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# Population Studies of Tidal Marsh Breeding Birds at Rush Ranch: A Synthesis

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## ABSTRACT

Rush Ranch, with the largest contiguous area of fully-tidal marsh remaining in northern Suisun Bay, is critical habitat for a number of endemic bird species that breed in brackish tidal marsh. Despite the abundance of non-native invasive plants (particularly perennial pepperweed, *Lepidium latifolium*) and altered hydrology, it is the best remaining representative in Solano County of the tidal marsh that once covered more than 27,000 ha (67,000 acres) in Suisun Bay. This paper presents a synthesis of bird population studies conducted at Rush Ranch since the late 1970s, concentrating on California clapper rail (*Rallus longirostris obsoletus*), California black rail (*Laterallus jamaicensis coturniculus*), Suisun song sparrow (*Melospiza melodia maxillaris*), common yellowthroat (*Geothlypis trichas*), and marsh wren (*Cistothorus palustris*). These studies indicate declines in clapper rail abundance, when we compared the past 8 years to surveys conducted 10 to 25 years ago. However, black rails appear to be increasing at Rush Ranch, and overall in Suisun Bay. Nest monitoring of reproductive attempts by song sparrows conducted between 1996 and 2005 indicates low overall nest survival rates, mainly from high predation rates, but also great year-to-year variability. Low nest survival rates of tidal marsh song sparrows observed at Rush Ranch appear to be too low to sustain populations, and such low rates are consistent with the apparent population declines observed for this subspecies at Rush Ranch. Nest survival and other components of reproductive success of tidal marsh birds should be monitored in the future to provide information on ecosystem condition and population health, as well as the response of these species to management, including control of non-native plant species.

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## KEY WORDS

California black rail, California clapper rail, *Geothlypis trichas*, *Melospiza melodia maxillaris*, *Laterallus jamaicensis coturniculus*, *Lepidium latifolium*, perennial pepperweed, *Rallus longirostris obsoletus*, common yellowthroat, Suisun song sparrow

## INTRODUCTION

Rush Ranch, with the largest contiguous area of fully-tidal marsh remaining in northern Suisun Bay, is a critical area for a suite of endemic breeding bird species adapted to brackish tidal marsh habitat. Birds using this tidal marsh habitat are the focus of this study, with some mention of the species using the adjacent upland edges, grasslands, and human-occupied areas.

Rush Ranch is the best representative of tidal marsh habitat remaining in Solano County that once covered more than 27,000 ha (67,000 acres) in Suisun Bay (Goals Project 1999), despite an abundance of non-native invasive plants (including perennial pepperweed, *Lepidium latifolium*), high predation rates likely due to non-native predators and other native but human-associated predators (such as raccoons and skunks), an altered upland edge, and altered hydrology. For this reason, Rush Ranch was designated as a National Estuarine Research Reserve (NERR) site, and has been included in a number of bird studies of Suisun Bay tidal marshes in the last 3 decades. Current management plans for Suisun Marsh include extensive restoration of tidal marsh habitat, and Rush Ranch can potentially play an important role in providing re-colonizing plants and animals for future restoration efforts (USBR and others 2010).

The most common bird species in the tidal marsh at Rush Ranch are Suisun song sparrow (*Melospiza melodia maxillaris*), a California Species of Special Concern (CDFG 2011; Spautz and Nur 2008); common yellowthroat (*Geothlypis trichas*), possibly an inter-grade of the upland subspecies (*G. t. occidentalis*) with the salt marsh subspecies (*G. t. sinuosa*), a California Species of Special Concern (Marshall and Dedrick 1994; Evens and Gardali 2008); marsh wren (*Cistothorus palustris*); red-winged blackbird (*Agelaius phoeniceus*); and California black rail (*Laterallus jamaicensis coturniculus*), a state-listed Threatened and fully-protected species (Trulio and Evens 2000; CDFG 2011). Recent surveys for California clapper rail, a federally and state-listed Endangered and fully-protected species (CDFG 2002, 2003, 2004a, 2005, 2006, 2007, 2008) have resulted in only two clapper rail detections at Rush Ranch, down from a maximum of 25 detected in the late 1970s through the early 1990s (Harvey 1980; Collins and others 1994).

## BIRD STUDIES AT RUSH RANCH

Studies of birds at Rush Ranch have included focused surveys for special-status species (including CDFG 2002, 2003, 2004a, 2005, 2006, 2007, 2008; Collins and others 1994; Evens and others 1991; Spautz and others 2005; Herzog and others 2005; Liu and others 2006, 2007) and general bird surveys, both standardized (e.g., Herzog and others 2005; Liu and others 2006, 2007) and non-standardized (e.g., Christmas Bird Counts and Breeding Bird Surveys conducted by local chapters of the National Audubon Society). We summarize these studies below. Results from these studies have allowed the development of a comprehensive bird list for Rush Ranch (Table 1).

### California Clapper Rail, California Black Rail, and other Rallids

#### *Surveys from 1978 to 1993*

Historically, northern Suisun Bay was not considered to be within the range of the California clapper rail (Gill 1979). Harvey (1980) and Evens and colleagues (Evens and others 1991; Evens and Collins 1992; Collins and others 1994) conducted regional surveys for California clapper rail and California black rail that included portions of Rush Ranch and several other tidal marshes in Suisun Bay, as well as numerous marshes throughout San Pablo Bay and San Francisco Bay. These surveys took place from 1978 to 1979 and 1992 to 1993 (California clapper rail), and from 1986 to 1989 (California black rail).

During these surveys, California clapper rails were detected from several locations at Rush Ranch, including 1st and 2nd Mallard Branches and Cutoff Slough. Between 3 and 25 individuals were detected each survey year, with populations slightly higher in the winter, which implies post-breeding dispersal from other portions of the estuary (Harvey 1980; Evens and Collins 1992; Collins and others 1994), in addition to probable breeding attempts within Rush Ranch. Variability in population sizes may relate to fluctuations in salinity and associated vegetation (Albertson and Evens 2000), but variability may also be from irregular colonization and extinction events in these small outlier habitat fragments in the regional meta-population, as well as from variations in survey methodology and detectability of this cryptic species.

Surveys for California black rail conducted in and around Rush Ranch in the same areas surveyed for

**Table 1** Birds observed at Rush Ranch. List is based on data and observations from Robin Leong, Napa–Sonoma Audubon Society; PRBO Conservation Science (unpublished data); and sighting data available on eBird (2012).

| Common name | Scientific name | Residency |
|---|---|---|
| **Grebes** | | |
| pied-billed grebe | *Podilymbus podiceps* | W |
| Clark's grebe | *Aechmophorus clarkii* | M |
| western grebe | *Aechmophorus occidentalis* | M |
| **Pelicans and allies** | | |
| American white pelican | *Pelecanus erythrorhynchos* | Y |
| double-crested cormorant | *Phalacrocorax auritus* | Y |
| **Herons and allies** | | |
| American bittern | *Botaurus lentiginosus* | W |
| great blue heron | *Ardea herodias* | Y |
| great egret | *Ardea alba* | Y |
| snowy egret | *Egretta thula* | Y |
| cattle egret | *Bubulcus ibis* | Y |
| green heron | *Butorides virescens* | Y |
| black-crowned night-heron | *Nycticorax nycticorax* | Y |
| **Ducks and geese** | | |
| tundra swan | *Cygnus columbianus* | W |
| greater white-fronted goose | *Anser albifrons* | W |
| snow goose | *Chen caerulescens* | W |
| Canada goose | *Branta canadensis* | Y |
| wood duck | *Aix sponsa* | W |
| green-winged teal | *Anas crecca* | W |
| mallard[a] | *Anas platyrhynchos* | Y, B |
| northern pintail | *Anas acuta* | W |
| cinnamon teal | *Anas cyanoptera* | Y |
| northern shoveler | *Anas clypeata* | W, M |
| gadwall | *Anas strepera* | Y |
| Eurasian wigeon | *Anas penelope* | W |
| American wigeon | *Anas americana* | W |
| ring-necked duck | *Aythya collaris* | M |
| greater scaup | *Aythya marila* | W |
| lesser scaup | *Aythya affinis* | W |
| common goldeneye | *Bucephala clangula* | W |
| bufflehead | *Bucephala albeola* | W |
| hooded merganser | *Lophodytes cucullatus* | W |
| ruddy duck | *Oxyura jamaicensis* | W |
| **Vultures** | | |
| turkey vulture | *Cathartes aura* | Y |
| **Hawks, eagles, and falcons** | | |
| osprey | *Pandion haliaetus* | Y |
| white-tailed kite | *Elanus leucurus* | Y, B |
| bald eagle | *Haliaeetus leucocephalus* | M |
| northern harrier[a] | *Circus cyaneus* | Y, B |
| sharp-shinned hawk | *Accipiter striatus* | W |
| Cooper's hawk | *Accipiter cooperii* | W, M |
| red-shouldered hawk | *Buteo lineatus* | W |
| Swainson's hawk | *Buteo swainsonii* | M |
| red-tailed hawk | *Buteo jamaicensis* | Y |
| ferruginous hawk | *Buteo regalis* | W, M |
| rough-legged hawk | *Buteo lagopus* | M |
| golden eagle | *Aquila chrysaetos* | Y |
| American kestrel | *Falco sparverius* | Y, B |
| merlin | *Falco columbarius* | W |
| peregrine falcon | *Falco peregrinus* | W, M |
| prairie falcon | *Falco mexicanus* | W, M |
| **Pheasants and quails** | | |
| ring-necked pheasant[a,b] | *Phasianus colchicus* | Y, B |
| **Rails and allies** | | |
| yellow rail | *Coturnicops noveboracensis* | W, M |
| California black rail[a] | *Laterallus jamaicensis coturniculus* | Y, B |
| California clapper rail[a] | *Rallus longirostris obsoletus* | Y, B |
| Virginia rail[a] | *Rallus limicola* | Y, B |
| sora | *Porzana carolina* | Y |
| common moorhen | *Gallinula chloropus* | W |
| American coot | *Fulica americana* | W |
| **Shorebirds** | | |
| black-bellied plover | *Pluvialis squatarola* | W, M |

a Species documented nesting in tidal marsh at Rush Ranch.
b Non-native species.

Residency codes: Y: year-round; S: summer; W: winter; M: spring and/or fall migration; B: breeding documented or assumed at Rush Ranch and environs.

**Table 1** (Continued) Birds observed at Rush Ranch. List is based on data and observations from Robin Leong, Napa–Sonoma Audubon Society; PRBO Conservation Science (unpublished data); and sighting data available on eBird (2012).

| Common name | Scientific name | Residency |
|---|---|---|
| **Shorebirds** | | |
| Killdeer | *Charadrius vociferus* | Y, B |
| black-necked stilt | *Himantopus mexicanus* | W, M |
| American avocet | *Recurvirostra americana* | M |
| greater yellowlegs | *Tringa melanoleuca* | W, M |
| lesser yellowlegs | *Tringa flavipes* | W |
| Willet | *Tringa semipalmata* | W |
| long-billed curlew | *Numenius americanus* | W, M |
| marbled godwit | *Limosa fedoa* | W, M |
| ruddy turnstone | *Arenaria interpres* | W, M |
| western sandpiper | *Calidris mauri* | W, M |
| least sandpiper | *Calidris minutilla* | W, M |
| Dunlin | *Calidris alpina* | W, M |
| long-billed dowitcher | *Limnodromus scolopaceus* | W, M |
| Wilson's snipe | *Gallinago delicata* | W, M |
| **Gulls and terns** | | |
| Bonaparte's gull | *Larus philadelphia* | W |
| ring-billed gull | *Larus delawarensis* | Y |
| Western gull | *Larus occidentalis* | W, M |
| California gull | *Larus californicus* | W, M |
| glaucous-winged gull | *Larus glaucescens* | W |
| Caspian tern | *Sterna caspia* | S, M |
| Forster's tern | *Sterna forsteri* | S, M |
| **Pigeons and doves** | | |
| rock pigeon[b] | *Columba livia* | Y, B |
| band-tailed pigeon | *Patagioenas fasciata* | W |
| Eurasian collared-dove[b] | *Streptopelia decaocto* | Y |
| mourning dove | *Zenaida macroura* | Y, B |
| **Owls** | | |
| barn owl | *Tyto alba* | B, Y |
| great horned owl | *Bubo virginianus* | Y |
| western burrowing owl | *Athene cunicularia hypugea* | Y, W |
| short-eared owl | *Asio flammeus* | W |
| **Hummingbirds and swifts** | | |
| white-throated swift | *Aeronautes saxatalis* | S, W |
| Anna's hummingbird | *Calypte anna* | Y |
| Allen's hummingbird | *Selasphorus sasin* | S |
| **Kingfishers** | | |
| belted kingfisher | *Ceryle alcyon* | W |
| **Woodpeckers** | | |
| northern flicker | *Colaptes auratus* | Y |
| **PASSERINES** | | |
| **Flycatchers** | | |
| willow flycatcher | *Empidonax traillii* | M |
| Pacific-slope flycatcher | *Empidonax difficilis* | M |
| black phoebe | *Sayornis nigricans* | Y |
| Say's phoebe | *Sayornis saya* | W, M |
| western kingbird | *Tyrannus verticalis* | Y |
| **Larks** | | |
| horned lark | *Eremophila alpestris* | Y |
| **Swallows** | | |
| tree swallow | *Tachycineta bicolor* | Y |
| violet-green swallow | *Tachycineta thalassina* | M |
| northern rough-winged swallow | *Stelgidopteryx serripennis* | M |
| cliff swallow | *Petrochelidon pyrrhonota* | S, B |
| barn swallow | *Hirundo rustica* | S, B |
| **Corvids – jays, crows and ravens** | | |
| western scrub-jay | *Aphelocoma californica* | Y |
| yellow-billed magpie | *Pica nuttalli* | W, S |
| American crow | *Corvus brachyrhynchos* | Y |
| common raven | *Corvus corax* | Y |
| **Bushtits** | | |
| bushtit | *Psaltriparus minimus* | Y |
| **Wrens** | | |
| Bewick's wren | *Thryomanes bewickii* | W |
| house wren | *Troglodytes aedon* | W |
| marsh wren[a] | *Cistothorus palustris* | Y, B |

a Species documented nesting in tidal marsh at Rush Ranch.
b Non-native species.

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**Table 1** (Continued) Birds observed at Rush Ranch. List is based on data and observations from Robin Leong, Napa–Sonoma Audubon Society; PRBO Conservation Science (unpublished data); and sighting data available on eBird (2012).

| Common name | Scientific name | Residency |
|---|---|---|
| **Kinglets** | | |
| golden-crowned kinglet | *Regulus satrapa* | W |
| ruby-crowned kinglet | *Regulus calendula* | W |
| **Bluebirds** | | |
| western bluebird | *Sialia mexicana* | Y |
| **Thrushes** | | |
| American robin | *Turdus migratorius* | Y |
| varied thrush | *Ixoreus naevius* | W |
| **Pipits** | | |
| American pipit | *Anthus rubescens* | W |
| **Mockingbirds** | | |
| northern mockingbird | *Mimus polyglottos* | Y, B |
| **Shrikes** | | |
| loggerhead shrike | *Lanius ludovicianus* | Y, B |
| **Starlings** | | |
| European starling[b] | *Sturnus vulgaris* | Y, B |
| **Warblers** | | |
| orange-crowned warbler | *Vermivora celata* | M |
| yellow warbler | *Dendroica petechia* | M |
| yellow-rumped warbler | *Dendroica coronata* | W, M |
| black-throated gray warbler | *Dendroica nigrescens* | M |
| Townsend's warbler | *Dendroica townsendi* | M |
| common yellowthroat[a] | *Geothlypis trichas* | Y, B |
| Wilson's warbler | *Wilsonia pusilla* | M |
| **Tanagers** | | |
| western tanager | *Piranga ludoviciana* | S, M |
| **Sparrows** | | |
| spotted towhee | *Pipilo maculatus* | W |
| California towhee | *Pipilo crissalis* | Y |
| lark sparrow | *Chondestes grammacus* | W |
| savannah sparrow[a] | *Passerculus sandwichensis* | Y, B |
| grasshopper sparrow | *Ammodramus savannarum* | S |
| Suisun song sparrow[a] | *Melospiza melodia maxillaris* | Y, B |
| Lincoln's sparrow | *Melospiza lincolnii* | W |
| golden-crowned sparrow | *Zonotrichia atricapilla* | W, M |
| white-crowned sparrow | *Zonotrichia leucophrys* | W, M |
| dark-eyed junco | *Junco hyemalis* | W, M |
| **Cardinals and grosbeaks** | | |
| black-headed grosbeak | *Pheucticus melanocephalus* | S |
| **Blackbirds and allies** | | |
| red-winged blackbird[a] | *Agelaius phoeniceus* | Y, B |
| tri-colored blackbird | *Agelaius tricolor* | Y, B |
| western meadowlark | *Sturnella neglecta* | Y, B |
| Brewer's blackbird | *Euphagus cyanocephalus* | Y, B |
| great-tailed grackle | *Quiscalus mexicanus* | W |
| brown-headed cowbird | *Molothrus ater* | Y, B |
| Bullock's oriole | *Icterus bullockii* | S, B |
| **Finches** | | |
| purple finch | *Carpodacus purpureus* | W |
| house finch | *Carpodacus mexicanus* | Y, B |
| lesser goldfinch | *Carduelis psaltria* | Y |
| American goldfinch | *Carduelis tristis* | Y |
| **Old World sparrows** | | |
| house sparrow[b] | *Passer domesticus* | Y |

clapper rails indicated that California black rails are moderately to highly abundant: 0.65 to 1.90 rails per ha (Evens and others 1989; Nur and others 1997). Habitat associations at Rush Ranch and other areas in Suisun Bay included higher marsh elevation, and denser vegetation associated with freshwater influence, particularly stands of *Schoenoplectus* spp. (Evens and others 1989).

a Species documented nesting in tidal marsh at Rush Ranch.
b Non-native species.

Residency codes: Y: year-round; S: summer; W: winter; M: spring and/or fall migration; B: breeding documented or assumed at Rush Ranch and environs.

### *Surveys from 1996 to 2008*

PRBO Conservation Science initiated a regional program to study tidal marsh breeding birds in 1996 that has become one of PRBO's long-term data collection efforts in the western United States (Nur and others 1997). Rush Ranch was chosen as one of the sites representative of Suisun Bay tidal marsh habitat, and was a reference marsh used as a comparison with tidal marsh restoration sites in several studies in Suisun Bay (Nur and others 1997, 2003, 2004, 2005). Studies conducted at Rush Ranch have included the following:

- standardized point count surveys conducted during the breeding season, and, for some years, also during winter and migration periods: breeding season 1996–2007, fall 2002, and winter 2002–2003 (Nur and Spautz 2002; Spautz and others 2003; Liu and others 2007);
- standardized surveys for black rail, 2001–2002 (Spautz and Nur 2002; Spautz and others 2005);
- nest monitoring during 1996–2006 (Spautz and others 2001; Chan and others 2002; Herzog and others 2005; Liu and others 2006, 2007; Figure 1).

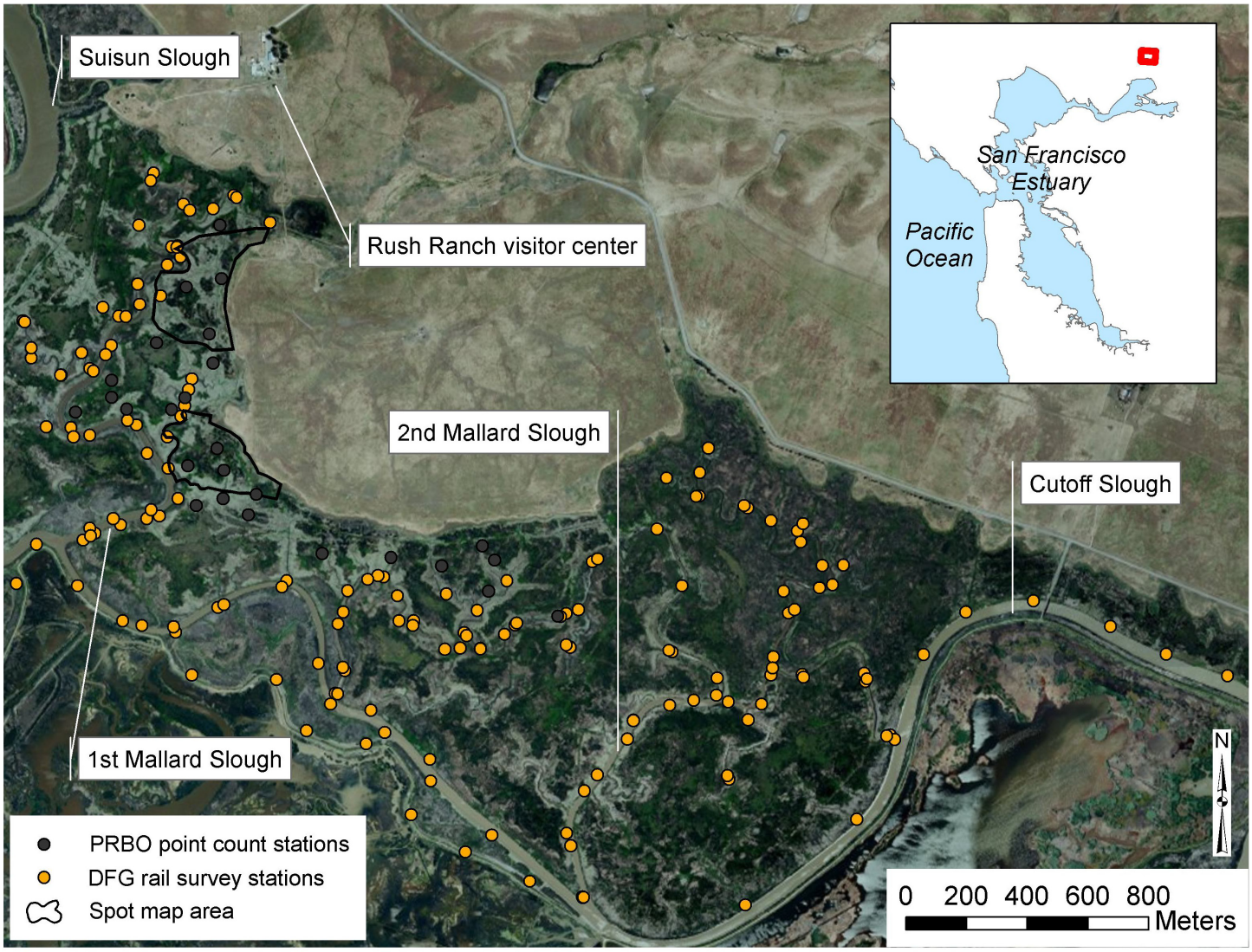



**Figure 1** Map of Rush Ranch study areas (1996–2008). Nest monitoring was conducted in spot map areas. Rush Ranch is a component site of the San Francisco Bay National Estuarine Research Reserve.

Most of these studies included collection of vegetation and other habitat characteristics in the field, and/or generation of landscape characteristics based on aerial photography analysis via Geographic Information System (GIS) to develop statistical models of habitat selection (see Spautz and others 2006 for methods). These models were developed to identify factors that may help predict marsh bird distribution, abundance, and reproductive success, and ultimately, to help inform tidal marsh habitat restoration efforts in Suisun Bay and the San Francisco Estuary as a whole (Nur and others 1997; Chan and others 2002; Spautz and others 2003, 2006; Spautz and Nur 2004).

PRBO surveys for black rails were conducted during the breeding season in 1996, 2000, and 2001 (Evens and Nur 2002; Spautz and Nur 2002). Surveys were conducted following a standardized tape call-back/response protocol (Evens and others 1991; Evens and Nur 2002). The protocol involves listening passively for 1 minute after arriving at the listening station, then broadcasting tape-recorded black rail vocalizations. At each station, black rails heard calling <30° apart were considered the same bird, and those >30° apart were considered different birds. Forty-three stations were surveyed in 1996, and 10 stations from 2000 to 2001. Survey stations were placed 100 m to 200 m apart. A black rail abundance index (birds detected per ha) was calculated using all detections within 30 m. Because black rails have been estimated to move toward the observer before vocalizing an average of 6.2 m (Evens and Page 1985; Evens and Nur 2002), it was assumed that the effective survey area had a 36.2-m radius.

Abundance of California black rails at Rush Ranch was 0.85 birds $ha^{-1}$ in 1996 (Evens and Nur 2002) and 0.97 birds $ha^{-1}$ in 2001 (Spautz and Nur 2002). In an earlier study (1988) in the same area of Rush Ranch, abundance was somewhat lower: 0.65 birds $ha^{-1}$ (reported in Nur and others 1997). We observed three California black rail nests, two of which were built in three-square (*Schoenoplectus americanus*) and one in Baltic rush (*Juncus balticus*) (Spautz and Nur 2002; PRBO unpublished data).

Analyzing black rail detections using general landbird/marsh bird survey methods (described below) rather than using playback surveys (which were only conducted in only 1996, 2000, and 2001), we have found that the density index of black rails has increased in recent years. The estimated trend for all Suisun sites ($n$ = 13 marsh sites) was a 10.3% increase per year (S.E. = 4.0%; z = 2.63, $P$ = 0.009) for the period 2000 to 2009, analyzing ln-transformed density index, fitting a linear model for year, and controlling for marsh site as a random effect (PRBO unpublished; SFEIT 2011). For Rush Ranch only, black rail density index from 2000 to 2009 increased at 14.2% per year (S.E. = 11.5%), consistent with the pattern seen at all Suisun sites, but also not significantly different from zero ($t$ = 1.57, $n$ = 10 yrs, $P$ = 0.16); fitting a linear model to ln-transformed density index (PRBO unpublished).

Habitat associations for California black rail, from an analysis of data for the entire estuary, included higher proportion of vegetation cover (all plant species), higher channel density, proximity to channels, proximity to the next closest marsh patch (a measure of patch isolation), and the proportion of natural upland in the surrounding area (Spautz and others 2006). Black rail probability of occurrence was positively associated with marsh size (Spautz and Nur 2002).

From 2002 to 2008, the California Department of Fish and Game (DFG) Bay–Delta Region conducted annual breeding season (January to May) call-count surveys for the California clapper rail and California black rail in Suisun Marsh (DFG 2002, 2003, 2004a, 2005, 2006, 2007, 2008; Figure 1). DFG provided annual summaries to the U.S. Fish and Wildlife Service (USFWS) and the California Department of Water Resources (DWR).

In 1981, the USFWS issued a Section 7 Biological Opinion (BO) to implement of the Suisun Marsh Plan of Protection (USFWS 1981; DWR 1984). In the BO, the USFWS included recommendations both for monitoring existing California clapper rail populations every 3 years, and for increasing potential habitat. After DWR and DFG conducted a survey in 1994 for a biological assessment, construction and maintenance activities in some areas of Suisun Marsh

became restricted at certain times of the year, based on breeding season detections (USFWS 1994). These areas were designated: Rush Ranch (Spring Branch), Joice Island, Mothball (Reserve) Fleet (Benicia), Cutoff Slough (including 1st and 2nd Mallard Branches), and Hill Slough. Both the Rush Ranch location and the Cutoff Slough location are within the boundaries of Rush Ranch. From 2002 to 2008, the DFG sampled these five areas where California clapper rails were last known to have breeding sites. The goal was to re-document their presence in these areas. In addition to these areas, the DFG sampled areas where populations may occur based on suitable habitat, past breeding season, or non-breeding-season detections. Survey locations varied from year to year (see "DFG rail survey stations," Figure 1).

Most listening stations were established every 200 m (depending on marsh characteristics) along waterways in, or adjacent to, marsh areas. Additional stations were located at the same intervals along marsh features such as existing trails, levees, or roads. Station locations were chosen to minimize the effect of observers on intact marsh vegetation and disturbance to rails.

Surveys were conducted at dawn or dusk using standardized breeding season call-count methods for California clapper rail (USFWS 2005). Between 1 hour before sunrise or sunset and 1 hour after sunrise or sunset, observers first listened passively at each station. If no presence was detected after 5 minutes, an audiotape of California clapper rail calls (i.e., "keks" and "clatters") was played for 1 minute, followed by an additional 4 minutes of listening. Typically, seven or eight stations were surveyed per 2-hour session. Calls from California black rail, Virginia rail (*Rallus limicola*), and sora (*Porzana carolina*) were also recorded.

Seven clapper rails were detected during these breeding season surveys in Suisun Marsh in seven survey years (2002–2008); two were within Rush Ranch and five were elsewhere. By contrast, clapper rail biologist detected eight in the fall during other field studies; six were within Rush Ranch and two were elsewhere.

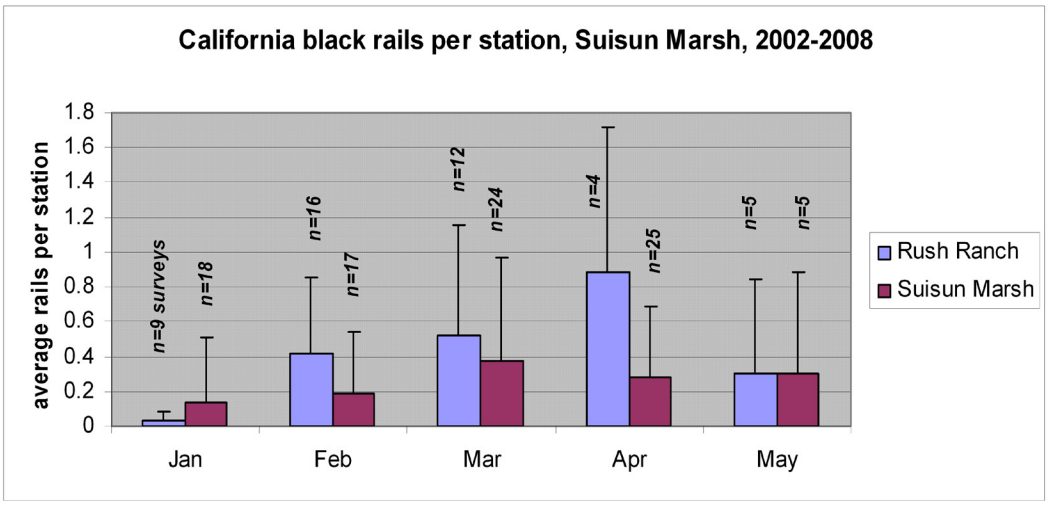
The average number of rails per survey station was calculated by dividing the number of individuals of that species detected during surveys that month by the total number of stations surveyed that month. California black rails were less vocal early in the year, reaching a peak in April (0.89 per station, Figure 2). By contrast, Virginia rails and soras were most often detected in January (1.47 and 0.51, respectively) and February (1.08 and 0.28, respectively; Figure 2). These annual surveys are expected to continue as funding permits.

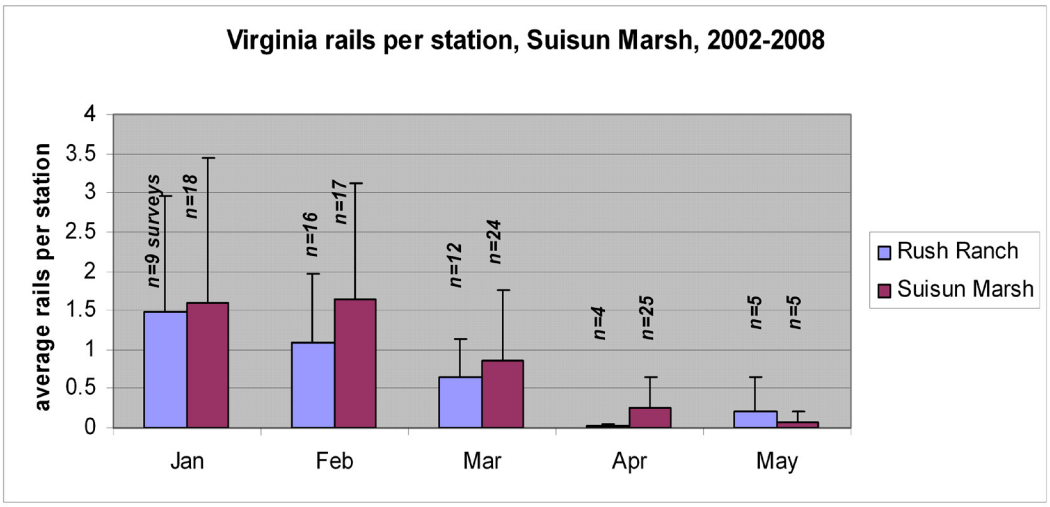
The Wildlife Habitat Data Analysis Branch of DFG conducts periodic vegetation surveys of the Suisun Marsh north of the Solano County line. The process uses aerial photograph interpretation in conjunction with ground verification, and GIS editing and processing. According to the photo interpretation, California clapper rails in Suisun Marsh were found primarily in vegetation which includes silverweed (*Potentilla anserina*), tule (*Schoenoplectus acutus* var. *occidentalis*), three-square, California bulrush (*S. californicus*), and cattails (*Typha* spp.); (CDFG 2000, 2004b).

### Suisun Song Sparrow, Common Yellowthroat, and Marsh Wren

PRBO Conservation Science's regional program for the study of tidal marsh breeding birds, initiated in 1996, included point count surveys for all bird species and nest monitoring and focused on song sparrow, common yellowthroat, and marsh wren (1996–2006; Spautz and others 2001; Chan and others 2002; Herzog and others 2005; Liu and others 2006, 2007; Figure 1).

At Rush Ranch, standardized point count surveys were conducted for all bird species at 10 to 20 stations placed at least 107 m apart in tidal marsh habitat (Nur and others 1997; Liu and others 2007; Figure 1). The number of birds of each species was determined during 5-minute point count surveys within 50 m of the point count. The density index was calculated as the number of detections per survey per ha of marsh habitat (see Spautz and others 2006). This index represented a minimum number of individuals, since it did not take into account detection probability, which is less than 100% (but see Nur and others 1997). The year-specific density indices



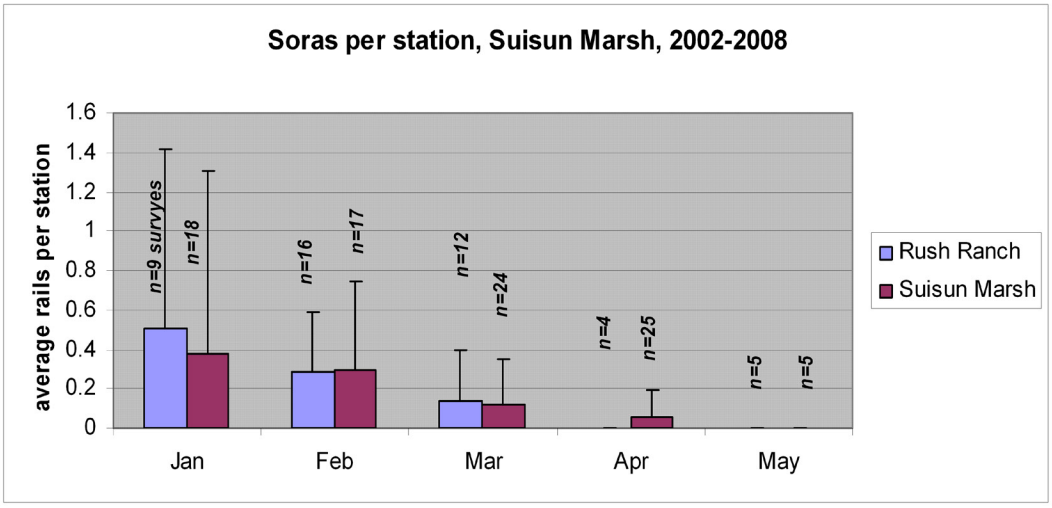




**Figure 2** The average number of California black rails, Virginia rails, and Sora per station, calculated by dividing the number of individuals of that species detected during surveys that month by the total number of stations surveyed that month. Suisun Marsh data include Rush Ranch and other sites surveyed in Suisun Marsh. Error bars are standard deviations.

were obtained by averaging over point count stations and survey visits. The statistical analysis included the natural-log-transformed mean density indices (Nur and others 1999) fitting either linear models with fixed effects for a single marsh site, or, when analyzing data from multiple sites, fitting mixed-effect models that included marsh site as a random effect (Kutner and others 2004).

Density indices for all species varied greatly across years at Rush Ranch, as well as in the rest of Suisun Bay and throughout the estuary from 1996–2007 (Liu and others 2007; SFEIT 2011).

Suisun Bay had higher density indices for common yellowthroat (geometric mean density = 1.23 birds ha$^{-1}$) and marsh wren (geometric mean density = 2.35 birds ha$^{-1}$) between 1996 and 2007, relative to the estuary as a whole (including Suisun Bay, San Pablo Bay, and San Francisco Bay; common yellowthroat geometric mean density: = 0.14 birds ha$^{-1}$; marsh wren geometric mean density: = 0.45 birds birds ha$^{-1}$; PRBO unpublished, SFEIT 2011). This is likely related to the strong association of these two species for the generally taller vegetation found in brackish tidal marshes (such as those in Suisun) rather than the shorter vegetation typical of more saline

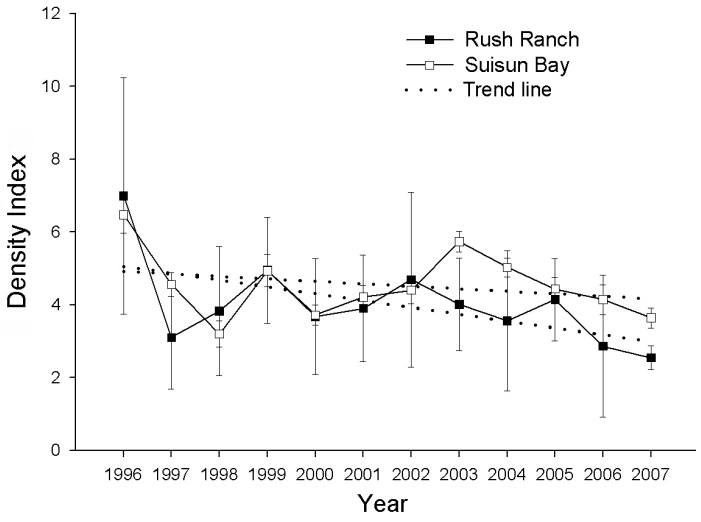



**Figure 3** Suisun song sparrow density index trends (mean + S.E.). Density index is number of birds detected per ha of surveyed area. Rush Ranch and all sites in Suisun Bay, 1996–2007 (Liu and others 2007; PRBO unpublished data). See text for statistics for trend line.

marshes in other portions of the estuary (Nur and others 2003; Spautz and others 2006). Plant communities in Suisun include cattail, various tule species, primarily alkali bulrush (*Schoenoplectus maritimus*) and three-square, and perennial pepperweed (Nur and others 1997; Spautz and Nur 2004; Spautz and others 2006). Research has shown a significantly positive trend between the presence of common yellowthroat and that of perennial pepperweed (Spautz and others 2006); for other bird species the association with pepperweed is neutral or only marginally positive (Spautz and others 2006).

There has been a marginally statistically significant downward trend in song sparrow density at Rush Ranch from 1996 to 2007 (–3.7%; 95% CI = –7.4% to 0.2%, $t = -2.12$, $n = 12$, $P = 0.060$, analysis of ln-transformed density index, fitting a linear model for year; Figure 3). At all other sites in Suisun Bay, the downward trend was even weaker, and it was not significant (–0.4% per year, S.E. = 1.9%; $P > 0.8$, $n = 85$ marsh-years [data from 27 marshes, each observed for 1 to 12 years], fitting a linear model for year, with site as a random effect, analyzing ln-transformed density index).

For the same period, 1996–2007, there was also a downward trend for song sparrows in San Pablo Bay marshes (–1.1% per year, S.E. = 0.8%; $P = 0.19$, $n = 177$ marsh-years, linear model for year, fitting site as a random effect, analysis of ln-transformed density index), although it is not statistically significant, while in San Francisco Bay the trend was positive and significant (+7.1%, 95% CI = 2.4% to 12.0%, $z = 2.99$, $P = 0.003$ $n = 187$ marsh-years, linear model for year, fitting site as a random effect). Density indices for Suisun song sparrow in Suisun Bay fall intermediately between San Pablo Bay (Samuel's song sparrow, *M. m. samuelis*) and San Francisco Bay populations (Alameda song sparrow, *M. m. pusillula*; Liu and others 2007). From 1996–2007, geometric mean song sparrow density indices in each year ranged from approximately 2.3 to 6.3 birds ha$^{-1}$ in Suisun (geometric mean over all years = 4.15), from approximately 4.3 to 6.6 birds ha$^{-1}$ in San Pablo Bay (geometric mean = 5.34), and from 1.0 to 7.9 birds ha$^{-1}$ in San Francisco Bay (geometric mean = 3.55 birds ha$^{-1}$; PRBO unpublished

data). Thus the song sparrow density index in San Francisco Bay was 11.4% less than the density index in Suisun Bay, but this was not significant (analysis of ln-transformed density index, controlling for linear year effect and site as a random effect, $z = 0.66$, $n = 284$ marsh-years, $P > 0.5$); at the same time the song sparrow density index in San Pablo was 32.5% (S.E. = 22.0%) greater than Suisun, but this was only marginally significant (analysis of ln-transformed density index, controlling for linear year effect and site as a random effect, $z = 1.69$, $n = 274$ marsh-years, $P = 0.09$).

Habitat associations for song sparrows throughout the estuary included the proportion of shrubs (marsh gumplant, *Grindelia stricta*, and coyote brush, *Baccharis pilularis*, neither of which are as common in Suisun Bay as they are in more saline areas), proportion of surrounding natural upland, and proximity to upland edge (Spautz and others 2006).

Intensive nest monitoring at Rush Ranch from 1996–2005 has produced data for 286 Suisun song sparrow nests. Each year a few nests of other species were found, including those of common yellowthroat, marsh wren, black rail, red-winged blackbird, and northern harrier (*Circus cyaneus*) (Liu and others 2007; PRBO unpublished data). Here we focus on song sparrow nest-monitoring; see Liu and others (2007) for detailed methodology. Field biologists searched for and monitored nests at seven marsh sites in San Pablo Bay and Suisun Bay. Nesting attempts were located at all stages (nest-construction, egg-laying, incubation, and nestling periods). All known nests were monitored using a standard protocol (Martin and Geupel 1993). Nests were usually visited every 2 to 4 days (median = 3 days; range: 1 to 9 days) with careful attention given to minimize human disturbance. Frequent visits to nests allowed relatively accurate estimation of the dates of predation events as well as the dates of egg laying, hatching of eggs, and fledging of young. Nest contents were recorded at each visit, at which time the nest was judged to be either still active (i.e., the brood had neither fledged nor failed) or no longer active (i.e., brood fledged or nesting attempt failed). The ultimate outcome of each nest (success or failure) was determined based on re-sighting of fledged young, or nest condition and behavior of the breeding pair (Martin and Geupel 1993). Nest survival rates—i.e., daily survival rates for a nesting attempt—were calculated using the Mayfield method, which takes into account the age of the nest when found, to produce an unbiased estimate (Mayfield 1975). Daily nest survival probabilities were then used to determine the total nest survival probability over the entire nesting period, which we report. The above protocol was used at the seven marsh sites over the period 1996 to 2007, for a total sample of 3,183 nesting attempts monitored and analyzed.

During 9 years of nest monitoring studies (1996–2002, 2004–2005), song sparrow annual nest survival probability over the entire nesting period at Rush Ranch showed a significant decrease between 1996 and 1997, from 0.219 (S.E. = 0.012) to 0.048 (S.E. = 0.023; $t = -5.47$, $P = 0.002$, fitting a linear model to year), and a significant increasing trend from 1997 to 2005 (beta = 0.0208 per year, SE = 0.0044, $t = 4.75$, $P = 0.003$; Figure 4, fitting a linear model to year). The result was that at Rush Ranch the 2 years with the highest nest survival were the first year (1996) and the last year (2005) of the study, both with a nest survival over the entire nesting period of about 0.22. Song sparrow nest survival at Rush Ranch was lower than at any other site monitored in the San Francisco Estuary for 4 of the

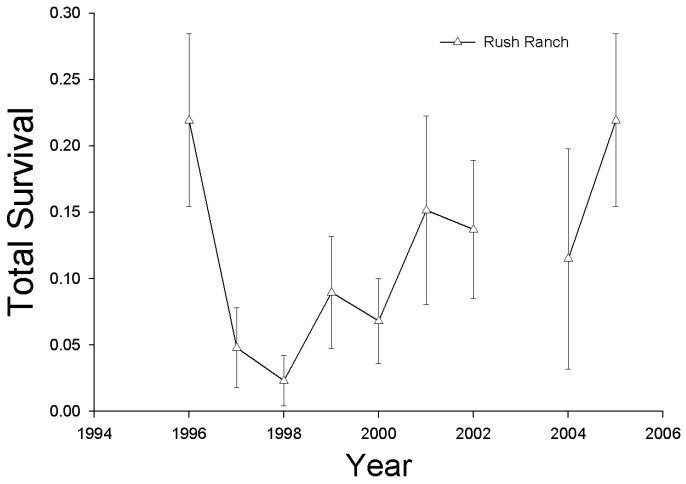



Figure 4 Suisun song sparrow nest survival probability for the entire nesting period in relation to year (mean + S.E.). Rush Ranch, 1996—2002, 2004—2005 (Liu and others 2007).

9 years and for those years nest survival was below 0.10 (Liu and others 2007, Figure 4). However, analyzing all years, nest survival at Rush Ranch was not significantly lower than the other six sites (from both San Pablo and Suisun bays, difference in nest survival probability = –4.59%, S.E. = 3.53%, $t$ = –1.30, $n$ = 43 marsh-years, $P$ = 0.20). High predation rates were the main cause of nesting failure (Spautz and Nur 2004; Greenberg and others 2006). Predation was also the most common fate of song sparrow nests in other parts of the estuary, although at other tidal marsh study sites a moderate proportion of nests were also lost to flooding during high tides; those sites have greater tidal ranges, and a higher likelihood of tidal flooding on the marsh plain than Rush Ranch (Greenberg and others 2006). For tidal marsh breeding birds, including song sparrows in the San Francisco Estuary, there is a trade-off between loss of nests to predation and flooding by high tides: nests built higher off the ground are depredated more often than nests built lower to the ground, but if they are lower to the ground they are more likely to be lost during high tides (Herzog and others 2005; Greenberg and others 2006).

Song sparrow nests have been found on virtually every type of plant at Rush Ranch, the most common being *Schoenoplectus* spp. (41%) and perennial pepperweed (13%) (Spautz and Nur 2004; PRBO unpublished data). There was no indication that nests built in pepperweed had a failure rate that was different from nests built in other vegetation (Spautz and Nur 2004).

Potential nest predators at Rush Ranch include mammals (rodents, raccoons, and skunks), snakes, and northern harrier (PRBO unpublished data). One hypothesis for higher predation rates at Rush Ranch than at other sites studied in the San Francisco Bay area is that Rush Ranch may have higher predator populations, or its physical structure is less likely to deter predation. It's possible that the combined factors of higher vegetation and reduced tidal inundation rates at Rush Ranch (relative to more saline marshes closer to the Golden Gate Bridge) may provide greater refuge during high tides for small mammals and snakes, the main predators of bird eggs in tidal marshes, resulting in higher densities of these predators within the marsh and in adjacent upland habitat. To our knowledge, however, this hypothesis has not been tested.

Nest survival for tidal marsh birds has been identified as a key indicator for evaluating estuarine health in the San Francisco Estuary (SFEIT 2011), including response to management actions, such as wetland restoration or enhancement. Because of the lack of funding, neither PRBO or others have monitored nests at Rush Ranch since 2005, or elsewhere in Suisun Bay since 2006. We therefore recommend that nest-monitoring be re-instituted at Rush Ranch and elsewhere in Suisun Bay, especially in light of recent findings that nest survival will likely respond strongly to future climate change (Nur and others 2012).

We do not know how the increase in perennial pepperweed is affecting the ecology of Rush Ranch, nor do we know the ramifications of the possible affinity of tidal marsh birds for pepperweed, as demonstrated by common yellowthroats. Specifically, we do not know whether spatial and temporal differences in plant structure and plant species are affecting (directly or indirectly) other species that are part of the food web, and how those differences might be affecting food availability, vulnerability to predation, and overall survivorship for yellowthroats and other bird species. A NERR-sponsored study is currently underway at Rush Ranch to examine differences in the food web between areas that have and have not been invaded by perennial pepperweed, based on stable isotope signatures of plant, invertebrate, and song sparrow tissues (C. Whitcraft and R. Wigginton, unpublished data). Results are expected in 2012.

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