2007

The use of stable isotopes to determine the ratio of resident to migrant king rails in southern Louisiana and Texas

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THE USE OF STABLE ISOTOPES TO DETERMINE THE RATIO OF RESIDENT TO MIGRANT KING RAILS IN SOUTHERN LOUISIANA AND TEXAS

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

In

The School of Renewable Natural Resources

by
Marie Perkins
B.S. Central Michigan University, 2002
May, 2007

ACKNOWLEDGEMENTS

I thank my advisor, Dr. Sammy King for all of his help and support. I also thank my graduate committee, Dr. Phil Stouffer and Dr. Brian Fry for their assistance with this project.

This project could never have been accomplished without the help of Jeb Linscombe, who spent countless hours with me out in the field and helped to perfect the technique of capturing rails at night with an airboat. He was always willing to take time out of his busy schedule to help me, and for this I am deeply indebted to him.

This project was funded by The Louisiana Department of Wildlife and Fisheries and Rockefeller Wildlife Refuge. I thank Rockefeller Wildlife Refuge, Marsh Island Wildlife Refuge, Sherburne Wildlife Management Area, Anahuac National Wildlife Refuge, McFaddin National Wildlife Refuge, Grand Cote National Wildlife Refuge, Cameron Prairie National Wildlife Refuge, and Lacassine National Wildlife Refuge. They provided me with access to their land, airboats, airboat drivers, volunteers, housing, and logistical support. Sweet Lake Land and Oil, Inc., and rice farmers Jim Johnson, Ronnie Guidry, Brad Thibodeaux, Richard Byler, and Phil Watkins also provided me with access to their land, and were good natured about me running all over their harvested fields in an ATV.

I thank all of my airboat drivers: Jeb Linscombe, George Melancon, Philip “Scooter” Trosclair, Darren Richard, Dwayne Lejeune, Tom Hess, Matt Whitbeck, Steve Lejeune, Patrick Walther, Mike Nance, Troy Blair, Cassidy Lejeune, Steve Regan, Mike Hoff, and Billy Leonard. I also thank the LSU undergraduate and graduate students, LSU faculty and staff, and refuge staff that volunteered to help me capture rails. I would

especially like to thank Jessica O'Connell, Sergio Pierluissi, and Aaron Pierce, who were willing to help out anytime I needed an extra hand in the field. Also, I thank my technicians John Trent and Michelle Maley who were invaluable to this project.

I am grateful for the USGS National Wetlands Research Center and Steve Travis, Ben Sikes, and Kevin Wessner for their help with the genetic analysis. I also thank Dr. Mike Kaller for help with the statistical analyses.

The Museum of Comparative Zoology, Peabody Museum of Natural History, California Academy of Sciences, Field Museum of Natural History, Sam Noble Oklahoma Museum of Natural History, The University of Arkansas Collections Facility, University of Kansas Natural History Museum, and Tom Kashmer provided the feather material from northern breeding rails.

Lastly, I thank my family. My parents, Tom and Sharon Perkins, my sister, Theresa, brother-in-law, Jamie, and nephew, Connor, were always there when I needed them, particularly during the writing of this thesis.

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ABSTRACT

Over the past 30 years, the king rail (*Rallus elegans*) has purportedly declined precipitously throughout its range, with the most severe declines seen in the migratory populations. King rails, however, are considered a game species in Louisiana and Texas, thus, it is important to determine what proportion of king rails wintering there are migratory. This is complicated because there is no reliable method to distinguish between king and clapper rails and few studies have attempted to capture wintering rails. The objectives of this study were to: 1) Determine the best method for capturing wintering rails; 2) Determine if morphometric measurements could be used to identify and sex king and clapper rails; 3) Determine the ratio of resident to migrant king rails in southern Louisiana and Texas using stable isotope analysis of feathers. I captured 523 rails, including 187 tentatively identified king rails, 68 tentatively identified clapper rails, 107 Virginia rails, 123 sora, and 38 yellow rails. The effectiveness of capture techniques were: 1) drop-door traps with drift fencing - 0.0063 rails per trap hour, 2) capturing by hand or net from an airboat at night - 2.13 rails per hour, and 3) capturing by hand or net from an ATV at night - 1.80 rails per hour. Discriminate analysis of morphometric measurements revealed that wing, tarsus and culmen measurements could be used to differentiate between king and clapper rails. Multiple stable isotope analysis of rail feathers, δD, $\delta^{13}C$, $\delta^{15}N$, and $\delta^{34}S$, showed distinct differences among winter collected king rails and known migrants, but did not show differences between the winter collected king rails and residents. This indicates that most, if not all, of the winter collected king rails were resident to Louisiana and Texas. A linear relationship was seen between δD_f values and estimated δD_p values at the collection locations ($r^2 = 0.42$). The fractionation

factor that resulted from this analysis could be used to determine an approximate breeding location for the winter collected rails, and also indicated that most, 99%, of the winter collected king rails were resident to Louisiana and Texas.

CHAPTER 1
INTRODUCTION

There are six species of rail that occur in North America, these are: king rail (Rallus elegans), clapper rail (Rallus longirostris), Virginia rail (Rallus limicola), sora (Porzana carolina), yellow rail (Coturnicops noveboracensis), and black rail (Laterallus jamaicensis). These secretive marsh birds rely on wetlands containing areas of emergent vegetation for breeding and wintering habitat, as well as during migration (Eddleman et al. 1988). The loss of these wetlands is thought to be the main threat to all rail species. Many of these species are currently listed as endangered or threatened in areas throughout the United States; and others have shown population declines (Eddleman et al. 1988, Conway 1995, Melvin and Gibbs. 1996).

The king rail is a large secretive waterbird that resides in fresh to brackish wetlands in the eastern half of the United States (Meanley 1992). Its breeding grounds extend from the Gulf of Mexico to southern Ontario and from the central plain states to the Atlantic coast, and it winters along the Gulf and Atlantic coasts (Figure 1). The king rail is migratory throughout much of its range, (Meanley 1969), however, little is known about its migration patterns (Meanley 1992). Over the past 30 years it is believed that king rail populations throughout North America have declined precipitously, with the most severe declines occurring on the northern breeding grounds (Meanley 1992). The king rail is listed as endangered in Canada by the Committee on the Status of Endangered Wildlife (Environment Canada 2006a), and thirteen states have the king rail listed as threatened or endangered (Cooper 2006). However, populations in the southern United States, particularly Louisiana and Florida, do not appear to be declining as rapidly

(Meanley 1992). Despite these population declines, the king rail is considered a game species in thirteen states along the Atlantic and Gulf coasts (Reid et al. 1994).

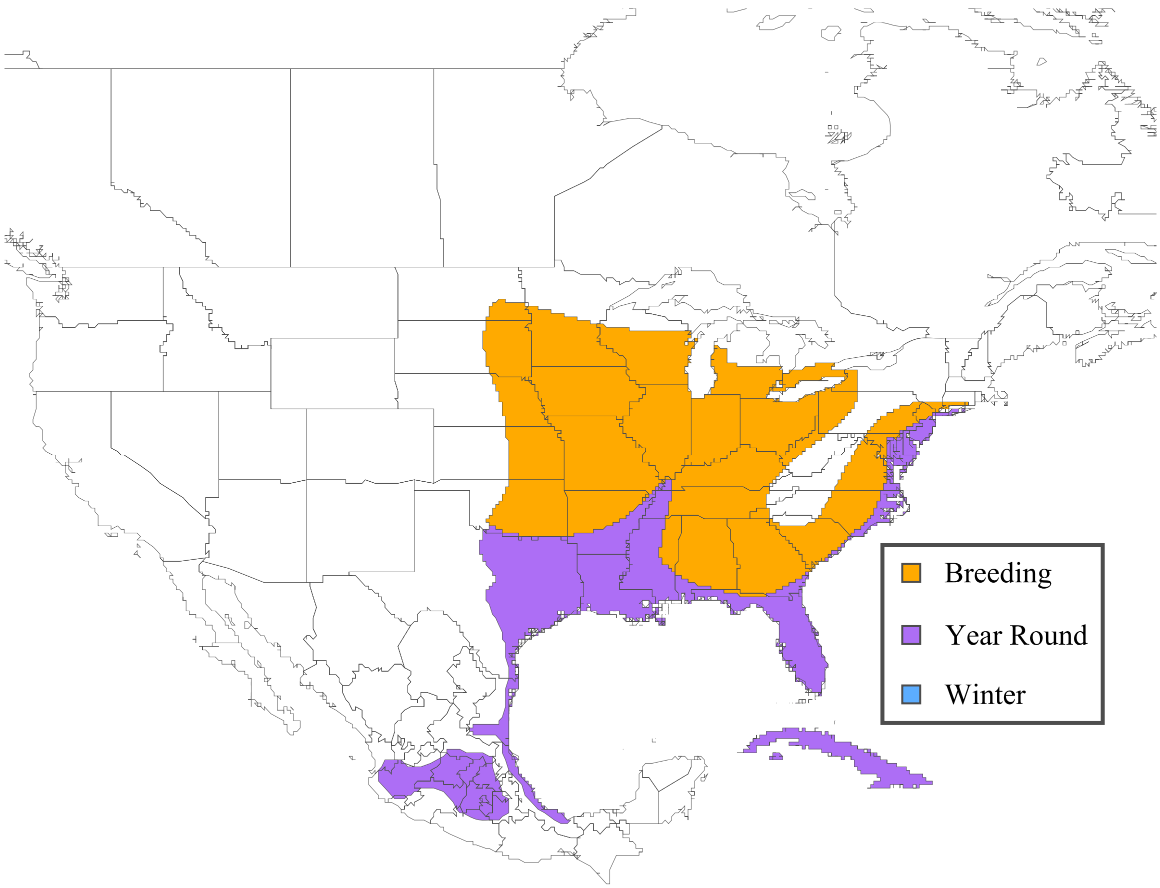


Figure 1: King rail range map, data modified in ArcGIS 9.1 from http://www.natureserve.org/getData/birdMaps.jsp. Accessed 19 June 2006.

The clapper rail is a large secretive waterbird that is similar to the king rail in both size and appearance; and frequently occurs in the same habitat. There are eight recognized subspecies of the clapper rail. All subspecies, except for the Yuma clapper, reside in saline to brackish wetlands along the coasts of North America (Eddleman and Conway 1994). Only the northern clapper rail, which breeds along the northeast Atlantic coast, is thought to be migratory (Figure 2). The clapper rail population throughout the United States is thought to currently be stable (Eddleman and Conway 1994), however,

there is evidence of past declines in coastal Louisiana and Texas (Eddleman and Conway 1998). Three clapper rail subspecies, the Yuma clapper rail, California clapper rail, and light-footed clapper rail, are considered federally endangered (Eddleman et al. 1988). Thirteen Gulf and Atlantic coast states allow hunting of clapper rails, even though there are no current population size estimates for clapper rail populations in the eastern United States (Eddleman and Conway 1994).

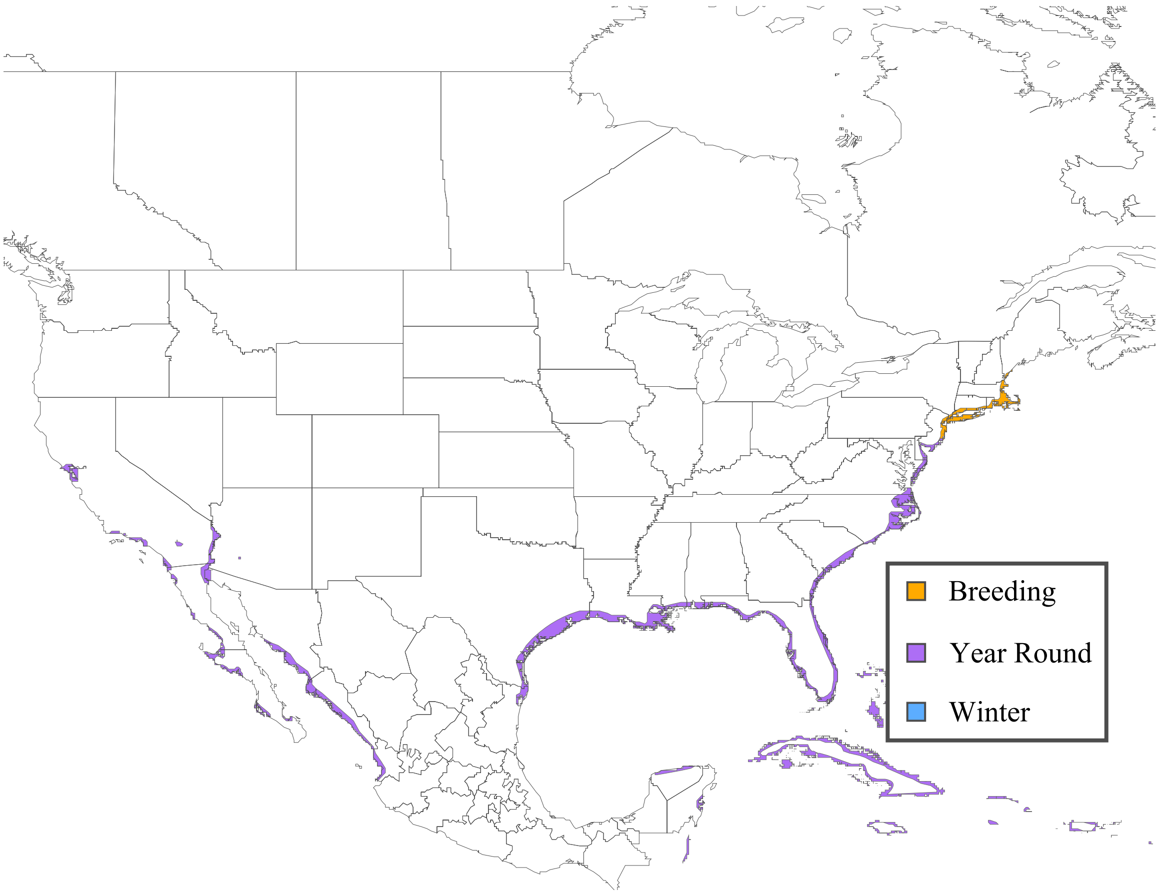


Figure 2: Clapper rail range map, data modified in ArcGIS 9.1 from http://www.natureserve.org/getData/birdMaps.jsp. Accessed 19 June 2006.

The Virginia rail is a small, secretive marsh bird that breeds predominately in robust emergent vegetation of freshwater marshes in Canada and the northern and western United States (Conway 1995). It winters along the Pacific, Gulf, and southern

Atlantic coasts (Figure 3). Most populations of the Virginia rail are migratory, however, many aspects of its migration are unknown (Conway and Eddleman 1994). Virginia rails are thought to have declined throughout the United States, with the largest declines located in the central states, but populations have not been well monitored (Conway 1995). Despite population declines, most states within its range consider the Virginia rail to be a game species. The area of highest hunting pressure is located along the Gulf and southern Atlantic coasts (Conway and Eddleman 1994), although hunting pressure for all Virginia rails is estimated to be low (U.S. Fish and Wildlife Service 2006).

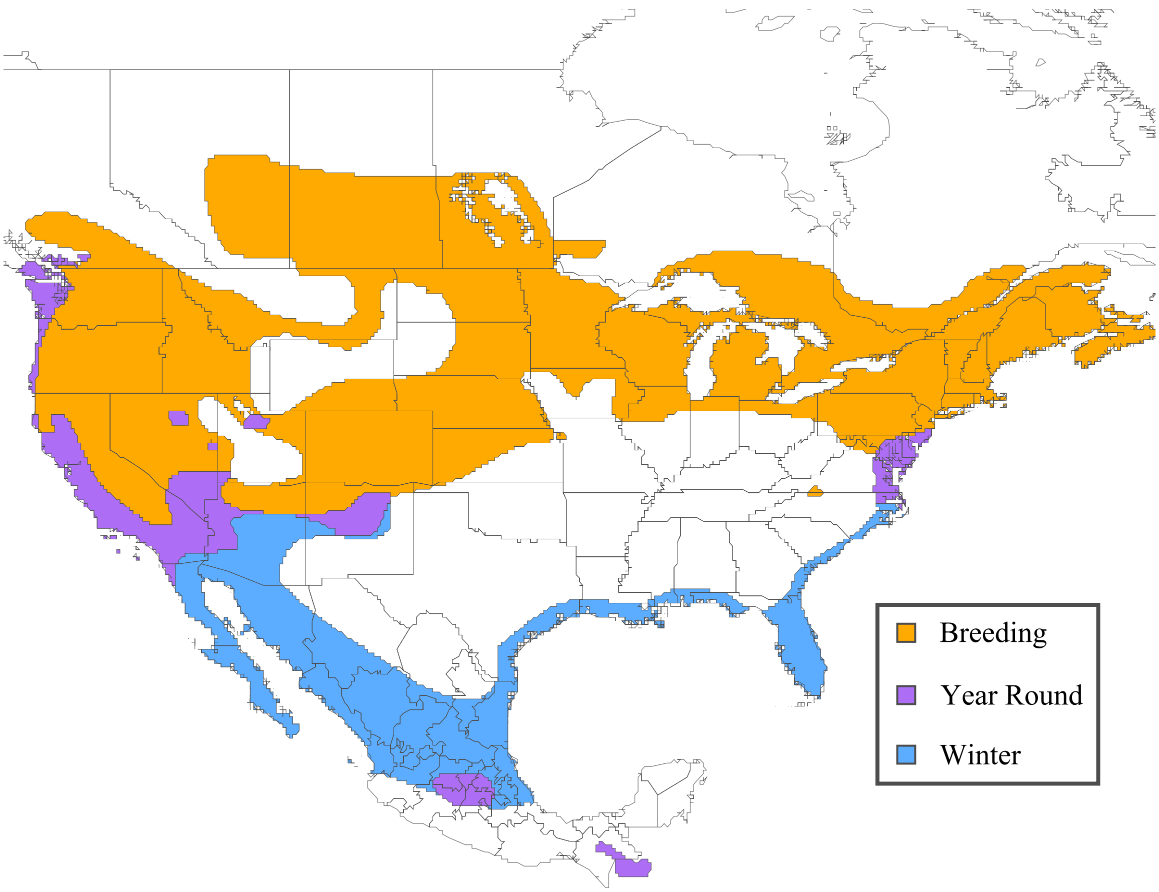


Figure 3: Virginia rail range map, data modified in ArcGIS 9.1 from http://www.natureserve.org/getData/birdMaps.jsp. Accessed 19 June 2006.

The sora is also a small secretive marsh bird and is the most abundant and widely spread of the North American rails (Melvin and Gibbs. 1996). The majority of its range coincides with that of the Virginia rail (Figure 3, Figure 4). The largest proportion of wintering sora in the U.S. occurs in the southern Louisiana bayous, southern Florida, the Texas coastal plains, and the Colorado River valley (Melvin and Gibbs. 1996). Sora and Virginia rails tend to occur in similar habitats during migration and the breeding season (Sayre and Rundle 1984), as well as on the wintering grounds (personal observation). Populations of sora are thought to be declining throughout the United States; however, this trend is uncertain. The sora is also considered to be a game species by most states within its range (Melvin and Gibbs 1994).

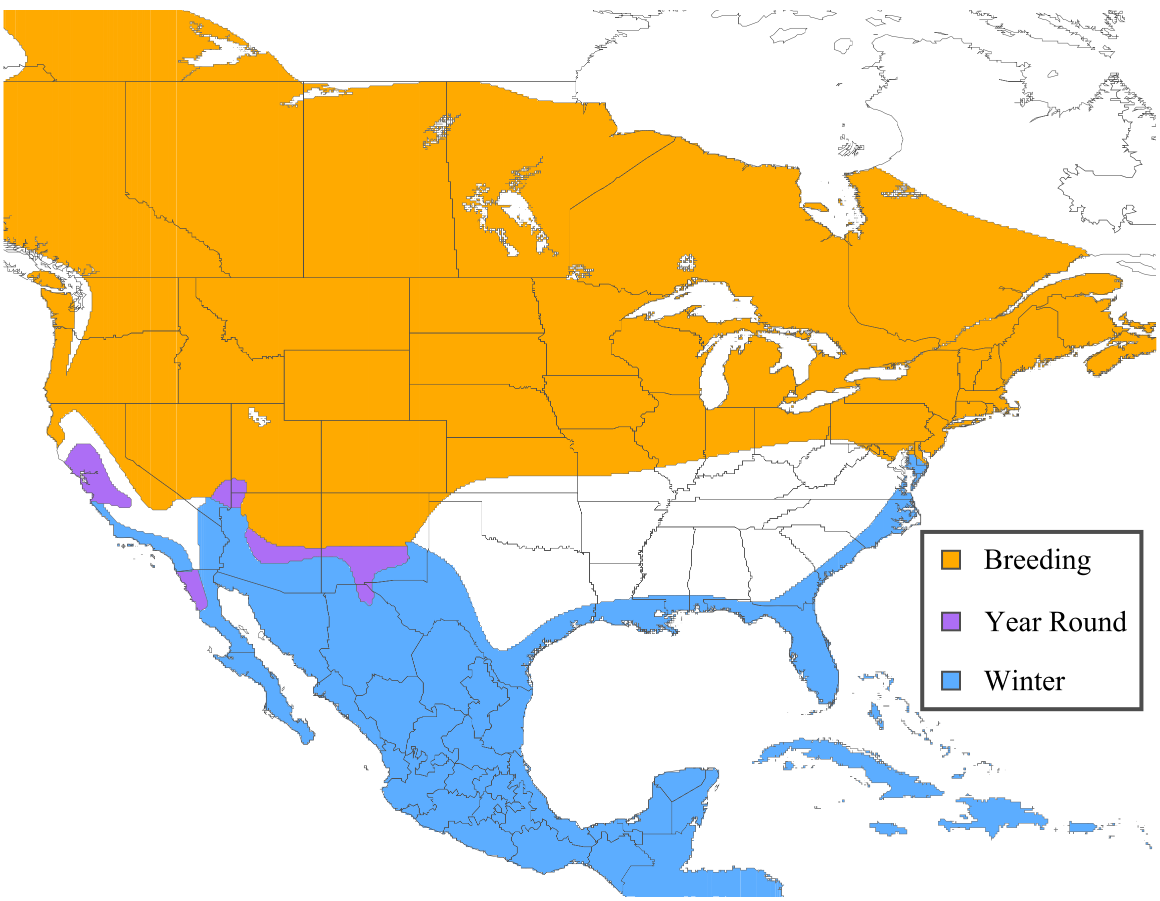


Figure 4: Sora range map, data modified in ArcGIS 9.1 from http://www.natureserve.org/getData/birdMaps.jsp. Accessed 19 June 2006.

The yellow rail breeds locally throughout Canada and the northern United States, and winters along the southern Atlantic and Gulf coasts (Figure 5). Very little is known about the aspects of the life history of the yellow rail, as it has been little studied (Robert and Laporte 1997), though all populations of yellow rails are thought to be migratory (Bookhout 1995). The population status of yellow rails in North America is unknown; however, it is listed as a species of concern by the Committee on the Status of Endangered Wildlife in Canada (Environment Canada 2006b). Since yellow rails are very secretive, it is possible that populations have been underestimated. Robert et al. (2004) found it to be a common bird in the marshes around southeastern James Bay, Canada. The yellow rail is not considered a game species in North America (Bookhout 1995).

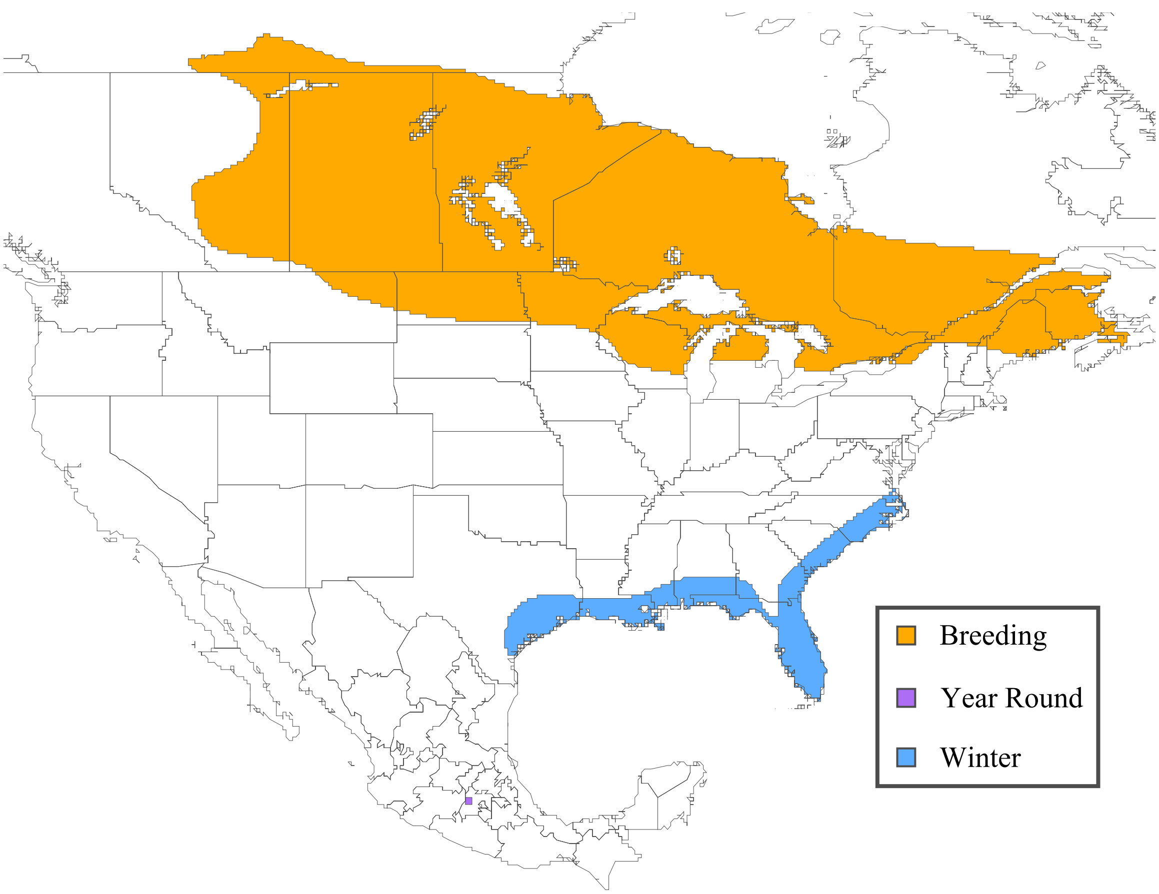


Figure 5: Yellow rail range map, data modified in ArcGIS 9.1 from http://www.natureserve.org/getData/birdMaps.jsp. Accessed 19 June 2006.

The black rail is the smallest of the North American rails and is thought to inhabit wetlands throughout the Americas (Figure 6). The secretive nature of the black rail has made it difficult to study, thus, very little is known about the aspects of its life history. Migration patterns of the black rail are poorly known, however, the eastern population is thought to be migratory (Eddleman et al. 1994). Population trends are also not well known for the black rail, but populations are thought to have declined significantly over the past century. Encounters of black rails in the Midwest and Gulf coast have been minimal over the past 40 years. The black rail is not considered a game species in North America (Eddleman et al. 1988).

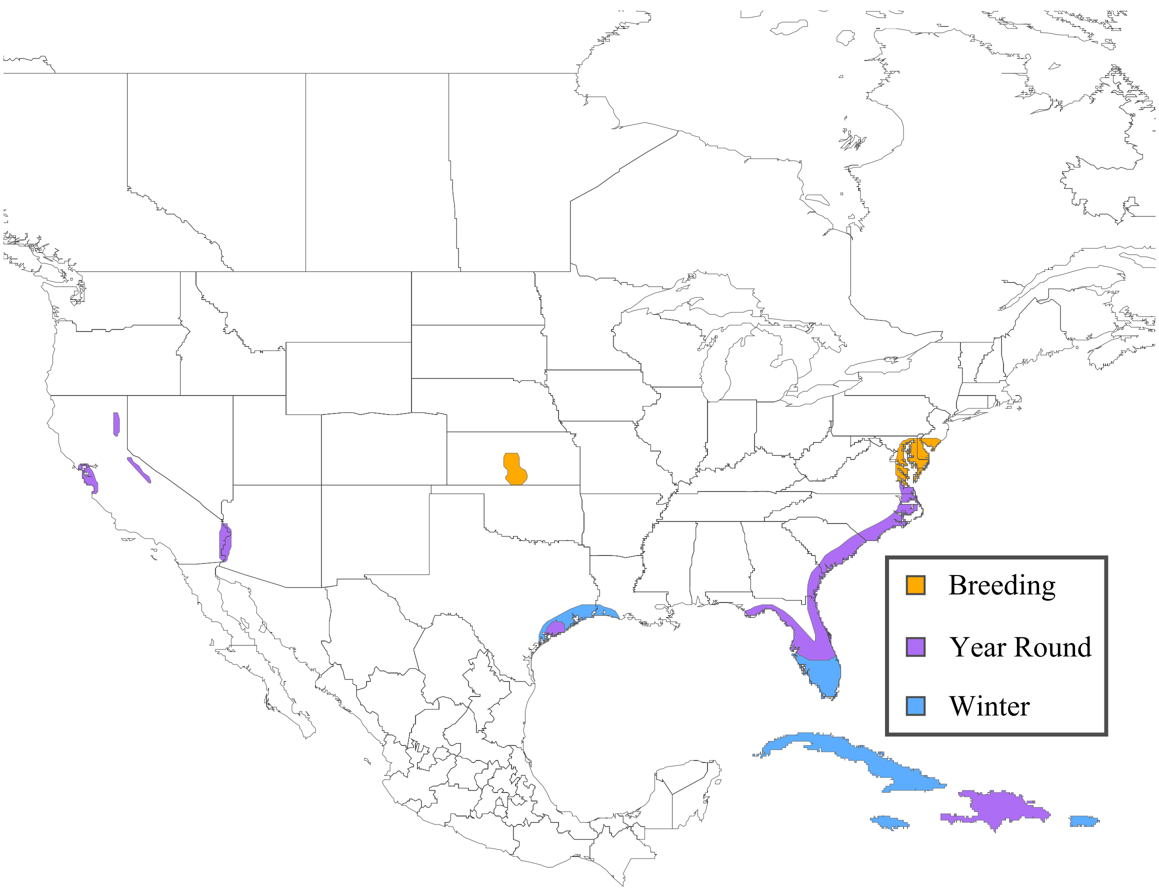


Figure 6: Black rail range map, data modified in ArcGIS 9.1 from http://www.natureserve.org/getData/birdMaps.jsp. Accessed 19 June 2006.

Although all six North American rails species are thought to be in decline, the king rail is currently of particular conservation concern. It is thought that king rail populations are declining rapidly throughout the United States, with the migratory populations suffering the most dramatic declines (Cooper 2006). The Gulf coast supports both resident and migratory king rails during the winter months (Figure 1), however, because resident Louisiana and Texas populations of king rails seem to be relatively large, it is currently considered a game species in these states (Reid et al. 1994). It is unknown what affect, if any, hunting has on the migratory king rail population. In order to get a better idea of this possible effect, it is important to determine what proportion of the wintering king rails in Louisiana and Texas are resident versus migratory.

Recent evidence has shown that stable isotope analysis of feathers can be used to determine the breeding origin of wintering birds (Chamberlain et al. 1997, Hobson and Wassenaar 1997); and this method may be a good way to determine the proportion of resident to migrant king rails in Louisiana and Texas. The stable isotope values vary geographically, and feathers contain the isotopic values of the area in which the feather was grown. Although stable isotope analysis is a promising technique for determining the proportion of resident to migrant king rails in Louisiana and Texas, two major issues must be resolved.

First, successful capture techniques for wintering king rails have not been well established. In order to use stable isotope analysis to study king rail migration, feathers must be obtained from wintering rails. Thus, it is important to develop a successful technique for capturing wintering king rails in Louisiana and Texas in order to use stable isotope analysis.

A second issue is that in coastal Louisiana and Texas the ranges of king and clapper rails overlap, and they are often difficult to tell apart by physical appearance (Eddleman and Conway 1998). When studying king rails in this region it is important to have a method to successfully differentiate between king and clapper rails. It has been indicated by previous studies that king and clapper rails may differ in size (Meanley 1969, 1992), therefore, it may be possible to use morphometric measurements to differentiate between king and clapper rails.

This study had three objectives; the first was to evaluate capture techniques for capturing wintering rails, including king rails, in southern Louisiana and Texas. This was done by using a variety of capture methods to determine which worked best to capture rails. Techniques were focused on capturing king rails, however, an effort was made to capture all rails encountered. The second objective was to evaluate the effectiveness of morphometric measurements for distinguishing between king and clapper rails. A sample of positively identified king and clapper rails was used in discriminant analysis in order to determine a discriminant function that could be used to predict the species of unknown rails. The third objective was to determine the ratio of resident to migrant king rails in southern Louisiana and Texas by using hydrogen, carbon and sulfur stable isotope analysis. The stable isotope values of winter collected king rails were compared with the values for known migrant rails and rails that were resident to Louisiana and Texas.

CHAPTER 2
CAPTURE TECHNIQUES FOR WINTERING RAILS IN SOUTHERN LOUISIANA AND TEXAS

Few studies have evaluated capture techniques for rails. These secretive birds inhabit thick emergent marshes and rarely fly, making their capture difficult. They are even more difficult to capture during the winter months when they are most likely less responsive to calls (personal observation). The technique predominantly used in previous studies was un-baited traps with drift fences, which were used to lead the rails into the traps. Three different trap types were used: (1) drop-door traps (Roth et al. 1972, Zembal and Massey 1983, Conway et al. 1993, Flores and Eddleman 1993, 1995, Lagare et al. 1999), (2) funnel traps (Stewart 1951, Adams and Quay. 1958), and (3) cloverleaf traps (Meanley 1969, Kearns et al. 1998).

Zembal and Massey (1983) caught clapper rails by fitting drop-door traps snugly in tidal creeks and small trails, finding that the rails would take the easiest way through the trap, rather than walk around it. They also baited drop-door traps with calls, calls and mirrors, and prey items. No differences were found in capture rates between the baited and un-baited traps. Flores and Eddleman (1993, 1995) used drop-door traps similar to that of Zembal and Massey (1983) to capture black rails in southwestern Arizona. They placed 1 m high drift fences, with the bottoms covered in vegetation, perpendicular to areas where black rails occurred, leading them into the traps. Meanley (1969) captured king rails, Virginia rails, and sora by placing a row of 4 cloverleaf traps, spaced 9.14 m apart and connected with drift fences, in a patch of Typha sp. Kearns et al. (1998) found that combining an audio lure with cloverleaf traps and drift fences dramatically increased capture rates of soras and Virginia rails during fall migration.

Grabbing rails by hand or using a dip net was also a commonly used method to capture rails. Adams and Quay (1958) found they could catch flightless clapper rails by hand or with a crab net. Meanley (1969) used a 2.29 m long dip net to capture king rails while they were sitting on nests. During extremely high tides, Stewart (1951) also caught clapper rails with a crab net by either wading into the marsh or using a pole boat. Zembal and Massey (1983) tried to capture clapper rails with a dip net from an inflatable boat; however, they were relatively unsuccessful as they captured only one rail in 9 nights. Robert and Laporte (1997) captured yellow rails by using a dip net at night by locating calling rails or by luring the rails to the catcher by imitating their call.

The use of a lighted airboat at night has proven to be an advantageous way to capture rails by hand or dip net (Blandin 1963, Cummings and Hewitt 1964, Hon et al. 1977). Hon et al. (1977) captured 2,066 clapper rails with this method. This method was only moderately successful for Blandin (1963) who captured 13 clapper rails, however, since the use of this technique was discontinued, few details were reported. Cummings and Hewitt (1964) caught mostly waterfowl with this technique; however, they did catch two sora.

Since few of these studies included capturing a wide range of rail species during the winter months, the objective of this study was to determine the best technique for capturing rails in Louisiana and Texas during winter. This was done by implementing a variety of capture techniques, including, capturing rails by net or hand using an airboat or ATV, and drop-door traps with drift fencing. These techniques were implemented in a variety of habitats in southern and central Louisiana and southeast Texas; including salt, brackish, and freshwater marsh, harvested and fallow rice fields, and moist soil units. The

majority of the capture effort was carried out during the winter months, though a lesser effort was made to capture rails using an airboat and drop-door traps during the summer. The capture of king rails was the main focus for this study, however, an effort was made to capture all rails detected.

METHODS

Study Sites

Capture techniques were implemented on national and state wildlife refuges, as well as private lands, in southern Texas and southern and central Louisiana (Figure 7). The study sites in Louisiana included Rockefeller Wildlife Refuge, Marsh Island Wildlife Refuge, Sherburne Wildlife Management Area, Cameron Prairie National Wildlife Refuge, Grand Cote National Wildlife Refuge, Sweet Lake Land and Oil, Inc. and privately owned rice farms in Jefferson Davis Parish. The study sites in Texas included McFaddin National Wildlife Refuge and Anahuac National Wildlife Refuge.

Rockefeller Wildlife Refuge, Marsh Island Wildlife Refuge, and Sherburne Wildlife Management Area are managed by the Louisiana Department of Wildlife and Fisheries. Rockefeller Wildlife Refuge encompasses 308 km^2 in western Vermilion and eastern Cameron Parishes, it extends for 43 km along the Gulf of Mexico and runs inland 10 km to the Grand Chenier ridge (Louisiana Department of Wildlife and Fisheries 2005b). Marsh Island Wildlife Refuge is an island located between the Gulf of Mexico and Vermillion Bay in Iberia Parish. It is approximately 283 km^2 of brackish marsh habitat (Louisiana Department of Wildlife and Fisheries 2005a). Capture techniques were implemented at both Rockefeller and Marsh Island Wildlife Refuges in Spatina patens marsh. Sherburne Wildlife Management Area is located in parts of Pointe Coupee, St.

Martin, and Iberville Parishes, and is situated between the East Protection Guide Levee and the Atchafalaya River (Louisiana Department of Wildlife and Fisheries 2005c). It is 166 km^2 in size and 48 km^2 is owned by the Louisiana Department of Wildlife and Fisheries. Rails were captured in a 3 km^2 moist soil unit (Fredrickson and Taylor 1982) at the north farm and a 1 km^2 moist soil unit at the south farm (S. Soileau, Louisiana Department of Wildlife and Fisheries, personal communication).

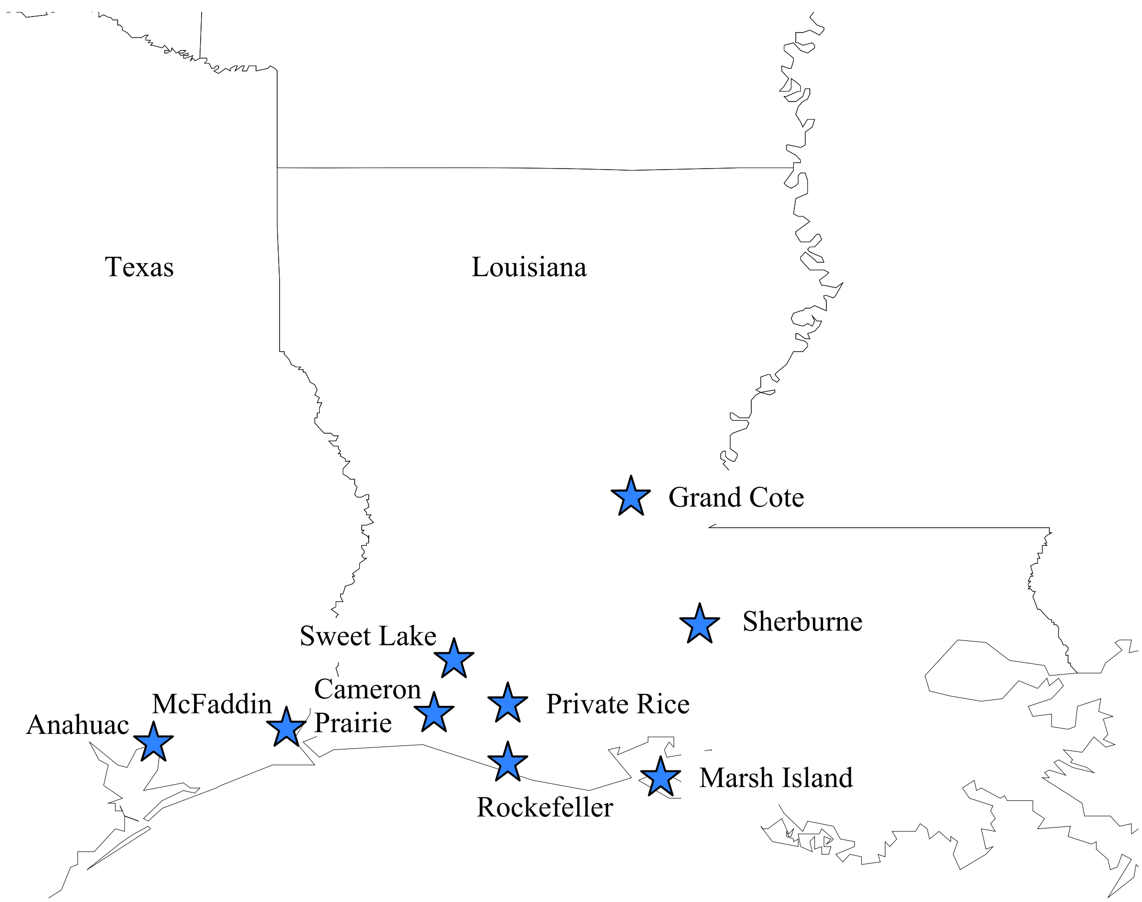


Figure 7: The approximate locations of the sites used in this study.

Rails were also captured at two National Wildlife Refuges located in south and central Louisiana. Cameron Prairie National Wildlife Refuge is located in Cameron Parish in southwestern Louisiana and consists of 39 km^2 of freshwater marsh and moist

soil units (U.S. Fish and Wildlife Service 2007a). Rails were captured in both of these habitat types. Grand Cote National Wildlife Refuge is 25 km^2 in size, and is located in Avoyelles Parish in central Louisiana (U.S. Fish and Wildlife Service 2007b). The refuge has a variety of habitat types including 3 km^2 of moist soil and 8 km^2 of croplands. Most capture techniques were implemented in harvested rice fields, though they were occasionally implemented in moist soil units.

Sweet Lake Land and Oil, Inc. is a private corporation that owns land throughout southwestern Louisiana. Capture techniques were implemented in both fallow and harvested rice fields on Sweet Lake Land and Oil, Inc. property located in Calcasieu Parish. Capture techniques were also implemented on privately owned rice fields in Jefferson Davis Parish in southwestern Louisiana.

Anahuac National Wildlife Refuge is located in Chambers County in southeastern Texas. This refuge is 138 km^2 in size, of which approximately 10% is moist soil units and rice fields (Western Hemisphere Shorebird Reserve Network 2006). Capture techniques were implemented in moist soil units, unharvested organic rice fields, and fallow rice fields. McFaddin National Wildlife Refuge is 223 km^2 in size and is located in Jefferson County in southeastern Texas (U.S. Fish and Wildlife Service 2007c). The refuge provides a range of habitats, from freshwater marsh to intermediate to brackish marsh. Capture techniques were implemented in marsh habitat composed primarily of <u>Spartina patens</u>.

Capture Techniques

Rails were captured in Louisiana and Texas over two winter seasons, from 24 September 2004 until 8 April 2005, and again from 17 October 2005 until 23 March

2006, using three main capture techniques. These capture techniques consisted of capture by hand or net from an airboat at night, capture by hand or net from an ATV at night and during rice harvest, and drop-door traps with drift fencing. Resident king and clapper rails from southwestern Louisiana were captured from 14 May 2005 until 24 May 2005 and again on 11 and 12 July 2006 using an airboat at night and drop-door traps with drift fencing.

The technique of capturing rails by hand or net from an airboat at night was implemented approximately ½ hour after sunset, as soon as it was dark. As a safety precaution, two to three airboats were used whenever possible. Each airboat was equipped with an airboat driver, and one or more rail catchers. The driver and the rail catchers used spotlights, Q-beam Max Million and Q-beam Black Max (The Brinkman Corporation, 4215 Mc Ewan Road, Dallas, Texas 75244, USA), to navigate the marsh at night, as well as to spot rails. Each boat was equipped with 1 - 3 lights, which were attached to the boat battery. The number of lights was dependant upon the number of lights available, as well as the number of people on the boat.

In order to capture the rails, the airboat was driven at approximately 4.5 meters per second through the marsh, and rails were either flushed up from the vegetation or were seen running near the airboat. If flushed, the rails were kept in sight with a spotlight and followed until they landed. These rails would either disappear into the vegetation, flush again or be seen running in or on top of the vegetation. Rails seen running near the airboat were captured by the catcher who was positioned in the bow of the boat. The driver would maneuver the airboat as close to the bird as possible, often moving the boat in front of the rail to slow its movements. Catches were made by hand or with a dip net

by either leaning over the side of the bow or by getting out of the boat and chasing the rail. If the rail was captured using the dip net, it was important for the catcher to immediately grab the rail by hand, in order to keep it from escaping from the net. The dip nets used in this study had 65 cm long handles, which extended to 105 cm. The net portion was 43 cm long, 42 cm wide and 65 cm deep. The nets were made of nylon and had a mesh size of 2.5 cm.

During the second capture season ATVs were used at night in a method similar to that of the airboat capture technique. This technique was implemented in areas where no airboat was available or the water was too shallow for an airboat, such as harvested rice fields and moist-soil units. It was also begun approximately ½ hour after sunset, as soon as it was dark. Each ATV had a driver and a catcher; one or both held a spotlight in order to navigate through the habitat, as well as to search for rails. The spotlights were initially attached to the ATV battery by alligator clips; however, this caused a drain on the ATV battery. The spotlights were then attached to a marine deep cycle/RV battery that was securely tied onto the back of the ATV. The driver maneuvered the ATV slowly, staying in first gear, through the habitat. The catcher sat sideways on the back of the ATV in order to be able to easily jump off the ATV if necessary. Once a rail was seen near the ATV, the driver maneuvered the ATV close to the bird, keeping the rail on the same side of the ATV as the catcher. The rail was then captured by the catcher using a dip net or by hand. When possible, two ATV's were used, making sure to keep within site of one another.

ATV's were also used, in a similar manner, during the day to capture rails flushed by a rice combine during the harvest of the ratoon rice crop in Jefferson Davis Parish in

southwestern Louisiana. This technique was used from late October to early November 2004. The driver maneuvered the ATV to stay parallel with the combine, driving in the area of the rice field that had already been harvested. As rails were flushed from the combine, the ATV driver followed these rails until they landed in the already harvested rice. These rails were often seen running through the vegetation. The driver then maneuvered the ATV close to the bird, keeping the rail on the same side of the ATV as the catcher. The rail was then captured by the catcher using a dip net or by hand.

Drop-door traps with drift fencing were used to capture rails during the first field season (Figure 8). Two different trap types were used in order capture rails of different sizes, however, king rails were the focus of this capture technique and, therefore, the large traps were used most often. The large traps had double drop-doors with a release pedal in the center of the trap. They were 22.9 cm x 22.9 cm x 61 cm in size with 2.5 cm mesh. Some of these traps were covered with 0.64 cm chicken wire to prevent the rails from injuring themselves by sticking their bills and heads through the trap mesh. This was unsuccessful, however, because the rails still injured their bills and faces on the traps; the chicken wire was removed at a later date. I also used single drop-door traps (17.8 cm x 17.8 cm x 48.2 cm) with 2.5 cm mesh, containing a release pedal in the center of the trap. Drift fences of varying lengths were placed to extend in a V shape from the trap opening and used to lead birds into the traps. On occasion, drift fences extending in a V shape were placed at the back of the trap as well. The drift fences were made from 1.22 m high plastic garden fence with 2.5 cm mesh; these were cut in half to create two 61 cm high fences. They were attached, using a staple gun, to 91 cm high wooden stakes, which were placed every 2.5 m along the fence. The lengths of each fence ranged from 1 m to

16 m in length and were often placed so the ends were in open water or road/mowed grass. An effort was made to place the bottom of the fences flush against the ground in order to keep the rails from getting underneath the fence. Vegetation was often placed along the bottom of the fence for this purpose.

Figure 8: A large drop-door trap with drift fencing, with king rail inside the trap.

Traps and fencing were set up beside levees or roads running along ditches, management units, and unmanaged marsh. They were also set up along canal sides, as well as in the interior of managed units. When possible, the traps were set in pre-existing paths, often created by rabbits. The traps were opened at or just before sunrise and checked every 3-4 hours. At sunset, the traps were closed and removed from in between the drift fences to leave a corridor between the fences. The traps were opened between 2 to 6 days before they were moved to a new location; 3-12 traps were placed at one location. Traps were also placed on or beside levees in rice fields during the harvest of

the ratoon rice crop in southwestern Louisiana. The drift fences were placed across the levees and ran along side them, but did not extend into the rice. The traps were set up a few hours before the harvest began and were removed a few hours after harvesting was completed.

For each capture technique, the number of people needed, equipment used, number of birds caught, and the amount of time spent on each technique was recorded. At each capture site, or trap site, a Garmin GPS 72 (Garmin International, Inc., 1200 East 151st Street, Olathe, Kansas 66062 USA) was used to record the UTM coordinates and the salinity was measured using an YSI model 63 (Yellow Springs Instruments Inc., 1725 Brannum Lane, Yellow Springs, Ohio 45387 USA). The depth of the nearest water was recorded at the time of capture.

Each rail captured was banded with an individually numbered aluminum leg band (USGS). They were also weighed, and measurements of the wing, tail, tarsus, and exposed culmen were taken. Yellow rails, Virginia rails, and soras were aged by descriptions given in Bookhout (1995), Conway (1995), and Melvin and Gibbs (1996). King rails were aged by the description given in Meanley (1992) and clapper rails were aged by the description given in Eddleman and Conway (1998). King and clapper rails were identified in the field based on coloration, size, and habitat type at the capture location. Rails weighing greater then 400g were considered king rails (Eddleman and Conway 1998), as were rails captured in freshwater marsh. Rails captured in tidal salt marsh were considered clapper rails. Species identification was later verified using discriminant analysis of the morphometric measurements as described in Chapter 3, however, the current manuscript reports field identifications only. Genetic analysis was

used to confirm the sex of the king and clapper rails. The outer retrices of king and clapper rails were pulled for genetic analysis and the fourth primary from both wings was pulled from all rails for isotopic analysis.

RESULTS

The capture techniques used in this study resulted in the capture of 523 new rails, as well as 21 recaptured rails. The new rail captures consisted of 187 king rails, 68 clapper rails, 107 Virginia rails, 123 soras, and 38 yellow rails. The recaptured rails consisted of 8 king rails, 6 clapper rails, 3 Virginia rails, 2 sora, and 2 yellow rails.
The use of an airboat at night yielded the highest capture rate of 2.13 rails per hour. Five rail species; king rail, clapper rail, Virginia rail, sora, and yellow rail, were captured using this capture technique (Table 1). This technique led to the capture of 415 new rails and 17 recaptures over all capture seasons. The recaptured rails consisted of 7 king rails, 6 clapper rails, 1 Virginia rail, 2 soras, and 1 yellow rail. The use of an ATV at night yielded the second highest capture rate of 1.80 rails per hour. It led to the capture of 85 new rails, consisting of sora, Virginia rail, and yellow rail (Table 2). Two Virginia rails and one yellow rail were recaptured using this technique.

The use of an ATV while following a rice combine led to the capture of one sora, one Virginia rail, and one yellow rail, and had a capture rate of 0.25 rails per hour. The capture technique of using passive drop-door traps with drift fencing lead to the capture of 20 new rails and one recaptured king rail. This capture technique had a capture rate of 0.0063 rails per trap hour (Table 3). Captures consisted of three rail species: clapper rails, king rails, and sora. No rails were captured when passive drop-door traps were placed on levees during rice harvest; however, this technique was only implemented for three days.

Table 1: A summary of the rail capture effort and success using an airboat at night. Dates for the time periods are: winter 1, 29 September 2004 – 28 March 2005, summer 1, 7 April 2005 – 24 May 2005, winter 2, 11 November 2005 – 23 March 2006, summer 2, 11 and 12 July 2006. The capture rate for this technique was 2.13 rails/hour.

Time Period	Site	Hours	King Rail	Clapper Rail	Virginia Rail	Sora	Yellow Rail	Recapture
Winter 1	Rockefeller	63.75	30	31	26	36	0	4
	McFaddin	9.25	13	0	5	6	0	0
	Anahuac	7	8	0	3	1	3	0
	Cameron Prairie	9.25	4	0	4	7	2	2
Summer 1	Rockefeller	24.25	28	7	0	2	0	2
	Cameron Prairie	3.75	3	0	0	1	0	1
Winter 2	Rockefeller	27.75	40	0	9	5	0	3
	McFaddin	17.5	20	0	13	11	0	2
	Anahuac	15.75	15	0	6	7	16	0
	Marsh Island	13.5	9	1	5	9	2	2
Summer 2	Rockefeller	11	1	26	0	0	0	1
Total		202.75	171	65	71	85	23	17

Table 2: A summary of the rail capture effort and success using an ATV at night. Dates for time periods are: winter 2, 17 October 2005 – 9 February 2006. The capture rate for this technique was 1.80 rails/hour.

Time Period	Site	Hours	King Rail	Clapper Rail	Virginia Rail	Sora	Yellow Rail	Recapture
Winter 2	Grand Cote	24.5	0	0	27	31	2	2
	Sherburne	22.5	0	0	8	5	11	1
	Sweet Lake	2	0	0	0	0	1	0
Total		49	0	0	35	36	14	3

Table 3: A summary of the rail trapping effort and success using passive drop-door traps with drift fencing. Dates for the time periods are: winter 1, 24 September 2004 – 8 March 2005, and summer 1, 14 and 15 May 2005. The capture rate for this technique was 0.0063 rails/trap hour.

Time Period	Site	Trap Hours	King Rail	Clapper Rail	Virginia Rail	Sora	Yellow Rail	Recapture
Winter 1	Rockefeller	2235.5	12	3	0	1	0	1
	Sweet Lake	620.75	1	0	0	0	0	0
	Rice in Jefferson Davis Parish	456	0	0	0	0	0	0
Summer 1	Rice in Jefferson Davis Parish	9	3	0	0	0	0	0
Total		3320.25	16	3	0	1	0	1

The average water depth of capture for all rails was 8.0 centimeters; with a maximum depth of 45.7 cm (Table 4). All rail species were captured in areas where there was no standing water at the location of capture. The salinity at the capture sites ranged from 0 to 29.2 ppt.

Table 4: Average water depth at the location of capture for each rail species.

Species	n	Average water depth (cm)	Standard deviation (cm)	Range (cm)
King rail	180	10.2	8.6	0 - 45.7
Clapper rail	67	5.6	6.8	0 - 30.5
Virginia rail	103	9.8	9.1	0 - 40.6
Sora	124	10.0	10.0	0 - 45.7
Yellow rail	38	4.5	4.8	0 - 15.2

DISCUSSION

The use of an airboat at night proved to be a good technique for capturing rails wintering in southern Louisiana and Texas. This technique yielded the greatest number of king rails captured, as well as the greatest number of rails overall, and had the highest capture rate. Due to the fact that this technique was so effective and the marshes are southern Louisiana and Texas are most easily accessible by airboat, an airboat at night was the most commonly used capture technique. Rail capture using airboats was done at night because the rails were disoriented and slower moving, making them relatively easy to capture. A preliminary assessment of this technique showed that it was ineffective during the daytime.

Other researchers have had mixed results capturing rails with an airboat at night. In Georgia, Hon et al. (1977) captured 2,066 clapper rails with an average capture rate of

16 rails per hour. However, they found this technique restricted by winter tides during the migration and winter seasons. Blandin (1963) found this technique to be time consuming for capturing clapper rails in South Carolina. Also, his research was a re-nesting study and he found that this capture technique made it difficult to find the nests of the captured birds. Therefore, he only captured 13 birds between 12 March and 21 August 1963 using this technique.

The use of an airboat at night can be used proficiently with an airboat driver and catcher, and with only one spotlight. However, the best method for using this technique is to have an airboat driver and two catchers on the airboat. This number of people made for optimal rail searching, without over crowding the airboat or making it too heavy to easily maneuver though the marsh. Each person should be equipped with a spotlight in order to maximize the search effort. When capturing rails from an airboat, the preferred method was to remain in the boat and lean over the side of the bow, instead of getting out of the boat and chasing the rail. This was because it was easier to chase the rail with the airboat than to run after them through the marsh habitat. The airboat used for this technique must be light and powerful, in order to be maneuvered easily through thick emergent marsh vegetation without getting stuck. It is also important to have a highly skilled airboat driver. The airboat driver's ability to follow the rails through the marsh, and to position the boat properly to allow for easy capture of the rail, is pertinent for this capture technique. As the airboat driver and catcher gained experience with this technique, their success at capturing rails increased. Rails were captured successfully with this capture technique in salt, brackish, and freshwater marsh, including moist soil units and organic rice fields. However, in all habitat types, the presence of open water or short or laid down

vegetation was important for spotting rails. This was because rails tended to run instead of flush when disturbed and openings in the vegetation made these rails easier to spot. Typical brackish marsh habitat where rails were captured using this technique can be seen in Figure 9.

Figure 9: Typical *Spartina patens* marsh in which rails were captured using the airboat capture technique.

Data on weather conditions and moon phase were not recorded during this study. However, rails seemed to be more difficult to capture on windy nights when using the technique of an airboat at night. Rails tended to be seen less on windy nights, possibly indicating that they were less active. Also, wind caused an increase in the movement of the emergent vegetation, making it more difficult to spot the rails moving in the vegetation. Once a rail was spotted, the airboat was more difficult to maneuver when

strong winds were present. Cummings and Hewitt (1964) found it easier to capture full-winged birds on darker nights, but found little difference in capturing flightless birds on dark or moonlight nights. In the current study, there seemed to be no difference in the ease of capturing rails on dark or moonlight nights.

The use of an ATV and spotlights at night also proved to be a good capture technique for capturing wintering rails. This technique had a capture rate of 1.80 rails per hour and 85 new rails were captured, as well as 3 recaptured rails. King rails were not captured using this technique; however, during the implementation of this technique only one king rail was detected. Using an ATV to capture rails was particularly beneficial in areas where no airboat was available. Rails were captured using this technique in moist soil units and harvested rice fields. In these areas, the soil is often manipulated, creating the flat, stable substrate which allowed the ATV to be driven easily through the habitat without getting stuck or flooded. However, care should be taken to avoid the small ditches which sometimes occur in these fields. Habitat with areas of open water or short or laid down vegetation were also important for this technique because it made rails running through the vegetation easier to spot. As with the airboat capture technique; capture rates did not seem to be affected by moon phase, but did seem to decrease on windy nights.

The use of an ATV during rice harvest had a capture rate of 0.25 rails per hour. During the implementation of this technique, large quantities of rails were observed flushing from the vegetation near the rice combine. Therefore, this low rate of capture was not due to few rails being spotted, but instead, was most likely due to the fact that the flushed rails often landed out of reach in another field or a nearby ditch. Rails were also

faster moving and found refuge easier due to the fact that this technique took place during daylight hours. This was the first study that I am aware of to use ATV's to capture rails at night or during rice harvest. However, Drewien et al. (1999) did use ATV's and night-lighting to capture 4 trumpeter swans in harsh winter conditions in Idaho and Montana.

Passive drop-door traps with drift fencing had a very low capture rate and trap placement required considerable time and effort, therefore, this capture technique was only used during the first winter field season. The capture rate for this technique was 0.0063 and it lead to the capture of 20 new rails and one recaptured rail. Three species of rails were captured using this technique. Previous studies have also had low capture rates using this technique to capture rails. Zembal and Massey (1983) had a capture rate of 0.029 clapper rails per trap night and Conway et al. (1993) captured only 42 clapper rails over a 32-month period. Flores and Eddleman (1993, 1995) captured only 36 black rails in Arizona from March 1987 - December 1988, and Lagare et al. (1999) had a capture rate of 0.013 black rails per trap night during the breeding seasons of 1992-1995. The trapping effort in the previous studies can not be directly compared to the trapping effort in the current study, due to the fact that none of the previous studies documented their trapping effort in trap hours. They all seem to have captured few rails over a long time period, which is similar to this study. However, since the rails captured in these previous studies were considered rare or endangered, trapping may have been implemented in areas of low rail density.

There are a few factors that may explain the poor capture rate of drop-door traps with drift fencing seen in this study. One reason may be due to the rails being less active during winter months, possibly due to colder weather and the establishment of winter

territories. The passive trapping results show that of the 21 captured rails, 12 rails were captured during September, October, and May when the weather was warm and migratory birds were moving into or out of the area. During December and January, 8 rails were captured, however, 5 of these rails were captured in very small, isolated patches of marsh where the rails were more likely to encounter the traps. Only one rail was captured in March and no rails were captured in either November or February. Trap placement may also have had an effect on the low capture rate. Traps were most often placed along road and canal sides because these areas were the easiest access. They may have been better placed in marsh interior, in small paths or creeks, such as was done in Zembal and Massey (1983). This was not logistically possible at our main trapping site, Rockefeller Wildlife Refuge, where most of the marsh is only accessible by airboat and airboats were not available on a daily basis. It may also be beneficial to place traps in small isolated wetlands, where the rails would more likely encounter them. In the current study this led to the capture of 5 of the 21 captured rails.

In addition to low capture rates, 12 of the 21 rails captured were released with injuries. These injuries occurred even though traps were left open only during daylight hours and were checked every 3-4 hours. Injuries included bleeding scrapes on the head and chin, as well as one juvenile king rail having a scraped leg from being pinned under the trap door. This juvenile rail was most likely walking behind an adult who tripped the trap. In order to try to minimize injuries to the face and head, 0.64 cm chicken wire was placed over many of the traps; however, this did not help to prevent injuries.

Safety precautions should be taken before implementing these rail capture techniques. When capturing rails from an ATV, a two-person ATV should always be

used when both the driver and catcher are riding on the ATV, and appropriate safety equipment should be worn at all times. All sites should be visited during daylight hours to identify any hazards, such as ditches, logs, posts, or other obstructions, that may be less visible at night. All obstructions should be marked with visible signs, as well as on a GPS. Sites with water less then ~15 cm of standing water and very sturdy soils are recommended, this allows for slight elevation changes without submerging the ATV. When capturing rails from an airboat, it is important to have a qualified and highly skilled airboat driver, as well as a light and powerful airboat. This is not only important for safety, but will also increase capture success. Whenever possible, two or more airboats should be used in case one breaks down or gets stuck. Appropriate safety equipment should be worn by all occupants. A safety plan should always be in effect, with a contact that knows the exact location of the study site, as well as the hours that the capture technique will be implemented. This contact should have access to an airboat or ATV if that is the only method in which the study site is accessible.

CHAPTER 3
THE USE OF MORPHOMETRIC MEASURMENTS TO DIFFERENTIATE BETWEEN SPECIES AND SEX OF KING AND CLAPPPER RAILS

King and clapper rails are large secretive waterbirds whose ranges overlap along the Atlantic and Gulf coasts; both species breed and winter in coastal Louisiana and Texas (Figure 1, Figure 2). King rails inhabit fresh to brackish wetlands, while clapper rails inhabit saline to brackish wetlands (Meanley 1992, Eddleman and Conway 1994). Both king and clapper rails inhabit brackish marsh habitat; they are known to overlap in their ranges and they are thought to hybridize. The two species have been observed together in brackish marshes in Grand Chenier, Louisiana; Savannah, Georgia; Chincoteague, Virginia; Somerset County, Maryland; Kent County, Delaware; and in the New York City region (Meanley and Wetherbee 1962).

Very little is known about many of the life history traits of king and clapper rails. Increasing, this knowledge base is important for the conservation of these species. Over the past 30 years it is believed that king rail populations have declined precipitously throughout eastern and central North America (Meanley 1992). It is listed as endangered in Canada by the Committee on the Status of Endangered Wildlife (Environment Canada 2006a) and is listed as endangered or threatened in thirteen states (Cooper 2006). Coastal Louisiana has perhaps the greatest number of wintering king rails, though peak numbers of wintering king rails have been seen and heard from Florida to eastern Texas (Meanley 1992). This makes the Gulf coast an optimal region for studying king rail populations. However, in order to study king rails in this region, it is important to have a method to accurately distinguish king rails from clapper rails.

In areas in which their ranges overlap, king and clapper rail are often difficult to tell apart by physical appearance. The clapper rail is more drab in color, gray or dull brown, in comparison to the brighter, reddish coloration of the king rail (Eddleman and Conway 1998). However, the subspecies of clapper rail that occurs along the Gulf coast has coloration similar to the king rail (Meanley 1992). The clapper rail, ranging from 35-40 cm in size, is known to be smaller than the king rail; which ranges from 38-48 cm in size. The sex of both king and clapper rails is indistinguishable; however, males are larger than females for both species. Male king rails are known to weigh 25% more than females (Meanley 1992), and male clapper rails are known to be 20% larger than females on average (Eddleman and Conway 1998).

Discriminant analysis using morphmetric measurements has been used to determine the sex of bird species that are sexually size dimorphic but do not differ in appearance (Azure et al. 2000, Cuthbert et al. 2003, Shephard et al. 2004). It has also been used to separate bird species or subspecies that differ in size but not in appearance (Cuthbert et al. 2003, Pearce and Bollinger 2003). Size differences for multiple morphometric measurements have been observed between king and clapper rails, however, this difference has never been quantified. This size difference may be a useful method for separating king and clapper rails. The difference in size between the sexes of the species may also be a useful technique for sexing these rails in the field.

In this study, captured rails were positively identified as king rails if they were captured in freshwater areas, and as clapper rails if they were captured in tidal salt marsh. All king and clapper rails were genetically sexed. The objectives of this study were to use the morphometric measurements of positively identified, genetically sexed king and

clapper rails captured in southern Louisiana and Texas to (1) differentiate between king and clapper rails. This was accomplished using discriminant analysis of the morphometric measurements of these rails. This discriminant function was then used to predict the species of a sample of tentatively identified king and clapper rails. The positively identified, genetically sexed king and clapper rails were also used to (2) differentiate between the sex of king and clapper rails. This was also done using discriminant analysis of their morphometric measurements.

METHODS

Rails were captured as described in chapter 2. A small number of the rails captured in this study were positively identified as king or clapper rails based on their capture location. Rails captured in freshwater areas were positively identified as king rails, and rails captured in tidal salt marsh were positively identified as clapper rails. The species of all other rails captured in this study were tentatively identified in the field based on coloration, size, and habitat type at the capture location. Rails weighing greater then 400g were considered king rails (Eddleman and Conway 1998).

All rails captured were banded with an individually numbered aluminum leg band (USGS), and the outer retrices of each bird were pulled for genetic analysis. Each rail was weighed to the nearest 1 gram using a 500g x 5g Avinet spring scale (Avinet, Inc., PO Box 1103, Dryden, New York 13053-1103 USA); the exact weight of any rail weighing over 500 grams was estimated (n = 2). Measurements of the wing cord and tail were taken to the nearest 1 mm using a 30 cm wing rule (AFO Mist Nets, Manomet, Inc. P.O. Box 1770, Manomet, Massachusetts 02345 USA.). Tarsus and exposed culmen were

measured to the nearest 0.01 mm with a digimatic caliper (Mitutoyo, 965 Corporate Blvd., Aurora, Illinois 60502 USA).

Genetic analysis was used to confirm the sex of each king and clapper rail. The collected retrices were placed in a labeled ziplock bag and frozen in a kitchen freezer within 24 hours of being collected. They were stored there for up to a month, and then transferred to an ultra-cold freezer where they were stored at -80° C for up to a year. Once frozen, feathers were transported on dry ice to avoid thawing the feathers before extraction. The DNA was extracted from the feathers using a Qiagen mini-kit (Qiagen Inc., 27220 Turnberry Lane, Suite 200, Valencia, CA 91355 USA). The DNA was then refrigerated for up to eight months. The rails were genetically sexed using the method described in Griffiths et al. (1998). Both the DNA extraction and genetic sexing were conducted at the National Wetlands Research Center in Lafayette, Louisiana.

All statistical analysis was carried out using SAS 9.1.2 (SAS Institute Inc., 100 SAS Campus Drive, Cary, NC 27513-2414, USA). I used ANOVA to compare all morphometric measurements between the positively identified male king rails, female king rails, male clapper rails, and female clapper rails.

I used discriminant analysis to determine if morphometric measurements could be used to differentiate between king and clapper rails. Males and females of both species are sexually size dimorphic, and female king rails and male clapper rails are similar in size (Meanley 1969). Due to this, the sex of each rail was taken in account for analysis. All rails used in this study were separated into four categories: male king rails, female king rails, male clapper rails, and female clapper rails. These classifications were based upon field identifications and genetic sexing results. Discriminant analysis was carried

out using a sample of positively identified king and clapper rails, standard step-wise procedures were carried out in order to determine the best model. Cross validation was used to calculate probabilities. This determined the best discriminant function to separate these four rail categories; this discriminant function was then used to predict the correct category of the remaining rails.

I also used discriminant analysis to determine if king and clapper rails could be sexed using morphometric measurements. Standard step-wise procedures were carried out using the sample of positively identified, genetically sexed king rails. The rails were grouped by males and females, and cross validation was used to calculate probabilities. The best discriminant function was then used to predict the sex of the rails that were identified as king rail using both field identification and discriminant analysis of the morphometric measurements. Standard step-wise procedures were carried out separately for the positively identified, genetically sexed clapper rails; and cross validation was used to calculate probabilities. The discriminant function was then used to predict the sex of the rails that were identified as clapper rails using both field identification and discriminant analysis of the morphometric measurements.

RESULTS

A total of 255 king and clapper rails were captured from 24 September 2004 – 12 July 2006; 187 were field identified as king rails and 68 were field identified as clapper rails. Capture techniques, dates, and locations for the captured rails can be found in Chapter 2. One additional clapper rail was captured on 26 September 2004, and one king rail was captured on 6 June 2006. Both were captured using drop-door traps with drift fencing, combined with a playback of the king rail call. Morphometric measurements and

genetic material were not collected for 3 of the captured rails because one rail was accidentally released and 2 were hatchlings. A total of 237 adult rails were used in this study because 15 of the captured rails had incomplete morphometric measurements and 2 were molting hatch-year birds; thus their wing cord and tail measurements would most likely be inaccurate. Of the rails used in this study, 26 were positively identified as king rails because they were captured in freshwater areas, and 23 were positively identified as clapper rails because they were captured in tidal salt marsh.

The method for genetically sexing birds described in Griffiths et al. (1998) was successful for 249 of the 254 king and clapper rails samples for which it was applied. It identified 91 females, 158 males. The sex of 5 rails could not be determined using this analysis, one of which had incomplete morphometric measurements and was not used in this study.

The morphometric measurements for positively identified, genetically sexed king and clapper rails were significantly different between species and gender (wing $F_{3,45} = 47.59$, $p < 0.0001$; tail $F_{3,45} = 10.72$, $p < 0.0001$; tarsus $F_{3,45} = 44.02$, $p < 0.0001$; culmen $F_{3,45} = 12.62$, $p < 0.0001$; weight $F_{3,45} = 23.64$, $p < 0.0001$). Male king rails were larger than female king rails for all morphometric measurements, and male clapper rails were larger then female clapper rails for all morphometric measurements except for the tail (Figure 10, Table 5). There was overlap in the measurement for culmen between the species; and for all other measurements, male clapper rails and female king rails were not different. The mean measurements of wing, tarsus and weight, were different between male king and clapper rails and between female king and clapper rails (Figure 10, Table 5).

Step-wise discriminant analysis of morphometric measurements indicated that the most important variables for separating female king rails, male king rails, female clapper rails, and male clapper rails were wing, tarsus, and culmen (Figure 11). Cross validation results for the positively identified rails were 75% for the female clapper rails, 73% for the male clapper rails, 80% for the female king rails, and 100% for male king rails. The classification formulas produced by this discriminant analysis were: $v1 = \alpha + 0.95\,(\text{Wing}) + 0.95\,(\text{Tarsus}) + 0.18\,(\text{Culmen})$ and $v2 = \alpha + 0.19\,(\text{Wing}) + 0.14\,(\text{Tarsus}) + 0.96\,(\text{Culmen})$.

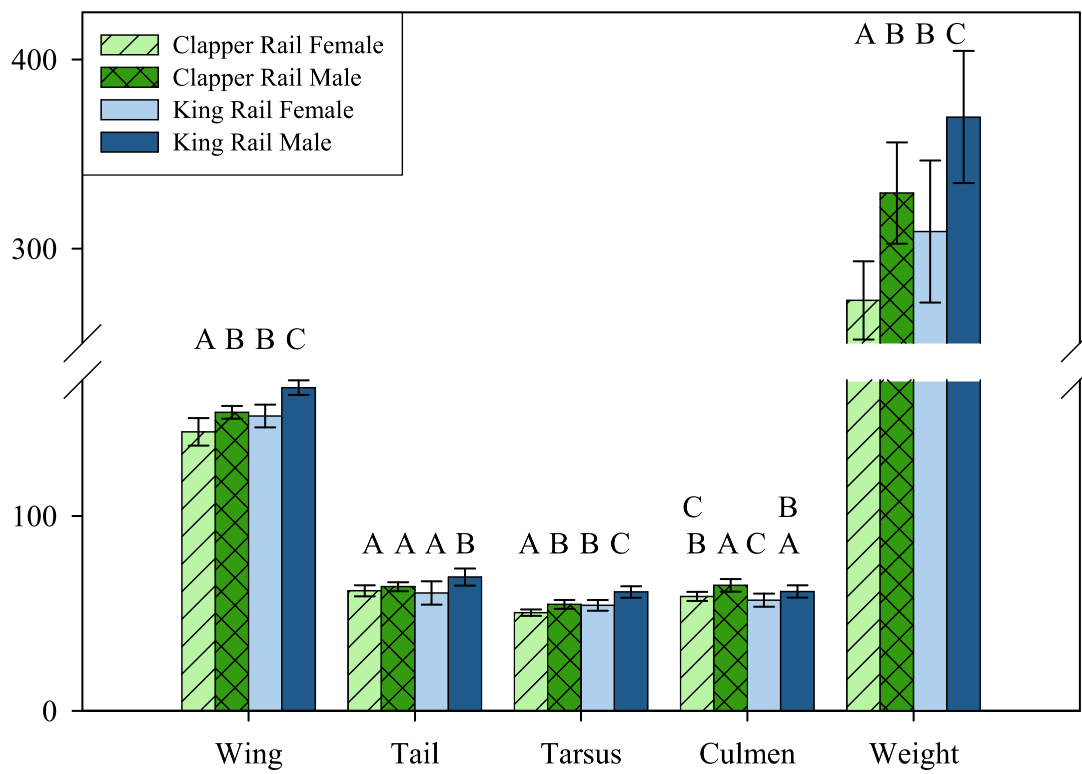


Figure 10: Means and standard deviation for the measurements of wing (mm), tail (mm), tarsus (mm), culmen (mm), and weight (g) for male and female clapper rails and male and female king rails. Bars sharing a letter do not differ (p > 0.05).

Table 5: The mean, standard deviation, and range (in parenthesis) of positively identified male and female king rails and male and female clapper rails.

	King Rail Male n = 16	King Rail Female n = 10	Clapper Rail Male n = 11	Clapper Rail Female n = 12
Wing	165.9 ± 3.7 (158 - 173)	151.4 ± 5.9 (138 – 158)	153.3 ± 3.3 (140 – 162)	143.3 ± 7.1 (132 – 160)
Tail	68.7 ± 4.4 (59 – 77)	60.5 ± 6.0 (48 – 69)	63.7 ± 3.3 (60 – 67)	61.6 ± 2.8 (56 - 65)
Exposed Culmen	61.3 ± 3.2 (56 – 67)	56.8 ± 3.4 (50 – 62)	64.4 ± 3.2 (59 – 69)	58.7 ± 2.3 (56 – 64)
Tarsus	61.0 ± 2.9 (56 – 66)	54.2 ± 2.8 (47 – 57)	54.6 ± 2.3 (52 – 60)	50.4 ± 1.6 (47 – 53)
Weight	369.6 ± 34.9 (320 – 425)	309.0 ± 37.5 (262 – 353)	329.4 ± 26.7 (289 – 377)	272.6 ± 20.7 (243 – 315)

The discriminant function was used to predict the classification of the remaining 188 rails. These predicted classifications were then compared with the original classifications based upon field identifications and genetic sexing. The predicted classification and the original classification were the same for 140 of the rails. Discriminant function predicted a different species, but the same sex as the original classification for 26 of the rails (Table 6). It predicted the same species, but a different sex from the original classification for 13 of the rails, and predicted different species and sex for 5 of the rails (Table 6). Two field identified clapper rails could not be genetically sexed, they were predicted by discriminant analysis of their morphometric measurements to be a male clapper rail and a male king rail. Two field identified king rails could also not be genetically sexed, they were both predicted by discriminant analysis of their morphometric measurements to be a male clapper rails. The mean, standard deviation, and range for the wing, tail, exposed culmen, tarsus, and weight measurements of the positively identified king and clapper rails are shown (Table 5). The mean, standard

deviation, and range for the wing, tail, exposed culmen, tarsus, and weight measurements of the 141 rails that were identified by both original classifications and discriminative analysis are shown (Table 7).

Table 6: Differences seen for field identified, genetically sexed rails, and the predicted classification of rails by discriminant analysis of their morphometric measurements.

Field and Genetic Identification	Discriminant Analysis Identification	Number of Rails
Female Clapper Rail	Female King Rail	4
Female King Rail	Female Clapper Rail	6
Male King Rail	Male Clapper Rail	18
Male Clapper Rail	Female Clapper Rail	6
Female King Rail	Male King Rail	3
Male King Rail	Female King Rail	4
Female King Rail	Male Clapper Rail	2
Male King Rail	Female Clapper Rail	1

Wing and tarsus measurements were indicated by stepwise discriminant analysis to be the most important variables for separating king rails by sex. Cross validation results were 100% for both male and female king rails. The classification formula produced by this discriminant analysis is: $v1 = \alpha + 0.99\ (\text{Wing}) + 0.9\ (\text{Tarsus})$. The discriminant function correctly classified the sex of 96% of the rails that were identified as king rail using both field identification and discriminant analysis of the morphometric measurements (Figure 12). For clapper rails, wing, tarsus, and culmen measurements were determined by stepwise discriminant analysis to be the most important variables for separating the sexes. Cross validation results were 92% for female clapper rails and 91%

for male clapper rails. The classification formula produced by this discriminant analysis is: v1 = α + 0.82 (Wing) + 0.90 (Tarsus) + 0.87 (Culmen). The discriminant function correctly classified the sex of 100% of the rails identified as clapper rail using both field identification and discriminant analysis of the morphometric measurements (Figure 13).

Table 7: The mean, standard deviation, and range (in parenthesis) of male and female king rails and male and female clapper rails identified by both field techniques and genetic sexing, and by discriminant analysis.

	King Rail Male n = 81	King Rail Female n = 35	Clapper Rail Male n = 13	Clapper Rail Female n = 13
Wing	166.3 ± 5.0 (155 - 178)	153.5 ± 3.9 (144 - 161)	152.7 ± 5.3 (144 - 166)	141.3 ± 4.4 (134 - 150)
Tail	68.6 ± 3.5 (60 - 77)	63.3 ± 3.6 (57 - 73)	63.9 ± 5.3 (56 - 74)	58.7 ± 4.6 (52 - 66)
Exposed Culmen	63.0 ± 3.0 (57 - 70)	56.6 ± 2.1 (53 - 60)	65.1 ± 2.7 (61 - 71)	59.6 ± 2.3 (55 - 64)
Tarsus	61.4 ± 2.6 (57 - 71)	54.4 ± 1.8 (51 - 59)	54.9 ± 2.4 (50 - 59)	49.1 ± 2.2 (46 - 53)
Weight	395.0 ± 40.1 (292 - 490)	317.4 ± 41.6 (242 - 384)	339.6 ± 25.6 (291 - 371)	278.2 ± 20.6 (250 - 311)

DISCUSSION

Previous morphometric measurements taken from king and clapper rails suggest that the two differ in size; clapper rail being smaller than the king rail (Meanley 1969, 1992, Eddleman and Conway 1998). The morphometric measurements taken in this study showed that male clapper rails were smaller then male king rails and female clapper rails were smaller than female king rails. However, they showed no difference between male clapper rails and female king rails (Figure 10). This suggests that morphometric measurements may be helpful in distinguishing between these two species as long as the rail's gender is known.

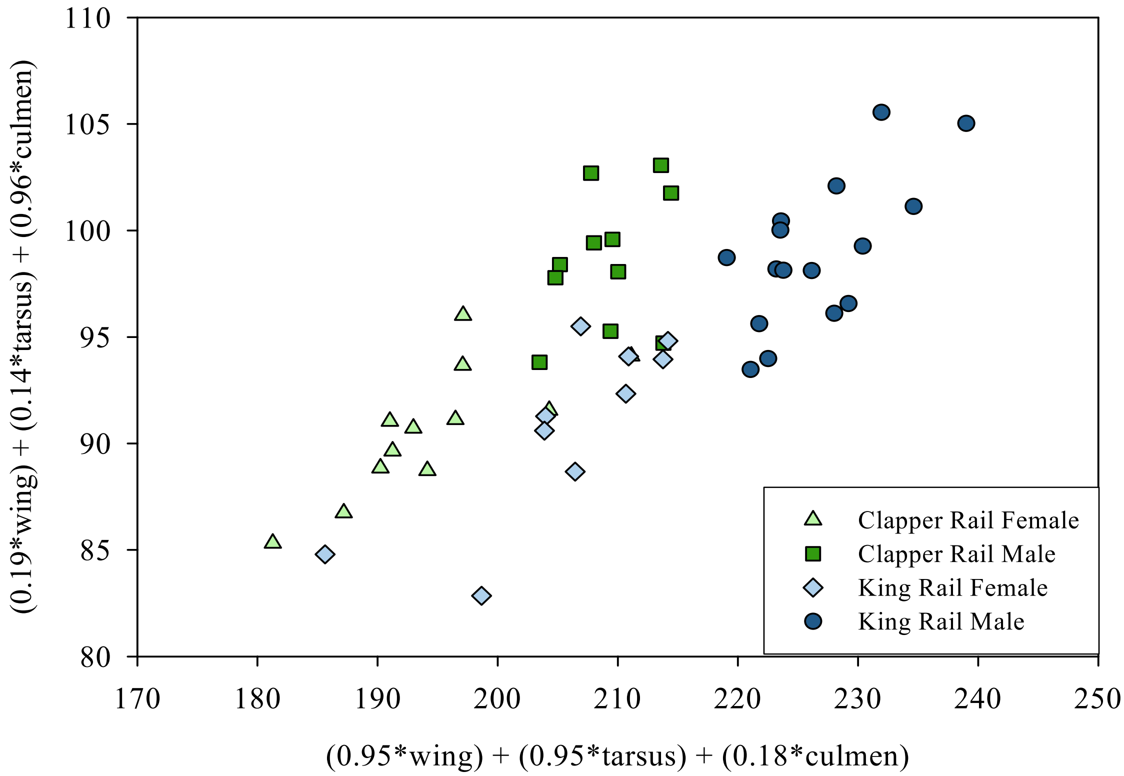


Figure 11: The discriminant functions used to separate female clapper rail, male clapper rails, female king rails, and male king rails.

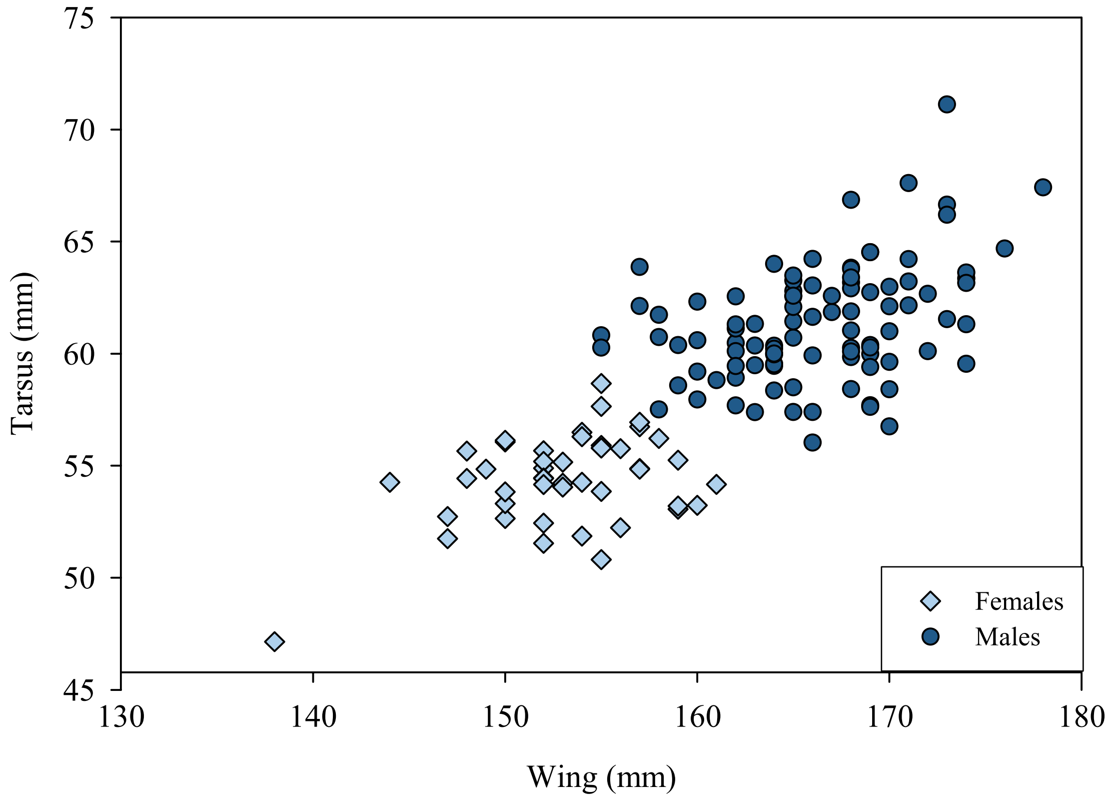


Figure 12: Wing and tarsus measurements of king rails; shown by discriminant analysis to separate males and females.

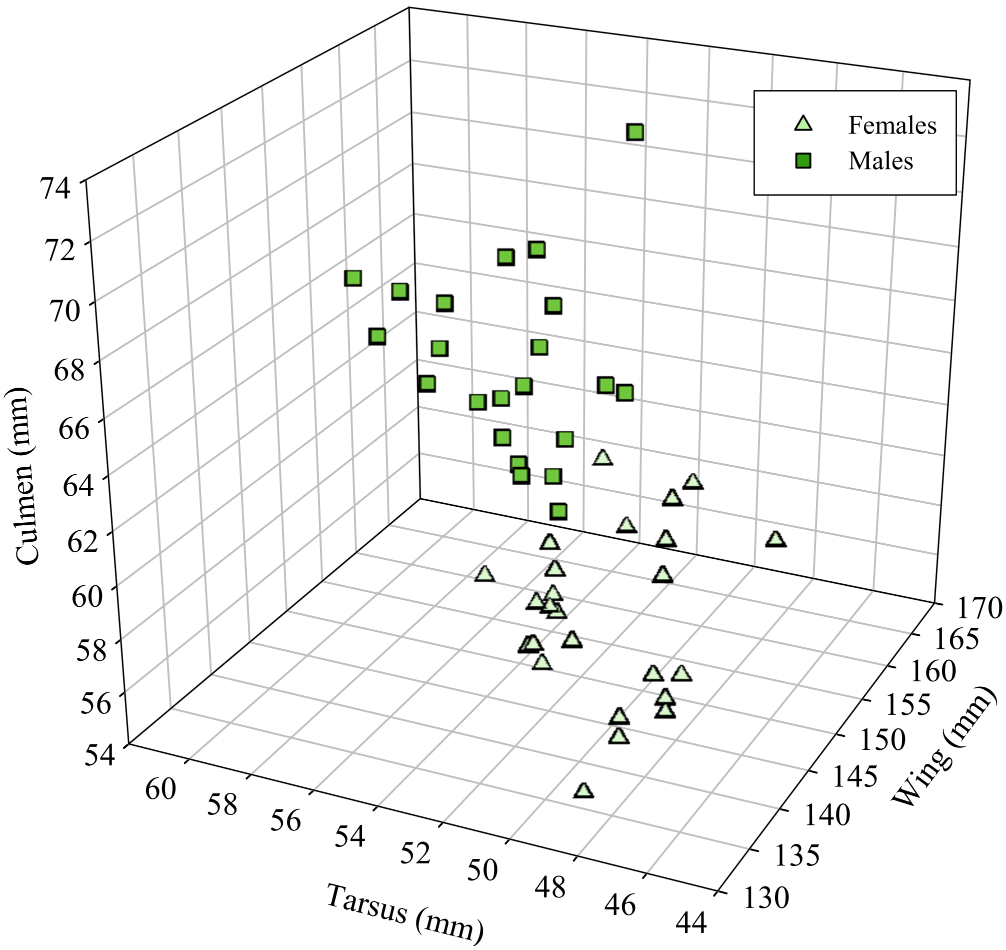


Figure 13: Wing, culmen, and tarsus measurements of clapper rails; shown by discriminant analysis to separate males and females.

Very little morphometric data for king rails has been published; the most widely used set of measurements was taken from 18 male and 14 female museum specimens (Meanley 1969, 1992). Although more detailed morphometric data has been published for the clapper rail (Eddleman and Conway 1998), only one publication has compared the measurements of these two species. Meanley (1969) compared measurements of weight, wing, tail, exposed culmen, tarsus, and middle toe without claw. For all measurements except the culmen, the male clapper rail averaged smaller than the male king rail; the female clapper rail averaged smaller than the female king rail for all measurements. The measurements for the male clapper rail and female king rail were similar, for half of the measurements the clapper rail was smaller and for half the king rail was smaller. The morphometric measurements for the two species have never been compared using multivariate statistics.

In this study, the use of discriminant analysis of morphometric measurements was moderately successful for distinguishing between king and clapper rails collected in southern Louisiana and Texas. Cross-validation results ranged from 100% to 73%, and some overlap was seen in the morphometric measurements between these two species (Table 5, Figure 11). The discriminant function derived from the analysis was used to predict the species and sex for field identified, genetically sexed king and clapper rails; this function predicted an incorrect sex for 18 of these rails. However, since the objective of this study was to determine the species of rails for which the sex is already known, this error does not have a large influence on this study.

The variability of this model may be due to king and clapper rails having overlapping morphometric measurements. However, there may be a few other reasons

why this analysis was not more successful. This may have been due to inaccurate field identification of the rails used in the discriminant function. All king rails considered to be positively identified as such, were captured in freshwater wetlands, supposedly uninhabited by clapper rails. All clapper rails positively identified as such, were captured in tidal salt marsh, supposedly uninhabited by king rails. This tidal salt marsh is in close proximity to brackish marsh where king rails are thought to reside (personal observation). Since movements of these rails in this region have not been well studied, it is unknown whether king rails could have ventured into this salt marsh. Also, the possible hybridization of king and clapper rails was not taken into effect. King and clapper rails are thought to hybridize in brackish marsh, and hybridization has been witnessed in southwestern Louisiana (Meanley and Wetherbee 1962). It is currently unknown what physical characteristics these hybrids may have. Therefore, increased variability may be seen in the model if hybrids had been included in the sample of rails used in this study. Variation in this model should not have been due to differences in size between migratory and resident king rail, because the majority of king rails in used in this study were most likely residents to Louisiana and Texas (chapter 4).

There is also some evidence that the king and clapper rail are not actually different species, but races of the same species. Using the idea that song is a mechanism of species isolation, Rabatsky (1997) determined that the king and clapper rails could be considered the same species due to the fact that both rails responded with equal frequency to each others calls. Avise and Zink (1988) found no conclusive proof of genetic differences between king rails and clapper rails using mtDNA and allozyme assays. The differences in the mtDNA for the king rails and clapper rails was slightly less than the

difference in mtDNA found in red-winged blackbirds. These two studies, along with the similarity in appearance and calls of the king rails and clapper rails and that the two species are thought to hybridize, give evidence that the two are actually just different races of the same species. More genetic analysis is needed in order to prove or disprove this theory. The variability of this discriminant analysis indicates that the use of morphometric measurements combined with educated field identification based upon coloration and habitat, and genetic sexing, may be the best method for distinguishing between king and clapper rails in areas where their populations overlap.

The sex of both king and clapper rails is indistinguishable in appearance and both incubate the eggs; therefore, it has not been possible to correctly sex them in the field. Both king and clapper rails are sexually size dimorphic, with males averaging larger than females for most measurements. Based upon the little morphometric data that has been published for king rails, Meanley (1992) suggested that size differences were largest for wing cord and weight. The use of discriminant analysis of morphometric measurements seems to be a good method for determining gender in both species. However, because of the size similarities between female king rails and male clapper rails, this technique must be used with caution in areas where king and clapper rails overlap.

This study showed that discriminant analysis of morphometric measurements was useful in helping to distinguish between king and clapper rails in habitats where their populations overlap. It also proved useful for determining the gender of both king and clapper rails. However, there are many recognized subspecies of the clapper rail, which vary in size (Eddleman and Conway 1998). This study only included the Gulf Coast population of clapper rail. This subspecies ranges from the Florida Panhandle across the

Gulf Coast to northern Mexico. Therefore, it is unknown whether discriminant analysis of morphometric measurements of Atlantic and Pacific Coast clapper rails would be useful in differentiating species or sex. Also, it is currently unknown if there are size differences among different populations of king rails, such as migratory and resident populations. Further research is needed to determine if this analysis would be successful for other populations of king and clapper rails.

CHAPTER 4
THE USE OF STABLE ISOTOPES TO DETERMINE A RATIO OF RESIDENT TO MIGRANT KING RAILS IN SOUTHERN LOUISIANA AND TEXAS

Over the past 30 years it is believed that king rail populations have declined precipitously throughout eastern and central North America, with the most severe declines occurring in the migratory population (Meanley 1992). The king rail is listed as endangered and threatened in thirteen states, as well as endangered in Canada (Cooper 2006, Environment Canada 2006a). It is a large secretive waterbird that resides in fresh to brackish wetlands in the eastern half of the United States (Meanley 1992). Little is known about its migration patterns, though southern Louisiana and Texas are thought to be important wintering areas (Meanley 1992). Resident king rail populations are thought to be relatively large in this region, therefore, the king rail is currently considered a game species in both Louisiana and Texas (Reid et al. 1994). It is unknown what effect, if any, hunting may have on the migratory population. Therefore, it is important to determine what proportion of the wintering king rails in Louisiana and Texas are migratory.

Due to the secretive nature of king rails, many of the techniques for studying bird migration are of little use. Historically, re-sightings of this species have been rare (Meanley 1992), ruling out banding and re-sighting. Satellite telemetry is not a suitable technique for studying king rail migration because the majority of these birds weigh less than 500 grams, and the transmitters are only suitable for birds weighing at least 600 grams (Webster et al. 2002). Recent evidence has shown that stable isotope analysis of feathers can be used as a method of studying bird migration (Chamberlain et al. 1997, Hobson and Wassenaar 1997). The geographical variation of stable isotopes is incorporated into bird feathers; stable isotope analysis of these feathers has been used to

determine breeding origins of wintering birds (Kelly et al. 2002, Hobson et al. 2004a). This may be a good technique for studying the migration of king rails because the rails would need to be captured only once on the wintering grounds. Also, king rails are known to undergo a complete molt on the breeding grounds, directly after the nesting period, (Meanley 1992), therefore, their feather material should represent stable isotope values from the breeding grounds.

The basic foundation of stable isotope ecology is that many elements have one or more stable isotopes that occur in nature; these are atoms of an element that contain different numbers of neutrons within the nucleus (Hoefs 1980). The addition of more neutrons in the nucleus creates a “heavy” isotope; the isotope with fewer neutrons is referred to as the “light” isotope. Isotope values are signified with the δ notation and are reported in parts per thousand (‰). They are measured relative to a standard; for example: $\delta^{13}C = [(R_{sample}/R_{standard})-1)]*1000$, where R is the ratio of “heavy” to “light” carbon isotopes. The standard for hydrogen isotopes is Standard Mean Ocean Water (SMOW), the standards for carbon isotopes is PeeDee Belemnite (PDB) and Vienna-PDB (VPDB), the standard for nitrogen isotopes is Air (AIR), and the standards for sulfur isotopes is Canyon Diablo Troilite (CDT) and Vienna-CDT (VCDT) (Fry 2006).

The difference in the molecular weight of isotopes creates differences in the rate of physical and chemical reactions; this is referred to as fractionation. Fractionation separates isotopes and mixing brings them back together. The patterns of fractionation and mixing of these isotopes produce distinctive isotope distributions across the Earth (Fry 2006). It has been shown that the values of stable isotopes found in nature are incorporated, with little change, into bird feathers (Mizutani et al. 1992, Hobson and

Wassenaar 1997). Most birds molt on or near their breeding grounds (Gill 1995), and once a feather is fully grown, it is metabolically inert and no longer receives isotopic values from the environment (Kelly and Finch 1998). Therefore, birds captured on their wintering grounds carry isotopic values from the breeding grounds in their feathers. One feather can be pulled on the wintering grounds and analyzed; then the approximate location of the bird's breeding ground can be deduced. Commonly used isotopes for studying bird migration are hydrogen, carbon, nitrogen and sulfur.

The majority of research studying bird migration has used hydrogen stable isotope values (δD). This is because the δD of growing season precipitation shows a distinct latitudinal pattern across North America (Sheppard et al. 1969). The δD values decrease with increasing latitude. The δD of bird feathers (δD_f) have shown a strong correlation with the δD values of the growing season precipitation (δD_p) of the location where the feather is grown (Chamberlain et al. 1997, Hobson and Wassenaar 1997). It has been demonstrated that the δD values of bird feathers can be used to determine the breeding latitude of a variety of birds species, such as Bicknell's thrush (Hobson et al. 2004a), Wilson's warbler (Kelly et al. 2002), Cooper's hawk (Meehan et al. 2001), and six insectivorous forest song birds (Hobson and Wassenaar 1997). The strong correlation between δD_p and δD_f values has also been seen in red-winged blackbirds, which breed in wetland habitats. This correlation was seen in these wetland birds regardless of the other possible hydrological inputs into the wetlands, such as groundwater and spring snowmelt (Wassenaar and Hobson 2000b).

When using δD to determine the breeding areas of birds, it may be important to determine whether the birds have been foraging in marine environments. This is because

the δD of marine water is relatively stable and is not correlated with growing season precipitation; it is often found to be greater than the terrestrial freshwater nearby (Hoefs 1980). Therefore, a bird feeding on marine plants or prey could show abnormally high δD values relative to typical values for that latitude. Lott et al. (2003) found a strong statistical difference in δD_f and δD_p values in birds that foraged along the coast. Hobson et al. (2000) confirmed that the feathers of marine foraging thick-billed murres and black-legged kittiwakes showed highly enriched values for δD.

The use of the stable sulfur isotope values ($\delta^{34}S$) may be a good way to differentiate between birds breeding in coastal and inland habitats. $\delta^{34}S$ values are greater in marine systems than inland systems (Hoefs 1980). Inland plants have an average $\delta^{34}S$ value of between 2‰ to 6‰, values of marine plants average from approximately 17‰ to 21‰ (Fry 2006). A similar trend in values has also been seen in bird feathers. Lott et al. (2003) found the highest sulfur stable isotope values in raptors foraging along the coast and lower values in inland foragers. This trend was also seen in Canada geese (Caccamise et al. 2000). However, there is some error in using $\delta^{34}S$ to determine the marine influence of foraging birds, as some inland areas with high salt content soils also have high $\delta^{34}S$ values. Cornwell et al. (1995) found $\delta^{34}S$ values of different plant species to range between -5.7‰ to as high as 18.3‰ in a prairie marsh in Manitoba, Canada. Little evidence exists as to what effect, if any, this has on the $\delta^{34}S$ values of the feathers from bird foraging in these areas. Herbert and Wassenaar (2005) saw low sulfur stable isotopes in the feathers of juvenile mallards and pintails collected from the northern Prairies. I am unaware of any other studies that have looked at the $\delta^{34}S$ values of feathers from birds breeding in this region.

There is also evidence that nitrogen stable isotope values ($\delta^{15}N$) may also be greater in marine habitats than inland habitats (Hobson 1999b). This trend has been observed in both Canada geese and red knots (Caccamise et al. 2000, Atkinson et al. 2005). However, a difference in $\delta^{15}N$ values between freshwater and marine habitats has not been seen in all studies. Marbled murrelets collected in coastal and freshwater locations did not show differences in the nitrogen stable isotope values of their muscle tissue (Hobson 1990). It has been indicated that differences in nitrogen stable isotope values show more local differences in a population, such as trophic level. McCutchan et al. (2003) showed a mean increase of 2.3‰ $\delta^{15}N$ per trophic level. Nitrogen stable isotope values have also been shown to discriminate between birds breeding in different habitat types, such as boreal forests and agricultural complexes (Hobson 1999a).

Carbon stable isotope values ($\delta^{13}C$) can be used to differentiate between plants with different photosynthetic pathways because these plants fractionate carbon stable isotopes differently. Due to this, C_4 plants typically have higher $\delta^{13}C$ values and C_3 plants typically have lower $\delta^{13}C$ values (Smith and Brown 1973). These values are then incorporated into the feathers of birds which feed upon these different plants. This has been seen in Red-winged blackbirds; those foraging on C_3 plants, had carbon stable isotope values of -27.3‰ to -23.6‰, whereas those birds foraging on C_4 plants had $\delta^{13}C$ values of -16.5‰ to -12.5‰ (Wassenaar and Hobson 2000b). There are distinct areas in North America were either C_3 or C_4 plants are dominant, such as the corn belt of the Midwest (C_4) or the wheat dominated areas of South Dakota (C_3). Another region where C_4 plants tend to dominate is the coastal marsh. The most abundant plant species found in coastal marshes tends to be Spartina sp., a C_4 plant which has $\delta^{13}C$ values around -13‰

(Peterson and Howarth. 1987). Canada Geese feeding in coastal marsh, where the C_4 plants there make a large component of their diet, showed higher $\delta^{13}C$ than geese feeding in inland habitats (Caccamise et al. 2000). Therefore, the use of carbon stable isotope analysis has also been shown to differentiate between birds breeding in coastal and inland habitats.

A combination of multiple stable isotopes seems to be an improved method of studying migratory connectivity using stable isotope analysis. It has been shown that the use of hydrogen stable isotopes combined with carbon stable isotopes is a good method for studying bird migration (Wassenaar and Hobson 2000b, Hobson and Wassenaar 2001, Rubenstein et al. 2002, Hobson et al. 2004b). Lott et al. (2003) showed that $\delta^{34}S$ values could be used to determine the extent of marine foraging in raptors and suggested using a cut off 10‰ for $\delta^{34}S$ values when using the δD values of bird feathers to determine the latitude at which the feather was grown. $\delta^{13}C$, $\delta^{15}N$, and $\delta^{34}S$ are all known to show differences between marine and freshwater habitats, using a combination of these three stable isotopes could more accurately determine the extent of marine influence in the diets of birds. All four stable isotopes, δD, $\delta^{13}C$, $\delta^{15}N$, and $\delta^{34}S$, have been used successfully to differentiate between the breeding locations of mallards and northern pintails (Hebert and Wassenaar 2005).

The objective of this study was to analyze δD, $\delta^{13}C$, $\delta^{15}N$, and $\delta^{34}S$ values of feathers to determine the ratio of resident to migrant king rails in southern Louisiana and Texas. This was done by comparing the stable isotope values of wintering king rails with those from resident Louisiana and Texas rails, migratory Virginia and yellow rails, and rails collected from known breeding locations at different latitudes. Based on the

geographical differences seen in hydrogen, carbon, and sulfur stable isotope values, we can predict the approximate values that should be obtained from rails breeding in different geographical locations (Table 8). Nitrogen stable isotope values often represent local differences rather than geographical differences, making it more difficult to predict what nitrogen stable isotope values rails should have based on geographic locations.

Table 8: Expected values of hydrogen, carbon, and sulfur stable isotopes for rail feathers from four different breeding locations.

Location	Hydrogen	Carbon	Sulfur
Louisiana/Texas Brackish Marsh	High	High	High
Louisiana/Texas Fresh Marsh	High	Low	Low
Northern Fresh Marsh	Low	Low	Low
Prairie Potholes	Low	Low	High/Low

METHODS

Rails were captured as described in chapter 2. Each rail was banded with an individually numbered aluminum leg band (USGS). Morphometric measurements were taken for all rails, and primary #4 was pulled from each wing for isotopic analysis. All feathers were stored at ambient temperature in labeled zip-lock bags prior to cleaning. In areas where king and clapper rails both reside, these rails were identified in the field based on coloration, size, and habitat type at the capture location. Rails weighing greater then 400g were considered king rails (Eddleman and Conway 1998), as were rails captured in freshwater marsh. Rails captured in tidal salt marsh were considered clapper rails. Species identification was verified with discriminant analysis of the morphometric

measurements as described in Chapter 3. Rails identified as king rails in the field, but as clapper rails by discriminant analysis were separated from the other king rails for statistical analysis and referred to as “uncertain king rails”. I was unable to verify the species for 3 rails using morphometic measurements because not all of their measurements had been taken; these rails were also included in the group of “uncertain king rails”. Feather material was also collected from northern breeding rails; various natural history museums donated feather material, most often body feathers, for king and Virginia rails collected at a variety of different latitudes. Feather material was also collected from king and Virginia rails captured at Ottawa National Wildlife Refuge in Ohio.

Isotopic Analysis

One primary feather for each king and clapper rail, and two primary feathers for each Virginia and yellow rail were cleaned for isotopic analysis. For cleaning, feathers were held by the calamus and swirled in a 400mL beaker of 5% v/v solution of contrad 70 phosphate-free detergent (Decon Labs, 460 Glennie Circle, King of Prussia, Pennsylvania 19406 USA) for two minutes. They were then rinsed by swirling in three 400 mL beakers of deionized water for approximately 20 seconds each. Then each feather was swirled in 300 mL of a 2:1 solution of chloroform to methanol for two minutes and rinsed again by swirling in three more 400 mL beakers of deionized water for approximately 20 seconds each. Each sample was identified with a small sticky label affixed to the calamus. They were then placed in a drying oven at 50 degrees Celsius for 24-48 hours. Museum samples were cleaned using the same process; however, due to the small size of the body feathers, all feathers from each specimen were placed into a tea

ball. The tea ball containing the feathers was then swirled in the beakers in the steps described above. The museum specimen feathers were placed in individually labeled aluminum foil packets and dried at 50 degrees Celsius for 24-48 hours. Once dry, all feathers were stored in individually labeled zip-lock bags.

All cleaned feathers were sent to the Colorado Plateau Stable Isotope Laboratory at the University of Northern Arizona for analysis of δD, $\delta^{13}C$, $\delta^{15}N$, and $\delta^{34}S$ values. For $\delta^{15}N/\delta^{13}C$ and $\delta^{34}S$ analysis, small pieces were cut from the tip of each sample and weighed in tin capsules. $\delta^{15}N/\delta^{13}C$ were analyzed in continuous-flow mode using a Thermo-Finnigan Delta^{plus} Advantage gas isotope-ratio mass spectrometer interfaced with a Costech Analytical ECS4010 elemental analyzer. $\delta^{34}S$ was analyzed with the same elemental analyzer, using a two tube system; the first tube was filled with tungstic oxide and pure copper wire, and the second tube was filled with quartz chips.

It has been shown that a proportion of the hydrogen in bird feathers is exchangeable with the hydrogen in the environment. Wassenaar and Hobson (2000a) determined the average percent of exchangeable hydrogen in bird feathers to be approximately 22%. This exchangeable hydrogen must be corrected for to obtain hydrogen stable isotope values from feathers that reflect the values from the location at which the feather was grown. The Colorado Plateau Stable Isotope Laboratory corrected for exchangeable hydrogen by equilibrating the samples and standards with water vapor, using the method described in Wassenaar and Hobson (2003). Chicken Feather (CFS), Cow Hoof (CHS), and Bowhead Whale Baleen (BWB) calibration standards were acquired from L. Wassenaar for use in this process. Once the δD of all samples was converted from a combination of exchangeable and non-exchangeable δD to the δD of

only the non-exchangeable fraction, small pieces were cut from the tip of each samples and weighed in silver cups for isotopic analysis. The samples and standards were pyrolyzed at 1400°C; the H_2 gas produced was then separated from the CO gas by chromatographically and analyzed using an isotope-ratio mass spectrometer (Thermo-Finnigan TC/EA and DeltaPLUS-XL ™, see http://www4.nau.edu/cpsil/).

In order to determine the amount of analytical error for hydrogen, carbon, nitrogen, and sulfur stable isotope analysis, blind field replicates were analyzed. These replicates consisted of primary feathers collected from the opposite wing of each field collected rail and additional body feathers from each museum specimen. I ran paired t-tests on the replicates for each stable isotope analyzed. Replicates and standards were also run between samples; I averaged these replicates for statistical analysis.

Statistical Analysis

All statistical analysis was carried out using SAS 9.1.2 (SAS Institute Inc., 100 SAS Campus Drive, Cary, NC 27513-2414, USA). The rail species captured in this study are indistinguishable by sex, however, king and clapper rails were sexed genetically (chapter 3). I used ANOVA in order to determine if the isotopic values of king and clapper rail feathers differed between the sexes.

The breeding ranges of these species are not identical (Figure 1, Figure 3, Figure 5); therefore, I used MANOVA, blocked by collection period and location, to determine if the isotopic values were significantly different among winter collected king rails, uncertain king rails, Virginia rails, yellow rails, and the resident rail population. In order to look at the difference in the δD, $\delta^{34}S$, and $\delta^{13}C$ values, I produced a 3-D graph using

the values from the feathers of the winter collected king rails, Virginia rails, yellow rails, and the resident rails.

I used discriminant analysis to determine if δD, $\delta^{13}C$, $\delta^{15}N$, and $\delta^{34}S$ values could be used to differentiate between resident and migratory rails. Rails were grouped by species; with the resident population and uncertain king rails included as separate groups. Cross validation was used to calculate probabilities.

Since a bird feeding on marine plants or prey could show abnormally high δD values relative to typical values for that latitude and Lott et al. (2003) showed that $\delta^{34}S$ values could be used to determine the extent of marine foraging in raptors; I looked at the relationship between δD and $\delta^{34}S$ values of feathers from northern breeding and resident rails. I estimated δD values of the growing season precipitation for the location at which the rails were collected using the map developed by Meehan et al. (2004). I downloaded these GIS files into ArcGIS 9.1 (ESRI Corporation, 380 New York Street, Redlands, CA 92373-8100, USA). These files allowed me to create a map of North America with the δD_p values represented by 7‰ intervals. The approximate site of collection for each resident and northern breeding rail was identified on the map, and the middle δD_p value for the interval in which each site was located was used as the estimated δD_p. I then subtracted the δD values of the rails feathers from the estimated δD_p of their collection location to obtain the difference between these two values, $\delta D_{(f-p)}$. I ran a simple linear regression using $\delta^{34}S$ as the factor and $\delta D_{(f-p)}$ as the response variable.

To look at the relationship between the values of δD of rail feathers and δD values of growing season precipitation, I ran a simple linear regression using the resident and museum samples. The δD_p values were estimated as described above and used as the

factor in the regression, with the δD_f values as the response variable. The y-intersect of the simple linear regression equation from this model yielded an approximate fractionation factor for δD_p incorporation into rail feathers. This discrimination factor was then subtracted from the δD_f values of the winter collected king, Virginia, and yellow rails, as well as the resident rails to determine the estimated δD values of growing season precipitation from where the rail feathers were grown. King rails and uncertain king rails were combined for this analysis. These values were then compared to the map of δD of growing season precipitation in order to approximate breeding locations.

RESULTS

For use in this study, rails were captured from 28 September 2004 – 28 March 2005; then again from 17 October 2005 - 23 March 2006. A total of 151 wintering king rails, 105 wintering Virginia rails, and 38 wintering yellow rails were captured for use in this study. Of the captured king rails, 121 of these were identified as king rails by both field identifications and discriminant analysis of their morphometric measurements. Twenty-four were identified in the field as king rails, but identified as clapper rails by discriminant analysis. Three were identified as king rails in the field, but it was not possible to identify them using discriminant analysis due to missing measurements. Feather material representing resident rails from Louisiana and Texas was also collected for this study (Figure 14). These feathers were collected from 38 king and clapper rails captured from 17 May – 24 May 2005 at Rockefeller Wildlife Refuge, Louisiana. One king rail was captured on 15 May 2005 near a rice field in Jefferson Davis Parish, Louisiana; and another was captured on 6 June 2006 near a rice field in Avoyelles Parish, Louisiana. Molting feather material from one king rail, captured at Anahuac National

Wildlife Refuge, Texas, on 26 January 2006, was included in the resident population. This resulted in the collection of feather material from 40 king and clapper rails representing residents from Louisiana and Texas. Capture techniques, dates, and locations for all rails captured can be found in Chapter 2.

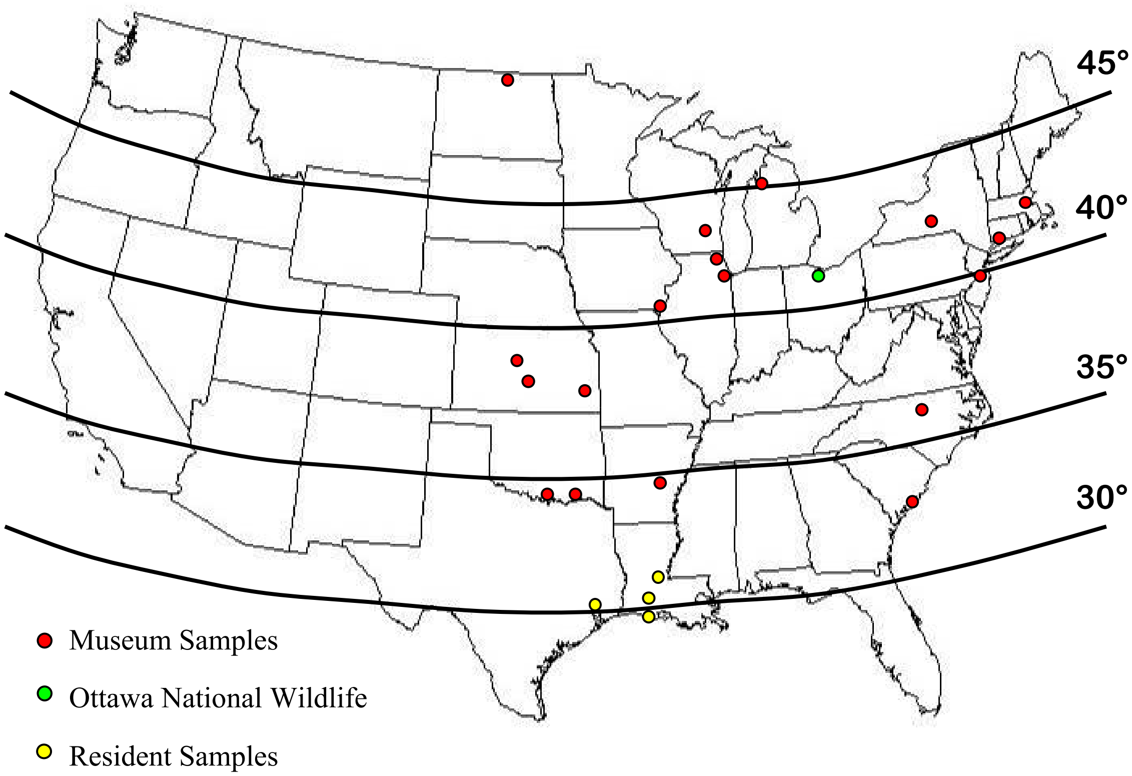


Figure 14: Approximate collection locations for northern breeding and resident rails.

Body feathers from 29 king rail and 8 Virginia rail museum specimens were collected, as well as primary #4 of one king rail museum specimen. Only feather material from museum specimens that were originally collected between 7 June and 7 September was used for this study. These specimens were collected between the years 1879 until 1984, at locations throughout the eastern United States ranging from 32 to 48 degrees latitude (Figure 14). When possible, feathers from juvenile birds were obtained (n = 18), since it is more likely that their feathers were grown on the breeding grounds. Primary #4

was also collected from 5 king rails and 10 Virginia rails captured at Ottawa National Wildlife Refuge in Ohio from 28 April until 24 May 2006. A table with species, stable isotope values, age, collection location, and collection date for all northern breeding rails whose feather material was used in this study is shown (Appendix A).

Due to a discrepancy in the feather material used in the δD analysis for one blind field replicate, 17 blind field replicates were used for δD analysis, while 18 were used for $\delta^{13}C$, $\delta^{15}N$, and $\delta^{34}S$ analysis. Of the 17 blind field replicates analyzed for hydrogen stable isotope values, one sample had an extremely large difference between the replicate and the original sample. For this sample, the blind field replicate and the original feather material were re-analyzed in order to determine the correct δD value; it was determined that the original value was incorrect. Due to this, it is assumed that approximately 6% of all the samples analyzed could have inaccurate hydrogen stable isotope values. This sample was removed from the paired t-test for hydrogen stable isotope analysis, thus, 16 samples were included for the analysis. Once this analytical error was recognized, one sample that seemed to be an outlier for its hydrogen stable value was reanalyzed. It was determined that the original hydrogen value for this sample was also incorrect.

The Paired t-tests for the blind field replicates showed that the difference between the replicates did not differ significantly from zero for all four isotopes (δD $p = 0.44$; $\delta^{15}N$ $p = 0.59$; $\delta^{13}C$ $p = 0.70$; $\delta^{34}S$ $p = 0.57$).

There were no differences in the stable isotope values of male and female king and clapper rails (δD $F_{1,147} = 1.55$, $p = 0.21$; $\delta^{15}N$ $F_{1,147} = 0.08$, $p = 0.78$; $\delta^{13}C$ $F_{1,147} = 0.32$, $p = 0.57$; $\delta^{34}S$ $F_{1,147} = 1.03$, $p = 0.31$); thus the sexes were combined for all further analysis.

The MANOVA showed that in general, the stable isotope values of the rail feathers differed by species (δD $F_{11,322} = 86.02$, $p < 0.0001$; $\delta^{15}N$ $F_{11,322} = 9.27$, $p < 0.0001$; $\delta^{13}C$ $F_{11,322} = 53.09$, $p < 0.0001$; $\delta^{34}S$ $F_{11,322} = 30.96$, $p < 0.0001$) (Figure 15, Figure 16, Figure 17, Figure 18). The hydrogen, carbon, and sulfur stable isotope values showed a distinct difference among most of the migratory yellow and Virginia rails and the resident population, though a few of the Virginia rails ($n < 7$) had values similar to the residents (Figure 19,). The hydrogen, carbon, and sulfur stable isotope values for the wintering king rails were similar to those of the resident population (Figure 19, Table 9). There was no difference for all stable isotope values between the resident group and the uncertain king rails (Figure 15, Figure 16, Figure 17, Figure 18). For δD and $\delta^{34}S$ values, king rails were not different from uncertain king rails or residents (Figure 16, Figure 18). For $\delta^{15}N$ values, there were no differences among king rails, uncertain king rails, and Virginia rails (Figure 17).

Table 9: Mean, standard deviation, and range (in parenthesis) of hydrogen, carbon, nitrogen, and sulfur stable isotope values (‰) for resident rails, king rails, uncertain king rails, Virginia rails, and yellow rails.

	Hydrogen (δD)	Carbon ($\delta^{13}C$)	Nitrogen ($\delta^{15}N$)	Sulfur ($\delta^{34}S$)
Resident n = 40	-65.1 ± 7.4 (-85.1 - -49.5)	-17.7 ± 3.0 (-28.5 - -15.1)	7.6 ± 1.5 (5.6 - 11.9)	11.6 ± 4.6 (1.4 - 22.0)
King Rail n = 121	-59.1 ± 10.5 (-90.1 - -38.0)	-19.9 ± 3.4 (-28.1 - -14.1)	8.5 ± 1.6 (5.2 - 12.0)	11.3 ± 5.6 (-1.7 - 23.2)
Uncertain King Rail n = 30	-60.6 ± 9.6 (-92.5 - -43.4)	-18.2 ± 3.6 (-26.2 - -10.9)	8.7 ± 1.8 (6.0 - 14.6)	12.6 ± 5.2 (1.1 - 25.9)
Virginia Rail n = 105	-104.0 ± 21.3 (-147.1 - -53.0)	-26.8 ± 2.1 (-31.2 - -20.2)	9.0 ± 2.2 (5.3 - 16.2)	-7.9 ± 10.9 (-35.2 - 14.4)
Yellow Rail n = 38	-130.5 ± 24.2 (-171.6 - -80.3)	-24.2 ± 1.5 (-28.0 - -20.3)	6.3 ± 1.4 (3.1 - 9.9)	5.0 ± 15.4 (-18.5 - 51.8)

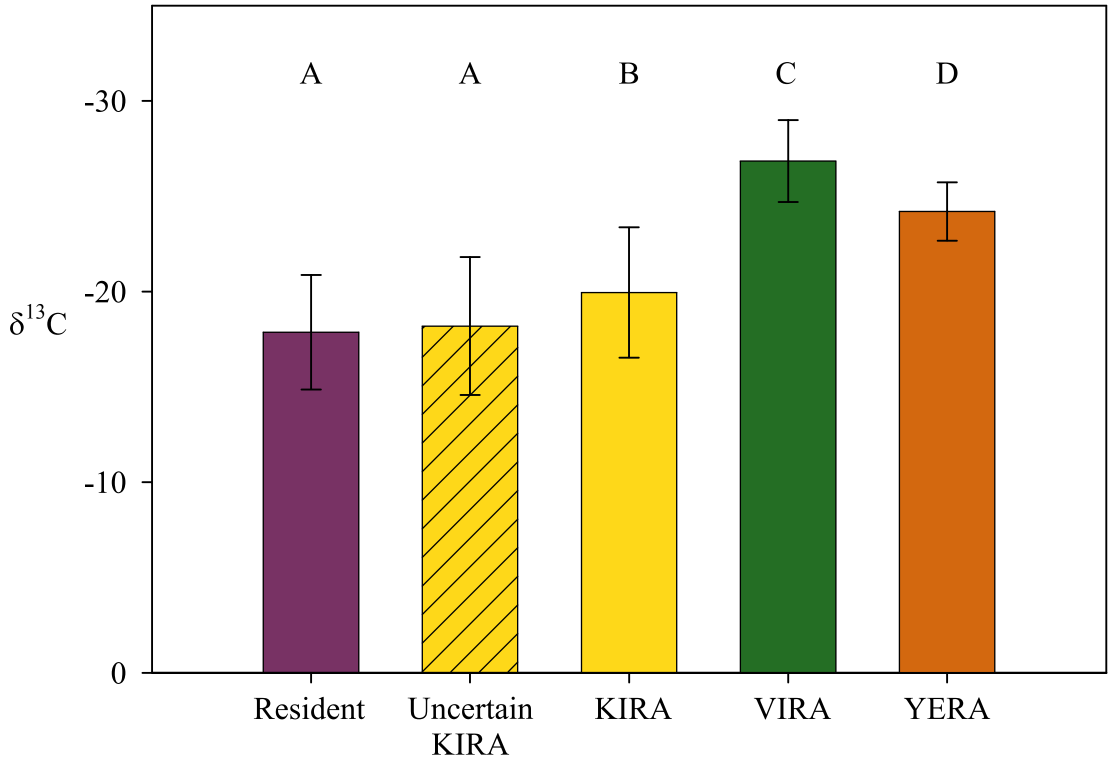


Figure 15: Means and standard deviation for carbon stable isotope values (‰) of resident rails, and winter collected king rails (KIRA), uncertain king rails, Virginia rails (VIRA), and yellow rails (YERA). Bars sharing a letter do not differ ($p > 0.05$).

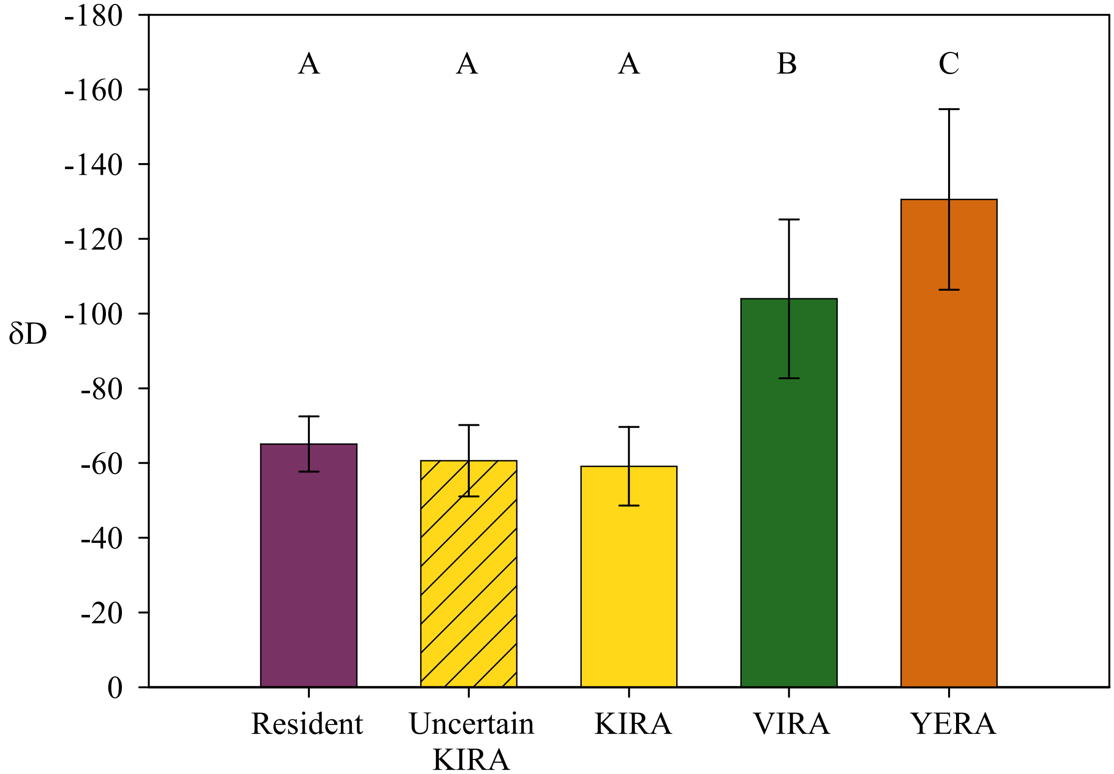


Figure 16: Means and standard deviation for hydrogen stable isotope values (‰) of resident rails, and winter collected king rails (KIRA), uncertain king rails, Virginia rails (VIRA), and yellow rails (YERA). Bars sharing a letter do not differ ($p > 0.05$).

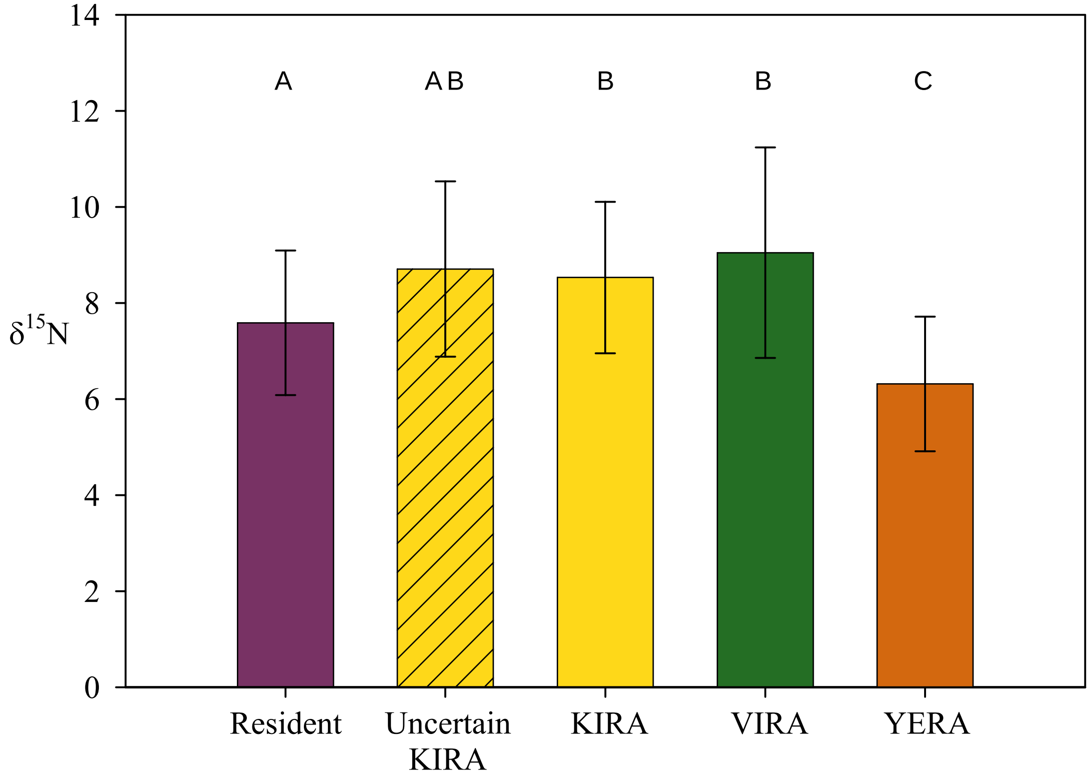


Figure 17: Means and standard deviation for nitrogen stable isotope values (‰) of resident rails, and winter collected king rails (KIRA), uncertain king rails, Virginia rails (VIRA), and yellow rails (YERA). Bars sharing a letter do not differ ($p > 0.05$).

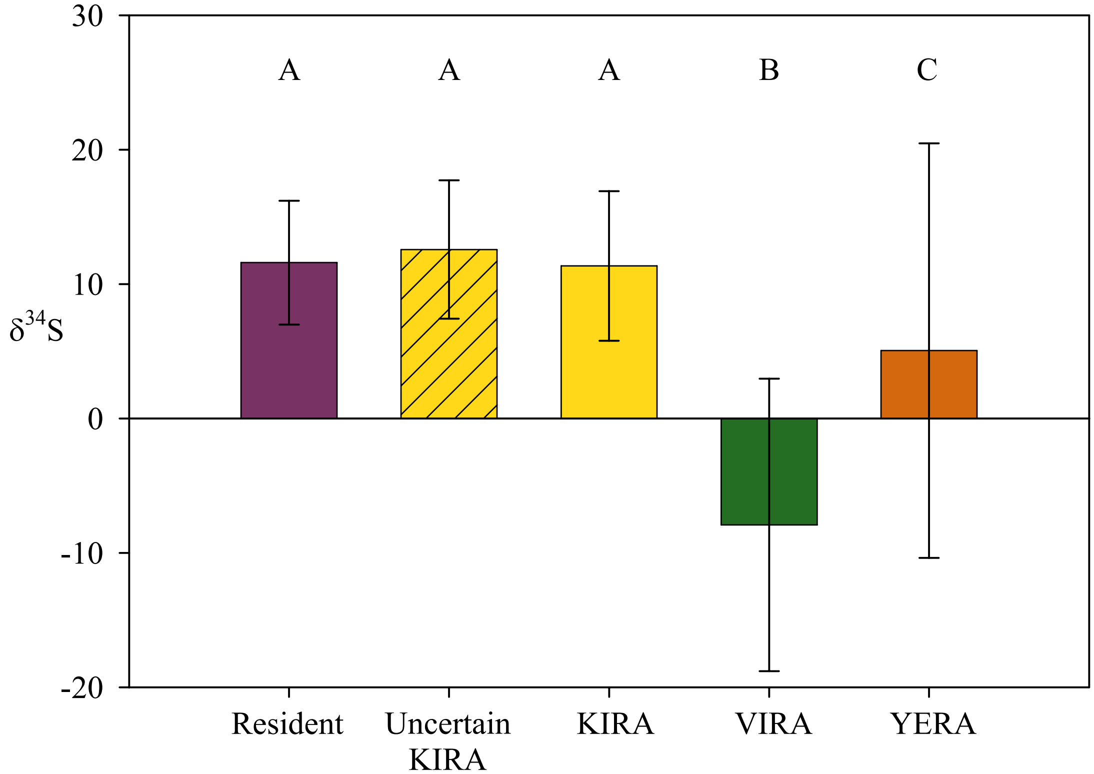


Figure 18: Means and standard deviation for sulfur stable isotope values (‰) of resident rails, and winter collected king rails (KIRA), uncertain king rails, Virginia rails (VIRA), and yellow rails (YERA). Bars sharing a letter do not differ ($p > 0.05$).

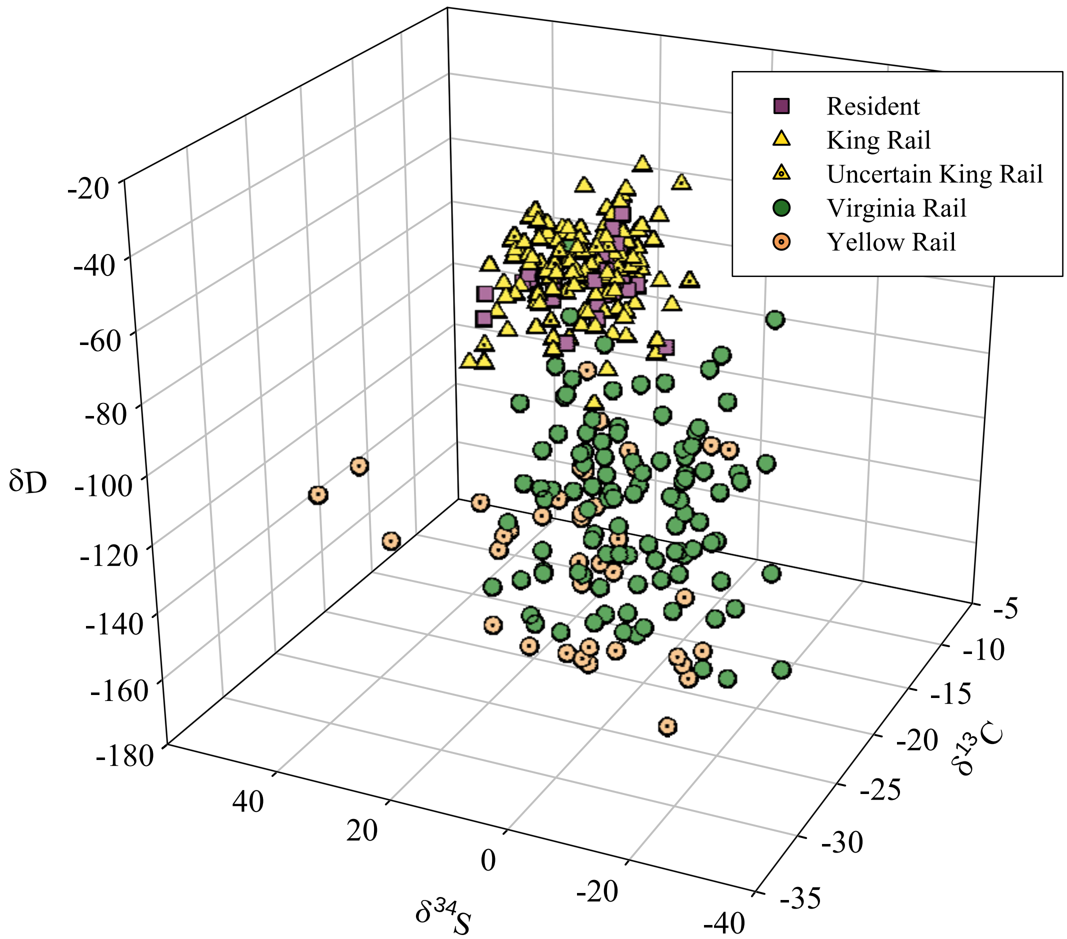


Figure 19: δD, $\delta^{13}C$, and $\delta^{34}S$ values (‰) from resident and winter collected rails.

Discriminant analysis of δD, $\delta^{13}C$, $\delta^{15}N$, and $\delta^{34}S$ values showed differences in the stable isotope values among Virginia rails, yellow rails and resident rails. They did not show a difference among resident rails, king rail, and uncertain king rails (Figure 20). Cross validation results were 89% for the king rails, 14% for the uncertain king rails, 15% for the resident rails, 84% for the Virginia rails, and 68% for yellow rails. Four discriminant functions were derived from the discriminant analysis. The discriminant function that accounted for greatest amount of the variability explained by this model, 88%, was: $\nu 1 = \alpha + 0.90$ (Hydrogen) + 0.83 (Carbon) + 0.02 (Nitrogen) + 0.69 (Sulfur).

This function relied heavily on the hydrogen and carbon values, and relied very little on the nitrogen values. The next discriminant function accounted for 11% of the variability explained by this model, the classification formula for that function was: $\nu 2 = \alpha - 0.40$ (Hydrogen) + 0.36 (Carbon) + 0.69 (Nitrogen) + 0.50 (Sulfur). This function relied most heavily on the nitrogen values, and less heavily on the values of the remaining three isotopes. The last two discriminant functions produced by this model, $\nu 3 = \alpha + 0.06$ (Hydrogen) - 0.42 (Carbon) + 0.01 (Nitrogen) + 0.51 (Sulfur) and $\nu 4 = \alpha - 0.15$ (Hydrogen) + 0.05 (Carbon) + 0.72 (Nitrogen) - 0.06 (Sulfur), accounted for a very small amount of the variability, 0.7% and 0.3%, respectively.

There was no relationship seen between $\delta D_{(f-p)}$ and $\delta^{34}S$ for the northern breeding and the resident rails ($p = 0.69$) (Figure 21).

Simple linear regression using the resident and museum specimens indicated that there was a linear relationship between the δD values of the rails feathers and the estimated δD values of growing season precipitation at the capture location ($F_{1,91} = 65.8$, $p < 0.0001$, $n = 93$). The model explained 42% of the variation and the regression equation which best explains this variation is: $\delta D_f = 0.65 * \delta D_p - 54.7$ (Figure 22). The y-intercept of this equation, -54.7, was subtracted from the δD_f values of the resident rails and the winter collected king rails, Virginia rails, and yellow rails. The resulting values were then compared to a map of δD values of growing season precipitation, in order to determine an approximate location were the feathers of these rails were grown. The proportion rails that fell into the categories of δD_p values were then plotted on the map (Figure 23, Figure 24, Figure 25).

Ninety-one percent (n = 137) of wintering king rails and uncertain king rails, and 93% (n = 37) of resident rails had values representing a region that included southern Louisiana and Texas. Eight percent (n = 12) of wintering king rails and uncertain king rails and 7% (n = 3) of resident rails had values representing a region that included northern Louisiana and Texas, and southern Arkansas. One percent (n = 2) of wintering king rails and uncertain king rails had values representing a region farther north than Louisiana and Texas (Figure 23). Values for winter collected Virginia rails represented regions from southern Louisiana and Texas, extending as far north as southern Canada (Figure 24), and values for winter collected yellow rails represented regions from northern Louisiana and Texas to northern Canada (Figure 25).

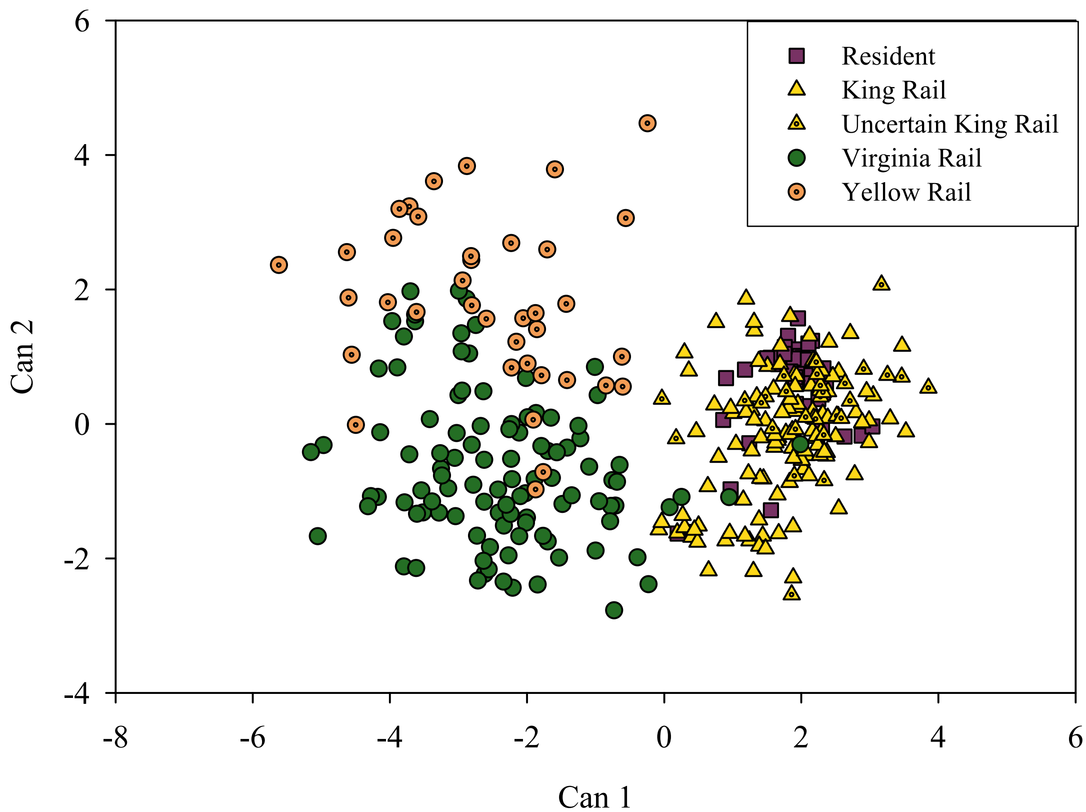


Figure 20: The discriminant analysis results for δD, $\delta^{13}C$, $\delta^{15}N$, and $\delta^{34}S$ values of rail feathers, based on the first two discriminant functions derived from the analysis.

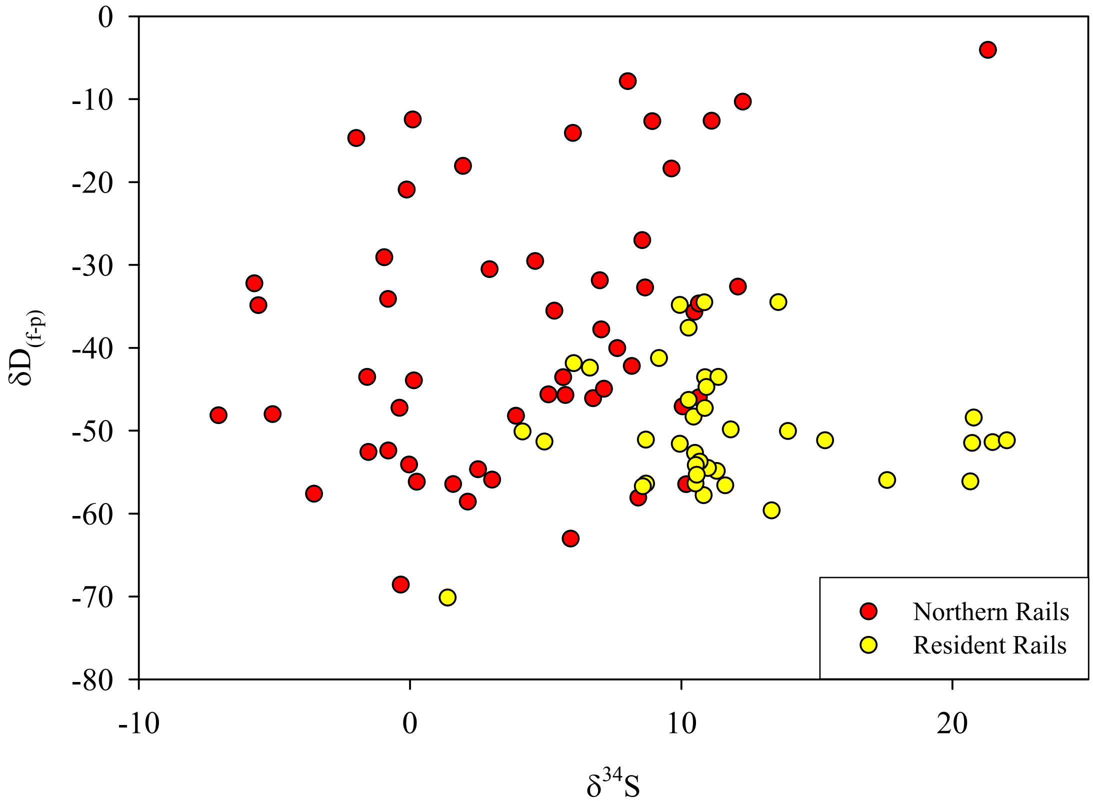


Figure 21: $\delta D_{(f-p)}$ (‰) verses $\delta^{34}S$ (‰) of feathers collected on the northern breeding grounds and from rails resident to Louisiana and Texas ($p = 0.69$).

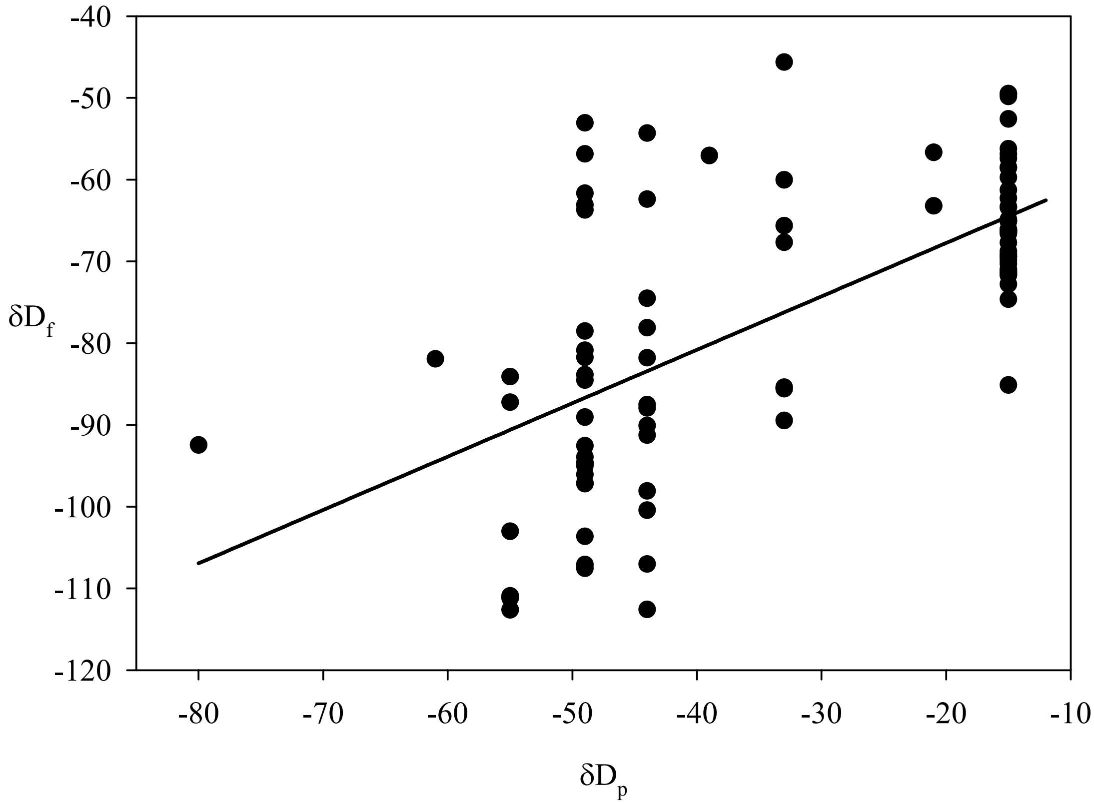


Figure 22: Relationship between δD of rail feathers (‰) and expected δD of precipitation (‰) at collection location for king rails collected in their northern breeding grounds. Regression model: $\delta D_f = 0.65 * \delta Dp - 54.7$, $r^2 = 0.42$.

Figure 23: The proportion of winter collected king rails and uncertain king rails, combined, (n = 151), and resident rails captured during the breeding season in Louisiana (n = 40), whose estimated values of δD_p fall within the categories of δD_p values on the map. Map created from GIS files developed by Meehan et al. (2004), downloaded into ArcGIS 9.1. King rail range map created using data modified in ArcGIS 9.1 from http://www.natureserve.org/getData/birdMaps.jsp. Accessed 19 June 2006.

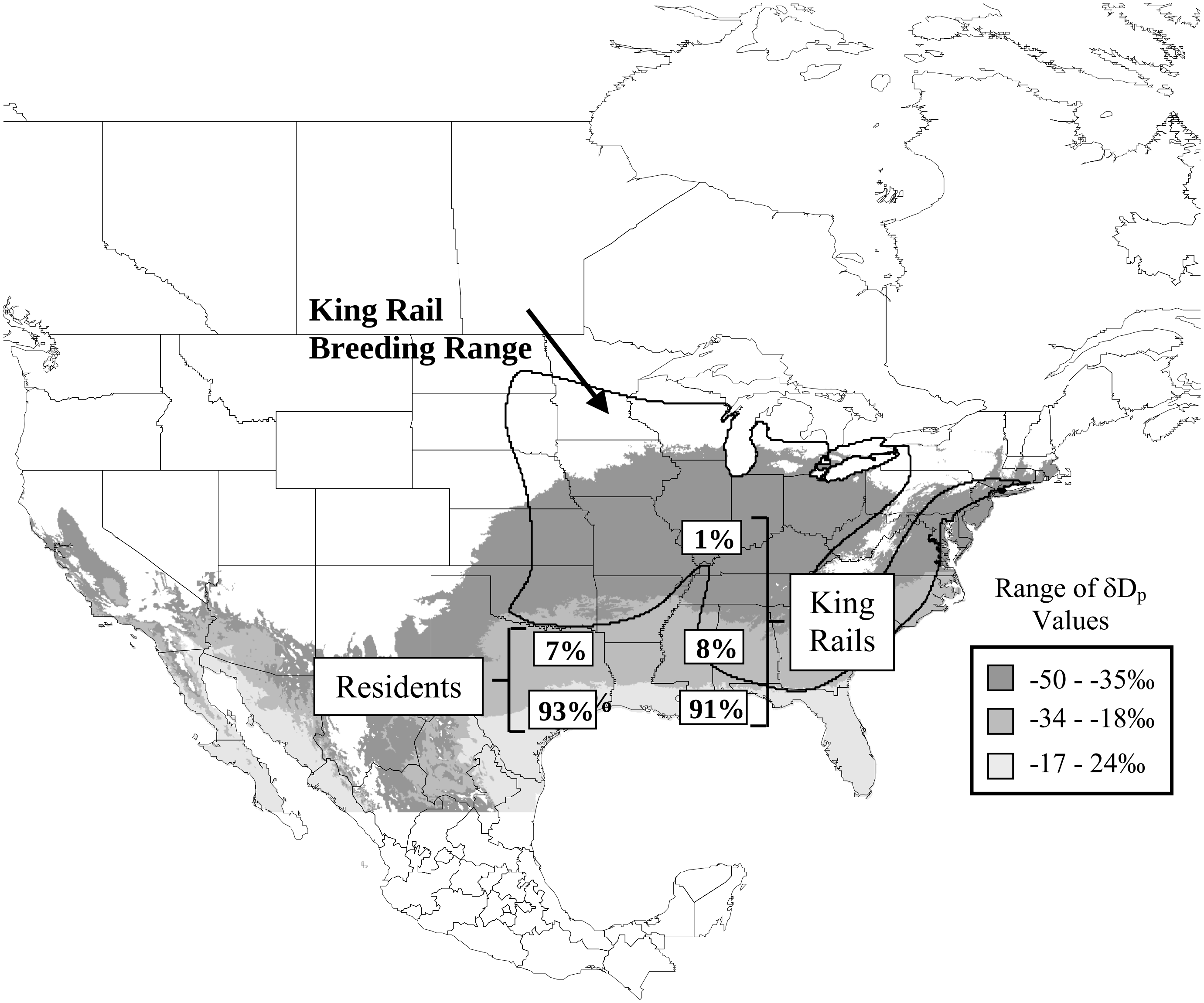

King Rail
Breeding Range
1%
7%
8%
King
Rails
Residents
93%
91%
Range of δDp
Values
-50 - -35‰
-34 - -18‰
-17 - 24‰

Figure 24: The proportion of winter collected Virginia rails (n = 105) whose estimated values of δD_p fall within the categories of δD_p values on the map. Map created from GIS files developed by Meehan et al. (2004), downloaded into ArcGIS 9.1. Virginia rail range map created using data modified in ArcGIS 9.1 from http://www.natureserve.org/getData/birdMaps.jsp. Accessed 19 June 2006.

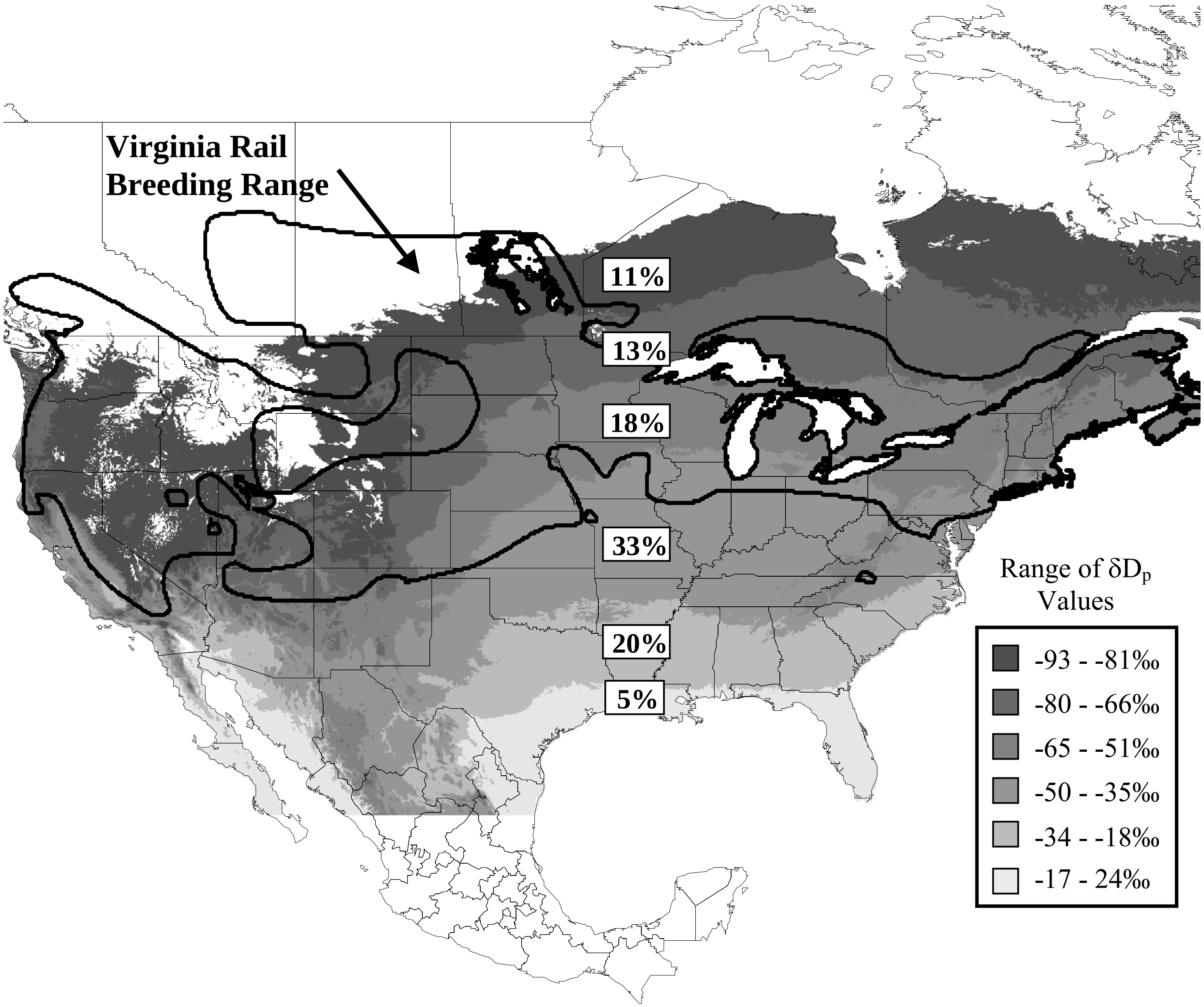
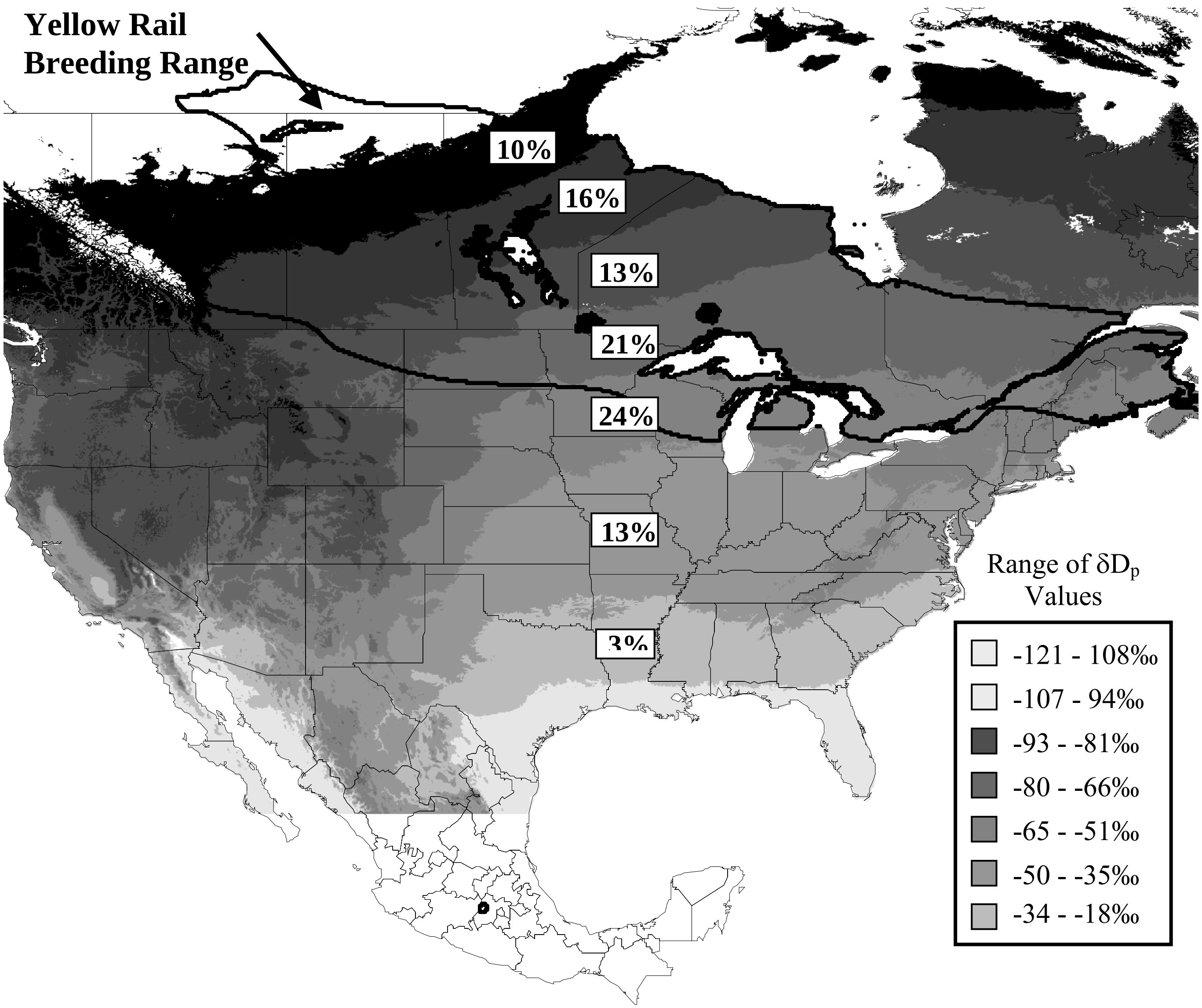

Virginia Rail
Breeding Range
11%
13%
18%
33%
20%
5%
Range of δD$_p$
Values
-93 - -81‰
-80 - -66‰
-65 - -51‰
-50 - -35‰
-34 - -18‰
-17 - 24‰

Figure 25: The proportion of winter collected yellow rails (n = 38) whose estimated values of δD_p fall within the categories of δD_p values on the map. Map created from GIS files developed by Meehan et al. (2004), downloaded into ArcGIS 9.1. Yellow rail range map created using data modified in ArcGIS 9.1 from http://www.natureserve.org/getData/birdMaps. Accessed 19 June 2006.


Yellow Rail
Breeding Range
10%
16%
13%
21%
24%
13%
3%
Range of δD$_p$
Values
-121 - 108‰
-107 - 94‰
-93 - -81‰
-80 - -66‰
-65 - -51‰
-50 - -35‰
-34 - -18‰

DISCUSSION

Multiple stable isotope analysis of rail feathers proved to be a useful technique for differentiating among rail species thought to breed in different geographical areas. This analysis also showed differences among rails that were resident to southern Louisiana and Texas and those that were migrants. A significant relationship was also seen between the δD_f values and estimated δD_p values for the collection locations of resident Louisiana and Texas rails, the museum specimens, and the rails collected in Ohio. The fractionation factor that resulted from this analysis could be used to determine an approximate breeding location for the winter collected rails.

The breeding ranges of king rails, Virginia rails, and yellow rails show that they breed in different geographical regions with some overlap in these ranges (Figure 1, Figure 3, Figure 5). Analyses of all stable isotopes were significantly different between Virginia and yellow rails, with some overlap in the values of individuals (Figure 15, Figure 16, Figure 17, Figure 18, Figure 20). This indicates that the Virginia and yellow rails wintering in southern Louisiana and Texas breed in different geographical regions, with some possible overlap; this is consistent with the range maps for these two species. Very little overlap was seen in the stable isotope values for the winter collected king rails and migratory Virginia and yellow rails (Figure 19, Figure 20). The winter collected king rails and uncertain king rails were significantly different than yellow rails for all stable isotopes and significantly different than Virginia rails for all stable isotopes except $\delta^{15}N$ (Figure 15, Figure 16, Figure 17, Figure 18).

The range maps of both Virginia and yellow rails indicate that the stable isotope values of their feathers should be representative of rails that are migrants to southern

Louisiana and Texas (Figure 3, Figure 5). In contrast, king and clapper rails captured during mid to late May were thought to be resident rails because king rails were observed nesting and with young during this time; the stable isotope values of their feathers should represent resident southern Louisiana and Texas rails. Yellow rails and Virginia rails were significantly different from the resident rails for all stable isotope values; but a few individual Virginia rails ($n < 7$) did have stable isotope values similar to those of the resident rails (Figure 19, Figure 20). This can, perhaps, be explained by the fact that Virginia rails are known to molt on both their breeding and wintering grounds, or "double molt" (Conway 1995). These results indicate that this is likely rare (< 7%).

Analysis of multiple stable isotope values show similarities for resident rails and winter collected king rails (Figure 19, Figure 20). There were differences seen in the carbon stable isotope values between these rails, though this was most likely because the winter collected king rails were captured in a variety of brackish and freshwater habitats. There was no significant difference observed between the residents and uncertain king rails for all stable isotopes, and there was no difference between the residents and winter collected king rails for hydrogen and sulfur stable isotope values (Figure 15, Figure 16, Figure 17, Figure 18). It was thought that both migratory and resident king rail populations would be present in southern Louisiana and Texas from the end of September through the end of March based on what little is known about the migratory timing of king rails. However, these similarities seen in the stable isotope values among the resident rails and the winter collected king rails suggest that most of the these king rails were resident to southern Louisiana and Texas.

There was a relationship seen between the δD_f and δD_p values; however, it seemed to be stronger for the southern breeding rails, represented by higher values of δD_p, than for the northern breeding rails (Figure 22). This may have resulted from a larger number of rails being collected from the southern breeding range and that most of these rails were collected during a single breeding season. The variation explained by the regression model was only 42%; this was a lower percentage than previous studies have seen for red-winged blackbirds ($r^2 = 0.83$), Cooper's hawks ($r^2 = 0.83$), and six insectivorous forest song birds ($r^2 = 0.91$) (Hobson and Wassenaar 1997, Wassenaar and Hobson 2000b, Meehan et al. 2001), but was within the range of a study looking at Bicknell's thrush ($r^2 = 0.48$) (Hobson et al. 2001).

The variation in the linear relationship between δD_f and δD_p values was most likely not due to the presence of marine derived hydrogen in the feathers of rails collected from salt or brackish marsh. I found little evidence of a relationship between the difference in δD_f and estimated δD_p values and $\delta^{34}S$ values of resident and northern breeding rails, even though many of the rails were known to be using salt or brackish marsh. These findings contrast with those of Lott et al. (2003), which showed that birds feeding on marine food sources had abnormally high δD_f values and that sulfur stable isotope values can be an indicator of these abnormally high values. This suggests that although the rails in this study are using salt or brackish marsh, the δD values of their feathers are similar to that of the estimated δD values of growing season precipitation, not the δD values of the marine environment.

One factor that may have affected the variation in the linear relationship between δD_f and δD_p values of rail feathers could be that body feathers from museum specimens

were used in this model. An effort to decrease the variability caused by using museum specimens was made by obtaining feather material from specimens that had been collected between 7 June and 7 September. This was done in order to help insure that these rails had already molted their feathers on the breeding grounds and had not yet started to migrate. However, these specimens were collected over a long time period, from 1879 until 1984, which could have resulted in increased variation in the stable isotope values of these feathers. Also, the estimated δD_p values for the capture locations were derived from a map of long-term average δD_p values, which increases the variation for the museum specimens and the recently captured rails. Another factor that could be affecting the variation in the linear relationship is that all other rails used in the model were collected in April and May; the values of these feathers could represent another local location at which they molted during the previous breeding season. Considering the large effect these other factors may have had on the model, the linear relationship between δD_f and δD_p values is significant.

The y-intersect of the regression equation from the simple linear regression indicates a fractionation factor of -54.7 for δD values of growing season precipitation being incorporated into the feathers of rails. This fractionation factor was similar to that seen for mallards and pintails ($\delta D_f = 0.83\ \delta D_p - 57$, $r^2 = 0.56$), but greater than that seen for red-winged blackbirds ($\delta D_f = 1.1\ \delta D_p - 27$), Cooper's hawks ($\delta D_f = 1.0\ \delta D_p - 34$), Bicknell's thrush ($\delta D_f = 0.68\ \delta D_p - 26$), and six insectivorous forest song birds ($\delta D_f = 0.9\ \delta D_p - 31$) (Hobson and Wassenaar 1997, Wassenaar and Hobson 2000b, Hobson et al. 2001, Meehan et al. 2001, Hebert and Wassenaar 2005).

This fractionation factor was subtracted from the δD_f values of the resident rails and the winter collected king rails, Virginia rails, and yellow rails; this resulted in the approximate value of δD_p for the location at which their feathers were grown. Plots of the approximate values of δD_p indicated that the winter collected Virginia rails and yellow rails had grown their feathers in regions throughout the eastern United States (Figure 24, Figure 25). Approximately 10% (Virginia rails, n = 11, and yellow rails, n = 4) of the rails from both species had values representing the region near to the northern limit of their known breeding ranges. Twenty-five percent (n = 26) of the winter collected Virginia rails and 16% (n = 6) of the winter collected yellow rails had values representing ranges located farther south than their known breeding range. This suggests that these rails may be either breeding or molting farther south than their breeding ranges indicate. It also suggests that approximately 5% (n = 5) of Virginia rails could be "double molting" on the wintering grounds.

Values for winter collected king rails and uncertain king rails mostly represented regions in the southern United States (Figure 23). The majority of these rails, 91%, had values representing a region that included southern Louisiana and Texas. Eight percent of wintering king rails and uncertain king rails had values representing a region that included northern Louisiana and Texas, and southern Arkansas. However, approximately the same proportion of residents also had values representing this region, indicating that this 8% is most likely not migratory. One percent of wintering king rails and uncertain king rails had values representing a region farther north than Louisiana and Texas, and no residents had values representing this range. This is in agreement with the results of the

previous analyses; that few of the winter collected king rails were migratory to southern Louisiana and Texas.

In summary, the use of multiple stable isotope analysis of rail feathers proved to be a useful technique for approximating the breeding areas of wintering rails. Multiple stable isotope analysis using δD, $\delta^{13}C$, $\delta^{15}N$, and $\delta^{34}S$, showed distinct differences among winter collected king rails and migrant Virginia and yellow rail. They did not show differences between the winter collected king rails and residents Louisiana and Texas rails. All analyses used in this study indicated that very few, approximately one percent, of the winter collected king rails were migratory to Louisiana and Texas.

CHAPTER 5
CONCLUSIONS

The objectives of this study were to: 1) Determine the best technique for capturing rails wintering in Louisiana and Texas; 2) Determine if morphometric measurements could be used to identify and sex king and clapper rails; and 3) Determine the ratio of resident to migrant king rails in southern Louisiana and Texas using stable isotope analysis of feathers. In order to use stable isotope analysis of feathers to study king rail migration, it was necessary to capture wintering rails. The results of this study showed that capturing rails by hand or net from an airboat or ATV at night were the most effective techniques for capturing wintering rails in Louisiana and Texas.

It was also necessary to be able to reliably identify king rails, particularly in areas where their range overlaps with clapper rails. The results of this study showed that discriminant analysis of the wing, tarsus, and culmen measurements could be used to distinguish between king and clapper rails from southern Louisiana and Texas. Discriminant analysis of the wing, tarsus, and culmen measurements could also be used to distinguish between male and female clapper rails and wing and tarsus measurements could be used to distinguish between male and female king rails.

The use of multiple stable isotope analysis of rail feathers proved to be a good technique for determining the ratio of resident to migrant king rails in southern Louisiana and Texas. Multiple stable isotope analysis using δD, $\delta^{13}C$, $\delta^{15}N$, and $\delta^{34}S$, showed distinct differences among winter collected king rails and migrant Virginia and yellow rail. They did not show differences between the winter collected king rails and residents. This indicates that most, if not all, of the winter collected king rails were resident to Louisiana and Texas. A linear relationship was seen between δD_f values and estimated

δD_p values at the collection locations. The fractionation factor that resulted from this analysis could be used to determine an approximate breeding location for the winter collected rails, and also indicated that most, 99%, of the winter collected king rails were resident to Louisiana and Texas.

LITERATURE CITED

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APPENDIX A: SPECIMEN INFORMATIION FOR MUSEUM SPECEMENS AND NORTHERN COLLECTED RAILS

Hydrogen, carbon, nitrogen, and sulfur stable isotope values of king and Virginia rail feathers obtained from museum specimens and Ottawa National Wildlife Refuge. Specimen age, capture location, and capture date are indicated. Values in red indicate that analysis was carried out using a small sample size, resulting in greater variability in the value.

Species	**δD‰**	**δ^{13}C‰**	**δ^{15}N‰**	**δ^{34}S‰**	**Age**	**Location**	**Date**	**Museum**	**Museum ID**
King Rail	-85.58	-20.93	9.75	-1.54	Uknown	Stuttgart, AR	6/7/1930	The University Museum, University of Arkansas	85-78-1986
King Rail	-98.10	-22.66	11.09	-0.03	Uknown	North Haven, CT	9/5/1902	The Field Museum of Natural History, Chicago	131789
King Rail	-81.75	-17.17	11.02	8.67	Juvenile	Chicago, IL	8/11/1904	The Field Museum of Natural History, Chicago	18131
King Rail	-96.07	-26.49	6.25	10.05	Juvenile	Warrenville, IL	7/16/1933	The Field Museum of Natural History, Chicago	410649
King Rail	-63.72	-22.22	10.79	-1.98	Juvenile	Wheaton, IL	7/25/1927	The Field Museum of Natural History, Chicago	404780
King Rail	-78.12	-24.82	8.55	-0.81	Juvenile	Worth, IL	8/24/1913	The Field Museum of Natural History, Chicago	45192
King Rail	-107.04	-26.98	7.23	5.92	Juvenile	Worth, IL	8/3/1913	The Field Museum of Natural History, Chicago	45190
King Rail	-87.94	-20.23	10.77	0.14	Juvenile	Worth, IL	8/9/1913	The Field Museum of Natural History, Chicago	45191
King Rail	-112.57	-26.37	13.76	-0.35	Juvenile	Worth, IL	8/3/1913	The Field Museum of Natural History, Chicago	415676
King Rail	-91.27	-27.15	10.78	-0.39	Juvenile	Worth, IL	8/10/1913	The Field Museum of Natural History, Chicago	45174
King Rail	-74.53	-19.63	16.81	2.94	Juvenile	Worth, IL	8/10/1913	The Field Museum of Natural History, Chicago	45175
King Rail	-62.40	-19.14	10.40	9.64	Juvenile	Worth, IL	8/3/1913	The Field Museum of Natural History, Chicago	331539
King Rail	-81.79	-17.53	9.29	7.05	Uknown	Burlington, IA	8/18/1894	The Field Museum of Natural History, Chicago	16109
King Rail	-80.87	-25.80	13.85	6.99	Uknown	Hoisington, KS	7/8/1961	The University of Kansas Natual History Museum	103156

(table cont.)

King Rail	-90.10	-26.07	14.04	6.75	Uknown	Little Salt Marsh, KS	8/22/1925	The University of Kansas Natural History Museum	18716
King Rail	-100.44	-24.41	9.34	1.59	Uknown	Moran, KS	7/4/1927	The University of Kansas Natual History Museum	18715
King Rail	-89.06	-26.77	12.74	7.64	Adult	Canton, MA	8/27/1894	Museum of Comparative Zoology, Harvard	292751
King Rail	-45.64	-24.93	6.46	11.12	Adult	Raleigh, NC	7/12/1887	Museum of Comparative Zoology, Harvard	213834
King Rail	-67.66	-24.61	14.42	10.65	Uknown	Raleigh, NC	7/18/1892	Peabody Museum of Natural History, Yale	126711
King Rail	-89.48	-25.82	10.34	10.18	Uknown	Raleigh, NC	6/14/1893	The Field Museum of Natural History, Chicago	21031
King Rail	-85.40	-26.26	9.50	-0.81	Adult	Wake Co., NC	6/26/1894	California Academy of Sciences	43750
King Rail	-60.02	-22.92	7.63	8.56	Uknown	Marshall Co., OK	7/27/1954	The Sam Noble Oaklahoma Museum of Natural History	1297
King Rail	-57.07	-19.54	12.80	1.95	Uknown	Tulsa, OK	6/25/1967	The Sam Noble Oaklahoma Museum of Natural History	6202
King Rail	-65.62	-23.23	8.64	12.09	Uknown	Choctaw Co., OK	6/27/1954	The Sam Noble Oaklahoma Museum of Natural History	1273
King Rail	-56.67	-24.07	8.41	10.48	Adult	Mt. Pleasant, SC	8/6/1918	Museum of Comparative Zoology, Harvard	150117
King Rail	-63.22	-22.16	11.06	8.18	Adult	Charleston, SC	7/10/1886	Museum of Comparative Zoology, Harvard	212297
King Rail	-103.02	-29.69	7.72	-5.07	Uknown	Beaver Dam, WI	8/24/1908	The Field Museum of Natural History, Chicago	52463
King Rail	-110.91	-21.37	12.77	3.03	Uknown	Beaver Dam, WI	9/6/1907	The Field Museum of Natural History, Chicago	52466
King Rail	-111.18	-22.52	9.21	0.24	Uknown	Beaver Dam, WI	9/7/1906	The Field Museum of Natural History, Chicago	52462
King Rail	-112.62	-25.00	13.22	-3.54	Uknown	Beaver Dam, WI	9/1/1908	The Field Museum of Natural History, Chicago	52464
King Rail	-63.09	-27.33	13.65	6.01	Adult	Ottawa NWR, OH	5/24/2006		

(table cont.)

King Rail	-61.67	-25.74	8.82	8.93	Adult	Ottawa NWR, OH	5/16/2006		
King Rail	-56.86	-25.66	8.89	8.03	Adult	Ottawa NWR, OH	5/16/2006		
King Rail	-78.53	-25.05	10.27	4.61	Adult	Ottawa NWR, OH	4/28/2006		
King Rail	-95.00	-28.63	9.57	10.64	Adult	Ottawa NWR, OH	5/6/2006		
Virginia Rail	-92.46	-26.88	10.86	0.10	Juvenile	Judds Ranch, ND	9/25/1902	The Field Museum of Natural History, Chicago	131847
Virginia Rail	-81.93	-26.37	9.60	-0.13	Juvenile	Petoskey, MI	8/21/1976	The Field Museum of Natural History, Chicago	324932
Virginia Rail	-87.52	-26.66	13.14	-1.58	Juvenile	North Haven, CT	8/23/1902	The Field Museum of Natural History, Chicago	131836
Virginia Rail	-53.07	-25.73	6.75	21.31	Juvenile	Waukegan Flats, IL	8/6/1933	The Field Museum of Natural History, Chicago	97588
Virginia Rail	-54.31	-21.70	14.17	12.27	Juvenile	Princeton, NJ	7/23/1880	The Field Museum of Natural History, Chicago	426174
Virginia Rail	-84.54	-23.89	15.80	5.32	Juvenile	Ithaca, NY	8/20/1879	The Field Museum of Natural History, Chicago	426176
Virginia Rail	-87.23	-26.53	14.50	-5.74	Juvenile	Fox Lake, WI	9/5/1899	The Field Museum of Natural History, Chicago	52338
Virginia Rail	-84.10	-24.57	8.62	-0.96	Juvenile	Beaver Dam, WI	9/1/1905	The Field Museum of Natural History, Chicago	97835
Virginia Rail	-83.87	-26.93	8.31	-5.60	Adult	Ottawa NWR, OH	5/20/2006		
Virginia Rail	-103.65	-28.18	8.87	2.51	Adult	Ottawa NWR, OH	5/20/2006		
Virginia Rail	-107.09	-31.14	5.74	8.41	Adult	Ottawa NWR, OH	5/20/2006		
Virginia Rail	-93.96	-28.33	6.21	7.14	Adult	Ottawa NWR, OH	5/21/2006		
Virginia Rail	-97.21	-25.87	11.37	3.90	Adult	Ottawa NWR, OH	5/21/2006		

(table cont.)

Virginia Rail	-92.56	-28.78	8.58	5.64	Adult	Ottawa NWR, OH	5/22/2006		
Virginia Rail	-94.69	-26.37	6.70	5.73	Adult	Ottawa NWR, OH	5/22/2006		
Virginia Rail	-94.64	-31.00	6.97	5.10	Adult	Ottawa NWR, OH	5/22/2006		
Virginia Rail	-97.16	-26.47	9.88	-7.06	Adult	Ottawa NWR, OH	5/22/2006		
Virginia Rail	-107.57	-30.64	6.37	2.13	Adult	Ottawa NWR, OH	5/23/2006		

APPENDIX B: SPECIMEN INFORMATIION FOR RAILS CAPTURED IN LOUISIANA AND TEXAS

Hydrogen, carbon, nitrogen, and sulfur stable isotope values of rail feathers obtained from rails captured in Louisiana and Texas. The group used for statistical analysis, as well as the specimen sex, morphometric measurements, capture location, and capture date are indicated. Missing data is represented by (.). * indicates rail positively identified as king or clapper rails. ** indicates road killed rail. *** indicates molting feather material.

Species	Group	δD‰	$\delta^{13}C$‰	$\delta^{15}N$‰	$\delta^{34}S$‰	Sex	Wing (mm)	Tail (mm)	Tarsus (mm)	Culmen (mm)	Weight (g)	Location	Date
Clapper Rail	.	.	.	.	.	Female	143	58	52.98	55.61	290	Rockefeller	9/26/2004
Clapper Rail	.	.	.	.	.	Male	152	65	52.97	62.59	340	Rockefeller	9/29/2004
Clapper Rail	.	.	.	.	.	Female	145	66	47.7	63.73	301	Rockefeller	9/29/2004
Clapper Rail	.	.	.	.	.	Male	145	65	52.62	61.78	337	Rockefeller	9/29/2004
Clapper Rail	.	.	.	.	.	Male	130	67	54.03	60.27	361	Rockefeller	9/29/2004
Clapper Rail	.	.	.	.	.	Female	144	60	48.35	60.43	250	Rockefeller	9/29/2004
Clapper Rail	.	.	.	.	.	Female	156	55	53.84	54.05	226	Rockefeller	10/3/2004
Clapper Rail	.	.	.	.	.	Female	150	62	53.3	57.55	245	Rockefeller	10/16/2004
Clapper Rail	.	.	.	.	.	Female	153	65	51.4	58.35	299	Rockefeller	10/16/2004
Clapper Rail	.	.	.	.	.	Female	142	66	47.9	62.33	299	Rockefeller	10/20/2004
Clapper Rail	.	.	.	.	.	Female	141	58	50.47	58.22	279	Rockefeller	10/20/2004
Clapper Rail	.	.	.	.	.	Female	145	60	52	60.48	311	Rockefeller	10/20/2004
Clapper Rail	.	.	.	.	.	Male	150	62	47.41	57.03	284	Rockefeller	10/20/2004

(table cont.)

Clapper Rail	.	.	.	.	.	Female	150	57	46.07	60.87	294	Rockefeller	11/3/2004
Clapper Rail	.	.	.	.	.	Female	139	58	52.69	60.59	256	Rockefeller	11/15/2004
Clapper Rail	.	.	.	.	.	Male	148	64	51.97	60.72	282	Rockefeller	2/17/2005
Clapper Rail	.	.	.	.	.	Female	142	54	52.05	57.33	255	Rockefeller	2/17/2005
Clapper Rail	.	.	.	.	.	Female	138	61	48.43	56.71	289	Rockefeller	3/22/2005
Clapper Rail	.	.	.	.	.	Female	136	55	47.08	59.22	264	Rockefeller	3/22/2005
Clapper Rail	.	.	.	.	.	Female	137	53	50.71	60.58	279	Rockefeller	3/22/2005
Clapper Rail	.	.	.	.	.	Male	157	71	54.39	66.28	371	Rockefeller	3/22/2005
Clapper Rail	.	.	.	.	.	Male	151	59	54.78	62.46	332	Rockefeller	3/22/2005
Clapper Rail	.	.	.	.	.	Male	149	62	58.3	65.9	337	Rockefeller	3/22/2005
Clapper Rail	.	.	.	.	.	Male	152	61	57.43	63.72	330	Rockefeller	3/22/2005
Clapper Rail	.	.	.	.	.	Male	151	65	54.18	61.15	343	Rockefeller	3/22/2005
Clapper Rail	.	.	.	.	.	Male	155	65	58.98	66.3	365	Marsh Island	2/23/2006
Clapper Rail	Resident	-52.58	-17.14	9.47	10.27	Male	148	69	48.77	56	326	Rockefeller	9/29/2004
Clapper Rail	Resident	-56.25	-17.36	8.80	9.17	Female	134	52	46.35	59.11	286	Rockefeller	3/22/2005
Clapper Rail	Resident	-49.85	-16.32	9.38	9.95	Female	144	63	48.19	55.36	254	Rockefeller	5/17/2005
Clapper Rail	Resident	-66.16	-15.95	5.94	15.30	Male	149	60	56.12	67.54	291	Rockefeller	5/17/2005

(table cont.)

Clapper Rail	Resident	-65.06	-16.22	7.96	13.93	Male	166	60	53.6	71.26	368	Rockefeller	5/17/2005
Clapper Rail	Resident	-66.10	-16.99	9.49	8.69	Male	144	69	53.98	65.44	300	Rockefeller	5/17/2005
Clapper Rail	Resident	-49.52	-15.78	9.28	10.85	Male	152	56	54.3	64.3	333	Rockefeller	5/17/2005
Clapper Rail	Resident	-74.63	-16.09	6.90	13.32	Male	139	65	49.95	60.41	269	Rockefeller	5/17/2005
Clapper Rail	Resident	-85.13	-16.76	8.98	1.39	Female	.	.	.	.	352	Rockefeller	5/24/2005
Clapper Rail*	.	.	.	.	.	Female	138	62	48.44	55.98	290	Rockefeller	11/15/2004
Clapper Rail*	.	.	.	.	.	Female	139	60	51.25	58.4	285	Rockefeller	11/15/2004
Clapper Rail*	.	.	.	.	.	Male	149	60	54.37	64.44	340	Rockefeller	11/15/2004
Clapper Rail*	.	.	.	.	.	Male	157	65	52.07	63.48	338	Rockefeller	11/15/2004
Clapper Rail*	.	.	.	.	.	Female	144	63	51.68	58.88	315	Rockefeller	11/15/2004
Clapper Rail*	.	.	.	.	.	Male	154	63	54.91	60.75	308	Rockefeller	7/11/2006
Clapper Rail*	.	.	.	.	.	Female	160	64	51.07	58.91	250	Rockefeller	7/11/2006
Clapper Rail*	.	.	.	.	.	Female	141	65	50.94	59.16	263	Rockefeller	7/11/2006
Clapper Rail*	.	.	.	.	.	Male	154	65	54.21	65.35	335	Rockefeller	7/11/2006
Clapper Rail*	.	.	.	.	.	Female	145	62	50.38	63.97	290	Rockefeller	7/11/2006
Clapper Rail*	.	.	.	.	.	Male	153	65	60.04	66.96	377	Rockefeller	7/11/2006
Clapper Rail*	.	.	.	.	.	Male	157	67	54.92	68.27	347	Rockefeller	7/11/2006

(table cont.)

Clapper Rail*	.	.	.	.	.	Female	132	57	48.27	55.71	243	Rockefeller	7/11/2006
Clapper Rail*	.	.	.	.	.	Male	151	64	54.62	69.12	353	Rockefeller	7/11/2006
Clapper Rail*	.	.	.	.	.	Female	146	64	49.84	61.41	268	Rockefeller	7/12/2006
Clapper Rail*	.	.	.	.	.	Male	150	64	56.53	65.63	331	Rockefeller	7/12/2006
Clapper Rail*	.	.	.	.	.	Male	159	66	54.83	59.19	291	Rockefeller	7/12/2006
Clapper Rail*	.	.	.	.	.	Female	142	60	47.36	57.54	258	Rockefeller	7/12/2006
Clapper Rail*	.	.	.	.	.	Female	142	56	51.6	56.8	280	Rockefeller	7/12/2006
Clapper Rail*	.	.	.	.	.	Male	150	62	52.77	60.34	289	Rockefeller	7/12/2006
Clapper Rail*	.	.	.	.	.	Female	139	62	50.73	59.93	253	Rockefeller	7/12/2006
Clapper Rail*	.	.	.	.	.	Female	151	64	53.1	57.74	276	Rockefeller	7/12/2006
Clapper Rail*	.	.	.	.	.	Male	152	60	51.7	64.88	314	Rockefeller	7/12/2006
King Rail	King Rail	-57.18	-19.53	9.86	14.54	Male	164	67	59.45	60.87	375	Rockefeller	9/28/2004
King Rail	King Rail	-51.06	-20.32	8.18	16.70	Male	162	72	62.55	61.68	443	Rockefeller	10/13/2004
King Rail	King Rail	-61.51	-19.74	8.50	15.78	Male	165	69	60.71	66.97	430	Rockefeller	10/15/2004
King Rail	King Rail	-48.24	-21.77	8.74	15.56	Male	164	70	60.35	57.04	398	Rockefeller	10/16/2004
King Rail	King Rail	-50.69	-15.56	10.28	13.67	Male	163	72	57.38	57.46	327	Rockefeller	10/16/2004
King Rail	King Rail	-66.85	-14.68	7.79	17.34	Male	162	72	60.11	63.12	412	Rockefeller	10/20/2004
King Rail	King Rail	-70.78	-14.72	8.22	13.44	Male	157	66	62.12	62.34	343	Rockefeller	11/3/2004
King Rail	King Rail	-62.38	-19.56	9.44	10.99	Male	169	70	60.27	69.12	420	Rockefeller	12/11/2004
King Rail	King Rail	-60.90	-16.74	9.92	9.34	Male	160	68	57.95	61.05	380	Rockefeller	12/13/2004
King Rail	King Rail	-47.85	-21.92	8.50	12.34	Female	156	65	55.76	52.6	265	Rockefeller	12/15/2004
King Rail	King Rail	-53.57	-22.08	9.00	19.47	Male	164	64	59.53	60.39	448	Rockefeller	12/15/2004
King Rail	King Rail	-53.36	-21.38	9.76	19.63	Female	150	57	56.13	57.15	339	Rockefeller	12/15/2004

(table cont.)

King Rail	King Rail	-59.21	-23.00	9.32	19.70	Male	159	72	60.37	64.67	490	Rockefeller	12/15/2004
King Rail	King Rail	-63.92	-20.69	9.11	7.70	Male	167	66	62.57	60.29	392	Rockefeller	1/9/2005
King Rail	King Rail	-49.99	-21.66	9.59	20.44	Female	155	62	50.81	53.01	363	Rockefeller	1/10/2005
King Rail	King Rail	-80.07	-18.22	8.57	0.89	Female	153	63	54.22	58.65	329	Rockefeller	1/10/2005
King Rail	King Rail	-52.66	-21.94	9.14	17.12	Male	178	70	67.41	65.57	470	Rockefeller	1/10/2005
King Rail	King Rail	-50.95	-22.38	9.16	18.69	Male	164	66	59.52	62.27	412	Rockefeller	1/10/2005
King Rail	King Rail	-67.21	-23.17	9.30	20.66	Male	174	70	63.15	66.32	461	Rockefeller	1/11/2005
King Rail	King Rail	-60.88	-14.10	9.71	20.62	Female	153	59	55.16	57.2	340	Rockefeller	1/11/2005
King Rail	King Rail	-48.68	-22.32	9.74	17.31	Female	159	66	53.06	54.26	344	Rockefeller	1/11/2005
King Rail	King Rail	-55.03	-22.06	9.74	16.84	Female	150	66	52.64	56.01	320	Rockefeller	1/12/2005
King Rail	King Rail	-48.74	-19.80	8.47	17.90	Male	162	64	57.68	62.2	420	Rockefeller	1/12/2005
King Rail	King Rail	-56.61	-21.46	10.36	17.42	Female	156	59	52.23	58.75	384	Rockefeller	1/12/2005
King Rail	King Rail	-64.84	-25.63	11.01	4.42	Female	152	63	54.45	54.49	304	Rockefeller	1/12/2005
King Rail	King Rail	-68.04	-23.84	9.63	12.88	Male	157	69	63.86	63.83	379	Rockefeller	1/30/2005
King Rail	King Rail	-77.19	-15.46	7.64	8.86	Male	162	72	59.44	66.16	438	McFaddin	2/2/2005
King Rail	King Rail	-58.16	-21.35	8.02	15.09	Male	168	66	61.02	60.74	427	McFaddin	2/2/2005
King Rail	King Rail	-68.72	-16.91	9.38	15.74	Female	150	60	53.31	59.07	280	McFaddin	2/2/2005
King Rail	King Rail	-65.35	-20.48	6.71	15.19	Male	160	71	59.19	60.34	391	McFaddin	2/2/2005
King Rail	King Rail	-68.06	-24.71	7.01	16.28	Male	173	70	66.64	65.2	473	Rockefeller	2/10/2005
King Rail	King Rail	-63.78	-15.87	8.49	9.21	Male	164	71	59.96	60.14	313	Anahuac	2/11/2005
King Rail	King Rail	-71.58	-19.53	8.05	19.76	Male	169	65	59.4	60.24	390	McFaddin	2/12/2005
King Rail	King Rail	-86.39	-15.81	7.67	9.79	Female	159	71	53.2	57.23	276	McFaddin	2/12/2005
King Rail	King Rail	-70.22	-14.86	8.32	9.41	Male	165	66	63.48	67.29	386	McFaddin	2/12/2005
King Rail	King Rail	-86.28	-15.86	5.81	12.10	Male	161	66	58.81	58.4	393	McFaddin	2/12/2005
King Rail	King Rail	-59.04	-15.76	7.51	9.72	Male	168	67	60.09	63.14	382	Rockefeller	2/17/2005
King Rail	King Rail	-65.60	-16.52	7.47	8.57	Male	168	65	66.85	70.27	411	Rockefeller	2/17/2005
King Rail	King Rail	-75.55	-15.28	8.34	13.57	Male	173	70	71.11	59.95	338	McFaddin	3/5/2005
King Rail	King Rail	-78.52	-16.08	5.73	9.44	Male	170	60	62.1	60.25	368	McFaddin	3/5/2005
King Rail	King Rail	-64.05	-18.24	9.84	7.81	Male	149	65	55.84	60.11	301	McFaddin	3/5/2005
King Rail	King Rail	-61.90	-14.93	5.45	9.28	Female	160	65	53.23	58.13	242	McFaddin	3/5/2005
King Rail	King Rail	-90.11	-15.79	6.45	4.57	Female	152	58	54.89	53.11	248	McFaddin	3/5/2005

(table cont.)

King Rail	King Rail	-63.83	-17.35	8.43	8.65	Male	176	73	64.68	65.06	447	McFaddin	11/11/2005
King Rail	King Rail	-48.38	-16.46	7.70	3.32	Male	168	71	61.87	64.72	415	McFaddin	11/11/2005
King Rail	King Rail	-63.52	-17.20	6.27	12.31	Female	152	65	51.54	56.04	287	McFaddin	11/11/2005
King Rail	King Rail	-64.44	-21.57	7.21	16.24	Male	171	68	62.15	61.83	404	McFaddin	11/11/2005
King Rail	King Rail	-43.12	-16.17	8.03	9.42	Male	170	72	59.63	63.17	394	McFaddin	11/11/2005
King Rail	King Rail	-58.86	-17.47	6.76	9.56	Male	170	73	56.75	57.05	357	McFaddin	11/11/2005
King Rail	King Rail	-52.39	-16.28	6.55	6.54	Male	166	71	59.91	59.77	292	McFaddin	12/2/2005
King Rail	King Rail	-58.76	-17.94	5.75	4.44	Female	148	62	54.43	56.65	279	McFaddin	12/2/2005
King Rail	King Rail	-46.75	-22.87	11.25	-1.74	Female	157	73	56.74	58.6	357	McFaddin	12/2/2005
King Rail	King Rail	-67.83	-16.00	6.80	3.60	Male	162	67	61.11	61.21	312	McFaddin	12/2/2005
King Rail	King Rail	-47.31	-24.49	11.35	12.33	Male	165	73	62.78	64.2	471	Anahuac	12/3/2005
King Rail	King Rail	-51.96	-22.16	8.04	10.12	Male	165	70	57.39	60.93	410	Anahuac	12/3/2005
King Rail	King Rail	-52.73	-25.46	10.41	7.41	Male	165	71	61.44	67.28	405	Anahuac	12/3/2005
King Rail	King Rail	-38.93	-23.73	8.93	12.60	Male	165	68	62.54	59.59	452	Anahuac	12/3/2005
King Rail	King Rail	-81.14	-23.66	5.63	22.23	Male	163	69	61.32	59.47	403	McFaddin	1/24/2006
King Rail	King Rail	-79.46	-24.53	6.67	23.24	Male	165	71	63.25	65.64	425	McFaddin	1/24/2006
King Rail	King Rail	-50.37	-20.06	7.87	17.37	Male	168	68	60.24	64.22	391	McFaddin	1/24/2006
King Rail	King Rail	-38.01	-18.98	8.15	12.32	Female	154	61	54.26	57.46	275	McFaddin	1/24/2006
King Rail	King Rail	-45.25	-21.04	6.93	15.38	Female	152	62	55.67	55.01	284	Anahuac	1/25/2006
King Rail	King Rail	-50.38	-24.89	8.10	18.86	Male	165	68	62.08	64.98	370	Anahuac	1/25/2006
King Rail	King Rail	-58.78	-20.36	8.58	10.11	Male	153	62	59.52	60.52	378	Rockefeller	2/8/2006
King Rail	King Rail	-50.80	-18.12	8.67	23.11	Male	174	70	63.35	65.17	436	Rockefeller	2/8/2006
King Rail	King Rail	-67.85	-17.98	8.13	15.09	Male	155	65	60.81	59.37	377	Rockefeller	2/8/2006
King Rail	King Rail	-59.27	-15.54	10.51	9.91	Male	160	66	62.31	63.21	369	Rockefeller	2/8/2006
King Rail	King Rail	-70.38	-19.83	7.61	7.55	Male	163	65	59.47	59.91	379	Rockefeller	2/8/2006
King Rail	King Rail	-53.05	-18.11	7.56	9.91	Male	168	73	63.77	67.1	426	Rockefeller	2/8/2006
King Rail	King Rail	-44.22	-23.77	10.17	6.00	Male	169	67	57.69	58.84	391	Rockefeller	2/14/2006
King Rail	King Rail	-47.61	-18.75	8.99	21.15	Male	174	75	63.61	66.38	430	Rockefeller	2/14/2006
King Rail	King Rail	-65.60	-17.69	8.19	10.04	Male	168	72	63.17	60.92	471	Rockefeller	2/14/2006
King Rail	King Rail	-54.16	-16.75	7.17	9.10	Female	155	64	58.67	59.4	365	Rockefeller	2/14/2006
King Rail	King Rail	-66.19	-19.32	6.85	7.67	Female	154	65	56.29	55.48	357	McFaddin	2/15/2006

(table cont.)

King Rail	King Rail	-57.35	-15.68	8.09	5.41	Male	155	64	55.19	59.41	294	Marsh Island	2/23/2006
King Rail	King Rail	-57.78	-23.56	6.60	15.93	Female	148	62	55.65	57.67	333	Rockefeller	3/1/2006
King Rail	King Rail	-38.60	-24.13	11.90	6.90	Male	155	62	55.63	56.53	332	Rockefeller	3/1/2006
King Rail	King Rail	-61.28	-18.76	7.55	12.05	Male	167	66	61.85	67.85	392	Rockefeller	3/1/2006
King Rail	King Rail	-75.14	-18.21	8.13	13.41	Female	152	68	52.44	55.86	276	Rockefeller	3/1/2006
King Rail	King Rail	-54.31	-17.29	7.41	10.94	Male	169	77	59.98	67.49	390	Rockefeller	3/1/2006
King Rail	King Rail	-53.99	-20.24	8.19	11.94	Male	155	62	60.26	62.94	345	Rockefeller	3/1/2006
King Rail	King Rail	-50.67	-16.29	8.92	11.74	Male	162	66	58.92	60.7	362	Rockefeller	3/7/2006
King Rail	King Rail	-53.80	-18.46	6.76	13.89	Male	168	65	62.9	64.1	409	Rockefeller	3/7/2006
King Rail	King Rail	-48.15	-19.97	8.85	14.49	Male	165	68	62.58	63.41	392	Rockefeller	3/7/2006
King Rail	King Rail	-61.09	-15.11	7.53	11.77	Male	168	65	59.84	64.41	349	Rockefeller	3/7/2006
King Rail	King Rail	-53.70	-18.14	8.57	15.56	Male	164	72	60.21	64.24	420	Rockefeller	3/7/2006
King Rail	King Rail	-55.15	-25.69	7.03	13.31	Male	171	76	67.61	58.12	440	Rockefeller	3/14/2006
King Rail	King Rail	-47.74	-14.91	6.06	11.98	Male	169	70	60.37	64.19	390	Rockefeller	3/14/2006
King Rail	King Rail	-48.84	-20.63	8.81	15.94	Female	152	60	55.19	54.67	364	Rockefeller	3/14/2006
King Rail	King Rail	-55.33	-17.46	6.25	18.10	Male	174	70	59.54	65.08	377	Rockefeller	3/14/2006
King Rail	King Rail	-61.95	-18.22	7.24	11.78	Female	159	63	55.25	55.55	383	Rockefeller	3/14/2006
King Rail	King Rail	-39.74	-14.25	8.10	9.48	Male	172	73	60.11	62.5	391	Rockefeller	3/14/2006
King Rail	King Rail	-55.84	-20.65	7.38	12.87	Male	166	65	61.63	61.76	375	Rockefeller	3/14/2006
King Rail	King Rail	-59.42	-18.69	6.79	10.33	Female	154	68	51.86	57.83	356	Rockefeller	3/14/2006
King Rail	King Rail	-57.54	-19.84	7.83	9.75	Male	169	70	62.73	64.11	433	Rockefeller	3/14/2006
King Rail	King Rail	-73.02	-25.11	12.00	-1.02	Female	147	62	51.74	56.32	304	Rockefeller	3/14/2006
King Rail	King Rail	-59.22	-17.93	8.84	11.35	Female	155	63	57.65	59.52	316	Rockefeller	3/14/2006
King Rail	King Rail	-65.87	-22.01	9.97	15.20	Male	169	66	64.52	65.12	407	Rockefeller	3/14/2006
King Rail	King Rail	-68.96	-17.86	5.18	11.63	Female	161	64	54.17	53.06	370	McFaddin	3/23/2006
King Rail	King Rail	-57.78	-18.15	6.41	16.18	Female	168	66	56.99	61.63	364	McFaddin	3/23/2006
King Rail	Resident	-63.31	-16.81	6.49	10.45	Male	174	70	61.31	63.87	382	Rockefeller	5/18/2005
King Rail	Resident	-69.88	-15.82	6.46	11.31	Male	171	66	63.21	67.55	397	Rockefeller	5/18/2005
King Rail	Resident	-58.54	-17.93	6.66	10.88	Male	173	68	61.53	67.25	342	Rockefeller	5/18/2005
King Rail	Resident	-64.87	-16.60	7.28	11.82	Female	155	66	53.85	53.86	276	Rockefeller	5/18/2005
King Rail	Resident	-58.53	-16.96	7.53	11.37	Female	144	60	54.26	56.49	298	Rockefeller	5/18/2005

(table cont.)

King Rail	Resident	-62.28	-15.79	7.93	10.86	Male	158	60	61.73	62.6	381	Rockefeller	5/18/2005
King Rail	Resident	-61.30	-16.26	6.85	10.27	Female	157	65	54.87	56.98	351	Rockefeller	5/18/2005
King Rail	Resident	-67.71	-16.25	7.14	10.51	Male	156	67	.	.	364	Rockefeller	5/18/2005
King Rail	Resident	-72.80	-18.51	6.23	10.82	Male	162	64	.	.	362	Rockefeller	5/18/2005
King Rail	Resident	-69.38	-15.68	6.99	10.69	Female	157	65	.	.	210	Rockefeller	5/18/2005
King Rail	Resident	-69.50	-16.63	7.14	10.98	Female	158	67	.	.	302	Rockefeller	5/18/2005
King Rail	Resident	-71.40	-16.31	6.93	8.70	Female	154	65	56.49	57.92	294	Rockefeller	5/19/2005
King Rail	Resident	-68.76	-16.53	6.73	10.68	Male	170	74	62.98	61.35	378	Rockefeller	5/19/2005
King Rail	Resident	-66.60	-16.53	7.28	9.95	Female	154	63	59.57	61.72	274	Rockefeller	5/19/2005
King Rail	Resident	-71.38	-16.88	6.24	10.52	Male	169	72	64.52	65.61	419	Rockefeller	5/19/2005
King Rail	Resident	-69.15	-15.61	7.19	10.54	Male	172	67	62.66	58.82	408	Rockefeller	5/19/2005
King Rail	Resident	-70.32	-15.58	7.80	10.57	Male	162	62	60.47	60.22	358	Rockefeller	5/19/2005
King Rail	Resident	-71.72	-15.40	7.42	8.58	Male	170	72	58.4	61.78	350	Rockefeller	5/19/2005
King Rail	Resident	-71.60	-15.09	7.36	11.62	Male	168	69	58.41	67.16	367	Rockefeller	5/19/2005
King Rail	Resident	-59.73	-16.37	7.68	10.93	Female	150	65	56.06	58.84	287	Rockefeller	5/19/2005
King Rail	Resident	-71.13	-17.17	5.71	20.66	Male	159	65	58.57	63.29	330	Rockefeller	5/24/2005
King Rail	Resident	-63.42	-19.75	6.57	20.78	Female	152	58	54.43	59.96	382	Rockefeller	5/24/2005
King Rail	Resident	-66.39	-19.16	5.58	21.47	Male	160	65	60.59	65.19	372	Rockefeller	5/24/2005
King Rail	Resident	-57.40	-20.20	6.27	6.63	Female	165	66	57.91	61.32	329	Rockefeller	5/24/2005
King Rail	Resident	-66.18	-19.62	6.02	22.00	Male	160	60	58.89	66.22	407	Rockefeller	5/24/2005
King Rail	Resident	-49.51	-28.49	7.39	13.58	Female	157	60	54.84	59.36	280	Rockefeller	5/24/2005
King Rail	Resident	-66.49	-24.47	7.48	20.72	Female	159	66	54.15	61.27	273	Rockefeller	5/24/2005
King Rail	Resident	-70.96	-19.17	6.59	17.59	Male	168	62	63.83	61.67	373	Rockefeller	5/24/2005
King Rail	Resident***	-66.32	-22.32	11.25	4.95	Male	.	.	.		.	Anahuac	.
King Rail	Uncertain King Rail	-61.51	-16.24	9.08	14.80	Male	152	62	58.53	64.49	402	Rockefeller	9/29/2004
King Rail	Uncertain King Rail	-73.05	-13.94	8.77	25.94	Male	147	66	55.03	64.55	342	Rockefeller	10/21/2004
King Rail	Uncertain King Rail	-62.87	-17.45	9.30	8.84	Male	159	71	56.3	65.06	429	Rockefeller	11/3/2004
King Rail	Uncertain King Rail	-72.59	-21.02	8.68	14.91	Female	153	66	53.5	60.7	283	Rockefeller	11/15/2004

(table cont.)

King Rail	Uncertain King Rail	-63.96	-19.62	11.05	17.23	Male	176	70	.		431	Rockefeller	1/11/2005
King Rail	Uncertain King Rail	-43.39	-24.93	14.57	7.08	Female	159	69	54.31	60.91	368	Rockefeller	1/11/2005
King Rail	Uncertain King Rail	-70.80	-14.27	7.18	1.05	Male	147	60	53.29	66.19	339	Rockefeller	1/11/2005
King Rail	Uncertain King Rail	-47.11	-22.37	10.50	18.83	Male	156	68	50.89	65.02	377	Rockefeller	1/11/2005
King Rail	Uncertain King Rail	-64.45	-21.47	9.55	16.22	Female	146	63	49.74	55.89	330	Rockefeller	1/12/2005
King Rail	Uncertain King Rail	-61.62	-14.18	11.73	16.57	Female	140	62	51.13	61.04	298	Rockefeller	1/12/2005
King Rail	Uncertain King Rail	-52.24	-20.71	9.50	9.89	Female	145	57	49.18	57.79	267	Rockefeller	1/28/2005
King Rail	Uncertain King Rail	-60.14	-13.81	10.14	13.63	Male	155	68	58.35	66.02	348	Rockefeller	2/10/2005
King Rail	Uncertain King Rail	-69.28	-26.23	6.99	17.63	Unknown	159	68	54.25	61.18	261	McFaddin	11/11/2005
King Rail	Uncertain King Rail	-55.49	-15.59	6.04	8.29	Male	158	67	53.97	63.79	406	Marsh Island	12/29/2005
King Rail	Uncertain King Rail	-56.28	-17.81	9.46	9.93	Male	152	66	55.1	61.71	391	Rockefeller	2/14/2006
King Rail	Uncertain King Rail	-54.58	-18.86	7.10	10.37	Male	163	70	55.55	61.96	387	Rockefeller	2/14/2006
King Rail	Uncertain King Rail	-63.38	-18.33	5.99	9.14	Female	145	62	52.25	57.2	297	Rockefeller	2/14/2006
King Rail	Uncertain King Rail	-60.58	-14.64	8.66	13.99	Female	152	57	48.21	55.58	337	Rockefeller	2/14/2006
King Rail	Uncertain King Rail	-53.09	-18.93	8.50	18.07	Male	157	70	57.35	65.92	422	Rockefeller	2/14/2006
King Rail	Uncertain King Rail	-64.40	-16.45	6.79	6.41	Male	156	62	54.25	64.55	331	McFaddin	2/15/2006
King Rail	Uncertain King Rail	-92.45	-21.72	9.94	6.43	Unknown	154	68	55.74	68.44	346	Marsh Island	2/23/2006

(table cont.)

King Rail	Uncertain King Rail	-54.05	-16.50	8.51	10.23	Male	156	62	53.77	64.98	316	Marsh Island	2/23/2006
King Rail	Uncertain King Rail	-59.89	-16.26	7.11	11.19	Male	146	68	55.19	66.92	321	Marsh Island	2/23/2006
King Rail	Uncertain King Rail	-63.56	-16.18	7.41	12.09	Male	152	62	54.22	65.15	321	Marsh Island	2/23/2006
King Rail	Uncertain King Rail	-47.39	-24.74	9.44	8.26	Male	164	65	.	.	440	Rockefeller	3/1/2006
King Rail	Uncertain King Rail	-56.61	-17.87	7.18	15.00	Female	154	62	.	.	326	Rockefeller	3/1/2006
King Rail	Uncertain King Rail	-63.05	-18.37	7.15	20.97	Male	151	62	58.79	63.03	340	Marsh Island	3/15/2006
King Rail	Uncertain King Rail	-50.41	-10.88	9.45	7.48	Male	158	70	58.65	66.16	367	Marsh Island	3/15/2006
King Rail	Uncertain King Rail	-53.87	-16.22	7.93	12.88	Male	155	70	54.66	62.94	339	Marsh Island	3/15/2006
King Rail	Uncertain King Rail	-66.02	-20.11	7.47	13.70	Male	145	63	49.75	57.33	354	McFaddin	3/23/2006
King Rail*	.	.	.	.	.	Female	150	61	53.83	57.54	350	Cameron Prairie	4/7/2005
King Rail*	.	.	.	.	.	Female	149	59	54.84	56.89	296	Cameron Prairie	4/7/2005
King Rail*	.	.	.	.	.	Male	162	66	61.3	63.62	393	Cameron Prairie	4/8/2005
King Rail*	King Rail	-65.00	-25.88	10.33	6.68	Female	152	62	54.16	61.5	263	Anahuac	2/11/2005
King Rail*	King Rail	-66.14	-26.65	9.99	5.46	Male	173	74	66.19	65.51	425	Anahuac	2/11/2005
King Rail*	King Rail	-58.48	-25.08	10.46	2.22	Male	165	67	58.49	56.71	375	Anahuac	3/4/2005
King Rail*	King Rail	-71.06	-17.36	6.62	-0.36	Female	138	54	47.15	54.14	262	Anahuac	3/4/2005
King Rail*	King Rail	-62.24	-25.03	10.77	3.37	Male	166	65	56.03	56.34	369	Anahuac	3/4/2005

(table cont.)

King Rail*	King Rail	-80.93	-14.97	7.62	12.67	Female	155	60	55.9	57.36	353	Anahuac	3/4/2005
King Rail*	King Rail	-60.93	-17.94	8.81	5.93	Female	147	48	52.73	49.52	305	Anahuac	3/4/2005
King Rail*	King Rail	-62.22	-23.35	10.29	-1.12	Male	168	73	63.39	67.44	401	Sweet Lake	3/4/2005
King Rail*	King Rail	-45.21	-26.66	8.99	4.84	Male	158	65	60.73	62.71	321	Cameron Prairie	3/11/2005
King Rail*	King Rail	-40.60	-19.15	9.99	6.04	Male	171	69	64.21	62.13	411	Cameron Prairie	3/11/2005
King Rail*	King Rail	-53.18	-24.40	10.09	5.50	Female	158	61	56.22	59.3	349	Cameron Prairie	3/28/2005
King Rail*	King Rail	-61.58	-20.79	9.50	4.37	Female	153	65	54.05	54.21	314	Cameron Prairie	3/28/2005
King Rail*	King Rail	-50.33	-28.12	6.90	10.79	Female	157	66	56.94	58.49	262	Anahuac	11/12/2005
King Rail*	King Rail	-49.50	-23.38	9.68	7.89	Male	166	77	57.39	62.95	385	Anahuac	11/12/2005
King Rail*	King Rail	-51.32	-23.51	11.47	6.64	Male	170	68	60.99	60.86	384	Anahuac	11/12/2005
King Rail*	King Rail	-53.88	-22.99	8.85	7.25	Female	155	69	55.79	59.19	336	Anahuac	11/12/2005
King Rail*	King Rail	-58.30	-21.35	11.66	7.21	Male	169	74	57.62	60.35	340	Anahuac	11/12/2005
King Rail*	King Rail	-64.10	-21.36	11.79	16.60	Male	163	68	60.36	61.21	320	Anahuac	1/26/2006
King Rail*	King Rail	-51.75	-22.96	10.88	2.30	Male	164	71	60	61	322	Anahuac	1/26/2006
King Rail*	King Rail	-50.72	-24.02	11.79	6.45	Male	164	70	58.35	58.64	339	Anahuac	1/26/2006
King Rail*	King Rail	-62.41	-24.85	11.00	1.39	Male	166	66	64.22	58.37	412	Anahuac	1/26/2006
King Rail*	Resident	-56.87	-21.91	11.85	6.03	Male	164	59	64	64.55	374	Private Rice	5/15/2005

(table cont.)

King Rail*	Resident	-65.11	-26.08	11.15	4.15	Male	166	67	63.03	58.07	342	Cheneyville	6/6/2006
Virginia Rail	Virginia Rail	-114.93	-27.52	8.96	-2.33	Unknown	101	46	32.57	40.29	84	Rockefeller	10/20/2004
Virginia Rail	Virginia Rail	-118.64	-30.37	7.37	1.24	Unknown	98	41	34.56	36.52	74	Rockefeller	10/21/2004
Virginia Rail	Virginia Rail	-113.20	-28.94	8.75	-8.95	Unknown	108	44	36.23	38.79	92	Rockefeller	11/3/2004
Virginia Rail	Virginia Rail	-89.51	-25.59	10.58	-27.63	Unknown	98	36	31.52	36.44	85	Private Rice	11/8/2004
Virginia Rail	Virginia Rail	-121.85	-30.26	9.45	-19.59	Unknown	104	43	32.23	41.9	90	Rockefeller	11/15/2004
Virginia Rail	Virginia Rail	-106.45	-26.06	12.76	-15.43	Unknown	106	46	35.99	45.53	98	Rockefeller	11/15/2004
Virginia Rail	Virginia Rail	-93.29	-23.98	7.12	-1.15	Unknown	106	45	35.92	43.17	109	Rockefeller	1/10/2005
Virginia Rail	Virginia Rail	-107.65	-27.66	7.64	-22.84	Unknown	100	45	34.71	35.5	95	Rockefeller	1/12/2005
Virginia Rail	Virginia Rail	-127.81	-26.69	13.39	-8.73	Unknown	96	38	32.42	34.05	71	Rockefeller	1/12/2005
Virginia Rail	Virginia Rail	-138.56	-28.26	6.23	6.96	Unknown	106	46	37.36	43.69	116	Rockefeller	1/12/2005
Virginia Rail	Virginia Rail	-129.92	-27.85	7.34	9.16	Unknown	104	43	35.77	40.47	99	Rockefeller	1/12/2005
Virginia Rail	Virginia Rail	-112.05	-27.85	11.71	-17.20	Unknown	107	45	35.16	39.31	107	Rockefeller	1/12/2005
Virginia Rail	Virginia Rail	-121.12	-27.49	6.05	6.11	Unknown	96	39	32.16	34.64	81	Rockefeller	1/12/2005
Virginia Rail	Virginia Rail	-67.41	-25.27	12.02	-17.88	Unknown	96	41	32.26	36.09	66	Rockefeller	1/27/2005
Virginia Rail	Virginia Rail	-140.77	-28.30	7.34	6.19	Unknown	100	43	35.5	37.29	72	Rockefeller	1/27/2005
Virginia Rail	Virginia Rail	-114.08	-25.05	8.07	2.23	Unknown	106	45	35.47	41.12	96	Rockefeller	1/27/2005

(table cont.)

Virginia Rail	Virginia Rail	-52.98	-20.15	8.14	13.21	Unknown	96	43	31.68	34.17	75	McFaddin	2/2/2005
Virginia Rail	Virginia Rail	-98.17	-28.74	6.82	-7.67	Unknown	107	45	35.85	38.55	110	Rockefeller	2/10/2005
Virginia Rail	Virginia Rail	-144.24	-28.32	9.36	-26.03	Unknown	104	45	33.95	34.29	84	Rockefeller	2/10/2005
Virginia Rail	Virginia Rail	-133.76	-25.07	8.19	3.09	Unknown	107	42	34.2	37.14	87	Rockefeller	2/10/2005
Virginia Rail	Virginia Rail	-132.17	-29.88	15.17	-11.20	Unknown	94	44	32.15	35.36	82	Rockefeller	2/10/2005
Virginia Rail	Virginia Rail	-96.07	-26.57	11.37	-15.76	Unknown	106	45	37.52	41.46	108	Rockefeller	2/10/2005
Virginia Rail	Virginia Rail	-114.38	-29.07	13.31	-25.65	Unknown	103	40	34.8	36.44	69	Anahuac	2/11/2005
Virginia Rail	Virginia Rail	-117.92	-28.08	11.34	-17.52	Unknown	108	47	37.54	41.25	94	Anahuac	2/11/2005
Virginia Rail	Virginia Rail	-88.26	-26.95	6.92	4.18	Unknown	101	44	31.55	35.98	68	McFaddin	2/12/2005
Virginia Rail	Virginia Rail	-136.58	-29.74	6.82	-0.55	Unknown	106	41	34.58	39.93	88	McFaddin	2/12/2005
Virginia Rail	Virginia Rail	-115.18	-27.09	10.42	-16.82	Unknown	93	45	34.48	35.75	86	Rockefeller	2/17/2005
Virginia Rail	Virginia Rail	-115.97	-27.87	9.78	-13.33	Unknown	96	40	32.93	35.27	79	Rockefeller	2/17/2005
Virginia Rail	Virginia Rail	-139.81	-23.94	6.77	1.84	Unknown	95	39	32.39	35.3	72	Anahuac	3/4/2005
Virginia Rail	Virginia Rail	-104.02	-25.06	7.54	-6.37	Unknown	108	45	34.99	39.93	93	McFadden	3/5/2005
Virginia Rail	Virginia Rail	-143.86	-25.12	5.36	-0.89	Unknown	108	46	36.83	40.87	84	McFaddin	3/5/2005
Virginia Rail	Virginia Rail	-144.92	-25.22	7.93	-7.68	Unknown	107	46	36.44	40.38	81	Cameron Prairie	3/11/2005
Virginia Rail	Virginia Rail	-103.00	-26.42	9.79	-0.68	Unknown	100	42	36.12	39.45	90	Rockefeller	3/21/2005

(table cont.)

Virginia Rail	Virginia Rail	-87.23	-29.28	7.02	3.15	Unknown	103	44	33.68	38.1	82	Rockefeller	3/21/2005
Virginia Rail	Virginia Rail	-113.97	-28.94	8.06	-6.90	Unknown	99	42	32.73	35.12	72	Rockefeller	3/21/2005
Virginia Rail	Virginia Rail	-97.12	-26.46	9.26	0.62	Unknown	105	45	34.62	40.75	87	Cameron Prairie	3/28/2005
Virginia Rail	Virginia Rail	-147.09	-25.37	7.04	-6.59	Unknown	101	44	33.85	36.43	81	Cameron Prairie	3/28/2005
Virginia Rail	Virginia Rail	-126.71	-27.59	7.28	5.81	Unknown	97	40	30.91	33.7	68	Cameron Prairie	3/28/2005
Virginia Rail	Virginia Rail	-87.48	-28.71	6.59	-6.19	Unknown	99	44	34.47	35.8	86	Grand Cote	10/17/2005
Virginia Rail	Virginia Rail	-136.76	-28.80	12.36	-35.22	Unknown	99	43	30.85	34.97	85	Grand Cote	10/17/2005
Virginia Rail	Virginia Rail	-95.46	-24.33	11.41	-12.91	Unknown	105	43	36.05	37.85	63	Grand Cote	10/26/2005
Virginia Rail	Virginia Rail	-91.29	-27.47	8.82	-0.31	Unknown	108	43	31.6	42.83	116	Grand Cote	10/26/2005
Virginia Rail	Virginia Rail	-128.07	-28.22	10.94	-23.69	Unknown	106	42	39.37	39.62	125	Grand Cote	10/26/2005
Virginia Rail	Virginia Rail	-109.48	-28.25	16.19	-19.90	Unknown	99	39	32.17	35.76	85	Grand Cote	10/26/2005
Virginia Rail	Virginia Rail	-101.19	-22.35	6.86	3.94	Unknown	99	.	33.8	34.81	.	Grand Cote	10/26/2005
Virginia Rail	Virginia Rail	-101.09	-30.31	7.65	-10.93	Unknown	94	46	32.52	35.19	79	Grand Cote	10/26/2005
Virginia Rail	Virginia Rail	-95.04	-27.74	7.65	-5.00	Unknown	115	46	37.21	38.65	115	Grand Cote	11/3/2005
Virginia Rail	Virginia Rail	-76.82	-27.00	9.64	2.76	Unknown	97	40	32.54	32.7	70	Grand Cote	11/3/2005
Virginia Rail	Virginia Rail	-92.37	-26.89	8.19	-7.99	Unknown	100	45	33.01	36.4	81	Grand Cote	11/3/2005
Virginia Rail	Virginia Rail	-95.32	-22.52	6.80	0.89	Unknown	106	43	37.46	37.41	100	Grand Cote	11/3/2005

(table cont.)

Virginia Rail	Virginia Rail	-74.38	-26.18	6.95	3.05	Unknown	100	41	33.29	35.57	87	Grand Cote	11/10/2005
Virginia Rail	Virginia Rail	-110.60	-26.00	11.89	-13.90	Unknown	97	10	33.31	35.22	97	Grand Cote	11/10/2005
Virginia Rail	Virginia Rail	-96.38	-25.73	10.65	-14.96	Unknown	95	45	32.68	32.53	83	Grand Cote	11/10/2005
Virginia Rail	Virginia Rail	-102.13	-29.78	8.69	-24.93	Unknown	95	41	34.06	36.01	89	Grand Cote	11/10/2005
Virginia Rail	Virginia Rail	-103.62	-27.11	9.00	-4.29	Unknown	95	40	33.33	35.87	82	Grand Cote	11/10/2005
Virginia Rail	Virginia Rail	-75.88	-20.19	10.86	-12.89	Unknown	106	44	32.14	33.22	97	Grand Cote	11/10/2005
Virginia Rail	Virginia Rail	-142.20	-28.61	9.20	-22.37	Unknown	103	41	34.15	36.15	84	Grand Cote	11/10/2005
Virginia Rail	Virginia Rail	-100.57	-28.39	6.43	4.82	Unknown	98	41	31.06	33.3	85	Grand Cote	11/10/2005
Virginia Rail	Virginia Rail	-85.02	-21.60	10.42	-15.87	Unknown	99	40	34.1	36.63	92	Grand Cote	11/10/2005
Virginia Rail	Virginia Rail	-100.88	-25.30	8.32	-20.00	Unknown	100	43	34.57	34.39	79	Grand Cote	11/10/2005
Virginia Rail	Virginia Rail	-124.62	-27.71	8.95	-0.33	Unknown	103	45	37.18	40.91	120	Grand Cote	11/10/2005
Virginia Rail	Virginia Rail	-75.81	-24.26	9.07	-9.36	Unknown	98	41	36.73	37.8	108	Grand Cote	11/10/2005
Virginia Rail	Virginia Rail	-80.75	-25.80	8.48	4.98	Unknown	107	48	35.58	37.74	82	McFaddin	11/11/2005
Virginia Rail	Virginia Rail	-109.46	-28.83	8.87	-17.93	Unknown	99	40	31.85	33.95	80	McFaddin	11/11/2005
Virginia Rail	Virginia Rail	-101.68	-26.58	10.53	-15.24	Unknown	106	48	34.72	38.61	79	McFaddin	11/11/2005
Virginia Rail	Virginia Rail	-92.90	-26.70	7.31	0.30	Unknown	96	41	32.67	33.52	66	McFaddin	11/11/2005
Virginia Rail	Virginia Rail	-105.71	-26.28	8.39	2.72	Unknown	98	48	32.54	35.74	65	McFaddin	11/11/2005

(table cont.)

Virginia Rail	Virginia Rail	-76.58	-25.77	7.91	-3.01	Unknown	100	40	33.35	35.6	97	Grand Cote	11/22/2005
Virginia Rail	Virginia Rail	-128.41	-29.27	7.80	-10.89	Unknown	98	40	32.4	36.01	86	Grand Cote	11/22/2005
Virginia Rail	Virginia Rail	-122.71	-25.78	7.74	-5.69	Unknown	95	40	33.8	37.45	96	Sherburne	11/28/2005
Virginia Rail	Virginia Rail	-103.36	-28.45	7.51	4.05	Unknown	99	42	33.96	34.09	81	Sherburne	11/28/2005
Virginia Rail	Virginia Rail	-93.66	-26.01	8.83	-18.33	Unknown	101	43	34.44	37.31	86	Sherburne	11/28/2005
Virginia Rail	Virginia Rail	-134.27	-27.74	7.06	14.41	Unknown	109	45	37.85	39.92	109	Sherburne	11/28/2005
Virginia Rail	Virginia Rail	-86.86	-28.23	9.30	-14.49	Unknown	98	39	37.87	39	98	Sherburne	11/30/2005
Virginia Rail	Virginia Rail	-121.03	-27.96	8.15	-14.49	Unknown	106	40	32.12	31.85	71	Sherburne	11/30/2005
Virginia Rail	Virginia Rail	-60.56	-24.84	7.45	5.47	Unknown	100	44	36.02	41.09	90	McFaddin	12/2/2005
Virginia Rail	Virginia Rail	-73.17	-22.29	13.82	3.66	Unknown	113	50	36.64	41.51	96	McFaddin	12/2/2005
Virginia Rail	Virginia Rail	-99.45	-27.78	6.20	-5.91	Unknown	107	50	35.85	38.74	100	Anahuac	12/3/2005
Virginia Rail	Virginia Rail	-85.89	-25.73	8.29	0.41	Unknown	102	45	36.25	41.15	101	Anahuac	12/3/2005
Virginia Rail	Virginia Rail	-125.56	-27.74	9.50	-26.15	Unknown	95	40	33.46	35.44	69	Anahuac	12/3/2005
Virginia Rail	Virginia Rail	-70.37	-26.66	6.19	5.01	Unknown	101	42	35.27	40.37	100	Anahuac	12/3/2005
Virginia Rail	Virginia Rail	-83.47	-25.46	9.09	-16.56	Unknown	108	46	37.24	40.39	101	Anahuac	12/3/2005
Virginia Rail	Virginia Rail	-91.02	-25.35	7.64	1.94	Unknown	100	42	30.43	37.37	75	Marsh Island	12/29/2005
Virginia Rail	Virginia Rail	-116.57	-26.39	7.33	-0.91	Unknown	104	44	36.13	41.66	113	Marsh Island	12/29/2005

(table cont.)

Virginia Rail	Virginia Rail	-74.81	-29.46	6.34	6.37	Unknown	100	42	33.51	34.25	80	Marsh Island	12/29/2005
Virginia Rail	Virginia Rail	-60.66	-21.32	9.35	-22.88	Unknown	100	45	36.43	40.59	91	Marsh Island	12/29/2005
Virginia Rail	Virginia Rail	-119.44	-25.75	9.43	-29.21	Unknown	103	39	33.14	37.7	86	Sherburne	1/17/2006
Virginia Rail	Virginia Rail	-88.96	-25.93	10.39	-14.76	Unknown	108	44	36.93	38.78	108	Sherburne	1/17/2006
Virginia Rail	Virginia Rail	-113.83	-27.25	8.71	-11.21	Unknown	100	40	32.14	34.3	86	Rockefeller	2/8/2006
Virginia Rail	Virginia Rail	-94.52	-28.83	11.52	-17.00	Unknown	108	49	36.19	39.41	85	Rockefeller	2/8/2006
Virginia Rail	Virginia Rail	-78.06	-26.84	9.40	-12.69	Unknown	107	46	36.56	39.61	108	Rockefeller	2/8/2006
Virginia Rail	Virginia Rail	-84.04	-27.22	11.64	-17.98	Unknown	104	47	34.84	39.28	104	Rockefeller	2/8/2006
Virginia Rail	Virginia Rail	-93.17	-30.73	9.45	3.80	Unknown	101	43	37.51	40.06	97	Rockefeller	2/14/2006
Virginia Rail	Virginia Rail	-87.75	-24.40	13.72	-14.73	Unknown	100	46	32.19	35.1	76	Rockefeller	2/14/2006
Virginia Rail	Virginia Rail	-74.77	-25.35	12.87	-6.93	Unknown	94	42	35.41	36.06	77	McFaddin	2/15/2006
Virginia Rail	Virginia Rail	-93.96	-29.41	8.82	-12.02	Unknown	99	47	30.45	34.54	68	McFaddin	2/15/2006
Virginia Rail	Virginia Rail	-91.33	-27.14	9.94	-25.73	Unknown	109	44	39.07	41.09	120	McFaddin	2/15/2006
Virginia Rail	Virginia Rail	-92.15	-27.67	9.19	-17.69	Unknown	101	42	34.84	39.59	90	McFaddin	2/15/2006
Virginia Rail	Virginia Rail	-103.46	-27.38	7.70	4.68	Unknown	103	45	36.63	39.48	97	Rockefeller	3/1/2006
Virginia Rail	Virginia Rail	-103.56	-31.24	5.26	5.66	Unknown	99	41	.	.	80	Rockefeller	3/1/2006
Virginia Rail	Virginia Rail	-91.20	-26.42	12.31	-24.39	Unknown	106	45	.	.	98	Rockefeller	3/1/2006

(table cont.)

Virginia Rail	Virginia Rail	-93.59	-27.38	10.47	-10.33	Unknown	100	44	33.54	37.23	88	Anahuac	3/22/2006
Virginia Rail	Virginia Rail	-103.09	-27.72	13.13	-20.13	Unknown	108	45	36.89	39.32	118	McFaddin	3/23/2006
Virginia Rail	Virginia Rail	-98.67	-25.69	7.15	2.05	Unknown	99	44	35.57	39.46	90	McFaddin	3/23/2006
Virginia Rail**	Virginia Rail	-137.28	-28.04	7.65	-3.53	Female	.	.	.	.	.	Lydia, LA	10/26/2005
Yellow Rail	Yellow Rail	-157.15	-24.23	5.82	-12.99	Unknown	77	28	20.72	14.26	46	Private Rice	11/8/2004
Yellow Rail	Yellow Rail	-140.02	-22.13	5.08	2.23	Unknown	89	31	22.56	13.48	50	Anahuac	2/11/2005
Yellow Rail	Yellow Rail	-108.00	-20.33	9.59	2.41	Unknown	87	47	23.86	14.11	54	Anahuac	3/4/2005
Yellow Rail	Yellow Rail	-94.26	-22.69	6.48	3.92	Unknown	89	37	23.84	14.62	58	Anahuac	3/4/2005
Yellow Rail	Yellow Rail	-128.35	-24.28	5.53	51.77	Unknown	80	30	23.22	13.91	44	Cameron Prairie	3/28/2005
Yellow Rail	Yellow Rail	-159.79	-24.87	6.27	3.54	Unknown	89	35	24.22	14.54	58	Cameron Prairie	3/28/2005
Yellow Rail	Yellow Rail	-112.20	-25.90	4.87	40.81	Unknown	83	35	22.47	13.43	50	Grand Cote	10/18/2005
Yellow Rail	Yellow Rail	-149.91	-26.59	6.96	-0.44	Unknown	85	32	22.03	13.11	46	Sherburne	11/7/2005
Yellow Rail	Yellow Rail	-105.74	-24.10	7.83	4.24	Unknown	81	34	22	13.9	43	Sherburne	11/8/2005
Yellow Rail	Yellow Rail	-125.95	-23.37	5.47	-0.43	Unknown	86	38	24.26	14.8	52	Sherburne	11/8/2005
Yellow Rail	Yellow Rail	-148.49	-25.16	6.78	-17.49	Unknown	82	34	22.78	12.45	51	Grand Cote	11/10/2005
Yellow Rail	Yellow Rail	-115.58	-24.02	5.56	2.50	Unknown	83	34	22.52	14.01	46	Anahuac	11/12/2005
Yellow Rail	Yellow Rail	-130.82	-24.76	5.77	4.17	Unknown	80	34	22.08	12.46	43	Anahuac	11/12/2005

(table cont.)

Yellow Rail	Yellow Rail	-101.30	-24.41	6.61	-4.88	Unknown	81	30	23.87	13.97	48	Anahuac	11/12/2005
Yellow Rail	Yellow Rail	-141.49	-22.72	5.47	-10.97	Unknown	82	31	22.87	13.68	45	Anahuac	11/12/2005
Yellow Rail	Yellow Rail	-111.06	-25.62	6.53	6.31	Unknown	86	32	25.81	14.53	63	Anahuac	11/12/2005
Yellow Rail	Yellow Rail	-134.57	-25.38	4.63	36.52	Unknown	87	34	22.99	12.2	51	Anahuac	11/12/2005
Yellow Rail	Yellow Rail	-166.58	-23.25	7.20	4.84	Unknown	87	38	24.94	14.46	62	Sherburne	11/28/2005
Yellow Rail	Yellow Rail	-120.01	-23.56	7.43	5.59	Unknown	88	30	24.78	14.13	56	Sherburne	11/28/2005
Yellow Rail	Yellow Rail	-103.08	-24.81	5.28	3.74	Unknown	84	35	24.13	15.4	60	Sherburne	11/28/2005
Yellow Rail	Yellow Rail	-158.32	-24.03	6.11	20.75	Unknown	85	37	25.1	14.59	53	Sherburne	11/28/2005
Yellow Rail	Yellow Rail	-160.76	-24.41	5.18	6.93	Unknown	85	34	24.31	13.11	55	Sherburne	11/28/2005
Yellow Rail	Yellow Rail	-80.31	-22.73	3.12	5.96	Unknown	82	30	22.83	13.79	41	Sherburne	11/30/2005
Yellow Rail	Yellow Rail	-94.38	-23.06	7.63	-15.41	Unknown	88	32	24.19	14.39	52	Sherburne	11/30/2005
Yellow Rail	Yellow Rail	-171.60	-25.75	4.63	-12.69	Unknown	89	35	24.05	13.85	57	Anahuac	12/3/2005
Yellow Rail	Yellow Rail	-133.65	-23.58	4.31	2.42	Unknown	80	31	23.09	13.22	49	Anahuac	12/3/2005
Yellow Rail	Yellow Rail	-129.35	-23.58	6.53	18.26	Unknown	90	36	25.8	14.64	69	Anahuac	12/3/2005
Yellow Rail	Yellow Rail	-132.27	-24.76	5.16	18.18	Unknown	88	.	23.86	15.38	66	Anahuac	12/3/2005
Yellow Rail	Yellow Rail	-118.64	-25.02	5.92	10.11	Unknown	82	34	24.37	13.82	52	Anahuac	12/3/2005
Yellow Rail	Yellow Rail	-122.47	-23.14	7.09	6.24	Unknown	89	37	23.49	12.96	55	Sherburne	1/17/2006

(table cont.)

Yellow Rail	Yellow Rail	-94.37	-23.18	8.17	-18.46	Unknown	86	35	25.22	15.21	57	Anahuac	1/25/2006
Yellow Rail	Yellow Rail	-142.33	-27.96	9.94	-17.34	Unknown	90	33	26.23	14.87	49	Anahuac	1/25/2006
Yellow Rail	Yellow Rail	-163.54	-22.33	7.10	1.49	Unknown	82	34	22.27	13.99	32	Anahuac	1/26/2006
Yellow Rail	Yellow Rail	-141.64	-23.38	6.21	5.92	Unknown	84	36	21.47	14.8	53	Anahuac	1/26/2006
Yellow Rail	Yellow Rail	-117.45	-28.03	8.54	11.73	Unknown	91	34	26.03	14.1	50	Anahuac	1/26/2006
Yellow Rail	Yellow Rail	-162.47	-24.02	6.23	14.19	Unknown	83	34	23.19	13.35	46	Sweet Lk.	2/9/2006
Yellow Rail	Yellow Rail	-166.06	-22.71	5.52	-11.85	Unknown	79	32	23.47	13.81	40	Marsh Island	3/15/2006
Yellow Rail	Yellow Rail	-116.69	-25.60	7.37	19.90	Unknown	85	34	25.42	15.4	56	Marsh Island	3/15/2006

VITA

Marie Perkins was born in Pontiac, Michigan, and grew up in Clarkston, Michigan. She received her Bachelor of Science in biology with a minor in natural resources from Central Michigan University, Mt. Pleasant, Michigan. In the fall of 2000, she studied abroad at the University of Exeter in southwest England. While getting her undergraduate degree, she worked as an intern at Seney National Wildlife Refuge in the Upper Pennisula of Michigan in the summer of 2000. She also ran MAPS banding stations for the Institute for Bird Populations in Texas during the summer of 2001. After Marie graduated, she worked as an intern at Dow Gardens in Midland, Michigan, doing Japanese beetle research. She then worked as a USGS intern, studying avian malaria in Volcanoes National Park on the Big Island of Hawaii. Following this, she then worked as an intern at Big Oak National Wildlife Refuge in Madison, Indiana. She came to Louisiana in the winter of 2004 to work as a field technician studying the use of rice by breeding birds. She began her Master of Science degree in the fall of 2004 and will receive that degree in the spring of 2007.