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Breeding waterbird use of rice fields in southwestern Louisiana

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BREEDING WATERBIRD USE OF RICE FIELDS IN SOUTHWESTERN LOUISIANA

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ABSTRACT

Rice fields are agricultural wetlands concentrated in several areas in the U.S., including southwestern Louisiana. Rice fields are flooded for much of the year and support thick emergent vegetation, potentially providing high-quality habitat for several species of breeding waterbirds. The objectives of this study were to (1) determine relative nest density, nest success, and habitat associations of breeding waterbirds in southwestern Louisiana rice fields and (2) determine the effectiveness of callback surveys as a monitoring tool. In the summers of 2004 and 2005, marsh bird surveys and nest searches were conducted in Cameron, Jefferson Davis, Vermilion, and Acadia Parishes in southwestern Louisiana. In 2004, 42 fields were searched and 30 of those were surveyed. In 2005, 40 fields were searched and 60 were surveyed. Purple gallinules nested in the highest densities in both years, followed by fulvous whistling-ducks, king rails, common moorhens, and least bitterns. A total of 283 purple gallinule nests, 176 fulvous whistling-duck nests, 77 king rail nests, 59 common moorhen nests, and 12 least bittern nests were found. The highest nest densities for purple gallinules and king rails were in fields with a high proportion of irrigation canals around the perimeters and a low proportion of trees. High relative nest density for purple gallinules was also associated with a high proportion of rice fields within 1 km of each field. Fulvous whistling-ducks responded the least to the local and landscape characteristics, but were associated with a high proportion of soybean fields near rice fields. Birds began nesting at the beginning of June and most nests were terminated by the time of harvest. Nest survival, or the percentage of nests to hatch at least one egg, was between 52% and 79% for purple gallinules, ~50% for king rails, and ~40% for fulvous whistling-ducks. Most survey responses were detected in

June, and survey detections were concentrated in similar areas as the highest nest densities. Callback surveys were an effective technique for monitoring secretive marsh birds in this region.

CHAPTER 1

INTRODUCTION

Southwestern Louisiana is part of the ecoregion known as the Gulf Coastal Plain, which, prior to settlement, consisted of more than one million hectares of coastal prairie (Louisiana Natural Heritage Program 1987). The prairie was relatively wet, and was dominated by various grasses, rushes, sedges, and forbs. Trees grew only in riparian areas and occasional ridges, inhibited by an impervious clay pan that underlies the region (USGS 2000). The clay pan prevented root growth and also prevented water from percolating downward. Fire may also have played a crucial role in shaping the plant communities. Common hydric gradients created a juxtaposition of wetlands and uplands. The coastal prairie is virtually gone, existing only in small patches and on the fringes of marshes.

Beginning around 1815, rice began to be cultivated in southwestern Louisiana (Anonymous 2002). Currently, the Coastal Prairie region of southwestern Louisiana is composed of rice fields, interspersed with crawfish ponds, pastures, soybean fields, and fallow rice fields. The conversion to agriculture mimics a national trend of wetlands being drained for agriculture (Tiner 1984). Most mass-produced crops do little to replace habitat provided by wetlands, however rice and crawfish agriculture may be one exception (Fasola et al. 1996, Czech and Parsons 2002, Huner et al. 2002). Rice fields are flooded for much of the year, thus they potentially provide habitat for many wetland-dependent species (Elphick 2000). Because rice cultivation requires flooding and draining, fields can be considered temporary wetlands (Lawler 2001). Annually, rice fields are flooded while the rice grows and are drained for harvesting, and may or may

not remain dry until the following planting season. This hydroperiod mimics that of natural wetlands in many areas, and many animal species dependent upon seasonal wetlands use rice fields extensively (Lawler 2001).

Waterbirds, more than any other group of wildlife, have found refuge in rice fields worldwide (Czech and Parsons 2002). Most rice production occurs in Asia, where there has been little research on bird use of rice fields. However, in the Mediterranean region and several areas in the U.S. where little natural wetland area remains, waterbird use of rice fields can be substantial (Hohman et al. 1994, Fasola et al. 1996, Fasola and Ruiz 1996, Elphick 2000). Between 80 and 90 percent of natural wetlands have been lost in the Mediterranean region, and rice fields are a critical replacement (Fasola and Ruiz 1996). They are the predominant feeding areas for waterbirds, and the distribution and size of heronries depend on the configuration of surrounding rice fields (Fasola et al. 1996). During the breeding season, rice supports 50-100% of all herons in the region (Fasola and Ruiz 1996). In northwest Italy and Spain, a combined 10 bird species breed in rice fields (Fasola et al. 1996), although nest abundances are higher in natural marshes because cultural practices in the rice fields disturb breeding. If fields are left flooded into the winter, a large amount of waterbird prey can accumulate (Gonzalez-Solis et al. 1996). In the Ebro Delta, between 25 and 50 percent of all of the waders forage in rice fields in the non-breeding season (Fasola et al. 1996). In California, which has lost 95% of its natural wetlands, flooded rice fields are used extensively by waterbirds in the winter (Elphick and Oring 1998). Also, marsh bird behavior differs little from that found in natural wetlands (Elphick 2000). Food abundance, feeding efficiency, and time allocation were all similar for several shorebirds and wading birds in rice fields compared

with natural wetlands in the winter. In this respect, it appears that rice fields may replace some habitat functions that were once provided by natural wetlands.

In the Camargue, southern France, however, waterbird abundance and species richness are lower in rice fields than natural marshes (Tourenq et al. 2001). This region, unlike many others that are commonly studied, still retains a substantial surface area (59%) of natural wetlands, while only 22% of the region is in rice production. Also, flooding and drying times of rice fields deviate significantly from the timing found in natural wetlands. Similarly, a study conducted in Spain found that rice fields were of significantly lower quality than riverine wetlands for purple herons (Campos 2001). The herons spent more time in riverine wetlands and were significantly more efficient in capturing prey. Rice fields in Australia were also not preferred foraging habitat for egrets, with the exception of the cattle egret (Richardson and Taylor 2003). Only 5-13% of intermediate and great egrets in adjacent breeding colonies to rice fields foraged in rice. While not included in the study, it was assumed that the remainder foraged in natural wetland remnants, which were 8 km away from the colony. The rice fields were no more than 5 km from the colony.

Annually, more than 1 million ha of rice are planted in the U.S. (Chambers and Childs 2000), which are concentrated in the Mississippi Alluvial Valley, Gulf Coastal Plain, Arkansas, and Central Valley of California. The first rice was grown in Louisiana in 1718, however, it was concentrated in the Mississippi alluvial plain for the first 150 years (Anonymous 1999). In 1884 rice production began in the southwestern portion of the state, and the cultivated area increased rapidly. Approximately 225,000 ha were in rice production by 2000 in Louisiana (Huner et al. 2002), at least 175,000 ha of which

was in the southwestern portion of the state. Crawfish production also began in earnest in the 1970's (S. Linscombe pers. comm.), encompassing approximately 48,000 ha by 2000 (Huner 2000). Crawfish farms tend to be flooded when rice fields are not (Table 1.1), ensuring that water is present somewhere on the landscape year-round. Crawfish ponds help form a landscape of varying water depths and vegetation structure, and are heavily used by waterbirds (Huner 2000).

Waterbird use of rice fields in Louisiana is extensive (Hohman et al. 1994, Huner et al. 2002). Surveys over the past 12 years indicate that 86 waterbird species use rice fields in the Gulf Coastal Plain (Huner et al. 2002). These include breeding, resident, wintering, and migrating birds. In the winter, the area is important for waterfowl, raptors, shorebirds, and wading birds (Remsen et al. 1991). For wintering shorebirds, it was suggested that the rice-growing region of Louisiana is the most important inland area in the U.S. (Remsen et al. 1991). It is also believed that several wintering wading bird populations have increased significantly during the past three decades, while declining in several other parts of the country, because of the increase in rice and crawfish production in the region (Fleury and Sherry 1995). In the spring, wading birds continue to forage in rice fields, and shorebirds use them extensively during their northward migrations (C. Jeske pers. comm.). Recent shorebird counts estimate that for some species the number of shorebirds using rice fields in this area exceed previous estimates of the entire population (Wayne Norling and Clint Jeske, unpublished manuscript). Personal observations have also shown that at least one migrating rail species, the sora, also uses rice during its spring migration. In the summer, when rice is tall enough, at least six bird species begin to nest in rice fields. One of them, the fulvous whistling-duck, expanded its

range into the U.S. at the same time rice production became wide-spread (Hohman et al. 1996). Flooded rice fields support a variety of waterbird prey, including aquatic invertebrates, amphibian adults and larvae, and fish (Czech and Parsons 2002). Also, many of the emergent species grown in rice fields produce seeds, which are used by a variety of waterbirds (Meanley 1969). In October and November, when the second crop of rice is being cut, four species of rails can be found in rice, three of which use it for their southern migration (personal observation).

Breeding birds that use rice have received perhaps the least attention (Hohman et al. 1994, Helm et al. 1987). Learning about breeding birds is important for several reasons. First, little is known about the species that breed in rice, whether in rice fields or elsewhere in their range. A lack of population information is another reason the breeding bird community in rice fields requires attention. Most of the breeding birds either are not studied enough to determine population trends or are confirmed to be declining in several areas of their range. Most of these species have declined because of loss of wetland habitat in different parts of the country. The potential is great that a relatively stable refuge exists in rice fields.

Nesting Species in Rice Fields

Little is known about rallids as a group, three species of which breed in rice. Information is needed on their basic biology, life history, and population trends (Eddleman et al. 1988, Meanley 1992, West and Hess 2002). Of the rallids that breed in rice, king rails have received the most attention recently. They are of special concern because of population declines in several other areas of the country (Meanley 1992). As of 1992, northwestern Iowa, the Arkansas rice belt, and the southwestern marshes of

Lake Erie were areas of the most pronounced declines (Meanley 1992) and king rails are now threatened or endangered in 13 states (Reid et al. 1994). They are also on the American Bird Conservancy's Green List as birds of Highest Continental Concern. King rails are of increasing interest by several state and federal agencies, and are a major reason the current study was funded. Little is known about king rail populations in Louisiana. Rice fields provide structural characteristics that are similar to preferred habitat of king rails in marshes, and rice fields have been called 'optimum all-purpose habitat' for king rails (Meanley 1969). King rails lay on average one egg per day. Their incubation period is 21 days, which is the period from when all eggs are laid until the first egg hatches (Meanley 1992). Hatching then requires 24-48 hours.

Fulvous whistling-ducks, common breeders in rice, have been rarely studied (Hohman and Lee 2001). Fulvous whistling-ducks are so closely tied to rice fields that their range expansion into the U.S. in the mid- to late nineteenth century coincided with the expansion of rice agriculture, and they rarely nest anywhere other than rice fields in the U.S. (Hohman and Lee 2001). Many see fulvous whistling-ducks as agricultural pests, and they are actively hazed because of the perception that they eat too much rice seed (Hohman et al. 1996). Although their diet consists almost exclusively of seeds, data regarding how much of their diet consists of rice are inconsistent. Meanley and Meanley (1959) measured gizzard contents of fulvous whistling-ducks and found 78% of the contents to be rice, and claimed that rice ingestion was substantially higher in dry- vs. wet-seeded fields. Hohman et al. (1996) found rice to compose between 4% and 24% of fulvous whistling-duck diets in southwest Louisiana. They also suggested that fulvous whistling-ducks may provide services to rice farmers by consuming seeds of unwanted

plants. Flooding of rice fields can encourage nesting on levees, but most nests are built in fields following flooding. In Florida, fulvous whistling-ducks began nesting in rice fields when rice was >60 cm high (Wyss 1996). In southwestern Louisiana rice fields, mean clutch size of fulvous whistling-ducks was 13.4 (Hohman and Lee 2001). Eggs are laid at a rate of one per day. Incubation begins after the clutch is complete, and lasts 24-25 days.

Too little information also exists on purple gallinules to determine population status (West and Hess 2002). Purple gallinules also thrive in rice fields and bordering canals and ditches (Helm 1994, West and Hess 2002). The increase in rice acreage has helped to offset the loss of natural marshes for this species, as most of its ecological requirements during the breeding season appear to have been met by rice fields (Helm 1982, Hohman et al. 1994). They prefer areas with plentiful emergent vegetation that are interspersed with open water, and also require vegetative and invertebrate food sources. Vegetable matter, such as seeds, flowers, fruits, annual grasses, sedges, and rice grain, make up the largest part of their diet (West and Hess 2002). Hatchlings are primarily fed mollusks, crawfish, insects, and insect larvae. Floating vegetation is an important habitat component during breeding, and is essential for brood rearing (Helm 1982, Helm 1994). There is no reliable information on population status in the country, yet 31 states have a hunting season for purple gallinules (West and Hess 2002). Purple gallinule clutch sizes were larger in rice fields (8.6) than in marshes (5.8) (Helm et al. 1987). They lay one egg per day (West and Hess 2002). Incubation begins with the penultimate egg and lasts 18-20 days.

Common moorhens have experienced local population declines, as well as population increases in other areas, but are also lacking in population information (Bannor and Kiviat 2002). Common moorhens have similar ecological requirements to purple gallinules. Floating and submergent plants, as well as much vegetation-edge interface are preferred by common moorhens (Bannor and Kiviat 2002). They also consume mostly plant material, however, animals such as snails make up a larger part of their diet than gallinules. Preferred water depth for nesting is 15 cm-120 cm, which is deeper than rice fields. Nests are anchored to emergent vegetation and can be on the water surface or elevated. In Louisiana, moorhens laid significantly more eggs in rice fields (8.8) than in marshes (6.7) (Helm et al. 1987). This was attributed to a difference in food source between the two habitats. An increase in animal matter relative to vegetative food in rice fields may have allowed more eggs to be laid and more young to be raised (Helm et al. 1987). Although more eggs were laid in rice fields, less time was available to nest there. Between 122 and 131 days were available to nest in marshes, while 72-95 days were available to nest in rice fields. Moorhens and gallinules did not begin nesting until mid-May, when rice was between 80 and 90 cm tall, and rice was harvested at the end of July (Helm et al. 1987). Incubation can begin at anytime during laying and lasts 19-22 days (Bannor and Kiviat 2002).

Least bitterns were on the National Audubon Society's Blue List from 1971 to 1986, and sufficient data do not exist to determine population trends in any state (Tate 1986, Gibbs et al. 1992). Hohman et al. (1994) found that least bitterns had the lowest nest densities in the rice fields in their study. Least bitterns are on the Audubon Society's Blue List and are a species of national management concern (Tate and Tate 1982,

USFWS 1987). Marshes with dense emergent vegetation coverage interspersed with open water areas are preferred habitat (Gibbs et al. 1992). Least bitterns are primarily predatory, feeding primarily on small fish, crawfish, and insects. Feeding takes place on the edges of emergent vegetation, and is accomplished by clinging to the base of vegetation and stalking prey. Nests are built 15-76 cm above water 8-96 cm deep, and clutch size is 2-7.

Rice and Crawfish Management

Rice fields can be dry or flooded before planting, but stay flooded while the rice is growing. Prior to planting, seedbeds may or may not be mechanically prepared by tilling. Tilling, or water leveling, helps control weeds but costs more in labor and wear on equipment that not tilling (Anonymous 2000). As the name implies, water leveling is done in flooded conditions by turning the mud over. Reduced tilling regimes involve preparing the field in the spring or fall before planting, and allowing native vegetation to establish. Usually an application of the herbicide Roundup is required to reduce vegetation cover before planting. Farmers use reduced tillage in approximately 16% of the rice growing region of southwestern Louisiana (Acadia, Jefferson Davis, and Vermilion Parishes) (Anonymous 2002). Fields are planted anytime from early March to early May, but the peak time is from mid-March to early April. Water is generally held on fields for several weeks before planting to control weeds. Most fields are water-seeded; that is, seeds are dropped from planes directly into the water. Otherwise, the field is dry and seeds are either drilled or broadcast. In southwest Louisiana, the ideal time to begin planting is between March 20 and April 30, or when the average daily temperature is above 20° C (Anonymous 1999). To decrease to risk of blackbird

depredation, Wilson et al. (1989) recommended the later portion of that time period. Seeding early increases blackbird damage and increases the chance that re-seeding will be necessary. Following planting, water is drawn off the fields until 7-14 days after rice has sprouted (Hohman et al. 1994). If fields are dry seeded, they can be 'flushed' for approximately one day after seeding, then drawn down, and permanently flooded 7-14 days later.

The ideal plant stand is between 150 and 200 plants m^{-2}, and plants are approximately 1 m tall at maturity. The minimum height required for birds to begin nesting is 65-70 cm (personal observation). Rice generally attains this height in late May or early June. Water is held at 7-10 cm until 2-3 weeks before harvest at the end of July or early August (Huner et al. 2002). This offers birds 50-60 days of available nesting habitat.

Crawfish is also farmed extensively in southwestern Louisiana, providing an important complement to rice fields (Huner 2000). Crawfish ponds are flooded from late fall until the summer, depending upon the crawfish market in a given year. The timing of flooding ensures that water is available almost year-round for waterbirds. The structure in crawfish ponds is different than rice fields; as they support more diverse plant communities and water is deeper (30-50 cm; Huner et al. 2002). Also, because rice is grown in rotation with crawfish, and crawfish ponds are stocked, an influx of the important waterbird food into the system occurs every year. Farming crawfish in conjunction with rice provides an agricultural wetland matrix not found elsewhere in the country.

Management practices vary from year to year; and in a given year, from field to field. These differences may affect the suitability and availability of vegetation cover and food, and it is largely unknown how bird use may be affected. Timing of flooding and drying (Table 1.1) depend on the weather of a given year, and will dictate when fields are available for use by waterbirds. Which crops are raised in fields may be an influential factor in determining bird use. Fields with crawfish and rice may attract more nesting birds that consume crawfish than pure rice fields. Pure crawfish ponds may have more food in this respect than pure rice fields, but vegetation structure is significantly different between the two, and water is deeper in crawfish ponds. Another factor that could influence bird use is the tillage method. In reduced-tillage regimes, more vegetative matter is left post-harvest. It is possible that the increased vegetative matter hosts more invertebrates than tilled fields, thereby increasing bird use.

Management practices indirectly related to rice growing may be important to breeding waterbirds as well. An extensive system of canals and levees are used in rice fields to allow effective water management. Levees are built in rice fields and follow the contours of the land so that each section, or ‘cut,’ can hold water at equal depths. Levees are kept in a variety of conditions, from bare dirt to tall, thick vegetation. Those with more vegetation may increase cover for some waterbirds, but may also increase cover for mammalian predators. Canals and ditches may have similar consequences for bird use. Canals are used to increase the water level in fields and ditches are used to drain fields. Several rice fields have bordering canals and ditches that facilitate flooding and water removal. Like the levees, they are maintained with varying amounts of vegetation, and in different sizes. Canals and ditches provide a reliable source of open water with or

without vegetation. This variation in structure may provide feeding areas in addition to those provided in rice fields, and also may provide escape routes for birds following the hatching of young and before harvesting. The presence and absence of canals, as well as their structure, may affect bird use by holding varying amounts of cover. Every 2-3 years, levees and canals are 'cleaned' by mowing, applying herbicides, and dredging.

Table 1.1. Rough timing of flooding and drying in different management schemes in southwest Louisiana (Huner et al. 2002).

Rice	
Flood for planting	Early March – late May
Draining for harvesting	Late July – early August
Rice/crawfish	
Flood for planting	Early March – late April
Crawfish stocking	May
Draining for rice harvest	Mid-July
Re-flood for ratoon crop	Mid-August
Crawfish harvest	November – April
Crawfish	
Flooding	Spring
Draining	Early June – early July
Reflooding	Late August – early October
Harvesting	November - March

Justification

Information on local and landscape habitat characteristics that influence waterbird nest densities and nest success is needed to guide management and restoration efforts and to assess potential effects of land use changes or changes in farming practices on these species. It is possible that the structure of rice attracts waterbirds in fields, but high nest predation or nest termination caused by cultural practices harms populations, at least in some areas. An understanding of key habitat features could be used to encourage

landowners to implement favorable management practices for breeding waterbirds, if incentives are present to do so. Furthermore, the information could be used to prioritize fields to be included, or excluded, from wetland restoration efforts in the region.

There is also concern that rising production costs, low rice prices, and damages inflicted by Hurricane Rita may reduce the rice acreage in Louisiana. The price of rice has been decreasing for several years, and has been worsened by a rise in input costs. Diesel and fertilizer have risen steeply in the past year, making rice more expensive to produce. There was a drought in 2005, which required pumps to be run longer than normal, increasing the need for diesel. Adding insult to injury was Hurricane Rita, which destroyed most or all of the second crop rice. As of three months after the hurricane, salt water was still prevalent in the bayous and rice fields. In combination, these factors have caused rice to be unprofitable to produce for many farmers. If these conditions continue, rice acreage in southwestern Louisiana may be threatened. It is important, then, to realize the benefits provided by rice. In the case that rice acreage decreases, this study may provide a quantifiable estimate of the habitat that would be lost. Identification of the most important local and landscape factors that influence bird use and nest success in rice fields will enhance conservation efforts in the area by giving conservation priority to some fields over others. The U.S. Fish and Wildlife Service through the Gulf Coast Joint Venture of the North American Waterfowl Management Plan began leasing rice fields in 1988 (Hohman et al. 1994). There are currently 7,300 ha of these 'mini-refuges' in southwestern Louisiana. More data on the relative importance of differently managed fields for waterbirds would help in the placement of mini-refuges. Should other agricultural programs become more prevalent in the region, this study may provide

guidelines for how best to implement them for waterbird conservation. Also, data may help analyze current rice cultural practices in relation to waterbird use.

In the current study, the status of breeding waterbirds in southwest Louisiana was determined with two methods. Nest searches and nest monitoring were conducted to determine the relative nest density and the nest success of breeding waterbirds. Also, call-broadcast surveys were used to sample secretive marsh birds in rice fields, including king rails, purple gallinules, common moorhens, and least bitterns. Call-broadcast surveys are effective in sampling these marsh birds because they are more likely to call in response to calls of other individuals, and are rarely seen (Conway and Gibbs 2001). Desire exists to develop a monitoring program for rails in Louisiana, and the surveys conducted in this study may help in that effort. Also, correlations may exist between the number of responses and nest densities, which would also help in future monitoring efforts.

Objectives of this study were to 1) determine the relative nest density and nest success of breeding waterbirds, 2) determine the effects of rice management and landscape context on the nest density of waterbirds, 3) determine the site occupancy of marsh birds, and 4) determine the effectiveness of call-broadcast surveys in monitoring marsh birds in rice fields of southwestern Louisiana.

CHAPTER 2

WATERBIRD RELATIVE NEST DENSITY AND NEST SURVIVAL

Breeding marsh birds require robust emergent vegetation, such as cattails, sedges, rushes, and maidencane, as a substrate for nest building (Burger 1985). They build nests in the thick emergents either on the surface of the water or suspended in the vegetation above water. Bitterns, moorhens, gallinules, rails, and fulvous whistling-ducks use various water depths and generally require at least some water for the duration of the nesting cycle (Mitsch and Gosselink 2000). Foods required by these birds include moist soil seeds, aquatic invertebrates, vertebrates such as amphibians, and crustaceans (Burger 1985).

Rice fields mimic the breeding habitat of these waterbirds in many respects. Rice covers about 1.5 million km^2 worldwide, which makes it the most widespread crop in the world. About 90% of rice is grown in Asia, in addition to local concentrations in the Mediterranean, the Nile Delta, various parts of Africa, and the United States (Lawler 2001). In the U.S., rice is concentrated in the Central Valley of California; Arkansas; and the northwestern Gulf Coast, in Louisiana and Texas (Huner et al. 2002**,** Elphick 2004). By and large, rice agriculture requires some flooding and draining, which makes many of the fields temporary wetlands with the potential to provide habitat for waterbirds.

In Louisiana, rice fields are flooded for almost the entire growing season, and rice grows as a thick emergent wetland plant. It provides plentiful substrate for nest building, allowing at least superficial concealment from mammalian predators. Rice is shorter than many wetland plants, and therefore may not allow nests to be as concealed from avian predators. Foods in rice fields are plentiful, although in general, there are

fewer seeds relative to animal matter (Helm et al. 1987). Seeds still exist when rice matures, and there is often high seed production from moist soil plants in fallow fields and irrigation canals. Frogs and crawfish, preferred foods of king rails, are plentiful in the system.

An improved understanding of the effects of local and landscape scale habitat factors on nest density and nest success of breeding waterbirds in rice fields is needed. At the local scale, time to maturity, timing of planting, water management, planting method, and tillage regime are all factors that could influence nest density and nest success. Because waterbirds need proper structural characteristics throughout the breeding season (Burger 1985), the timing of planting, maturation time of rice, and the continued presence of water are important considerations. Rice is planted from early march to late April, during the breeding season for waterbirds in Louisiana, and most varieties of rice in Louisiana have maturation times of 110-120 days. It is of sufficient height for nesting for 50-60 days (Helm et al. 1987), thus maturation time should not currently be an issue as < ~30 days are needed from nest initiation to hatching for these species. Similarly, unlike some areas of the country, rice fields in southwestern Louisiana are flooded continuously from the time of germination until 7-14 days prior to harvest; thus water management should not be a major issue. Although plant density could affect nest abundance, Hohman et al. (1994) found that planting method did not affect plant density. Tillage may influence the habitat available by disturbing the vegetation substrate available for invertebrate colonization and moist soil seeds. Not tilling fields may leave this intact, thus preserving some of the food base for waterbirds.

Landscape context is also an important factor that affects species richness, abundance, and site occupancy for many avian species (Riffell et al. 2003, Warren et al. 2005, McMaster et al. 2005). The composition of the surrounding landscape influences abundance and reproductive success within habitat patches (Rodewald 2004, McMaster et al. 2005). Landscapes most commonly studied include patches of forest or grassland surrounded by varying amounts of urban development or agriculture (Robinson et al. 1995, Knutson et al. 2004, Parker et al. 2005). In this study, however, agriculture is the landscape matrix and the organisms of interest are dependent upon agricultural resources.

Several landscape features may be important to breeding waterbirds in this region. In some areas, rice fields are intermixed with freshwater marshes, which may provide waterbird habitat when rice fields are unavailable, depending upon how close rice fields are to marshes. Bird activity may then be increased in fields near marshes. Some of the most notable features juxtaposed with rice fields are irrigation canals and ditches. In the current study, they are not distinguished from one another and are referred to as canals. They can form part or all the perimeter of a rice field, and are more common in fields near bayous or other surface water. Fields far from surface water generally have fewer canals and rely more heavily on deep water wells. Canals can be deeper than rice fields, and commonly support different species of wetland plants. Other features and land uses occurring around rice fields that may influence nest abundance and nest success are fallow rice fields, crawfish ponds, soybean fields, and trees. Fallow fields support a diversity of moist soil plants and provide potential cover when active rice fields are being planted or harvested. They also provide a potential wintering ground for resident rails. Crawfish ponds support varying coverages of emergent and submergent

vegetation. They are flooded deeper than rice fields and are flooded throughout the winter, when rice fields may or may not be flooded. However, they are drawn down in early summer, which may interrupt nesting attempts by purple gallinules and common moorhens (personal observation). Soybeans, while likely of little value to breeding waterbirds, have a unique structure, as they are bare ground during the beginning of the breeding season and begin maturing while waterbirds are nesting. The presence and abundance of trees may also decrease nest densities because of their ability to support avian and mammalian predators.

The effects of local habitat characteristics and rice management practices on nest density and nest success of breeding waterbirds in rice fields have received little attention (Helm et al. 1987, Hohman et al. 1994, Wyss 1996) and I am unaware of any studies that have evaluated landscape effects. Helm et al. (1987) compared certain aspects of the breeding biology of purple gallinules and common moorhens in rice fields and marshes in southwest Louisiana. In two years of field work, they found 51 common moorhen nests and 70 purple gallinule nests in 24 ha of rice. They found 107 common moorhen nests and 47 purple gallinule nests in the marsh. Purple gallinules had an apparent nest success of 80% in the rice and 55% in the marsh. Common moorhens had an apparent nest success of 86% in the rice field versus 68% in the marsh. Hohman et al. (1994), also working in southwest Louisiana, investigated nest densities of breeding waterbirds in rice fields and compared them between dry- and water-seeded fields. They found five nesting species in 28 rice fields: king rails (15.9 nests/km^2), fulvous whistling-ducks (15.1 nests/km^2), purple gallinules (5.1 nests/km^2), common moorhens (<1

nests/km^2), and least bitterns (<1 nests/km^2). They found no difference between the two planting practices; they did not estimate nest success.

An improved understanding of the local and landscape habitat features important to breeding waterbirds in southwest Louisiana rice fields are needed to guide conservation efforts. The objectives for this study were to (1) estimate the relative nest density and nest success of each waterbird species nesting in rice, and (2) to determine the most important local and landscape factors that influence nest density and nest success.

Site Selection

Because few studies on breeding waterbirds have been conducted in this system, I used the first field season to explore an array of local and landscape features that may influence relative nest density and nest success. These data were analyzed and used to refine our hypotheses for the second field season.

In 2004 the study was based near the town of Thornwell in Jefferson Davis Parish (Figure 2.1). In February, 2004, locations of all active rice fields, crawfish ponds, and fallow fields within an approximate 320 km^2 area were recorded. A field was defined as any area enclosed by main levees, i.e., there was no exchange of water over the main levees to other fields. Also, each field was treated as one management unit. Of the fields for which landowner permission could be obtained, I randomly stratified by tillage regime and distance from a marsh. All fields were either no-till or conventional-till, and were put into two distance classes: 0-2 km from the marsh, and $\geq$ 2 km. I chose 32 rice fields, all of which were searched; except two in which permission was only given to survey. When time was available, other rice fields, commonly adjacent to other searched

rice fields, were searched. In total, 42 rice fields were searched. Of those, 12 were no-till and were in the farther distance class, as no rice fields within 2 km of the marsh were no-till. Of the conventionally tilled fields, 12 were within 2 km of the marsh. Also, before the rice fields supported sufficient nesting habitat, six crawfish ponds were searched.

Figure 2.1. Approximate study locations.

Results from 2004 indicated that the proportion of surrounding canals and trees were the most important variables for analysis (see below). Site selection in 2005 explored these features. The study area also expanded in 2005 to gather information on a larger area and to visit some of the areas studied by Hohman et al. (1994). Furthermore, some of my results in 2004 differed from Hohman et al. (1994), however, his study areas

were farther east and inland. To address these issues in 2005, I expanded to new areas, including fields near Crowley, Morse, and Kaplan (Figure 2.1). All fields for which permission could be gained within an approximate 940 km^2 area were considered. Fields were stratified first based on location, to ensure equal numbers of fields were searched in both areas. Each field was also classified into categories based on the proportion of surrounding canals and trees: low, medium, and high coverage. Criteria for canals were <20% of the field edge for low, 20% - 49% for medium, and >50% of the field edge for high. Criteria for trees were 0-1% of the field edge for low coverage, 1-29% for medium, and >30% for high coverage. All fields were put into one of the nine categories, and some were randomly selected from each. This ensured that a full range of canal and tree coverage was sampled, as well as combinations of each. In each area, 30 fields were chosen to be searched. Total numbers chosen are given in Table 2.1. Midway through the season, logistical problems with the field crew prevented all fields from being searched, allowing only 40 to be searched, which are shown in Table 2.2. The limiting factors were fields with high canal coverage and high tree coverage, of which only two were found.

Table 2.1. Numbers of fields chosen for 2005 field season. 'Canals' refers to the proportion of the perimeter of each field bordered by canals. Low = <20%, medium = 20-49%, and high = >50%. 'Trees' refers to the proportion of the perimeter of each field bordered by trees. Low = <1%, medium = 1-29%, and high = >30%.

		Trees		
		Low	Medium	High
Canals	Low	7	7	4
	Medium	14	6	5
	High	8	7	2

Table 2.2. Numbers of fields searched in 2005. 'Canals' refers to the proportion of the perimeter of each field bordered by canals. Low = <20%, medium = 20-49%, and high = >50%. 'Trees' refers to the proportion of the perimeter of each field bordered by trees. Low = <1%, medium = 1-29%, and high = >30%.

		Trees		
		Low	Medium	High
Canals	Low	5	4	2
	Medium	13	3	3
	High	6	3	1

Tables 2.3a and 2.3b. Fields searched in each area in 2005. Left table is the original Thornwell area, right table represents the new areas in Acadia and Verimilion Parishes. 'Canals' refers to the proportion of the perimeter of each field bordered by canals where low = <20%, medium = 20-49%, and high = >50%. 'Trees' refers to the proportion of the perimeter of each field bordered by trees where low = <1%, medium = 1-29%, and high = >30%.

a)

		Trees		
		Low	Medium	High
Canals	Low	2	1	2
	Medium	5	1	1
	High	5	3	1

b)

	Trees		
	Low	Medium	High
Low	3	3	0
Medium	8	2	2
High	1	0	0

Methods

Each field was systematically searched for nests by a crew of 2-4 people walking 10-20 m apart. Crews walked parallel rows until the entire field was covered. Nests were found by observing flushed birds or by finding bent down rice used for nest construction. Cursory searches were conducted where birds were heard periodically until nests were found. The minimum height for nest construction appeared to be ~70 cm,

which was used as the minimum height to search all fields. Searches began at the end of May in 2004, and at the beginning of June in 2005. In 2004, 17 of the fields were searched twice; in 2005 four fields were searched twice. For both years, nest densities include only the second searches. At each nest, water depth, number of eggs, distance to the nearest levee, and GPS coordinates were recorded. For nests that would be difficult to relocate, flags were used on the perimeter or on a levee. At all nests, care was taken to minimize disturbance to the surrounding rice. When flags were used, someone other than the person who found the nest tied the flag, so a trail was not created from the nest to the flag. Each nest was visited once every 6-10 days until termination. At each visit the number of active eggs, hatched eggs, and chicks were recorded. Nests that hatched at least one egg were considered to be successful. With the exception of least bitterns, all of the birds studied are precocial, so the presence of chicks in the nest was not a reliable method for determining nest success. More often there were either fewer eggs than the previous visit or there were hatched eggs with the remaining active eggs. In both cases, remaining eggs were warm, indicating that they were still being incubated, and nests were still intact. The outcome of some nests could not be determined. Most often, this was because a nest was found after it had terminated and not enough evidence remained to determine nest fate. Nests that were found after they had terminated were used in estimates of relative nest density, but not in survival estimates. Those nests did not appear to have any difference in detection probability.

Data Analysis

<u>Nest Density</u>

Data were analyzed separately for the two field seasons because the first season was largely exploratory and used to develop models to test in 2005.

To obtain nest densities, total nests for each species in each field were divided by the field area. For the fields searched twice, only the second totals were used for density calculations, so not all of the found nests were used. In ArcView, each searched field was identified and digitized, as were all of the surrounding fields. Bordering canals, tree lines, and tree stands were also digitized. The perimeter of each field was measured, and the proportion of the perimeter surrounded by different land uses and features was calculated. The perimeter of each field was classified as trees, rice, crawfish, pasture, fallow, or soybean. Proportion of surrounding canals was independent of these land uses (one side of a field could be bordered by a canal and any other land use). In 2005, the perimeter land uses were measured as well as the land uses within 1 km of each field edge. The presence of any tree on the edge of each field was measured, whereas only areas with substantial tree lines or tree stands that could be detected from aerial photography were measured at the 1 km scale.

In 2004, factors other than land uses were measured, including tillage regime, distance from a marsh, and week of planting. Tillage was classified as either no-till (coded as 0) or conventional till (coded as 1). The main marsh in the area was a large impounded marsh at Lacassine National Wildlife Refuge, and distance was calculated from it to each rice field. There were eight weeks in which rice planting occurred. These were recorded and measured as weeks 1-8. Too few no-till fields were identified in 2005

to adequately test tillage effect. Planting date appeared to be unimportant in 2004 and was not measured in 2005. Distance to a marsh appeared to be unimportant in 2004, but was measured in 2005 because a larger geographic area was included, and distance could be measured on a larger scale.

Multiple regression was used to determine the most effective models to explain variation in nest density and to determine which landscape and management variables were the most important for each species. All variables were standardized with a mean of 0 and a standard deviation of 1. The response variable was the log of the nest density plus 1. One was added to each density so a log could be calculated; and densities were log transformed to achieve normally distributed residuals. In 2004 measured variables were planting date, tillage, distance from a marsh; and proportion of field perimeter in canals, trees, rice, crawfish, fallow, and soybean. In 2005 the variables measured were the proportion of the field perimeter in canals, trees, rice, fallow, soy, crawfish, and other; and the proportion of the area within 1 km covered by each feature. The variable 'other' consisted of anything other than agriculture, which was either residential area or open water; and was only measured at the larger scale. The variable 'canals' was measured as a proportion of the perimeter of each field for the fine scale, and as the total length in the broad scale. Also, the distance from a marsh was measured. Because it did not correspond to the other scales, it was analyzed separately. Separate models were constructed for local and landscape variables.

To determine the simplest, most effective models, the information-theoretic approach advocated by Burnham and Anderson (2002) was used. Using this approach, a set of candidate models are chosen a priori, usually with some background knowledge

about the system being studied. Candidate models are similar to hypotheses, but do not have the 'null vs. alternative' structure that most hypotheses do. Also, as there are several candidate models for each response variable, there are several hypotheses. For this study, 2004 was used to collect background information and all possible models were run. These models were used to develop candidate models for 2005. An AIC (Akaiki Information Criterion) value was calculated for each candidate model, and the model with the lowest AIC was chosen as the simplest, most explanatory model. In 2004, some samples were not independent because fields were adjacent to one another, so PROC MIXED was used in SAS (see below). This procedure uses likelihood and calculates AIC as $-2\log(L(\theta|y)) + 2k$. The expression $L(\theta|y)$ refers to the likelihood of each parameter, θ, given model 'y.' AIC operates on the principle of parsimony, which strives to reduce the number of parameters in the chosen models. This is evident in the 2k term in the formula for AIC. The variable k is the number of parameters in each model, so the higher the value of 'k', the more difficult it is for that model to maintain a low AIC. For this study, AIC_c was used, which is a small-sample modification of AIC. Its formula is $AIC + 2K(K + 1)/(n-K-1)$ where K is the number of parameters in each model and n is the sample size. This is used when there are relatively few samples per variable measured.

After the best model was chosen, the difference in AIC_c (ΔAIC_c) was calculated to determine how close other models were to the best (lowest AIC_c). This is beneficial because there is always some level of uncertainty that the chosen best model is actually the best, i.e., if the same data are collected over again there is some chance that a different model will be the best. It is therefore helpful to view other plausible models to

gain inferences on other important variables. Rough guidelines given by Burnham and Anderson (2002) are that differences from 0 to 2 have substantial support, 4-7 have considerably less support, and 10 and higher have essentially no support for being the best model. Each model was also assigned an Aikaike weight (w_i), which is calculated as $e^{-1/2\ \Delta AIC} / \ \Sigma\ e^{-1/2\ \Delta AIC}$. The weight of each model is the percent chance that each model is actually the best given the variables measured. To determine the relative importance of each variable, the weight of each model with a given variable was added. This calculation requires that there is a balance in the number of models that contain each variable. To achieve this balance, and just for the purpose of this calculation, all possible models were run. For each candidate model, AIC_c, ΔAIC_c, and w_i were calculated. Also, r-squared values were calculated to determine the percent of variation in nest density that each model explained.

In addition to the multiple regression models, two-tailed t-tests were conducted for several of the variables, comparing the fields with and without nests of each species. For most of the tests, the two samples had equal variances; for those with unequal variances, the Satterthwaite method was used to calculate degrees of freedom and p-values.

Analyses were conducted separately for each species with greater than 30 nests, and for each species for which residuals could be normalized. In 2004, several fields were adjacent to one another, causing a possible problem with sample independence. When calculating the multiple regression models, this was rectified using the MIXED Procedure in SAS. All contiguous fields were assigned the same number and the 'random' statement was used. This accounts for the spatial correlations among fields of

the same block. This is also the reason that r-squared values are not presented for 2004. Proc MIXED uses likelihood, whereas least squares are required for the calculation of r-squared values. In 2005, Proc REG was used, which uses least squares and is able to calculate r-squared values. Based on 2004 data, candidate models for 2005 were:

Purple gallinule perimeter
Canals
Other
Trees
Canals + rice
Canals + trees
Canals + fallow
Canals + rice + trees
Canals + rice + trees + fallow

Purple gallinule 1 km
Rice + trees
Other
Canals
Canals + rice
Canals + trees
Canals + craw
Canals + trees + rice + craw
Canals + trees + rice + soy + craw

King rail perimeter
Canals
Trees
Canals + trees
Canals + fallow
Canals + craw
Canals + rice
Canals + rice + trees
Canals + trees + fallow + craw + rice

King rail 1 km
Canals
Trees
Canals + trees
Canals + craw
Canals + rice
Canals + rice + trees
Canals + fallow
Canals + trees + fallow + craw + rice
Other

Fulvous whistling-duck perimeter
Soy
Soy + canal
Soy + fallow
Canal
Canal + trees
Soy + trees
Soy + canal + trees
Soy + canal + trees + fallow + rice
Soy + rice
Canal + rice

Fulvous whistling-duck 1 km
Soy
Soy + canal
Soy + fallow
Canal
Canal + trees
Soy + trees
Soy + canal + trees
Soy + canal + trees + fallow + rice
Soy + rice
Canal + rice

Nest Survival

Nest survival was also examined in 2004 and 2005. Nest survival is measured as the percentage of nests that hatch at least one egg. Because most of the species nesting in

rice are precocial, hatching is synonymous with fledging. This is important information in conjunction with nest density. If nest density is high but nest survival is low, the area would generally be of low habitat quality. This could be the case in the rice-growing region of Louisiana if rice is attractive for nest sites but cultural practices are such that nests are destroyed or disturbed before they hatch.

The Mayfield method (1961, 1975) and Johnson's (1979) modification to this method were used to determine nest survival, which is the percent of successful nests. A successful nest was defined as a nest that hatches at least one egg. These methods reduce bias that would be inherent if the number of successful nests was simply divided by the total number of nests. This bias exists because nests are commonly found during incubation, when they have already survived a given amount of time (Mayfield 1961). Any nests that failed before that time would not be taken into account.

The Mayfield method uses exposure to calculate the daily survival rate for each species. Exposure is expressed in nest-days, which is the total number of days that nests were observed. A nest found one day and checked the next accounts for one nest-day, and checked five days later accounts for five more nest-days. Likewise, two nests found one day and checked three days later account for six nest days. The daily survival rate is then raised to the power of the days it takes from laying the first egg to hatching the first egg to estimate the nest survival rate.

Johnson (1979) modified Mayfield's method by relaxing the assumption that exact time of failure is known. This is helpful because unless nests are visited very often, time of failure is unknown. The method also uses a maximum likelihood estimator. Both methods assume that daily survival rate is constant, and both yield similar estimates.

Mayfield logistic regression was used to determine if any of the local and landscape variables were related to nest survival (Hazler 2004). This method incorporates the exposure time of each nest and uses nest failure or success as the binomial response variable. Each variable used to evaluate variation in nest density was used to estimate variation in nest survival. Each was standardized with a mean of 0 and standard deviation of 1. These were all stand level measurements, made at the rice field level. Because there are not measurements made on each nest, using each nest as an independent sample appears to be a case of pseudo-replication. This was compensated for by using the AGGREGATE option in PROC LOGISTIC, which groups the nests on the basis of the stand-level variables (Hazler 2004). Only nests that had observation days were used in this analysis. Therefore, nests that were depredated when initially found could not be used. Analyses were conducted for all species with adequate sample sizes ($n > 30$).

Results

In 2004, nest searching began May 25 and lasted until July 15. Fields with the tallest rice at the beginning of the period were searched first. Rice at that time was 65-70 cm tall, and most nests found at that time had only recently initiated. Minimum height of rice for purple gallinules and king rails to begin nesting was 65 cm, whereas minimum height for fulvous whistling-ducks was 75 cm.

A total of 250 nests were found in the first field season, consisting of 136 purple gallinule, 37 king rail, 37 fulvous whistling-duck, 30 common moorhen, 6 mottled duck, three least bittern, one black-necked stilt, and one common nighthawk (Table 2.4). Nests were found in 32 of 42 fields searched. In 2005, 365 nests were found (Table 2.4). Of

the 40 fields searched, nests were found in 30. The difference between yearly nest totals was mostly due to a substantial increase in the number of fulvous whistling-duck nests (2004—37; 2005—139). Mean clutch sizes were consistent among species between years (Table 2.5). Nest survival was also consistent except for the purple gallinule, which increased from 52% to 79% (Table 2.5).

Table 2.4. Total nests and relative nest densities of each species in both years.

	Total nests		Relative nest density (nests/km^2)		Most nests/field		Mean nests/field $\pm$ 1 s.e.	
	2004	2005	2004	2005	2004	2005	2004	2005
Purple gallinule	136	147	13.5 $\pm$ 2.6	16.0 $\pm$ 6.1	21	33	2.8 $\pm$ 0.60	3.3 $\pm$ 1.1
Fulvous whistling-duck	37	139	3.0 $\pm$ 0.67	13.7 $\pm$ 3.3	6	22	0.76 $\pm$ 0.20	3.3 $\pm$ 0.82
King rail	37	40	3.4 $\pm$ 0.87	4.8 $\pm$ 0.93	4	4	0.71 $\pm$ 0.17	0.98 $\pm$ 0.20
Common moorhen	30	29	2.6 $\pm$ 0.76	2.8 $\pm$ 1.0	4	6	0.52 $\pm$ 0.16	0.70 $\pm$ 0.24
Least bittern	3	9	0.30	0.92 $\pm$ 0.45	1	3	0.071 $\pm$	0.23
Mottled duck	6	0	0.60	0	1	0	0.14 $\pm$ 0.055	0.0
Black-necked stilt	1	1	0.03	0.03	1	1	0.024 $\pm$ 0.024	0.025 $\pm$ 0.025
Common nighthawk	1	0	0.03	0	1	0	0.024 $\pm$ 0.024	0.0
Total	250	365	23.0	38.0	26	42	4.9 $\pm$ 0.87	8.5 $\pm$ 1.7

Purple Gallinules

Purple gallinule nests were found in 27 of the 42 fields searched in 2004, and 20 of 40 fields in 2005. Relative nest densities ranged from 0 to 78 nests/km^2 in 2004, and from 0 to 205 nests/km^2 in 2005. The best model in 2004 includes only perimeter canals, and includes only perimeter canals and trees in 2005 (Table 2.6). The most important factor in both years was the proportion of canals surrounding the perimeter (Figures 2.2

and 2.3). Fields with purple gallinule nests had a higher proportion of canals around the perimeters than in fields without in 2004 (with – 0.39 $\pm$ 0.05; without - 0.14 ± 0.05; t=3.20, df=40, *P*=0.003) and 2005 (with – 0.49 $\pm$ 0.0041; without – 0.20 ± 0.045; unequal variances - t=3.98, df=30.4, P=0.0004). The earliest nest initiated was estimated to be on May 22, the latest initiation date was July 12, and the mean initiation date was June 13.

Table 2.5. Mean clutch sizes and nest survival of each species in both years. Survival estimates for the last four species are blank because too few nests were found to calculate an estimate. Results are not given for the last four species because too few nests were found to calculate daily survival rate or Mayfield survival rates.

	Mean Clutch Size		Daily Survival Rate		Mayfield Survival	
	2004	2005	2004	2005	2004	2005
Purple gallinule	7.95 $\pm$ 0.14	7.76 $\pm$ 0.14	0.985 $\pm$ 0.0042	0.991 $\pm$ 0.0019	51.8	79.4
Fulvous whistling-duck	12.41 $\pm$ 0.55	12.37 $\pm$ 0.56	0.958 $\pm$ 0.017	0.981 $\pm$ 0.0021	38.8	42.6
King rail	9.32 $\pm$ 0.35	9.06 $\pm$ 0.35	0.979 $\pm$ 0.0058	0.977 $\pm$ 0.0074	52.1	50.3
Common moorhen	8.14 $\pm$ 0.58	8.60 $\pm$ 0.27				
Least bittern	4.67	3.63				
Mottled duck	8.33	N/A				
Black-necked stilt	3	1				
Common nighthawk	2	N/A				

A total of eight nests were found in crawfish ponds in 2004. Of those, only one was successful. The rest were abandoned when water was drawn down at the end of the crawfish season.

In 2005, nest density was similar between the original area studied (22.9 $\pm$ 10.7 nests/km^2) and areas further east and inland (7.5 $\pm$ 1.8 nests/km^2; P=0.21). However, 112 nests were found in the original area and only 35 were found in the areas further inland.

The earliest initiation date was estimated to be May 23, the latest was July 11, and the mean was June 16. The most important factor at the 1 km scale was the proportion of active rice fields (Figure 2.3). Fields with purple gallinule nests had a higher proportion of rice fields within 1 km of the field edge (0.45 $\pm$ 0.029) than fields without nests (0.32 $\pm$ 0.028; *P*=0.0022). The proportion of trees around fields with purple gallinule nests (0.096 $\pm$ 0.028) was not lower than fields without nests (0.16 $\pm$ 0.040; t=1.24, df=40, *P*=0.22) in 2004; however it was lower in 2005 (0.045 $\pm$ 0.022 with nests, 0.14 $\pm$ 0.048 without nests; unequal variances - t=1.80, df=26.6, *P*=0.083). Purple gallinule clutch sizes were similar between years (Table 2.5).

Purple gallinule nest survival increased from 52% to 79% from 2004 to 2005 (Table 2.5). In 2004, 21 nests were found post-fate; 11 of those were unsuccessful and 10 were successful. A total of seven nests were abandoned when fields were de-watered before harvesting. An additional 18 nests were depredated; two were avian and 16 were mammalian. In 2005, 36 nests were found post-fate; three of those were unsuccessful, the causes of two were unknown, and 31 were successful. A total of eight nests were depredated by mammals, and two were abandoned. The abandonment was not the cause of de-watering. Logistic regression indicated that none of the measured characteristics were related to nest survival in either year (Tables 2.7, 2.8, and 2.9). Included in the analysis in 2004 were 95 purple gallinule nests, of which 16 failed; and in 2005, 106 nests, of which nine failed.

Table 2.6. AIC best models explaining the variation in purple gallinule nest density. In the perimeter models, ‘Canal,’ ‘rice,’ ‘tree,’ and ‘soy’ refer to the proportion of each around each fields’ perimeter. ‘Week’ refers to the week rice was planted, ‘distance’ refers to the distance of each field to a marsh, and ‘tillage’ refers to the tillage regime of each field. A negative tillage estimate is equivalent to an association with no-till fields. In the 1 km models, each variable refers to the proportion it covers within 1 km of each field edge. ‘Canal’ refers to the total length of canals within the field edge.

Perimeter, 2004	Δ AIC$_c$	W$_i$
0.57 canal	0	0.22
0.49 canal + 0.18 rice	0.8	0.15
0.58 canal – 0.15 craw	1.2	0.12
0.55 canal – 0.12 trees	1.7	0.094
0.56 canal – 0.090 distance	2.0	0.081
0.56 canal + 0.072 soy	2.2	0.073
0.58 canal + 0.064 week	2.2	0.073
0.51 canal – 0.12 craw + 0.15 rice	2.5	0.063
0.57 canal – 0.027 fallow	2.5	0.063
0.58 canal – 0.062 tillage	2.5	0.063

Perimeter, 2005	r^2	Δ AIC$_c$	W$_i$
0.40 canal – 0.15 trees	0.39	0	0.29
0.42 canal	0.35	0.8	0.25
0.42 canal – 0.16 trees – 0.07 rice	0.40	2.0	0.11
0.41 canal – 0.21 trees – 0.13 rice – 0.10 crawfish	0.42	4.2	0.036
0.43 canal – 0.039 rice	0.35	2.7	0.078
0.42 canal – 0.019 crawfish	0.35	2.5	0.085
-0.18 trees	0.068	14.6	0.00019
-0.17 trees + 0.044 rice	0.071	17.0	0.000061
0.084 rice	0.014	16.9	0.000055
1 km, 2005			
0.17 canal + 0.31 rice	0.34	3.3	0.049
0.38 rice	0.30	3.4	0.046
0.18 canal + 0.32 rice + 0.053 trees	0.34	5.7	0.015
0.38 rice – 0.0032 trees	0.30	5.9	0.013
0.18 canal + 0.32 rice + 0.053 trees – 0.0097 crawfish	0.34	8.4	0.0037
0.30 canal	0.19	9.2	0.0025
0.27 canal – 0.12 other	0.22	10.2	0.0015
0.31 canal + 0.012 crawfish	0.19	11.7	0.00074
0.30 canal – 0.013 trees	0.19	11.7	0.00074
-0.19 other	0.072	14.4	0.00019
-0.14 trees	0.040	15.8	0.000094
Distance	0.002	17.0	

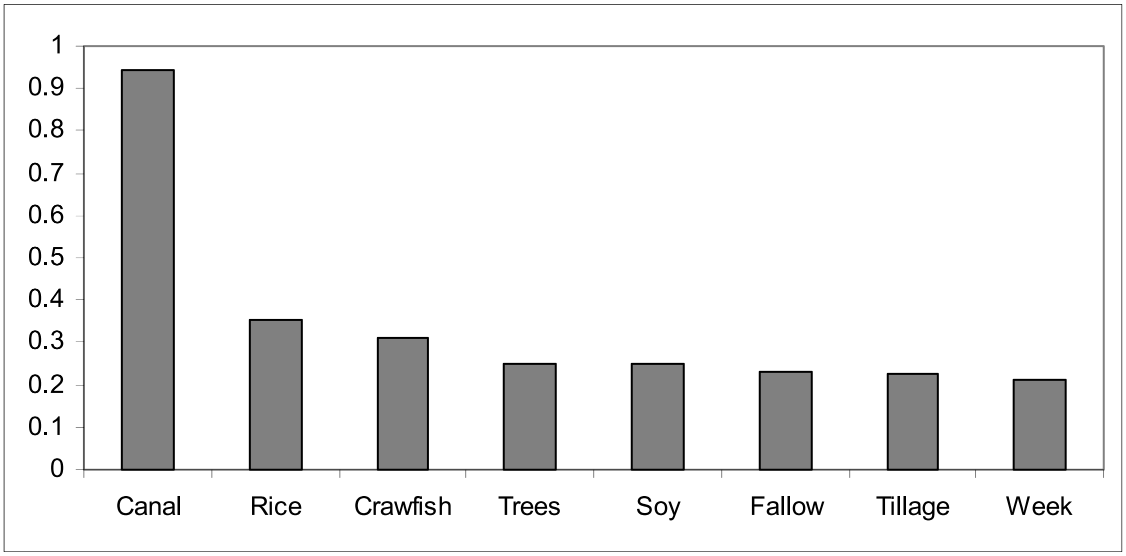

Figure 2.2. Relative importance of canals, rice, crawfish ponds, trees, soybean fields, fallow fields, tillage, and planting date to purple gallinules in 2004. 'Canal,' 'rice,' 'tree,' 'crawfish,' and 'soy' refer to the proportion of each around each fields' perimeter. 'Week' refers to the week rice was planted, 'distance' refers to the distance of each field to a marsh, and 'tillage' refers to the tillage regime of each field.

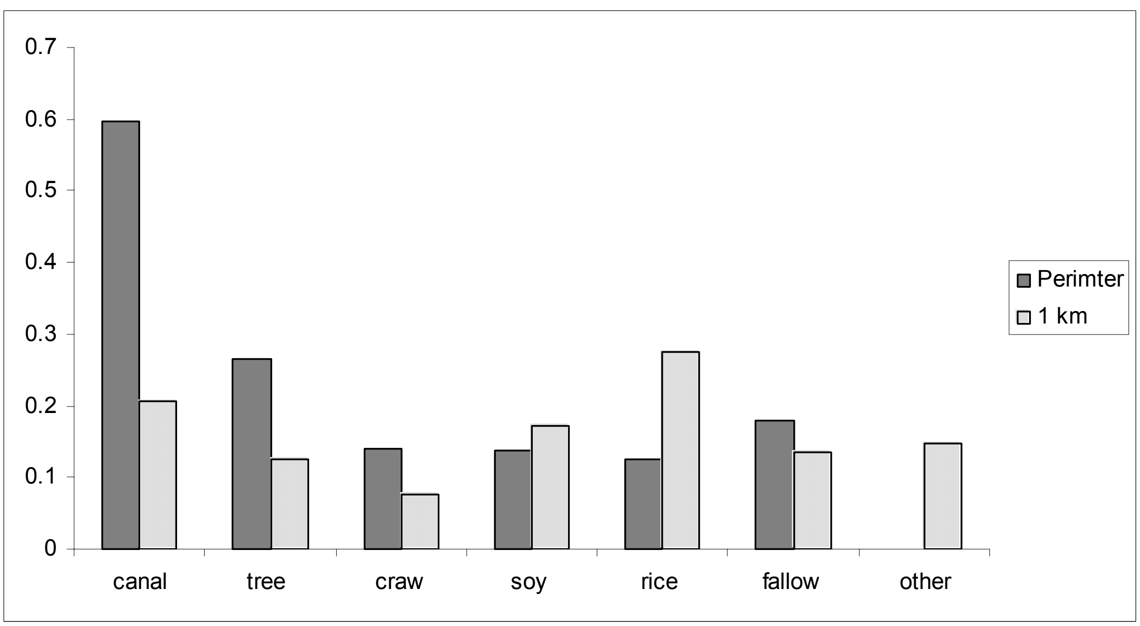

Figure 2.3. Relative importance of canals, trees, soybean fields, crawfish ponds, rice fields, fallow fields, and other land uses to purple gallinules at both scales in 2005. 'Canal,' 'tree,' 'craw,' 'soy,' 'rice,' and 'fallow' refer to the proportion of each covering the proportion of the respective scale. 'Other' refers to anything other than agriculture.

Table 2.7. Logistic regression results for purple gallinule nest survival in 2004. 'Canals,' 'trees,' 'rice,' 'crawfish,' 'soy,' and 'fallow' refer to the proportion of each land use around the perimeter of each field. 'Tillage' refers to the tillage regime of each field; the negative values indicate that no-till fields are associated with increased nest survival. 'Distance refers to the distance of each field from a marsh.

	Estimate	Standard error	Wald χ^2	Prob. > χ^2
Canals	0.11	0.83	0.018	0.89
Trees	-0.16	1.54	0.011	0.92
Rice	-1.20	1.51	0.64	0.42
Crawfish	0.014	1.01	0.0002	0.99
Soy	-0.17	1.25	0.019	0.89
Fallow	-0.23	0.77	0.089	0.77
Tillage	-1260	2948	0.18	0.67
Distance	-1.25	2.14	0.34	0.56

Table 2.8. Logistic regression results for purple gallinule nest survival in 2005, perimeter scale. Those variables negatively associated with nest survival are in bold. 'Canals,' 'trees,' 'rice,' 'crawfish,' 'soy,' 'fallow,' and 'other' refer to the proportion of each covering the perimeter of each field.

	Estimate	Standard error	Wald χ^2	Prob. > χ^2
Canals	0.030	0.71	0.0018	0.97
Trees	0.25	0.86	0.86	0.77
Rice	0.40	0.40	0.044	0.83
Crawfish	0.35	1.18	0.086	0.77
Soy	2.69	171.5	0.0002	0.99
Fallow	0.40	1.52	0.069	0.79

Table 2.9. Logistic regression results for purple gallinule nest survival in 2005, 1 km scale. 'Trees,' 'rice,' 'crawfish,' 'soy,' 'fallow,' and 'other' refer to the proportion of each within 1 km of each field edge. 'Other' refers to any land use other than agriculture. 'Canals' refers to the total length of canals within 1 km of each field edge.

	Estimate	Standard error	Wald χ^2	Prob. > χ^2
Canals	-1.45	0.81	3.20	0.073
Trees	0.49	1.32	0.14	0.71
Rice	1.33	2.13	0.39	0.53
Crawfish	0.69	1.98	0.12	0.73
Soy	1.48	4.54	0.11	0.74
Fallow	2.63	2.87	0.84	0.36
Other	0.92	0.60	2.38	0.12

King Rails

King rail nests were found in 17 out of 42 fields in 2004 and in 20 out of 40 fields in 2005. In 2004, relative nest densities ranged from 0 to 26.5 nests/km^2, and in 2005 relative nest density ranged from 0 to 22.8 nests/km^2. In 2004, the earliest nest initiation date was May 22, the latest was June 27, and the mean was June 1. In 2005, the earliest initiation date was June 7, the latest was July 6, and the mean was June 19.

The best model in 2004 included only canals and tillage, meaning that king rail nest density was positively associated with perimeter canals and no-till fields (Table 2.10). Canals and tillage were also the two most important factors overall (Figure 2.4). In 2005, nest density was positively associated with perimeter canals and negatively associated with perimeter trees (Table 2.10); and these were the two most important factors (Figure 2.5). All models were better at the perimeter scale than the 1 km scale (Figure 2.5). In 2004, fields with king rail nests had a higher proportion of canals around

the perimeter (0.43 ± 0.080) than fields without (0.23 ± 0.039; t=2.58, df=40, *P*=0.014). This was also true in 2005 (0.44 ± 0.068 with nests, 0.24 ± 0.045 without; *P*=0.019). In 2004, no-till fields had higher nest densities (6.7 ± 2.1 nests/km^2) than conventionally tilled fields (2.1 ± 0.75 nests/km^2; t=2.03, df=13.7, *P*=0.013). In 2004, there was a lower proportion of trees around the perimeter of fields with king rail nests (0.060 ± 0.023) than fields without (0.15 ± 0.034; t=2.08, df=40, *P*=0.044). This was also true in 2005 (0.027 ± 0.014 with nests, 0.16 ± 0.049 without; *P*=0.013).

King rail nest survival was consistent among years, at 52.1% in 2004 and 50.3% in 2005 (Table 2.5)**.** In 2004, four nests were found post-fate; two of those were unsuccessful and the fate of one could not be determined. In 2005, seven nests were found post-fate; three of those were unsuccessful and fates of three could not be determined. In 2004, three nests were depredated and six were depredated in 2005. The causes were all mammalian. Also, three were abandoned in 2005. In both years, there were no nests found that were abandoned because of de-watering. In 2004, all of the perimeter characteristics were related to nest survival (Table 2.11). Higher proportions of canals were negatively associated with nest survival, as were distance from a marsh and conventionally tilled fields. Higher proportions of trees, crawfish ponds, soybean fields, and fallow fields were positively associated with nest survival. In 2004**,** 26 nests were used in the analysis, of which two failed. In 2005, none of the perimeter variables were related to nest survival (Table 2.12). Of the variables measured within 1 km of each field, canals were negatively associated with nest survival, and the proportion of rice fields was positively associated (Table 2.13). In 2005, 33 nests were used for analysis, of which eight failed.

Table 2.10. AIC best models explaining variation in king rail nest density. 'Canal,' 'rice,' 'tree,' and 'soy' refer to the proportion of each around each fields' perimeter. 'Week' refers to the week rice was planted, 'distance' refers to the distance of each field to a marsh, and 'tillage' refers to the tillage regime of each field. A negative tillage estimate is equivalent to an association with no-till fields. In the 1 km models, each variable refers to the proportion it covers within 1 km of each field edge. 'Canal' refers to the total length of canals within the 1 km area.

King rail perimeter, 2004	Δ AIC$_c$	W_i
0.34 canal – 0.79 tillage	0	0.29
0.36 canal – 0.81 tillage + 0.13 fallow	1.6	0.13
0.32 canal – 0.71 tillage – 0.12 trees	1.8	0.12
0.37 canal – 0.81 tillage – 0.069 rice	2.4	0.087
0.34 canal – 0.81 tillage + 0.060 week	2.4	0.087
0.34 canal – 0.76 tillage + 0.040 soy	2.5	0.083
0.34 canal – 0.78 tillage + 0.018 distance	2.6	0.079
0.37 canal – 0.71 tillage – 0.18 trees – 0.15 rice	3.7	0.046
0.35 canal – 0.74 tillage – 0.10 trees + 0.11 fallow	3.8	0.043
0.37 canal – 0.84 tillage + 0.076 week + 0.13 fallow	4.0	0.039

King rail perimeter, 2005	r^2	Δ AIC$_c$	W_i
0.19 canal – 0.18 tree	0.28	0	0.43
0.18 canal – 0.39 tree – 0.29 fallow – 0.17 craw – 0.32 rice	0.35	1.9	0.17
0.19 canal – 0.17 tree – 0.008 rice	0.28	2.0	0.16
0.21 canal	0.17	4.0	0.057
-0.19 tree	0.14	5.2	0.032
0.20 canal + 0.047 rice	0.17	5.7	0.026
0.21 canal + 0.022 craw	0.17	6.0	0.022
0.21 canal + 0.0065 fallow	0.17	6.0	0.021
0.10 rice	0.040	9.6	0.0035
0.16 rice + 0.088 fallow	0.056	11.0	0.0018
King rail 1 km, 2005			
-0.15 other	0.088	7.6	0.0096
0.15 canal	0.086	7.7	0.0092
0.16 canal + 0.11 craw	0.13	7.8	0.0089
0.084 canal + 0.15 rice	0.15	6.7	0.015
0.20 rice + 0.072 fallow	0.15	6.8	0.014
-0.13 tree	0.067	8.5	0.0061
0.11 canal – 0.084 tree	0.11	8.7	0.0055
0.076 canal + 0.14 rice – 0.056 tree	0.17	8.3	0.0069
0.15 canal – 0.0057 fallow	0.086	9.7	0.0034
0.091 craw	0.031	10.0	0.0029
Distance	0.0001	11.3	

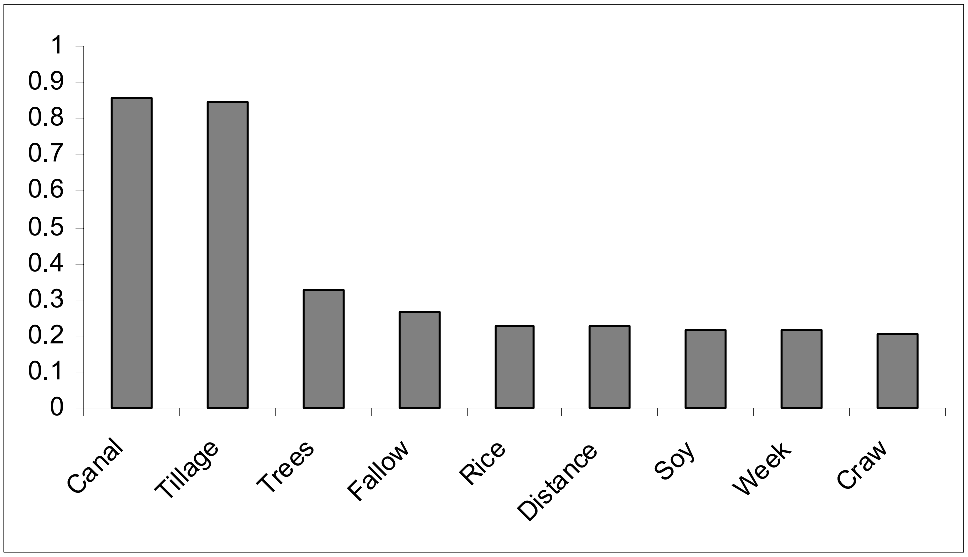

Figure 2.4. Relative importance of the 2004 variables to king rails. 'Canal,' 'rice,' 'tree,' 'crawfish,' and 'soy' refer to the proportion of each around each fields' perimeter. 'Week' refers to the week rice was planted, 'distance' refers to the distance of each field to a marsh, and 'tillage' refers to the tillage regime of each field.

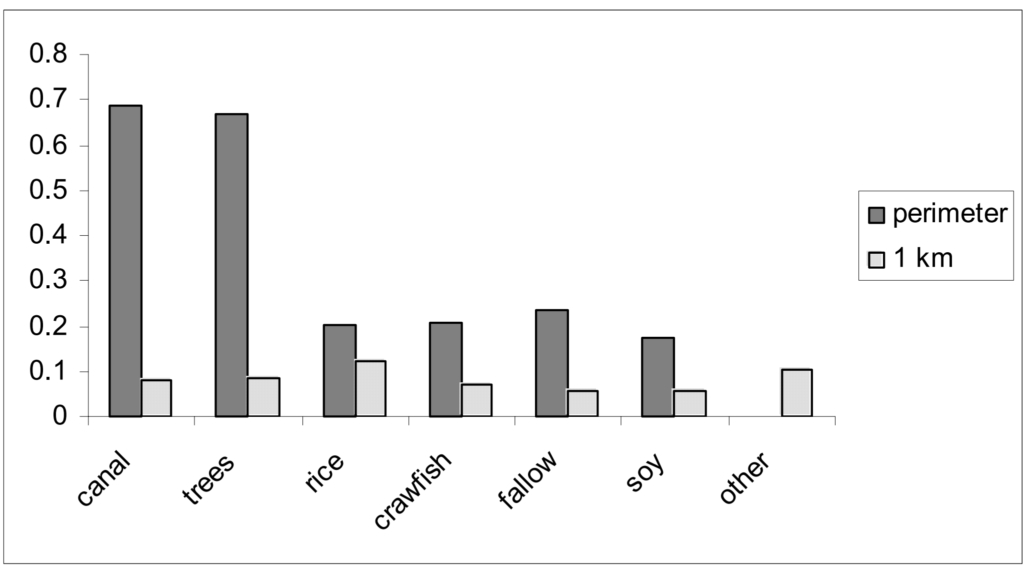

Figure 2.5. Relative importance of 2005 variables to king rails at both scales. 'Canal,' 'tree,' 'craw,' 'soy,' 'rice,' and 'fallow' refer to the proportion of each covering the proportion of the respective scale. 'Other' refers to anything other than agriculture.

Table 2.11. Logistic regression results for king rail nest survival in 2004. ‘Canals,’ ‘trees,’ ‘rice,’ ‘crawfish,’ ‘soy,’ and ‘fallow’ refer to the proportion of each land use around the perimeter of each field. ‘Tillage’ refers to the tillage regime of each field; the negative values indicate that no-till fields are associated with increased nest survival. ‘Distance refers to the distance of each field from a marsh.

	Estimate	Standard error	Wald χ^2	Prob. > χ^2
Canals	-24.5	3.26	56.57	<0.0001
Trees	10.2	2.69	14.38	<0.0001
Rice	-1.08	1.85	0.34	0.56
Crawfish	17.57	2.46	50.99	<0.0001
Soy	30.8	4.50	46.9	<0.0001
Fallow	12.24	2.48	24.4	<0.0001
Tillage	-115308	18030	40.9	<0.0001
Distance	-49.4	6.77	53.3	<0.0001

Table 2.12. Logistic regression results for king rail nest survival at the perimeter scale in 2005. Those variables negatively associated with nest survival are in bold. ‘Canals,’ ‘trees,’ ‘rice,’ ‘crawfish,’ ‘soy,’ ‘fallow,’ and ‘other’ refer to the proportion of each covering the perimeter of each field.

	Estimate	Standard error	Wald χ^2	Prob. > χ^2
Canals	-1.62	1.70	0.90	0.34
Trees	0.62	1.41	0.19	0.66
Rice	1.83	2.23	0.68	0.41
Crawfish	-0.27	1.44	0.035	0.85
Soy	2.09	155.6	0.0002	0.99
Fallow	0.43	1.61	0.071	0.85

Table 2.13. Logistic regression results for king rail nest survival at the 1 km scale in 2005. Those variables negatively associated with nest survival are in bold. 'Trees,' 'rice,' 'crawfish,' 'soy,' 'fallow,' and 'other' refer to the proportion of each within 1 km of each field edge. 'Other' refers to any land use other than agriculture. 'Canals' refers to the total length of canals within 1 km of each field edge.

	Estimate	Standard error	Wald χ^2	Prob. > χ^2
Canals	-2.05	0.66	9.60	0.0019
Trees	4.86	5.58	0.76	0.38
Rice	2.77	0.98	7.97	0.0047
Crawfish	-0.92	3.47	0.070	0.79
Soy	1.54	8.43	0.034	0.85
Fallow	0.26	4.01	0.0042	0.95
Other	1.70	1.47	1.33	0.25

Fulvous Whistling-Ducks

Fulvous whistling-duck nests were found in 17 of 42 fields in 2004 and 27 out of 40 fields in 2005. In 2004, relative nest densities ranged from 0 to 14.8 nests/km^2 and in 2005 from 0 to 80.0 nests/km^2. All of the best models in 2004 included tillage (Table 2.14), and tillage was the most important factor in determining nest density (Figure 2.6). Fulvous whistling-duck nest densities were higher in no-till fields (8.27 $\pm$ 1.3) than in conventionally tilled (0.873 $\pm$ 0.41; unequal variances - t=5.15, df=13.3, P=0.0002). The earliest initiation date was estimated to be May 24, the latest was June 18, and the Mean was June 6. In 2005, at both scales, the proportion of soybean fields was the most important factor (Table 2.14). The earliest initiation date in 2005 was estimated to be May 31, the latest was July 1, and the mean was June 13. Fulvous whistling-duck clutch sizes were similar between years (Table 2.5).

Fulvous whistling-duck nest survival was 38.8% in 2004 and 42.6% in 2005 (Table 2.5). In 2004, nine nests were found post-fate; six of those were unsuccessful and three were successful. A total of nine nests were unsuccessful, six of which were depredated and three of which were abandoned. Two of those were abandoned due to de-watering of rice fields. In 2005, 57 nests were found post-fate; 14 were successful, 36 were unsuccessful, and the causes of seven could not be determined. In 2005, 24 nests were abandoned for unknown reasons. These were all found underwater and it is unclear if they were abandoned first or sunk first. An additional 22 nests were depredated, all by mammals. In 2004, logistic regression indicated that most of the measured characteristics were related to nest survival (Table 2.15). The proportion of canals around each field perimeter was positively associated with nest survival, as were conventionally tilled fields and distance from a marsh. A total of 26 fulvous whistling-duck nests were used in the analysis, of which six failed. In 2005, none of the characteristics were important in influencing nest survival at either scale (Tables 2.16 and 2.17). A total of 74 nests were used in the analysis, of which 31 failed.

<u>Common Moorhens</u>

Common moorhen nests were found in 11 out of 42 fields in 2004, and 12 of 40 fields in 2005. In 2004, six nests were found post-fate, of which five were unsuccessful and one was successful. In 2004, 16 nests were found in crawfish ponds. Of those, eight were successful and eight were depredated or abandoned when water was drawn down. In 2005, 13 nests were found post-fate; six were successful, six were unsuccessful, and the fate of one was undetermined. Apparent success rate of nests in rice fields was 73% in 2004 and 75% in 2005. When attempting to run models of moorhen nest density, the

residuals could not be normalized; hence, no models are presented. However, the proportion of perimeter canals was significantly higher in fields with moorhen nests than in fields without in both years (2004: with – 0.54; without – 0.23; unequal variances - t=3.06, df=12.7, *P*=0.0004; 2005: with – 0.50; without -- 0.27; *P*=0.014). There was no difference in the tree coverage between fields with and without moorhen nests (*P*=0.52).

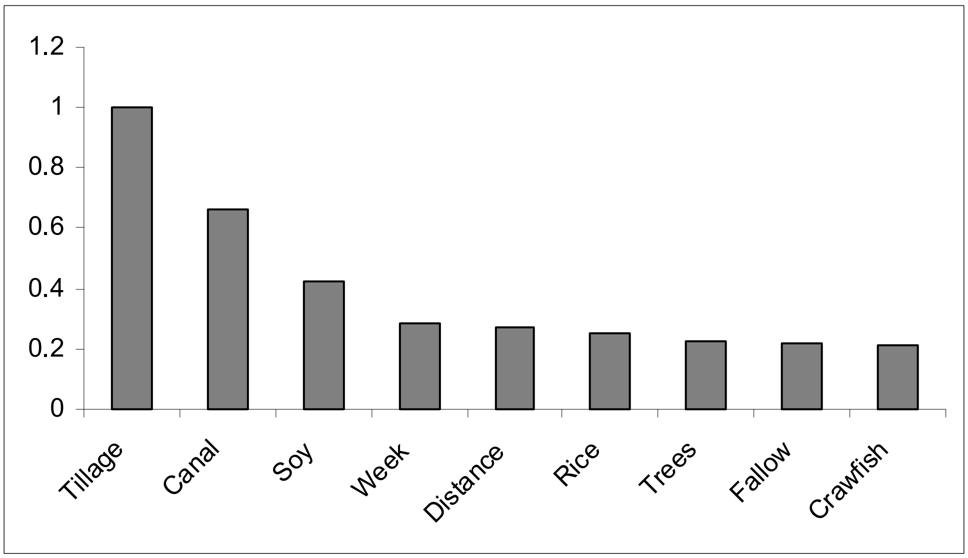

Figure 2.6. Relative importance of tillage, canals, soybean fields, planting date, distance to a marsh, rice fields, trees, fallow fields, and crawfish ponds to fulvous whistling-ducks in 2004. 'Canal,' 'rice,' 'tree,' 'crawfish,' and 'soy' refer to the proportion of each around each fields' perimeter. 'Week' refers to the week rice was planted, 'distance' refers to the distance of each field to a marsh, and 'tillage' refers to the tillage regime of each field.

Others

All three least bittern nests were successful in 2004, and seven of the nine were successful in 2005. Of the remaining two, one was depredated and one was probably depredated, though there was no evidence of predation. This was assumed because eggs disappeared well before they were expected to hatch. Of the six mottled duck nests found, two were successful. The remainder failed because of mammalian predation. Both black-necked stilt nests failed, as did the common nighthawk.

Table 2.14. AIC best models explaining variation in fulvous whistling-duck nest density. 'Canal,' 'rice,' 'tree,' and 'soy' refer to the proportion of each around each fields' perimeter. 'Week' refers to the week rice was planted, 'distance' refers to the distance of each field to a marsh, and 'tillage' refers to the tillage regime of each field. A negative tillage estimate is equivalent to an association with no-till fields. In the 1 km models, each variable refers to the proportion it covers within 1 km of each field edge. 'Canal' refers to the total length of canals within the field edge.

Fulvous whistling-duck perimeter, 2004	Δ AIC_c	W_i
1.52 tillage + 0.26 canal – 0.13 rice	0	0.28
1.46 tillage + 0.20 canal	1.4	0.14
1.34 tillage + 0.19 canal + 0.15 soy	1.9	0.11
1.57 tillage	2.2	0.093
1.43 tillage + 0.17 soy	2.4	0.084
1.43 tillage + 0.23 canal + 0.13 distance	2.4	0.084
1.44 tillage + 0.20 canal – 0.096 week	3.2	0.056
1.30 tillage + 0.18 canal + 0.17 soy – 0.12 week	3.2	0.056
1.54 tillage + 0.22 canal + 0.094 trees	3.2	0.056
1.33 tillage + 0.21 canal + 0.13 soy + 0.11 distance	3.7	0.044

Fulvous whistling-duck perimeter, 2005	r^2	Δ AIC_c	W_i
0.20 soy	0.10	4.6	0.038
0.23 soy + 0.16 rice	0.13	5.1	0.031
0.19 soy – 0.11 trees	0.13	5.1	0.031
0.21 soy + 0.11 canal	0.12	5.5	0.024
0.20 soy + 0.10 canal – 0.10 trees	0.15	6.2	0.017
0.20 soy – 0.012 fallow	0.10	6.6	0.014
0.083 canal	0.013	8.4	0.0062
0.073 canal – 0.12 trees	0.052	8.2	0.0056
0.24 soy + 0.065 canal + 0.018 trees + 0.18 fallow + 0.27 rice	0.19	8.5	0.0051
0.056 canal + 0.093 rice	0.021	9.9	0.0027
Fulvous whistling-duck 1 km			
0.29 soy + 0.25 rice	0.24	0.0	0.38
0.21 soy – 0.15 trees	0.19	2.3	0.12
0.23 soy	0.15	2.4	0.11
0.23 soy + 0.082 canal	0.16	3.8	0.057
0.21 soy + 0.020 canal – 0.14 trees	0.19	4.3	0.045
0.24 soy + 0.0076 fallow	0.15	4.3	0.045
0.30 soy + 0.29 rice – 0.097 canal – 0.055 trees + 0.091 fallow	0.26	4.5	0.041
0.0055 canal – 0.19 trees	0.077	7.6	0.0087
0.087 canal	0.015	8.2	0.0064
0.0054 canal + 0.18 rice	0.044	9.0	0.0043
Distance	0.020	10.1	

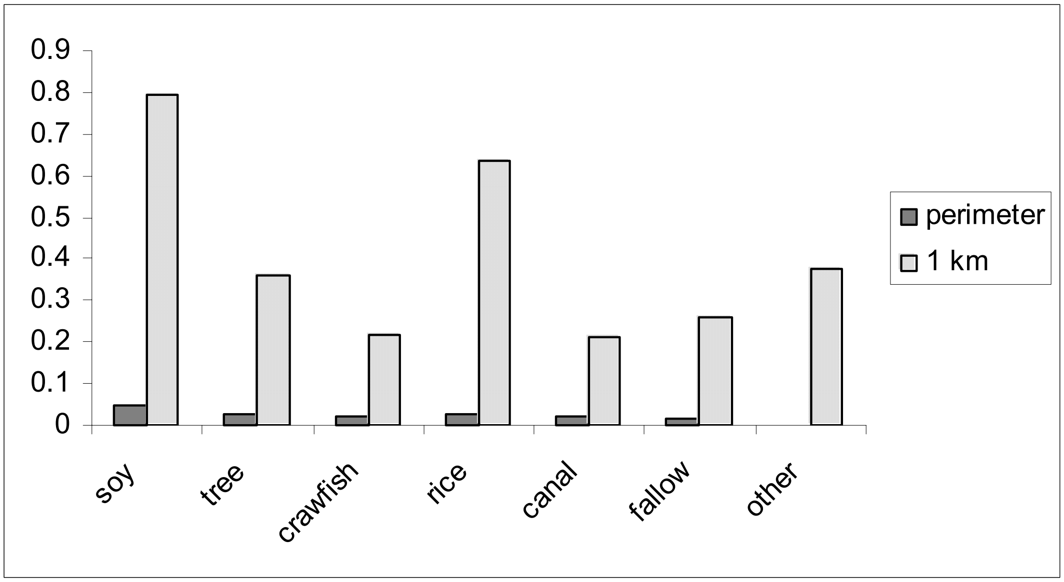

Figure 2.7. Relative importance of soybean fields, trees, crawfish ponds, rice fields, canals, fallow fields, and other land uses to fulvous whistling-ducks in 2005. ‘Canal,’ ‘tree,’ ‘craw,’ ‘soy,’ ‘rice,’ and ‘fallow’ refer to the proportion of each covering the proportion of the respective scale. ‘Other’ refers to anything other than agriculture.

Table 2.15. Logistic regression results for fulvous whistling-duck nest survival in 2004. ‘Canals,’ ‘trees,’ ‘rice,’ ‘crawfish,’ ‘soy,’ and ‘fallow’ refer to the proportion of each land use around the perimeter of each field. ‘Tillage’ refers to the tillage regime of each field; the positive value indicates that water-leveled fields are associated with increased nest survival. ‘Distance refers to the distance of each field from a marsh.

	Estimate	Standard error	Wald χ^2	Prob. > χ^2
Canals	4.02	1.07	14.1	0.0002
Trees	-4.14	1.26	10.8	0.001
Rice	2.09	0.98	4.58	0.032
Crawfish	-4.82	0.60	64.3	<0.0001
Soy	-9.43	0.97	93.9	<0.0001
Fallow	-0.45	1.41	0.10	0.75
Tillage	3.59	1.83	3.85	0.050
Distance	13.6	1.62	70.7	<0.0001

Table 2.16. Logistic regression results for fulvous whistling-duck nest survival in 2005, perimeter scale. 'Canals,' 'trees,' 'rice,' 'crawfish,' 'soy,' 'fallow,' and 'other' refer to the proportion of each covering the perimeter of each field.

	Estimate	Standard error	Wald χ^2	Prob. > χ^2
Canals	-0.094	0.34	0.078	0.78
Trees	0.039	0.34	0.013	0.91
Rice	0.77	0.82	0.86	0.35
Crawfish	0.066	0.44	0.022	0.88
Soy	0.35	0.47	0.54	0.46
Fallow	0.92	0.71	1.67	0.20

Table 2.17. Logistic regression results for fulvous whistling-duck nest survival in 2005, 1 km scale. 'Trees,' 'rice,' 'crawfish,' 'soy,' 'fallow,' and 'other' refer to the proportion of each within 1 km of each field edge. 'Other' refers to any land use other than agriculture. 'Canals' refers to the total length of canals within 1 km of each field edge.

	Estimate	Standard error	Wald χ^2	Prob. > χ^2
Canals	0.27	0.36	0.57	0.45
Trees	-0.78	0.82	0.90	0.34
Rice	-1.69	1.85	0.84	0.36
Crawfish	0.73	0.96	0.58	0.45
Soy	-1.17	1.59	0.55	0.46
Fallow	0.62	1.19	0.27	0.61
Other	0.44	0.52	0.70	40

Discussion

Nest Densities

Purple gallinules had more nests each year than any other species. Although relative nest densities were highly variable among fields in both years (Table 2.4), they were still 2-3 times higher than the 5.1 nests/km^2 reported by Hohman et al. (1994). Purple gallinules appeared to be more abundant closer to the coast than further inland, however, this effect is unconfirmed by this study and requires further research. Purple gallinule nest densities were substantially lower than the 108 nests/km^2 reported by Helm (1982), but his study was conducted in one 24-ha rice field and may or may not be representative of conditions prevalent throughout the region at that time. Also, their estimate includes the total nests found on several searches, whereas the densities presented in this study are from one search of each field. The maximum nest density in this study was 206 nests/km^2, which occurred in a 16 ha field. One other field exceeded 108 nests/km^2.

Relative nest densities of fulvous whistling-ducks were over 4 times greater in 2005 than 2004 (Table 2.4). The 2005 nest densities were similar to the 15.1 nests/km^2 reported by Hohman et al. (1994). Although relative nest densities in the new areas in 2005 were over twice as large as those in the Thornwell area (20.2/km^2 vs 9.8/km^2), the relative nest densities in the Thornwell area increased three-fold from 2004 (3.0/km^2 vs 9.8/km^2). I am uncertain of the reasons for the increase, but detectability is not an issue as fulvous whistling duck nests are the most obvious nests in the rice fields. They are large, unconcealed, and eggs are solid white. There was much less precipitation in 2005

than in 2004, which may have caused several marsh areas to dry, concentrating birds in rice fields.

Relative nest densities of king rails were consistent among years (3.4 /km^2 in 2004; 4.8/km^2 in 2005), but were substantially lower than the 15.1 nests/km^2 reported by Hohman et al. (1994) and the 16.5 nests/km^2 in an Arkansas rice field reported by Meanley (1969). Only one field out of the 28 fields studied by Hohman et al. (1994) contained no nests, whereas 45 of 82 in my study had no nests. Hohman et al. (1994) did not choose fields randomly (B. Hohman, personal communication), which may have affected results. Furthermore, relative nest densities are more accurate when compared to one another in the same study. King rails appear to still be relatively abundant in the rice-growing region of Louisiana, although it is unknown whether the population is stable, increasing, or decreasing. Their abundance is based on only two years of data, however, so more data collected every few years would help greatly in understanding population trends. They also appear to be relatively abundant based on conversations with several farmers. Several told me that since the drought in 2000, they had seen more king rails every year. It is quite possible, though, that populations have declined in southwestern Louisiana as they have elsewhere in their range from what they were 40-50 years ago.

Effects of Habitat Characteristics on Relative Nest Densities

The results of this study indicate that local and landscape scale habitat characteristics affect the presence and abundance of waterbird nests. Agricultural practices including tillage, crops planted, abundance of trees, and mechanism of irrigation were important determinants of the presence and abundance of nests. Although the

preferred characteristics differed somewhat among species, no-till rice fields surrounded by irrigation canals, perimeters with no trees, and abundance of rice nearby tended to support higher densities of waterbird nests.

Perimeter canals were important in determining king rail, purple gallinule, and common moorhen nest density in 2004 and 2005. Sites that had higher proportions of canals around the perimeter supported higher nest densities. Canals commonly provide varied cover when compared to rice fields, supporting different species of wetland vegetation. They also provide cover when cover in rice fields is unavailable. Before rice is tall enough and after rice is harvested, canals are relatively undisturbed and may offer refuge to pre-breeding waterbirds. Furthermore, the interspersion of shallowly flooded emergent vegetation interspersed with the open water edges of canals mimics preferred nesting habitat of purple gallinules and moorhens (West and Hess 2002).

Surrounding trees were deterrents to breeding king rails and purple gallinules. Fields with higher proportions of trees around the perimeter had fewer nests. This effect could be seen with as little as 15% of the field edge bordered by trees. Native nesting habitat is open areas of marsh and does not include substantial tree coverage (West and Hess 2002). Their avoidance of that structure in rice fields could be a relict of their adaptation to open areas. This could also be a predator-avoidance strategy, as trees are more likely to harbor mammalian or avian predators, although I observed few avian predators. Trees, where they exist, appear to fragment blocks of rice. Usually in studies of fragmentation, areas of forest or grassland are fragmented by agriculture and other development and lower avian nest success and abundance are often observed in fragments (Robinson et al. 1995, Bayne and Hobson 1997, Knutson et al. 2004, Frank

and Battisti 2005, Skagen et al. 2005). In this study, agricultural areas that were highly fragmented by trees did not have lower nest success, but they had substantially fewer nests.

No-till fields appeared to be important for king rails and fulvous whistling-ducks in 2004. This could be because leaving the rice stubble undisturbed leaves more of the invertebrate community and seed base intact, which are foods for the king rail and fulvous whistling-duck. Non-tillage is not a common practice in southwestern Louisiana, as only about 16% of rice fields are not tilled (Linscombe et al. 1999). Advantages of not tilling fields include reduced wear on equipment, reduced suspended sediments in the water, and lower input costs. However, there is a larger risk of losing weed control, and herbicides commonly have to be applied at higher rates. It should be noted, however, that all no-till fields were studied only in 2004 and few fields were identified. Also, all no-till fields were in the further distance class, so any no-till effect found applied only to fields further away. While more study on this topic would be helpful, no-till is not a common practice in the region, and developing adequate sample sizes to test this factor will be difficult.

Landscape habitat effects varied among species and may reflect life-history strategies. King rails responded more to land use surrounding rice fields than to composition within 1 km of rice fields. King rails fly only as a last resort and prefer to stay on foot (Meanley 1992). Purple gallinules responded mostly to the local scale, except for an association with the abundance of rice at the 1 km scale. Purple gallinules are similar to king rails in their reluctance to fly, except for their arrival to their breeding grounds after the spring migration. They appear to seek out large blocks of rice first, then

respond to canals and trees at the smaller scale. In contrast, the more mobile fulvous whistling-ducks responded substantially more to the larger scale. At both scales, distance to a marsh was unimportant for all species. If the appropriate local landscape context was present, birds nested in rice. This was true up to about 40 km from a marsh, which was the farthest away study sites reached.

Too few nests were found for common moorhens, least bitterns, and mottled ducks for detailed habitat analyses. Relative nest densities of common moorhens were similar among years and similar to that reported by Hohman et al. (1994). Although similar in appearance and ecology to purple gallinules, they nested in significantly lower densities than gallinules. The lower number of common moorhen nests relative to purple gallinules may be because of life-history characteristics of these species and inter-specific interactions with purple gallinules. Common moorhens use deeper and more open water than purple gallinules, which is less available in rice fields than a marsh (Bannor and Kiviat 2002). Furthermore, the timing of when rice is available as a suitable nesting substrate relative to the timing of breeding of common moorhens may also be important. Whereas gallinules migrate north to the rice-growing region of Louisiana and may find rice as the first available habitat, moorhens are year-round residents in Louisiana marshes. Therefore there may be a lower chance that a moorhen would leave the marsh habitat to migrate north ~10 km to nest. Also, because moorhens are residents, they are able to nest earlier than gallinules and are already breeding by the time suitable nest cover in rice fields becomes available (Bannor and Kiviat 2002). Nests are initiated at the earliest in the beginning of April, whereas rice fields are not available until the beginning of June (Helm et al. 1987). Finally, when common moorhens and purple

gallinules do coexist, common moorhens dominate and drive purple gallinules out of territories (Bannor and Kiviat 2002). Thus, common moorhens can establish territories in marshes earlier than purple gallinules and protect them from purple gallinule occupancy.

A low abundance of least bittern nests were also found in the rice fields. In total, only 12 least bittern nests were found during the study. Although it is possible that rice is of low value to least bitterns, I believe that the low abundance of nests observed is due to the low detection probability of this species. Their nests are the smallest of the species observed in this study, and they are more woven into the rice than nests of the other species. Little or no rice was bent down during nest construction, and nests were only seen when observers happened to walk very near them (i.e., < 1 m). Furthermore, least bitterns were commonly seen when conducting searches, and were seen in several fields that no nests were found. Thus, their relative nest density was probably substantially higher than observed.

Mottled duck nests were only found in 2004. This is partly because the levees were not searched as intensively in 2005. When half of the 2005 crew was lost during the season, levee searches were terminated to ensure that sufficient rice acreage was covered. All six of the nests were on levees in very dense vegetation. Two were successful and four were depredated. The predation appeared to be by mammals, most likely raccoons or opossums. Raccoon scat was commonly observed on interior levees, and levees are apparently commonly used by these mammals. The actual nest density is not expected to be substantially higher than that observed, as intense levee searches were conducted in 2004 and relatively few birds were seen. Also, while mottled ducks are associated with

the rice-growing region of Louisiana, they prefer to nest in pastures and fallow fields near active rice fields (Durham and Afton 2003).

Nest Survival

Successful nesting by these birds was compatible with and promoted by rice production as it was practiced. Nest survival was high for purple gallinules, king rails, fulvous whistling-ducks, common moorhens, and least bitterns in both years (Table 2.5). The analyses on local and landscape influences on nest survival of purple gallinules, king rails, and fulvous whistling ducks were inconsistent and inconclusive. It could be that too few failed nests were found to show variation in nest success among landscape types. Several factors appeared to be important for nest survival in 2004, but not in 2005. At the 1 km scale, which was only examined in 2005, canals were negatively associated with king rail nest survival, whereas the abundance of rice was positively associated. While it is possible that there is a trade-off between rice and canal abundance when concerned with nest survival, the overall high nest density in these areas probably outweighs any negative effects. Overall, it appears that the characteristics measured did not consistently influence nest survival.

Birds had ample time to complete a successful nesting cycle. Nesting cover was available at the end of May, and remained until de-watering of the rice fields, which began from the middle to end of July. This offered birds 50-65 days of nesting habitat, out of a total of 113-123 days from planting to harvest. The mean initiation dates for all birds was near the middle of June, leaving 30-45 days until de-watering, which at the least is slightly more than what the birds require for laying and incubating. As previously mentioned, rice historically had a longer growing season and grew taller, which

undoubtedly increased the time available to breed. Continuing this trend of faster maturing varieties could jeopardize or decrease the value of rice as habitat for breeding waterbirds. Currently, however, water management and time to maturity are adequate for marsh bird nesting.

Purple gallinule nest survival was high both years (52% and 79%; Table 2.5). There were several nests found post-fate, however, most were successful and appear to be consistent with the Mayfield estimates. The 2005 value is consistent with the apparent nest success of 78.6% reported by Helm et al. (1987), which is the only other report of purple gallinule nest success in rice fields. As well as clutch size being larger in rice fields, Helm et al. (1987) also reported that success was higher than in the marsh. Given the large clutch size laid in rice fields and the high nest survival rate, it appears that rice fields are excellent breeding habitat for purple gallinules.

King rail nest survival was consistent among both years (52% and 50%; Table 2.5). There were few nests found post-fate, and I do not believe that they would have an effect on nest survival. Few other reports exist on nest survival. Reid (1989) reported an 81% apparent success rate of 67 nests in Missouri. In Arkansas, 12 of 16 nests were successful (Meanley 1969). To my knowledge, no nest survival estimates exist for Louisiana.

Fulvous whistling-duck nest survival was consistent among years (38% and 42%; Table 2.5), however, the estimates are substantially higher than other studies. There were 36 nests found post-fate that were unsuccessful, which could not be used in Mayfield estimates, so the Mayfield nest survival estimate may be inflated. All other studies used apparent nest success, which in this study was 67% in 2004 and 48% in 2005. In

Louisiana, Hohman (2001) found apparent nest success for over-water nests in Louisiana to be 14.5% (n=733), whereas Meanley and Meanley (1959) reported apparent nest success of 30% (n=10, Meanley and Meanley 1959). In Florida rice fields, Mayfield success was only 5.6% (n=116) (Wyss 1996), whereas apparent nest success in Texas oxbow basins was 53% (n=17, Cottam and Glazener 1959). It is unknown why this difference occurred.

Although too few nests were found to conduct analyses of nest success, apparent nest success was high for common moorhens and least bitterns. In the current study, apparent nest success of common moorhens was 73% in 2004 and 75% in 2005, which is comparable to the 80% found by Helm et al. (1987). Of 12 combined least bittern nests, 10 were successful. This 83% success rate is similar to the 84% (n=38) found by Weller (1961) and the 70% (n=20) found by Kent (1951). Only two out of six mottled duck nests were successful. All nests were built on levees and depredated by unknown mammal species. Levees appear to the widely used by mammals, thus nests built on levees are expected to fail.

Although crawfish ponds provided nesting habitat, most nests found were unsuccessful. Several ponds in 2004 were drawn down by the beginning of June, causing nest abandonment. Crawfish ponds were not searched in 2005, and several ponds were flooded longer, into July. It is possible that birds nesting in crawfish ponds in 2005 were more successful. It is also possible that they are important for resident king rails, as several birds were seen in or near ponds before rice was tall enough to begin nesting.

Clutch Sizes

Purple gallinule clutch size in 2004 (7.95) was similar to 2005 (7.76) and similar to clutch sizes in rice reported by Helm et al. (1987) (8.6). Helm et al. (1987) also studied nests in marshes and found clutch size for gallinules to be significantly lower than in rice fields (5.8 in the marsh and 8.6 in rice fields). They attributed this difference to a difference in food resources in rice fields. Gallinules are usually omnivorous, but may consume more animal matter in rice fields, where a lot of their normal plant resources may not be available.

King rail mean clutch size was consistent between years (9.32 in 2004, 9.06 in 2005) but was lower than other reported values. Clutch size varied from 10.5 to 11.2 in four different U.S. populations (Reid 1989), and averaged 10.4 in Ohio (Trautman 1940). In contrast, fulvous whistling-duck mean clutch size (12.37) is similar to other Louisiana values. Hohman (2001) reported an average clutch size of 13.4 in over-water nests in Louisiana.

Similar to purple gallinules, clutch sizes of common moorhens also appear to be larger in rice fields than in marshes. Helm et al. (1987) also found that moorhens lay larger clutches in rice fields than in marshes and clutch sizes in this study are consistent with those findings.

Other Considerations

The results observed in coastal Louisiana are not necessarily applicable to other regions because of differences in cultural practices and their interaction with avian breeding requirements. In several areas of Europe, the timing of rice growth does not coincide with breeding waterbirds. In the U.S., however, rice is grown similarly in other

regions. In California, rice is flooded throughout the growing season, which coincides with the breeding season of marsh birds. Rice also grows to a similar height and has a similar time to maturity (California Rice Commission 2006). However, breeding waterbirds have not been studied there, and fulvous whistling-ducks are declining and have become species of concern in the state (Hohman and Lee 2001). In Arkansas, breeding densities of waterbirds have declined dramatically since Meanley's work, although the exact mechanisms for the declines are not fully understood. Even in portions of Louisiana, rice is not continuously flooded, which may reduce benefits to breeding waterbirds.

This study is limited by several factors. First, nest detection probabilities were not calculated, allowing for only relative nest densities to be calculated, rather than actual densities. Therefore, the exact number of nests and the proportion of nests of one species to another is unknown. For example, king rail nests were more difficult to locate than fulvous whistling-duck nests, so it is possible that a greater percentage of king rail nests were overlooked than those of fulvous whistling ducks. There were also several factors not measured that could have influenced nest density. Only 25%, 35%, and 42% of the variation in fulvous whistling-duck, king rail, and purple gallinule nest density could be explained by the variables measured. The food base in rice fields and abundance of predators were not directly measured, and could play a large role in influencing bird use. The importance of tillage is based only on 12 fields searched in 2004, and was not tested in 2005 because of the small number of no-till fields that could be identified. Therefore, this subject warrants further research. Despite these considerations, however, it is clear that rice fields provide important breeding habitat for several species of waterbirds.

CHAPTER 3

SECRETIVE MARSH BIRD SURVEYS IN RICE FIELDS OF SOUTHWESTERN LOUISIANA

Secretive marsh birds are wetland dependent species that are difficult to detect because of their affinity for thick marsh vegetation and their reluctance to fly far above ground for long distances. In the U.S. these species include rails, bitterns, grebes, gallinules, and limpkins (Burger 1985). They rely on marshes for breeding and foraging, and are similar in their requirement of thick emergent vegetation (Burger 1985). During the breeding season, the thick vegetation conceals nests from predators and provides food (Burger 1985). Rice fields are structurally similar to many emergent marshes and can provide benefits to many species of waterbirds (Czech and Parsons 2002). Although the importance of rice fields for wintering waterbirds has received some attention, they have received little attention as breeding marsh bird habitat (Helm et al. 1987, Hohman et al. 1994). In Louisiana, rice fields provide potentially high quality habitat for four breeding secretive marsh birds: purple gallinules, king rails, common moorhens, and least bitterns (Hohman et al. 1994; Chapter 1).

These four species, like several other marsh birds, are of conservation concern because of population declines and uncertainties about population status (see introductory chapter; Rich et al. 2004, Conway and Gibbs 2005). Little information has been accumulated on these birds in part because they are difficult to detect. Also, traditional monitoring programs, such as the Breeding Bird Survey, do not typically sample marsh birds (Conway 2002). As a result, our knowledge of marsh birds is limited relative to terrestrial birds and birds more easily viewed. Because of our limited knowledge of

marsh bird populations and concerns about their populations, there has been an increasing desire to monitor populations.

Habitat information on these birds is needed in rice fields of Louisiana, in part because of the lack of attention the area has received, and because of the instability of rice acreage recently. There are several local and landscape factors that vary in the region that could play a role in the habitat quality and bird use of rice fields. The land use surrounding rice fields (canals, trees, other rice fields, fallow fields, soybean fields, crawfish ponds), management factors (tillage regime, planting date), and placement on the landscape (distance to a marsh) can all influence bird use of a particular rice field (see chapter 2). One method that can be used to determine which rice fields are most commonly used by marsh birds is through the use of callback surveys (Conway 2001, 2002).

Callback surveys are a technique whereby calls of selected species are broadcast to elicit responses from breeding individuals in the area (Conway 2001, 2002). This usually involves at least three visits to each site during the breeding season. Each visit involves a silent period followed by a period in which several marsh bird calls are broadcast. This technique increases call frequencies of some marsh bird species (Conway and Gibbs 2005). To date, this is the most effective means of sampling the presence of marsh birds, and it is potentially a cost-effective means for gathering information about marsh bird populations and habitat use.

Surveys can be used to answer questions about habitat associations of marsh birds in rice fields. To determine which landscape contexts support the highest number of birds, survey response can be related to various land use characteristics surrounding that

point. In the current study, the aforementioned local and landscape characteristics were evaluated in relation to the number of birds detected at each point.

A second estimate of relative abundance was included in this study in the form of relative nest densities, as determined with intensive nest searches. This can help provide a measure of how well survey responses indicate breeding activity. If bird densities are concentrated in similar areas as nest densities, then conducting surveys rather than nest searches becomes more justified. Also, if the number of birds heard at a particular point correlates with the number of nests in that field, there would be an estimate of the extent of breeding activity given the number of birds detected.

Surveys can also be used to estimate site occupancy, or the percentage of fields occupied by a given species (MacKenzie et al. 2002, 2003). This is an important parameter, and using surveys to estimate it rather than nest searches is desirable because of the relative minimal time and labor (MacKenzie et al. 2002). One estimate of site occupancy is the percentage of rice fields in which birds are detected during surveys. However, this estimate assumes that every time a bird is present, it will be detected. For most species of wildlife, this assumption is false (Royle and Nichols 2003). Commonly, a bird that is present will not respond, meaning that the probability of detection is less than one. It can therefore be assumed that the actual site occupancy rate is higher than what is detected. Several techniques have become available that estimate site occupancy and the probability of detection, including Program Presence (MacKenzie et al. 2003). Although Program Presence uses presence/absence data, it does not give any information regarding relative abundance and other measures are needed to calculate relative abundance.

The objectives for this study were to 1) evaluate the effectiveness of callback surveys in indicating breeding activity of marsh birds, 2) estimate site occupancy of marsh birds in rice fields of southwestern Louisiana, and 3) determine which local and landscape factors are the most important in determining the presence of marsh birds.

Study Area and Methods

My study area was in Jefferson Davis and Cameron Parishes in 2004; and Jefferson Davis, Cameron, Acadia, and Vermilion Parishes in 2005 (Figure 2.1). Fields were only considered for sampling if landowner permission could be obtained. In 2004, 30 fields were chosen by randomly stratifying them based on distance from a marsh and tillage regime. Fields were put into two distance classes – 0-1.6 km from the marsh, and 1.6-16 km from the marsh. Nine rice fields were in the close distance class, which were all conventionally tilled. No fields with no-till management could be located within the close distance class. Of the remainder, nine were no-till and 12 were conventionally tilled.

In 2005, the survey expanded to include areas near Crowley, Kaplan and Morse, which are further east and further inland (Figure 2.1). In total 60 rice fields were surveyed, half near the area of study in 2004 and half near the new areas. They were randomly stratified based on the proportion of canals and trees surrounding the perimeter of each field, which were determined to be important based on the 2004 data.

I conducted callback surveys once per month from March to July in 2004 and from April to June in 2005 following the protocol of Conway (2002, 2003). Each survey period was no longer than 10 days. Surveys were cancelled if wind speeds exceeded 20 km/hour or during periods of extended rain or fog. They were conducted from 30

minutes before sunrise until 10:00 am CST. Each survey consisted of five minutes of passive listening followed by nine minutes of recorded calls in 2004, and five minutes in 2005. For each species, 30 seconds of its call was broadcast, followed by 30 seconds of silence. In 2004, nine species were played: black rail, least bittern, yellow rail, Virginia rail, king rail, American bittern, common moorhen, purple gallinule, and pied-billed grebe. In 2005, five species were played: least bittern, king rail, American bittern, common moorhen, and purple gallinule. During each survey, each individual was recorded during the minute interval it was heard, and the estimated distance from it was recorded. Individuals were recorded only in the specific field being surveyed; individuals in bordering fields were ignored. In 2004, all fields were searched for nests. In 2005, 40 out of the 60 fields surveyed were searched for nests.

In 2004, each field was recorded as either conventionally tilled or no-till, and distance from a marsh was measured. The week a field was planted was recorded, and ranged from one to eight; representing each week in the planting window of March 8 – May 3. The proportion of the perimeter of each field covered by canals, trees, other rice fields, fallow fields, soybean fields, and crawfish ponds was also measured. In 2005, all of the factors except tillage and distance to a marsh were measured.

Data Analysis

Program Presence 2.0 was used to determine site occupancy, or the number of rice fields estimated to be occupied (MacKenzie et al. 2002). This is an estimate because it is assumed that not all birds present will be detected. Program Presence was also used to determine the detection probability of each species, or the probability that a bird will be detected during a survey given that it is present. Program Presence uses the

probability that a site is occupied and the probability that a given species is detected given that it is present. This is a probabilistic argument to describe the observed detection history of each species at each field. The detection history refers to the presence or absence of a given species at each field during each survey. Likelihood theory can then be used to estimate parameters of site occupancy and detection probability (MacKenzie et al. 2002).

Correlation analysis was used to determine the relationship between survey responses and nest abundance (Proc Corr, SAS Institute Version 9.0, Cary, NC). For each field, the most individuals of a species in any of the three surveys was correlated with the number of nests in the field being surveyed that were within 300 m of the survey point. This was estimated to be the maximum distance at which surveys could influence detections. Total nests per bird detected was calculated by dividing the average number of nests at each distance by the average number of birds detected.

Multiple regression (Proc Reg, SAS Institute Version 9.0) was used to determine the effects of several local and landscape factors on the maximum number of individuals of each species heard during one of the three surveys. AIC values were used to determine the best models, and the weight of each model was used to determine the most important variables associated with survey responses (Burnham and Anderson 2002).

When regression models could not be constructed due to residuals not being normalized, t-tests were conducted comparing fields with and without detections. T-tests were also conducted comparing distances of nests to survey points between fields with and without detections. Unless otherwise stated, variances were equal and degrees of freedom were pooled.

Results

Of the 30 rice fields surveyed in 2004, responses of all birds were heard in 17. Responses were heard in 33 of 150 surveys. Of the nine species played in the callback period, four were heard (least bittern, purple gallinule, king rail, common moorhen). No birds were heard during the March survey, and detections for all species were the most frequent in the June survey (Figure 3.1). Responses were heard in four fields in the July surveys that did not record detections in June. Responses were heard in two fields in the May surveys that did not record detections in June. King rails, common moorhens, and purple gallinules responded to several different marsh bird calls (Table 3.1).

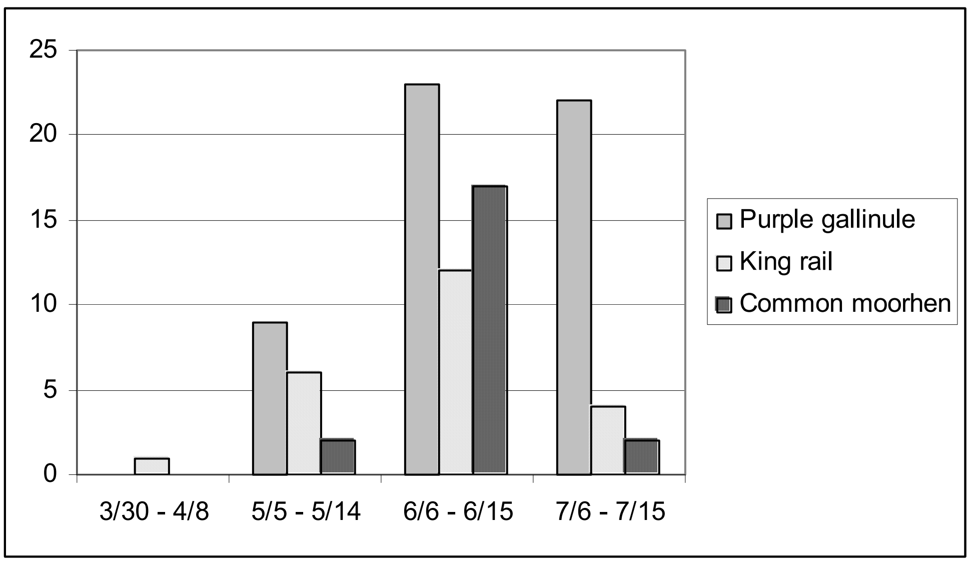

Figure 3.1. Number of detections for each species by survey period in 2004.

Of 60 rice fields surveyed in 2005, responses were heard at 27. Responses were heard in 30 of 180 surveys. Of the five species played in the callback survey, responses were heard for four (least bittern, king rail, common moorhen, purple gallinule). Responses were heard in one of the April surveys, six of the May surveys, and 23 of the June surveys. Detections for all species were the most frequent in the June surveys (Figure 3.2). King rail was the only species heard in some fields in the April and May

surveys but not in June. In two fields, birds were heard in April but not June. One of those did not record detections in May either. Five fields had king rail detections in May but not June. King rails, common moorhens, and purple gallinules responded more to their own calls than any other (Table 3.2). In general, broadcast calls increased responses (Table 3.3).

Table 3.1. Number of responses of each species heard during each broadcast call in 2004. Species on the top are those that were heard, and species on the left are those that were broadcast.

	Least bittern	King rail	Common moorhen	Purple gallinule
Black rail	0	5	4	5
Least bittern	1	2	7	12
Yellow rail	0	2	3	5
Virginia rail	0	5	4	10
King rail	0	7	3	8
American bittern	0	9	2	14
Common moorhen	0	6	3	7
Purple gallinule	0	9	4	20
Pied-billed grebe	0	2	2	10

In 2004, 22 king rails were heard in 9 fields, 10 of which were first heard during the passive period of the surveys. A total of 20 birds were heard during the playback period, which includes eight birds that called during the passive period. Nests were found in 8 of the 9 fields (2.3 nests / field) where king rails were heard and 13 of 30 fields surveyed. One nest was found in each of five fields that had no detections. Site occupancy was estimated to be 0.35 $\pm$ 0.11, and detection probability was 0.48 $\pm$ 0.12. The nearest nests to the survey points were farther away in fields without detections (434 $\pm$ 82 m) than fields with detections (217 $\pm$ 39 m; t=2.63, df=10, P=0.025).

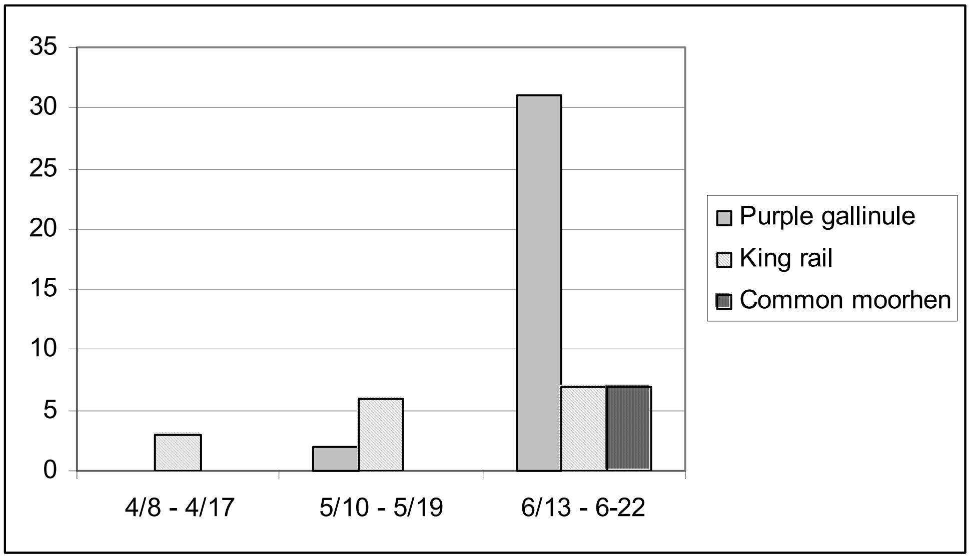

Figure 3.2. Number of detections for each species by survey period in 2005.

Table 3.2. Number of responses of each species heard during each broadcast call in 2005. Species on the top are those that were broadcast, and species on the left are those that were heard.

	Least bittern	King rail	Common moorhen	Purple gallinule
Least bittern	0	1	1	8
King rail	0	11	0	5
American bittern	0	3	0	4
Common moorhen	1	3	2	8
Purple gallinule	0	0	1	13

In 2005, 17 king rails were heard in 13 fields, all of which were first heard during the playback period of the surveys (Table 3.3). Ten of the 13 fields were also searched for nests; nests were found in six of those. Responses were heard in four fields without nests. Nests were found in 14 fields in which no birds were detected. In one field, a king rail was seen before the survey began but was not detected during the survey, and no nests were found. In addition, two individuals were seen but not heard, but were in a field in which two nests were found. Site occupancy in 2005 was estimated to be 0.78 $\pm$ 0.82, with a detection probability of 0.086 $\pm$ 3.03. There was no difference in distances

of nests to the survey points between fields with and without detections (200 ± 28 m with detections, 269 ± 32 m without detections; t=1.34, df=18, *P*=0.19). With both years combined, there was a difference (209 ± 24 m with detections, 313 ± 35 m without detections; t=2.22, df=30, *P*=0.034).

Table 3.3. Total number of birds heard during passive and playback periods of the survey in both years.

	2004		2005	
	Passive	Playback	Passive	Playback
Least bittern	0	1	1	1
King rail	10	20	0	17
Common moorhen	11	19	5	2
Purple gallinule	23	43	12	28

The best regression model for 2004 for king rails included a positive association of responses with the proportion of canals around the fields, and negative associations with planting date and the proportion of trees and crawfish ponds (Table 3.4). The most important variable was the proportion of canals, followed by planting date, the proportion of trees, and the proportion of soybean fields (Figure 3.3).

Residuals in 2005 could not be normalized, hence no regression models are presented. Proportion of canals in fields with detections (0.39 ± 0.080) was not higher than in fields without detections (0.32 ± 0.038; t=0.89, df=58, *P*=0.38). However, the proportion of trees was lower in fields with detections (0.0090 ± 0.0059) than in fields without detections (0.11 ± 0.027; unequal variances - t=3.8, df=50.2, *P*=0.046).

The number of responses was highly correlated with the total nests within 300 m of the survey point in 2004, but not in 2005 (Table 3.5). In general, more birds were detected in fields with higher nest densities (Figures 3.4 and 3.5).

Table 3.4. Best models explaining variation in king rail responses, 2004. 'Canal,' 'rice,' 'tree,' and 'soy' refer to the proportion of each around each fields' perimeter. 'Week' refers to the week rice was planted.

Model	ΔAIC_c	w_i
0.34 canals – 0.39 tree – 0.40 week – 0.18 craw	0	0.234
0.42 canals – 0.33 tree – 0.22 soy	1.0	0.142
0.39 canals – 0.28 tree	1.0	0.142
0.36 canals – 0.38 tree – 0.36 week	1.8	0.0950
-0.50 tree – 0.40 week	2.0	0.0860
0.48 canals	2.1	0.0818
0.39 canals – 0.41 tree – 0.33 week – 0.19 soy	2.8	0.0577
-0.39 tree – 0.43 week + 0.24 rice	2.8	0.0577
0.36 canals – 0.30 week + 0.26 rice	2.9	0.0548
0.42 canals – 0.33 tree – 0.24 soy – 0.13 craw	3.1	0.0496

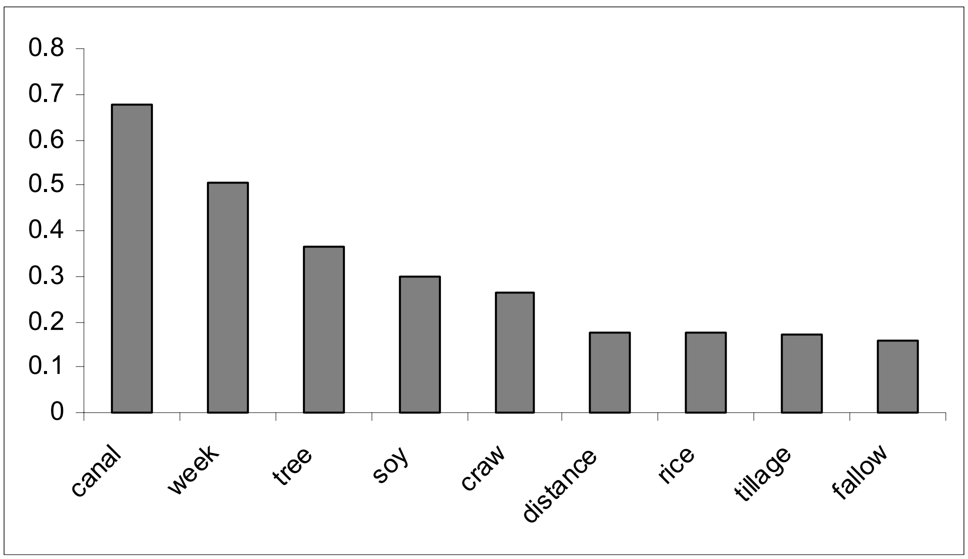

Figure 3.3. Relative importance of local and landscape variables in determining survey responses. Canals, trees, soy, craw, rice, and fallow refer to the proportion of the perimeter of each field bordered by each land use. Week refers to the week each field was planted. Distance refers to the distance each field was to a marsh. Tillage was classified as either conventionally tilled or no-till.

Table 3.5. Correlations between responses and nests found within 300 m of the survey point.

Year	Nests/ bird detected	Correlation coefficient	P-value
2004	1.00	0.49	0.0065
2005	0.96	0.34	0.037

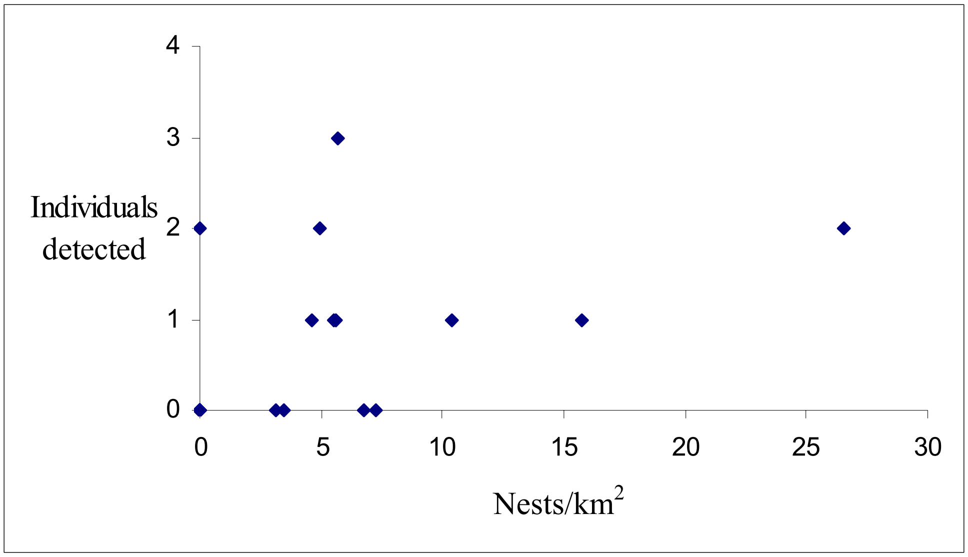

Figure 3.4. Scatter plot of relative nest densities and the maximum number of king rails heard in each field in 2004

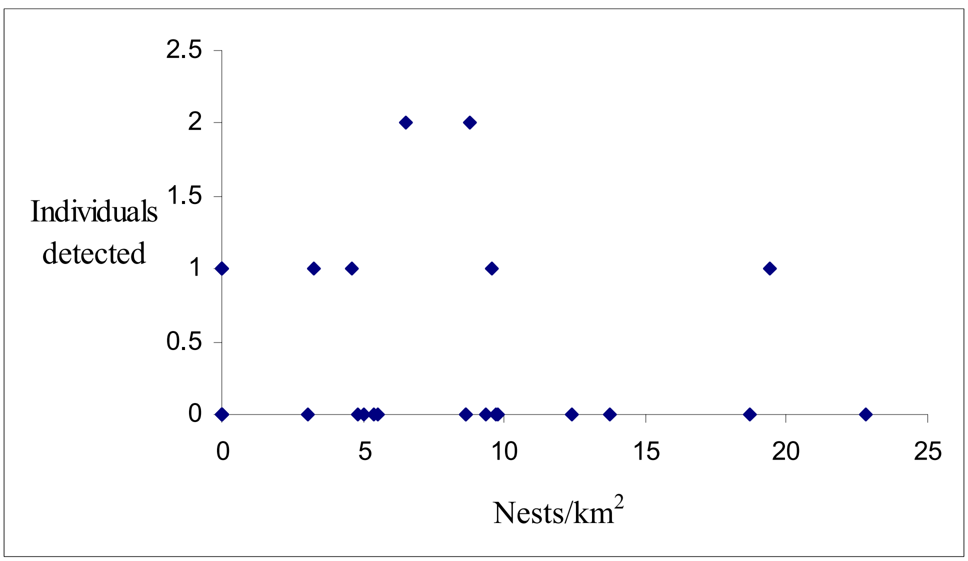

Figure 3.5. Scatter plot of relative nest densities and the maximum number of king rails heard in each field in 2005

In 2004, 54 purple gallinules were heard, 23 of which were first heard during the passive period of the surveys (Table 3.3). A total of 43 birds were heard during the playback period. Responses were heard in 17 of 30 fields surveyed. Of those 17, nests were found in 15. One nest was found in each of two fields that had no gallinule responses. Site occupancy in 2004 was estimated to be 0.72 $\pm$ 0.15 and detection

probability was 0.40 ± 0.091. There was no difference in distances of nests to the survey points between fields with and without detections (200 ± 28 m with detections, 269 ± 32 m without detections; t=1.34, df=18, *P*=0.19).

In 2005, 32 purple gallinules were heard, 12 of which were first heard during the passive period. A total of 28 birds were heard during the playback period. Responses were heard in 16 total fields. Of the 16 fields in which gallinules were heard, nine were searched for nests, and nests were found in seven. Nests were found in 12 fields in which no purple gallinules were heard. With both years combined, the nearest nest to the survey point was closer in fields with detections (170 ± 31 m) than fields without (308 ± 35 m; t=2.95, df=36, *P*=0.0055). In neither year were purple gallinules seen but not heard.

The best regression model explaining the variation in 2004 responses included the proportion of canals and rice surrounding each field, both positively associated with gallinule responses; and planting date, which was negatively associated with responses (Table 3.6). The proportion of canals surrounding each field was the most important variable, followed by the proportion of rice, planting date, distance from the marsh, and proportion of trees surrounding each field (Figure 3.6).

Residuals could not be normalized for the 2005 data, however the same variables appear to be important. The proportion of canals was higher in fields with purple gallinule detections (0.54 ± 0.069) than fields without detections (0.26 ± 0.034; t=4.14, df=58, *P*=0.0001). Also, the proportion of trees around the perimeter was lower in fields with detections (0.029 ± 0.023) than in fields without detections (0.11 ± 0.028; unequal variances - t=2.4, df=52.4, *P*=0.022). The proportion of rice around the perimeter was

not higher in fields with detections (0.54 ± 0.062) than fields without detections (0.43 ± 0.044; t=1.30, df=58, *P*=0.20).

Table 3.6. Best models explaining variation in purple gallinule responses, 2004. 'Canal,' 'rice,' 'tree,' and 'soy' refer to the proportion of each around each fields' perimeter. 'Week' refers to the week rice was planted, 'distance' refers to the distance of each field to a marsh, and 'tillage' refers to the tillage regime of each field. A negative tillage estimate is equivalent to an association with no-till fields.

Model	ΔAIC_c	w_i
0.46 canal – 0.30 week + 0.35 rice	0	0.251
0.49 canal + 0.27 rice	1.3	0.131
0.42 canal + 0.28 rice – 0.34 week – 0.20 distance	1.6	0.113
0.50 canal – 0.29 week – 0.31 distance	2.1	0.0878
0.61 canal	2.2	0.0835
0.44 canal + 0.29 rice – 0.33 week – 0.13 tree	2.4	0.0756
0.49 canal + 0.33 rice – 0.27 week – 0.11 soy	2.4	0.0756
0.52 canal + 0.26 rice – 0.15 soy	2.7	0.0651
0.46 canal + 0.37 rice – 0.30 week – 0.21 tillage	2.9	0.0589
0.53 canal – 0.23 distance	2.9	0.0589

In 2004, the number of purple gallinule responses was highly correlated with the number of nests found within 300 m of the survey point (Table 3.7). The correlation was substantially less in 2005. There were fewer responses in 2005 than 2004, hence the larger number of nests per bird detected. In 2004, there were more detections in fields with higher nest densities (Figure 3.7), however, this pattern is not as apparent in 2005 (Figure 3.8).

In 2004, 21 common moorhens were heard, 11 of which were first heard during the passive period. A total of 19 birds were heard during the playback period. Responses were heard in 10 different fields, eight of which had nests. Nests were found in three fields in which no birds were detected. Site occupancy for 2004 was estimated to be 0.75 ± 0.42, and detection probability was estimated to be 0.18 ± 0.11.

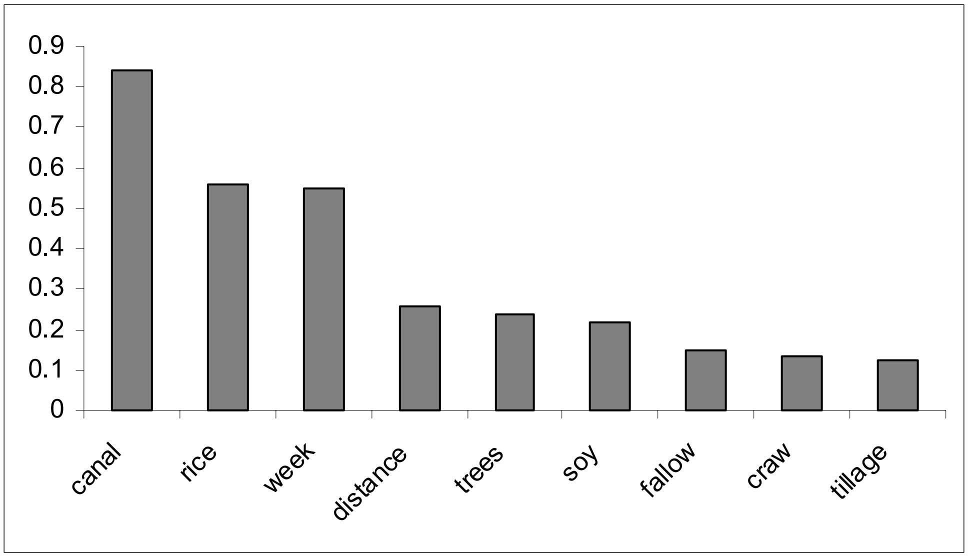

Figure 3.6. Relative importance of local and landscape variables in determining purple gallinule responses, 2004. ‘Canals,’ ‘rice,’ ‘trees,’ ‘soy,’ ‘fallow,’ and ‘craw’ refer to the proportion of each fields’ border covered by each. ‘Week’ refers to the week rice was planted, ‘distance’ refers to the distance of each field from a marsh, and ‘tillage’ refers to the tillage regime of each field.

Table 3.7. Purple gallinule responses correlated with nests found within 300 m of each survey point.

Year	Nests/ bird detected	Correlation coefficient	P-value
2004	2.03	0.77	<0.0001
2005	6.49	0.39	0.098

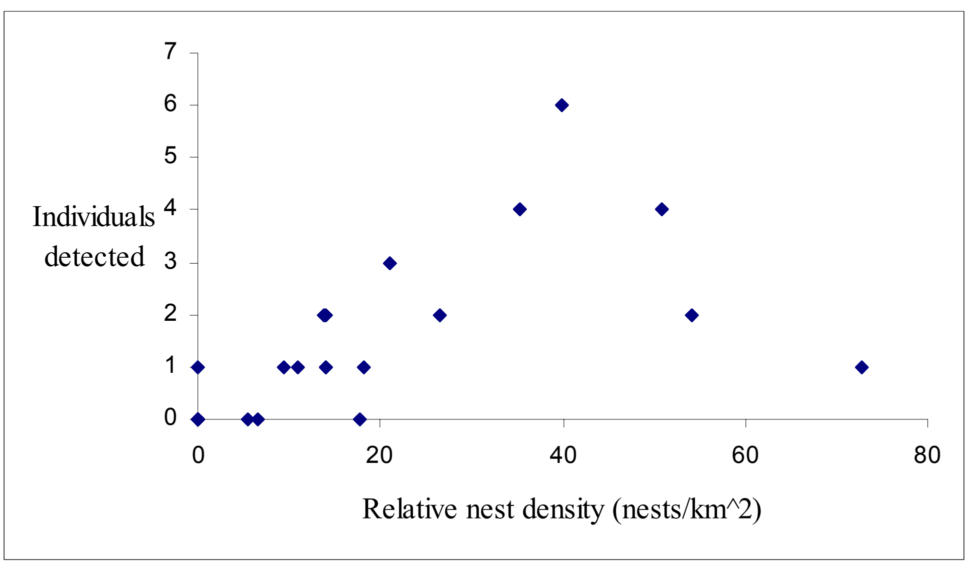

Figure 3.7. Scatter plot of relative nest densities and the maximum number of purple gallinules heard in each field in 2004

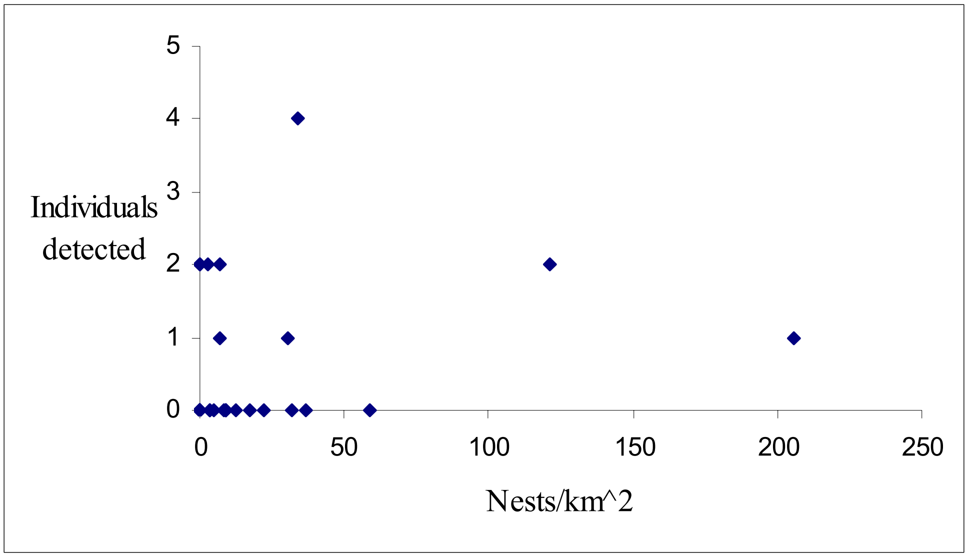

Figure 3.8. Scatter plot of relative nest densities and the maximum number of purple gallinules heard in each field in 2005

In 2005, seven common moorhens were heard, five of which were first heard during the passive period. Three were heard during the playback period. These were heard in seven different fields, five of which were searched for nests. Nests were found in two of those fields. Moorhen nests were found in 10 fields in which no birds were detected. In neither year were moorhens seen but not heard.

Moorhen detections were highly correlated with the number of nests within 300 m of the survey point in 2004, but not in 2005 (Table 3.8).

Table 3.8. Common moorhen responses correlated with nests found at five distance classes.

Year	Nests/ bird detected	Correlation coefficient	P-value
2004	0.32	0.64	0.0001
2005	1.17	-0.070	0.68

Discussion

Callback surveys are an effective means of surveying secretive marsh birds in southwest Louisiana rice fields. The areas birds were detected were similar to those

where breeding took place, and total responses were correlated with nest abundance. In general, if purple gallinules and king rails were detected, nests were present within ~300 m of the survey point. Nests were found in several fields in which no birds were detected; however nests were on average farther away from the survey point and are therefore less expected to record detections. Birds were detected in relatively few fields in which no nests were found. In those instances, it is possible that birds nested in bordering fields, which were not included in the analysis.

For king rails and purple gallinules, broadcast calls appeared to be successful in eliciting bird calls in 2005 but not 2004. In 2004, broadcast calls increased king rail detections by a factor of 2.0 (10 during passive, 20 during playback) and purple gallinule detections by 1.9 (23 passive, 43 playback). However, the playback period, including all species played, was 1.8 times as long as the passive period (9 minutes of playback, 5 minutes of passive) because of the larger number of species used in 2005 (9) relative to 2004 (5). In 2005, the playback and passive periods were equal (five minutes each). No king rails were detected in the passive period, whereas 17 were detected during playback. Likewise, 28 purple gallinules were detected during playback versus 12 during the passive period. Because broadcast calls did not decrease detections in 2004 and increased detections substantially in 2005, I recommend using them for future surveys.

There are two techniques that potentially could improve detection and site occupancy estimates in future studies. Sites could be visited more often, preferably five times per season (MacKenzie et al. 2002). Especially for species with relatively few detections, increased visits would increase detections and improve estimates. Also, to determine population trends, longer-term studies should be employed in which the same

sites are visited in each of multiple years (MacKenzie et al. 2003). This becomes problematic in rice fields because one rice field might be fallow from one year to the next. This can possibly be dealt with by identifying several large blocks of fields in which some of the blocks are expected to have active rice fields every year.

The most productive time to conduct surveys is during June, however all species can be detected from the middle of May through the middle of July. King rails can be detected as early as April. Multiple surveys during this peak time would help estimate site occupancy, and may improve standard error estimates for site occupancy. This study had several surveys during which birds were not detected, which may have caused the high standard errors. Surveys should be conducted in the morning. Several surveys were attempted in the evening, however, increased wind speeds at this time probably reduced detection probability. Surveys should include broadcast calls of ~5 species of marsh birds, given that the birds in this study responded to several different marsh bird calls.

Focus areas that could compare to this study would be near the town of Thornwell and near Lacassine National Wildlife Refuge – where the study was both years, and near the towns of Crowley, Kaplan, and Morse – where the study was conducted the second year. This study lacked a large geographical area, and detailed inferences about other areas cannot be made. Some birds, especially purple gallinules, appeared to be less abundant further inland. This effect needs more research and should be taken into account when designing surveys. Any expansion from the original area would also be useful for baseline information, as we have none further west, east, and north.

The earliest detection of purple gallinules was in the May surveys. In 2004 and 2005 the earliest I recorded purple gallinules in the marsh or rice was April 20 and April

9. They appeared to require rice to be around 70 cm in height before inhabiting fields. In 2004, the best models to explain variation in survey responses were similar to those that explained nest density variation, and the most important factors were similar between the two (see chapter 2). King rails were the only birds to respond before or soon after rice was planted, lending support to suggestions that they find wintering habitat in the rice growing region. If they were to migrate to rice fields from the marsh, there would be little reason to do so without nesting substrate. Responses at that time – April and early May – were usually in rice fields with brushy levees near crawfish ponds or wet fallow fields. They were seen near levees and canals only, as the rest of the fields were open water and afforded little cover. For this reason, brushy levees appear to be important for king rails, at least in the few months preceding the breeding season.

The only reliable site occupancy and detection probability estimates were of purple gallinules and king rails in 2004. In 2004, several responses were heard in each of three sampling periods. In 2005, no responses were heard in the first sampling period, so estimates were taken from only two sampling periods, whereas five is preferred (MacKenzie et al. 2002). This is because the first sampling period was slightly earlier the second year, and rice was planted slightly later.

For king rails, the 2004 site occupancy estimate from Program Presence was 0.35 $\pm$ 0.11. Estimated site occupancy from nest searches was 0.40 in 2004 and 0.50 in 2005. These estimates are from relative nest densities, meaning that actual site occupancy was probably higher, and that Program Presence potentially underestimated site occupancy. Nests were found in several fields in which no rails were aurally detected. One reason for this is that nests in those fields were further from the survey points, and birds are less

likely to respond the farther away they are. Of the 19 fields in which nests were found but no birds were detected, 10 had nests greater than 300 m from the survey point. Conversely, 11 of the 13 fields that had nests and detections had nests within 300 m of the survey point. In general, if birds were detected, there was a high probability that nests existed within 300 m of the survey point. Calls in 2004 correlated with nest abundance at all distances, whereas calls were only correlated in 2005 with nests between 300 and 400 m from the survey points. Both years consistently estimated about one nest per bird detected within 300 m of the survey point.

The 2004 site occupancy rate for purple gallinules was 0.72 $\pm$ 0.15. Actual site occupancy based on nest searches was 0.66, which may be negatively biased because nest detection probability was not calculated. There were substantial differences in the correlations between responses and nests in the two years. Correlations in 2004 were highly significant, whereas 2005 correlations were not. Reasons for this are unknown, however, fewer gallinules per survey point were detected in 2005 and similar densities were found. Based on the 2004 correlations, there were about three nests per bird detected within 500 m of the survey point.

Analyses of habitat data indicated that parameters important for relative nest density of king rails and purple gallinules, were also important for presence. For both species, the number of responses was positively associated with increasing canal and rice coverage around the perimeter. A large difference was the importance of planting date. The later a field was planted, the fewer responses were heard in that field. In 2005, reliable regression models could not be constructed, but comparisons between fields with and without detections indicate that similar factors were important in determining

responses. When examined in conjunction with nest density data, canals consistently appear to be paramount for purple gallinules and king rails in rice fields. The more canals surround rice fields, the more individuals are detected; which was true for both years of the study. Trees are also clearly negatively associated with purple gallinule and king rail use of rice fields.

CHAPTER 4

CONCLUSION

Rice fields in southwestern Louisiana provide valuable habitat for several species of breeding waterbirds. King rails, purple gallinules, fulvous whistling-ducks, and common moorhens benefit from the existence of rice. These species nested successfully, and, in certain areas, nested in high densities. They responded to several local and landscape characteristics, as measured by nest density and survey responses. Areas of high nest densities corresponded to areas with frequent survey responses.

Much emphasis recently has been put on farmlands being compatible with conservation, given the growth and introduction of USDA programs such as the Environmental Quality Incentives Program and the Conservation Security Program (NRCS 2002). The focus of these programs has been on nutrient reduction, water quality, and soil erosion; whereas little emphasis has been put on wildlife. Southwestern Louisiana is a unique area that combines working farmlands with wildlife conservation. Furthermore, two of the species supported by Louisiana rice fields are of some conservation concern, whereas much of the wildlife supported by other intensive agricultural systems is composed of pest and generalist species (Jobin et al. 1996). King rails are endangered in many states, and purple gallinules are suspected to be declining in several areas of the U.S. Several other wading birds and shorebirds, which were not the focus of this study, also use rice fields during a significant portion of their life cycles (Remsen et al. 1991, Huner et al. 2002).

The existence and value of this habitat is in jeopardy, however. Both years of the study were during tough economic times for rice growers. The price of rice was low,

which, when coupled with rising input costs, made rice unprofitable to produce for many rice growers. Adding insult to injury was Hurricane Rita, which struck in the fall of 2005. The eye of the hurricane made landfall very near the Louisiana-Texas border, and the wind, rain, and salt water intrusion destroyed most or all of many growers' second crop rice. Many fields were still too salty to grow rice as of February, 2006. Because of all of these factors, many growers will be unable to receive loans for 2006, and estimates of the decrease in rice for 2006 are from 25% to 40% (Steve Linscombe, LSU AgCenter, pers. comm.). If these economic conditions continue, the decrease in acreage could be long-lasting.

Losing rice acreage would undoubtedly compromise the existence of waterbird habitat in the region. There are few other agricultural activities that are practiced in that location and climate other than soybeans, sugarcane, and cattle. Soybeans and cattle were largely the only other activities in the areas studied; sugarcane is much more common further east. Most abandoned rice fields would most likely stay fallow, and those would undoubtedly be invaded by Chinese Tallow (Sapium sebiferum). None of these alternatives would keep the landscape flooded, and none would be useful to waterbirds. This becomes more critical when taken in the context of coastal marsh loss (Mitsch and Gosselink 2000). The rice growing region of southwestern Louisiana has been a relatively stable refuge for several waterbirds, and is especially important in the face of coastal wetland loss.

Federal incentive programs could be explored that provide monetary assistance to rice growers for supporting wildlife. Rice fields are among the most diverse agricultural systems in the country, yet there is insufficient incentive for rice growers to maintain

these systems. Incentive programs funded by the U.S. Department of Agriculture, such as the Conservation Reserve Enhancement Program, Environmental Quality Incentive Program, Conservation Security Program, and Wildlife Habitat Incentive Program, have been growing substantially the past 15 years. They provide benefits to farmers and landowners for farming and managing land using ecologically sound and wildlife friendly techniques. I believe that introducing or improving incentive programs in the region would fit the goals of several of the programs and would help prevent the loss of a large block of valuable waterbird habitat. Further, providing monetary incentive for supporting wildlife may make farmers less inclined to view birds as pests and more inclined to manage for them.

Conservation priority should be placed on open, treeless areas with large blocks of rice and several irrigation canals. While distance from a marsh itself was not important in determining nest density, those fields closer to the marsh tend to have more desirable characteristics for breeding marsh birds. They are lower in elevation and tend to be more connected to surface water, hence they have more irrigation canals. Rice fields further inland are managed more heavily with deep water wells and have fewer canals. However, because of saltwater intrusion into rice fields closer to the coast as a result of Hurricane Rita, fields closer to the coast may be the first to go out of production. Being more connected to surface water, they are more susceptible to damage from salt water. Those watered with deep water wells were less affected by the salt intrusion. Thus, the highest conservation priority areas may be the most in need of assistance.

In light of the changes likely to occur on the landscape of southwestern Louisiana, monitoring marsh birds with callback surveys and nest searches would be a useful

method to gain knowledge about population trends. This is a large area of great importance for several suites of wildlife, and more attention should be given to the dynamics of agriculture and wildlife in the region.

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