

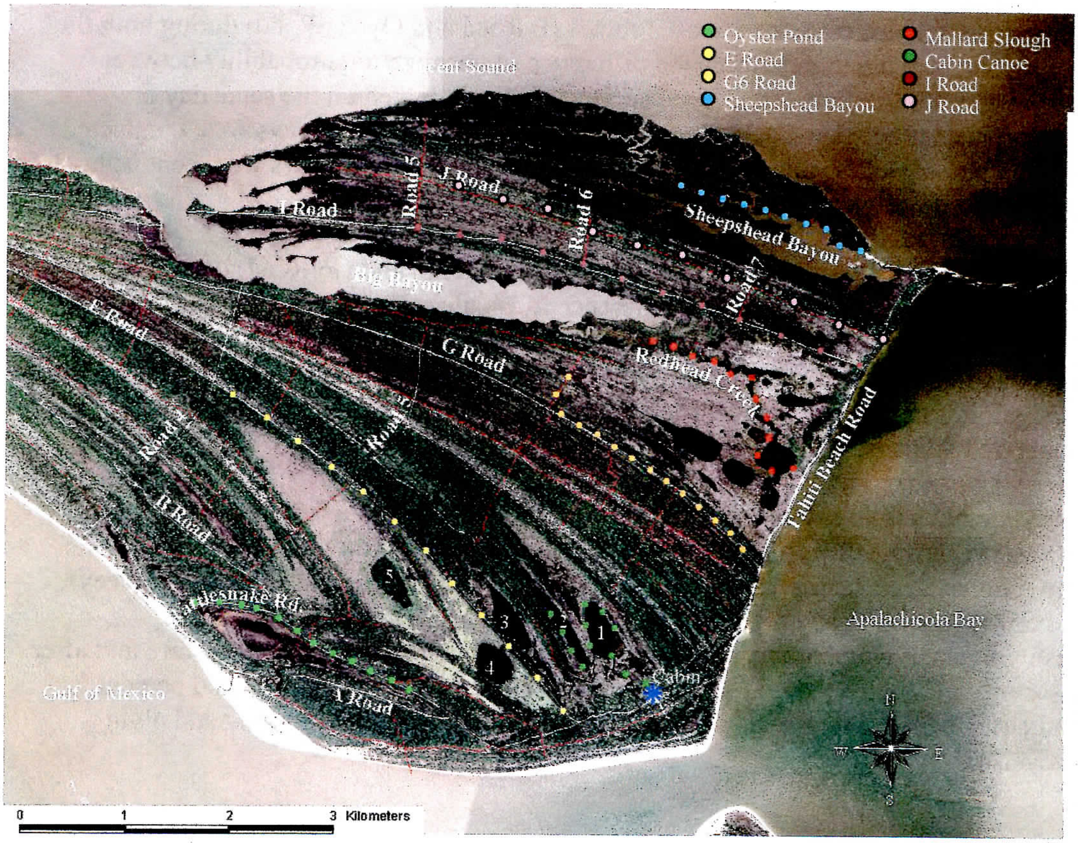

Figure 1. Map of St. Vincent Island Survey Routes

Double-Blind Multiple-Observer Surveys

We conducted double-blind multiple-observer surveys at 26 points between 25 June and 5 July 2006. We followed methods described in the Standardized North American Marsh

Bird Monitoring Protocols (Conway 2005). At each point, two trained observers recorded all aural and visual observations of primary marsh bird species during each minute of both a 5-minute passive listening period and a 5-minute call-broadcast period. The observers also estimated the distance to each bird, and recorded the call types heard. By recording birds in this manner, we were able to easily determine after the survey which birds had been detected by each observer. During the survey, the two observers recorded their data inconspicuously so as to not alert the other observer when they detected a bird, and they did not discuss their detections until the survey was complete.

We used the methods described by Nichols et al. (2000) to estimate observer detection probability for each of two observers (P1 and P2) for each of three time periods: 1) the entire survey (passive and call-broadcast combined), 2) the passive period only, and 3) the broadcast period only. We averaged P1 and P2 to determine an overall estimate of observer detection probability for each time period.

Vocalization Probability During Different Times of Day

We conducted 3 replicate surveys on 2 routes (E Road and Oyster Pond) during both the morning and evening to determine the difference in vocalization probability between morning and evening surveys. Paired surveys were conducted on the same day or consecutive days between 31 May and 30 June 2006. Morning surveys were conducted 0.5 hours before sunrise until no later than 10am, and evening surveys were conducted 3 hours before sunset until dark.

We also conducted 2 replicate surveys on 2 routes (I Road and G6 Road) during both the morning and night to determine the difference in vocalization probability between the morning and night surveys. Paired surveys were conducted on the same day or consecutive days between 7 June and 7 July 2006. Morning surveys were conducted 0.5 hours before sunrise until no later than 10am, and night surveys were conducted between 1:00am and 4:00am.

Survey methods followed the Standardized North American Marsh Bird Monitoring Protocols (Conway 2005) as described above (see Survey Methods). We compared the mean number of each species detected per route between morning and evening surveys, and between morning and night surveys using paired *t*-tests. We also averaged measurements of temperature, wind speed, and percent cloud cover taken before and after the survey, and used a paired *t*-test to compare temperature, wind speed, and percent cloud cover between morning and evening surveys, and between morning and night surveys.

Results

Surveys

In total, nine species of secretive marsh birds were detected on SVI: black rail, clapper rail, king rail, American coot, common moorhen, purple gallinule, sora, American bittern, and least bittern (Appendix II). Four species (clapper rail, common moorhen, purple gallinule, and least bittern) were detected on at least three of the four survey periods, and hence were likely breeding on SVI. Common moorhen was the only species confirmed to be nesting. An adult common moorhen with seven juveniles were observed multiple times on Oyster Pond from 18 May to 30 June 2006. The five other species detected (black rail, king rail, American coot, sora, and American bittern) were likely late spring migrants leaving the wintering grounds, or early fall migrants returning to the wintering grounds. We detected one black rail on the G6 road route on 25 May. We assume this was a late spring migrant because we did not detect black rails after this date. Survey methods and locations in 2002 were different from 2006, and so we could not make a reasonable comparison of the numbers and species detected between the 2002 and 2006 surveys. Date of the last prescribed fire, water quality measurements, and vegetation measurements surrounding each survey point are provided in Appendix III, IV, and V.

Double-Blind Multiple-Observer Surveys

Five species of secretive marsh birds were detected during double-blind multiple-observer surveys: clapper rail, king rail, common moorhen, American bittern, and least bittern. However, king rail and American bittern were omitted from analysis because only one individual of each species was detected. Observer detection probability was similar for all species across the entire survey (passive and call-broadcast periods combined): clapper rail, 77.38%; common moorhen, 69.44%; and least bittern, 77.92%. Detection probability for clapper rails was higher during the call-broadcast period compared to the passive period (Fig. 2). Detection probability for common moorhen and least bittern were slightly higher during the passive period compared to the call-broadcast period (Fig. 2).

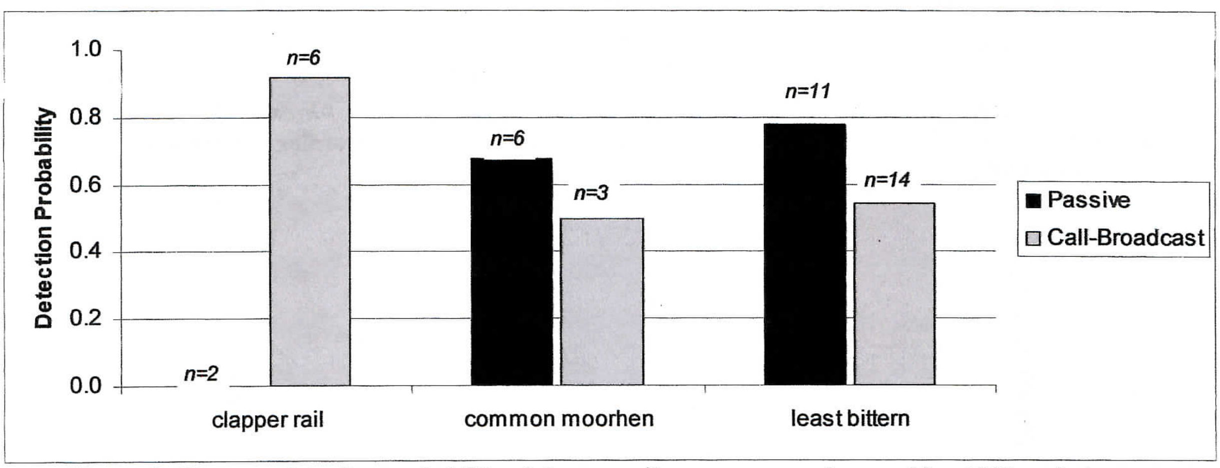

Figure 2. Observer detection probability of clapper rail, common moorhen, and least bittern between passive and call-broadcast periods.

Vocalization Probability During Different Times of Day

Five species of mash birds were detected on at least one survey of the 12 paired morning and evening surveys: clapper rail, American coot, common moorhen, purple gallinule, and least bittern. For all species the mean number of birds detected was higher on morning surveys than on evening surveys (Fig. 3). However, only common moorhen and least bittern had significant differences in the mean number of birds detected between morning and evening surveys ($P = 0.026$, and $P = 0.064$ respectively). Wind speed, and percent cloud cover did not differ between morning and evening surveys, but temperature was 4% higher on evening surveys ($P = 0.017$).

Three species of mash birds were detected on at least one survey of the 8 paired morning and night surveys: clapper rail, common moorhen, and least bittern. For all species, the mean number of birds detected was higher on morning surveys compared to night surveys (Fig. 4). However, only clapper rail had a significant difference in the mean number of birds detected between morning and night surveys ($P = 0.014$). There were no significant differences in the temperature, wind speed, or percent cloud cover between morning and night surveys.

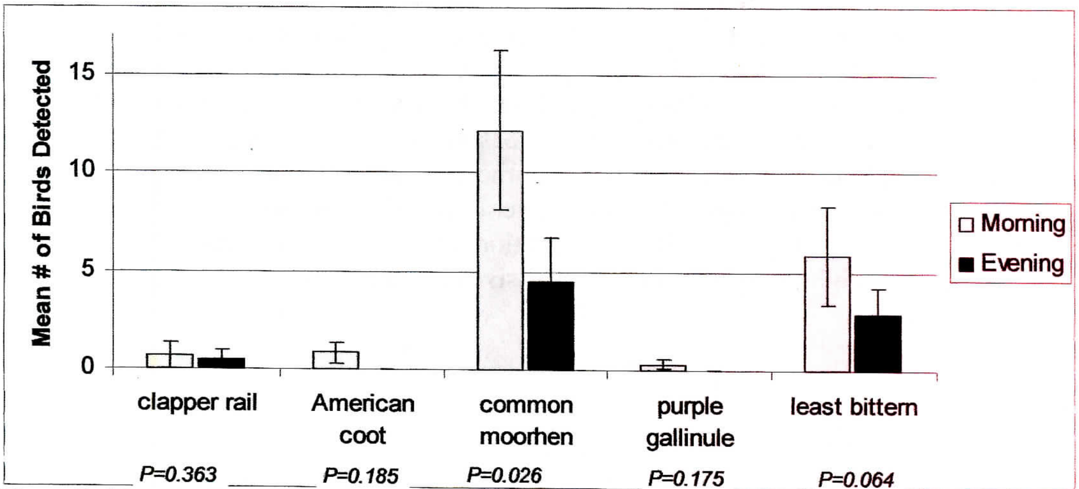

Figure 3. Mean (± SE) number of marsh birds detected between 6 paired morning and evening surveys on SVI

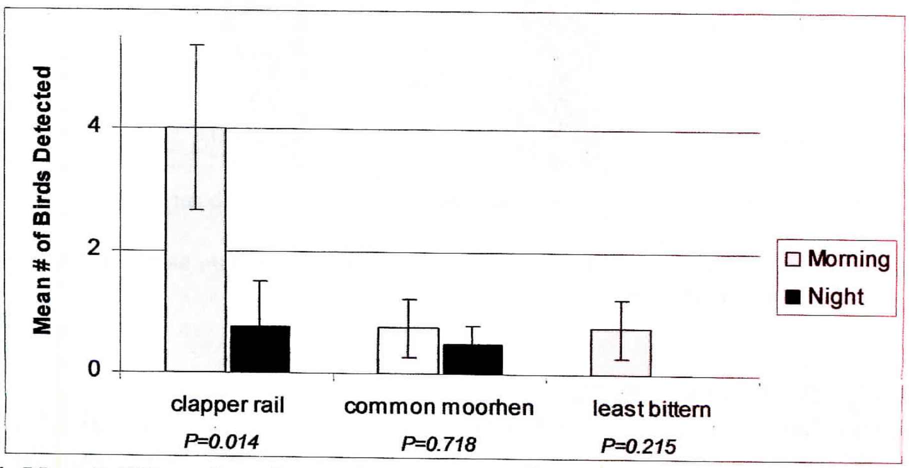

Figure 4. Mean (+ SE) number of marsh birds detected between 4 paired morning and night surveys on SVI

Discussion

Surveys

Due to the detection of non-breeding species (black rail and sora) early in our survey period, we believe surveys began close to the beginning or middle of the breeding season. However, we suggest that surveys begin earlier (early- to mid-April) in future years to better determine the peak breading season on SVI. We encourage future surveys on SVI use the same broadcast sequence as in 2006, and survey the same points established during this survey effort. See Appendix IV for a list of GPS coordinates for each point. Surveyors should use a training CD, and/or attend a Marsh Bird Training Workshop to assure they are familiar with all vocalizations of the 10 species occurring on SVI before conducting surveys. Training CDs can be obtained from the National Marsh Bird Monitoring Program.

Double-Blind Multiple-Observer Surveys

Although few other authors have calculated observer detection probability for secretive marsh birds, the observer detection probabilities reported here are similar to those reported by Conway et al. (2004) and Conway and Nadeau (2006). Conway and Nadeau also reported a higher observer detection probability for clapper rails during the broadcast period compared to the passive period. They suggest that the call-broadcast may help observers recognize calls of the species being broadcast, hence increasing detection probability. Detection probability was higher during the passive portion of the survey for common moorhen and least bittern, perhaps because observers may have difficulty hearing these species over the call-broadcast.

Vocalization Probability During Different Times of Day

Vocalization probability during different times of day may vary by region and by species (Conway et al. 2004). Furthermore, different times of day may have more favorable weather conditions for conducting surveys in different regions. Weather conditions did not differ between morning and evening surveys or between morning and night surveys on SVI. Weather conditions were favorable for surveys during the entire survey period, with the exception of a short time period surrounding Tropical Storm Alberto. For all species detected, vocalization probability was higher on morning surveys compared to both night and evening surveys. The results presented here suggest that marsh bird surveys on SVI be conducted in the mornings between 0.5 hours before sunrise until no later than 10:00am. However, further research is needed to determine the effect of tidal stage on detection probability.

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Appendix I: Location of 7 marsh bird survey routes on St. Vincent NWR

Route Name	# Pts	Pt Spacing	Type of Marsh	Mode of Transportation	Directions
G6 Road	14	200m	Estuarine	Vehicle/Foot	• Start at Tahiti Beach Rd. and G Rd. • Points 1-12 on G Rd. (vehicle) • Points 13 and 14 on Rd. 6 (on foot)
Mallard Slough Marsh	12	200m	Estuarine	Canoe	• Start at Tahiti Beach Rd. firebreak and Big Can Pond • Points 1-4 on west side of Big Can Pond • Points 5-12 on either side of tidal creek
I Road	12	400m	Estuarine	Vehicle	• Start at intersection of I Rd. and Rd. 5 • Ends at the intersection of I Rd. and Tahiti Beach Rd.
Sheepshead Bayou	10	200m	Estuarine	Canoe	• Drive with canoe north on Tahiti Beach Rd. Turn left at the fork in the road. Launch canoe in St. Vincent Sound when the road becomes impassable • Survey the north side of Sheepshead Bayou
Oyster Pond	12	200m	Managed	Vehicle	• Start on the west end of Rattlesnake Rd. • Follow Rattlesnake Rd. east to B Rd., and then B Rd. east to just before the intersection of A Rd.
E Road (Lakes 3, 4, & 5)	12	400m	Managed	Vehicle	• Start at the intersection of E Rd. and Jungle Trail • Route goes east towards Rd. 4 • Survey south side of E Rd at wetland interface
Cabin Canoe (Lakes 1 & 2)	12	200m	Managed	Canoe	• Start by canoeing from cabin to Lake 1 • Survey east side of the Lake 1, then west side of Lake 2

Appendix II: Summary of 2006 marsh bird survey results on SVI

Cabin Canoe

Date	Survey #	timeOfDay	Observer	AMBI	AMCO	BLRA	CLRA	COMO	KIRA	LEBI	PUGA	SORA
23-May-06	1	morning	Brad Smith	0	0	0	0	3	0	15	0	1
06-Jun-06	2	morning	Brad Smith	0	0	0	0	1	0	8	1	0
20-Jun-06	3	morning	Brad Smith	0	0	0	0	7	0	22	2	0
05-Jul-06	4	morning	Brad Smith	1	0	0	2	5	1	20	0	0
05-Jul-06	4	morning	Thom Lewis	1	0	0	1	4	0	23	0	0
			Total # Detected	1	0	0	2	16	1	65	3	1
			Mean # Detected	0.40	0.00	0.00	0.60	4.00	0.20	17.60	0.60	0.20

E Road

Date	Survey #	timeOfDay	Observer	AMBI	AMCO	BLRA	CLRA	COMO	KIRA	LEBI	PUGA	SORA
22-May-06	1	morning	Brad Smith	0	0	0	0	14	0	3	2	1
05-Jun-06	2	evening	Brad Smith	0	0	0	0	0	0	0	0	0
05-Jun-06	2	morning	Brad Smith	0	0	0	0	4	0	1	1	0
19-Jun-06	3	morning	Brad Smith	0	0	0	0	18	0	0	1	0
03-Jul-06	4	evening	Brad Smith	0	0	0	0	1	0	0	0	0
04-Jul-06	4	morning	Brad Smith	0	0	0	0	6	0	0	0	0
			Total # Detected	0	0	0	0	43	0	4	4	1
			Mean # Detected	0.00	0.00	0.00	0.00	7.17	0.00	0.67	0.67	0.17

G/6 Road

Date	Survey #	timeOfDay	Observer	AMBI	AMCO	BLRA	CLRA	COMO	KIRA	LEBI	PUGA	SORA
25-May-06	1	morning	Brad Smith	0	0	1	5	0	0	1	1	1
08-Jun-06	2	morning	Brad Smith	0	0	0	6	0	0	2	0	0
08-Jun-06	2	night	Brad Smith	0	0	0	3	0	0	0	0	0
21-Jun-06	3	evening	Brad Smith	0	0	0	3	0	0	0	0	0
21-Jun-06	3	evening	Thom Lewis	0	0	0	2	0	0	1	0	0
22-Jun-06	3	morning	Brad Smith	0	0	0	4	0	0	0	0	0
07-Jul-06	4	morning	Brad Smith	0	0	0	2	0	0	0	0	0
07-Jul-06	4	night	Brad Smith	0	0	0	0	1	0	0	0	0
			Total # Detected	0	0	1	23	1	0	3	1	1
			Mean # Detected	0.00	0.00	0.14	3.29	0.14	0.00	0.43	0.14	0.14

I Road

Date	Survey #	timeOfDay	Observer	AMBI	AMCO	BLRA	CLRA	COMO	KIRA	LEBI	PUGA	SORA
24-May-06	1	morning	Brad Smith	0	0	0	2	0	0	0	0	0
07-Jun-06	2	morning	Brad Smith	0	0	0	3	2	0	0	0	0
07-Jun-06	2	night	Brad Smith	0	0	0	0	0	0	0	0	0
21-Jun-06	3	morning	Brad Smith	0	0	0	3	1	0	1	0	0
21-Jun-06	3	night	Brad Smith	0	0	0	0	1	0	0	0	0
06-Jul-06	4	morning	Brad Smith	0	0	0	3	1	0	1	0	0
			Total # Detected	0	0	0	11	5	0	2	0	0
			Mean # Detected	0.00	0.00	0.00	1.83	0.83	0.00	0.33	0.00	0.00

Mallard Slough

Date	Survey #	timeOfDay	Observer	AMBI	AMCO	BLRA	CLRA	COMO	KIRA	LEBI	PUGA	SORA
26-May-06	1	morning	Brad Smith	0	0	0	36	0	0	6	0	0
09-Jun-06	2	morning	Brad Smith	0	0	0	23	0	0	5	0	0
23-Jun-06	3	morning	Brad Smith	0	0	0	16	0	0	5	0	0
13-Jul-06	4	morning	Brad Smith	0	0	0	28	0	0	2	0	0
			Total # Detected	0	0	0	103	0	0	18	0	0
			Mean # Detected	0.00	0.00	0.00	25.75	0.00	0.00	4.50	0.00	0.00

Oyster Pond

Date	Survey #	timeOfDay	Observer	AMBI	AMCO	BLRA	CLRA	COMO	KIRA	LEBI	PUGA	SORA
18-May-06	1	morning	Brad Smith	0	0	0	2	15	0	12	0	0
31-May-06	2	evening	Brad Smith	0	0	0	0	11	0	5	0	0
01-Jun-06	2	morning	Brad Smith	0	3	0	0	22	0	10	1	0
15-Jun-06	3	evening	Brad Smith	0	0	0	0	4	0	4	0	0
16-Jun-06	3	morning	Brad Smith	0	0	0	0	22	0	11	0	0
29-Jun-06	4	evening	Brad Smith	0	0	0	0	9	0	8	0	0
30-Jun-06	4	morning	Brad Smith	0	2	0	0	18	0	12	0	0
			Total # Detected	0	5	0	2	101	0	62	1	0
			Mean # Detected	0.00	0.71	0.00	0.29	14.43	0.00	8.86	0.14	0.00

Sheepshead Bayou

Date	Survey #	timeOfDay	Observer	AMBI	AMCO	BLRA	CLRA	COMO	KIRA	LEBI	PUGA	SORA
31-May-06	1	morning	Brad Smith	0	0	0	48	0	0	4	0	0
15-Jun-06	2	morning	Brad Smith	0	0	0	74	0	0	8	0	0
29-Jun-06	3	morning	Brad Smith	0	0	0	80	0	0	5	0	0
14-Jul-06	4	morning	Brad Smith	0	0	0	88	0	0	5	0	0
			Total # Detected	0	0	0	290	0	0	22	0	0
			Mean # Detected	0.00	0.00	0.00	72.50	0.00	0.00	5.50	0.00	0.00

Appendix III: Vegetative composition surrounding each of 84 survey points on SVI.

Point Name	Route Name	cattail *Typha spp.*	soft-stem bulrush *Schoenoplectus tabernaemontani*	Sedge spp. *Carex spp.*	common reed *Phragmites australis*	black needlerush *Juncus roemerianus*	smooth cordgrass *Spartina alterniflora*	sand cordgrass *Spartina bakerii*	salt grass *Distichlis spicata*	sawgrass *Cladium jamaicense*	arrowhead *Sagittaria spp.*	open water	upland	other
C01	Cabin Canoe	4%		2%				5%	1%	4%		25%	59%	
C02	Cabin Canoe		5%	7%	20%			50%	3%			15%		
C03	Cabin Canoe	20%	10%					5%				65%		
C04	Cabin Canoe	5%				3%		10%	2%			60%		20%
C05	Cabin Canoe	1%						4%	5%	25%		55%		10%
C06	Cabin Canoe	3%	4%					10%	3%	15%		30%		35%
C07	Cabin Canoe	10%				3%		10%		2%		50%		25%
C08	Cabin Canoe	1%				35%		10%		2%		42%		10%
C09	Cabin Canoe	5%	5%			40%		10%	0%			40%		
C10	Cabin Canoe					20%	15%		0%			50%	10%	5%
C11	Cabin Canoe					37%	14%			1%		48%		
C12	Cabin Canoe					20%		10%	5%	5%		50%	10%	
E01	E Road									30%			65%	5%
E02	E Road									50%			50%	
E03	E Road									40%		10%	50%	
E04	E Road									50%			50%	
E05	E Road									30%			50%	20%
E06	E Road									40%			50%	10%
E07	E Road									10%			60%	30%
E08	E Road												100%	
E09	E Road									45%			50%	5%
E10	E Road									35%			60%	5%
E11	E Road									40%			50%	10%
E12	E Road									40%			60%	
G01	G6 Road									35%			65%	
G02	G6 Road									20%			80%	
G03	G6 Road									30%			70%	
G04	G6 Road									30%			70%	
G05	G6 Road									65%			35%	
G06	G6 Road					5%				45%			50%	

Point Name	Route Name	cattail *Typha spp.*	soft-stem bulrush *Schoenoplectus tabernaemontani*	Sedge spp. *Carex spp.*	common reed *Phragmites australis*	black needlerush *Juncus roemerianus*	smooth cordgrass *Spartina alterniflora*	sand cordgrass *Spartina bakerii*	salt grass *Distichlis spicata*	sawgrass *Cladium jamaicense*	arrowhead *Sagittaria spp.*	open water	upland	other
G07	G6 Road					10%				45%			45%	
G08	G6 Road									55%			45%	
G09	G6 Road					15%				30%			55%	
G10	G6 Road					5%				50%			45%	
G11	G6 Road					35%				5%			60%	
G12	G6 Road					5%		3%	2%	10%		15%	65%	
G13	G6 Road					70%		15%				10%	5%	
G14	G6 Road					30%	10%	15%				45%		
I01	I Road			5%		10%		15%		20%		5%	45%	
I02	I Road					20%		4%		45%		1%	30%	
I03	I Road							4%		50%		1%	45%	
I04	I Road							1%		44%			55%	
I05	I Road							5%		35%		15%	45%	
I06	I Road							10%		35%			55%	
I07	I Road					10%		25%		35%			30%	
I08	I Road					40%		35%					25%	
I09	I Road					40%		4%		10%		1%	45%	
I10	I Road					38%		25%		8%		8%	21%	
I11	I Road					70%						20%	10%	
I12	I Road					20%		30%				5%	45%	
M01	Mallard Slough											50%		50%
M02	Mallard Slough					15%						50%		35%
M03	Mallard Slough					60%	10%					30%		
M04	Mallard Slough											75%		25%
M05	Mallard Slough					15%	10%					20%		55%
M06	Mallard Slough					15%	15%					30%		40%
M07	Mallard Slough					25%	10%					35%		30%
M08	Mallard Slough					5%	15%					20%		60%
M09	Mallard Slough					15%	10%					20%		55%
M10	Mallard Slough					5%						15%		80%
M11	Mallard Slough					30%	5%		1%			20%		44%
M12	Mallard Slough					10%	5%					60%		25%

Point Name	Route Name	cattail *Typha spp.*	soft-stem bulrush *Schoenoplectus tabernaemontani*	Sedge spp. *Carex spp.*	common reed *Phragmites australis*	black needlerush *Juncus roemerianus*	smooth cordgrass *Spartina alterniflora*	sand cordgrass *Spartina bakerii*	salt grass *Distichlis spicata*	sawgrass *Cladium jamaicense*	arrowhead *Sagittaria spp.*	open water	upland	other
OP01	Oyster Pond	62%		1%				7%		3%		7%	21%	
OP02	Oyster Pond	10%						15%				25%	50%	
OP03	Oyster Pond							10%				50%	40%	
OP04	Oyster Pond	1%					1%		1%	15%		33%	49%	
OP05	Oyster Pond	2%						7%	1%	10%		40%	40%	
OP06	Oyster Pond					1%				10%		39%	50%	
OP07	Oyster Pond					1%		9%				40%	50%	
OP08	Oyster Pond	5%				1%		10%	2%			32%	50%	
OP09	Oyster Pond	1%				5%		9%		1%		30%	45%	9%
OP10	Oyster Pond	15%						5%		20%		25%	35%	
OP11	Oyster Pond	5%								15%		30%	50%	
OP12	Oyster Pond	8%				2%				20%		20%	50%	
S01	Sheepshead Bayou					30%	5%					65%		
S02	Sheepshead Bayou					50%	5%					45%		
S03	Sheepshead Bayou					45%	5%					45%		
S04	Sheepshead Bayou					25%	5%					50%		
S05	Sheepshead Bayou					40%	5%					70%		
S06	Sheepshead Bayou					40%	5%					55%		
S07	Sheepshead Bayou					50%	5%					55%		
S08	Sheepshead Bayou					75%	10%					45%		
S09	Sheepshead Bayou					70%	20%					15%		
S10	Sheepshead Bayou					80%	10%					10%		

Appendix IV: GPS coordinates and date since last burn at each of 84 survey points on SVI

Point Name	Route Name	Latitude	Longitude	Burn Unit	date since last burn
C01	Cabin Canoe	29.63770344	-85.10326928	IN-7	17-Feb-04
C02	Cabin Canoe	29.63846929	-85.10523643	IN-7	17-Feb-04
C03	Cabin Canoe	29.64004124	-85.10667024	IN-7	17-Feb-04
C04	Cabin Canoe	29.64245120	-85.10640001	IN-7	17-Feb-04
C05	Cabin Canoe	29.64381192	-85.10761304	IN-7	17-Feb-04
C06	Cabin Canoe	29.64445112	-85.10941062	IN-7	17-Feb-04
C07	Cabin Canoe	29.64262588	-85.10925782	IN-7	17-Feb-04
C08	Cabin Canoe	29.64094623	-85.10883772	IN-7	17-Feb-04
C09	Cabin Canoe	29.63908863	-85.10952344	IN-7	17-Feb-04
C10	Cabin Canoe	29.64047994	-85.11069397	IN-7	17-Feb-04
C11	Cabin Canoe	29.64205876	-85.11160190	IN-7	17-Feb-04
C12	Cabin Canoe	29.64362240	-85.11276598	IN-7	17-Feb-04
E01	E Road	29.63523740	-85.11141758	E-6	no recorded burns
E02	E Road	29.63809454	-85.11408831	E-6	no recorded burns
E03	E Road	29.64073853	-85.11692424	E-6	no recorded burns
E04	E Road	29.64341403	-85.11962774	E-6	no recorded burns
E05	E Road	29.64607143	-85.12261111	E-6	no recorded burns
E06	E Road	29.64883000	-85.12530874	E-6	no recorded burns
E07	E Road	29.65129612	-85.12841349	E-6	no recorded burns
E08	E Road	29.65380591	-85.13157682	E-6	no recorded burns
E09	E Road	29.65591363	-85.13479974	E-5	17-Feb-05
E10	E Road	29.65806719	-85.13810204	E-5	17-Feb-05
E11	E Road	29.66006015	-85.14127552	E-5	17-Feb-05
E12	E Road	29.66202085	-85.14475593	E-5	17-Feb-05
G01	G6 Road	29.64960809	-85.09357654	MS north of road	9-Mar-05
G02	G6 Road	29.65074711	-85.09515292	MS north of road	9-Mar-05
G03	G6 Road	29.65183038	-85.09665060	MS north of road	9-Mar-05
G04	G6 Road	29.65297258	-85.09828088	MS north of road	9-Mar-05
G05	G6 Road	29.65406374	-85.09984972	MS north of road	9-Mar-05
G06	G6 Road	29.65508340	-85.10151722	MS north of road	9-Mar-05
G07	G6 Road	29.65609937	-85.10318689	MS north of road	9-Mar-05
G08	G6 Road	29.65705407	-85.10498540	MS north of road	9-Mar-05
G09	G6 Road	29.65797960	-85.10670268	MS north of road	9-Mar-05
G10	G6 Road	29.65899951	-85.10843782	MS north of road	9-Mar-05
G11	G6 Road	29.65981917	-85.11023615	MS north of road	9-Mar-05
G12	G6 Road	29.66071470	-85.11206743	MS north of road	9-Mar-05
G13	G6 Road	29.66239803	-85.11257085	MS to east; H6 to west	9-Mar-05
G14	G6 Road	29.66391214	-85.11143594	MS to east; H6 to west	9-Mar-05
I01	I Road	29.67651190	-85.12657869	I-7 south; J-6 north of road	20-Nov-03
I02	I Road	29.67588318	-85.12247910	I-7 south; J-6 north	20-Nov-03
I03	I Road	29.67552912	-85.11830843	I-7 south; J-6 north	20-Nov-03
I04	I Road	29.67443721	-85.11416475	I-7 south; J-6 north	20-Nov-03
I05	I Road	29.67356390	-85.11007547	I-7 south; J-7 north	20-Nov-03
I06	I Road	29.67234182	-85.10622181	I-7 south; J-7 north	20-Nov-03
I07	I Road	29.67125159	-85.10221618	I-7 south; J-7 north	20-Nov-03
I08	I Road	29.67022623	-85.09830250	I-7 south; J-7 north	20-Nov-03
I09	I Road	29.66908302	-85.09456870	I-7 south; J-7 north	20-Nov-03
I10	I Road	29.66777251	-85.09048043	I-7 south; J-8 north	20-Nov-03

Point Name	Route Name	Latitude	Longitude	Burn Unit	date since last burn
I11	I Road	29.66657826	-85.08647379	I-7 south; J-8 north	20-Nov-03
I12	I Road	29.66541653	-85.08257261	I-7 south; J-8 north	20-Nov-03
M01	Mallard Slough	29.66588298	-85.09910239	MS	9-Mar-05
M02	Mallard Slough	29.65614002	-85.09107496	MS	9-Mar-05
M03	Mallard Slough	29.65745129	-85.09252234	MS	9-Mar-05
M04	Mallard Slough	29.65898618	-85.09140311	MS	9-Mar-05
M05	Mallard Slough	29.66076180	-85.09172011	I-7	20-Nov-03
M06	Mallard Slough	29.66235101	-85.09278671	I-7	20-Nov-03
M07	Mallard Slough	29.66416033	-85.09317982	MS	9-Mar-05
M08	Mallard Slough	29.66441154	-85.09530958	MS	9-Mar-05
M09	Mallard Slough	29.66546698	-85.09699015	MS	9-Mar-05
M10	Mallard Slough	29.66588298	-85.09910239	MS	9-Mar-05
M11	Mallard Slough	29.66666962	-85.10102872	I-7	20-Nov-03
M12	Mallard Slough	29.66707287	-85.10308245	I-7	20-Nov-03
OP01	Oyster Pond	29.64410076	-85.14825848	OP	7-Feb-96
OP02	Oyster Pond	29.64421182	-85.14578490	OP	7-Feb-96
OP03	Oyster Pond	29.64394150	-85.14352572	OP	7-Feb-96
OP04	Oyster Pond	29.64368384	-85.14203299	OP	7-Feb-96
OP05	Oyster Pond	29.64295043	-85.13975261	OP	7-Feb-96
OP06	Oyster Pond	29.64184452	-85.13793005	OP	7-Feb-96
OP07	Oyster Pond	29.64078270	-85.13631024	OP	7-Feb-96
OP08	Oyster Pond	29.63991039	-85.13435651	OP	7-Feb-96
OP09	Oyster Pond	29.63924211	-85.13241048	OP	7-Feb-96
OP10	Oyster Pond	29.63848505	-85.13058281	OP	7-Feb-96
OP11	Oyster Pond	29.63765575	-85.12847786	OP	7-Feb-96
OP12	Oyster Pond	29.63691236	-85.12680600	OP	7-Feb-96
S01	Sheepshead Bayou	29.67512101	-85.08266472	SV-DB	no recorded burns
S02	Sheepshead Bayou	29.67558620	-85.08471661	SV-DB	no recorded burns
S03	Sheepshead Bayou	29.67692228	-85.08607155	SV-DB	no recorded burns
S04	Sheepshead Bayou	29.67735738	-85.08809150	SV-DB	no recorded burns
S05	Sheepshead Bayou	29.67796197	-85.09019905	SV-DB	no recorded burns
S06	Sheepshead Bayou	29.67848375	-85.09215396	SV-DB	no recorded burns
S07	Sheepshead Bayou	29.67892891	-85.09429168	SV-DB	no recorded burns
S08	Sheepshead Bayou	29.67935538	-85.09645186	SV-DB	no recorded burns
S09	Sheepshead Bayou	29.67986600	-85.09853192	SV-DB	no recorded burns
S10	Sheepshead Bayou	29.68042583	-85.10057048	SV-DB	no recorded burns

Appendix V: Water quality measurements taken on SVI at Oyster Pond, Lake 3, and Lake 4

Date	Oyster Pond		Lake 3 (E Road Route)		Lake 4 (E Road Route)	
	Salinity (mg/L)	Dissolved Oxygen (mg/L)	Salinity (mg/L)	Dissolved Oxygen (mg/L)	Salinity (mg/L)	Dissolved Oxygen (mg/L)
5/17/2006	9.4	12.86	9.1	7.86	3.1	7.54
5/24/2006	10.3	12.88	9.9	6.63	3.2	8.68
6/1/2006	10.9	4.27	9.8	4.28	3.8	4.38
6/7/2006	11.6	4.8	11	5.6	4.1	4.64
6/14/2006	10.7	2.44	17.4	10.9	3.7	9.86
6/22/2006	10.8	4.89	17.4	3.7	4.3	7.3
6/28/2006	11.8	4.66	18.55	4.99	5.4	6.82