

**The Breeding Ecology of Least Bitterns (*Ixobrychus exilis*) at Agassiz and Mingo
National Wildlife Refuges**

BY

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A thesis submitted in partial fulfillment of the requirements for the

Master of Science

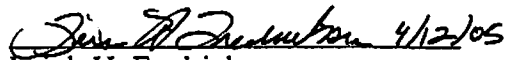
Major in Wildlife and Fisheries


South Dakota State University

2005

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National Wildlife Refuges**

This thesis is approved as a creditable and independent investigation by a candidate for the Master of Wildlife and Fisheries degree and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions reached by the major department.


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Acknowledgements

First and foremost, I owe an enormous amount of gratitude to my advisor, Dr. Leigh Fredrickson. I consider myself very fortunate to have been taken under his wing, and certainly would not be where I am today if not for his direction and encouragement. I also want to thank Dr. Jane Austin and Dr. Carter Johnson for their input and ideas. I am grateful to the staff at both Mingo and Agassiz National Wildlife Refuges for their graciousness in the use of bunkhouses, vehicles, airboats, canoes, kayaks, computers etc. In particular, I want to extend thanks to Maggie Anderson and Gary Huschle, for giving me enormous encouragement and guidance throughout this project. I am indebted to Dan Van Eps, Soch Lor, and Kari Odefey who gave up many a weekend and evening in order to search for least bitterns, pull me out of the mud, dog-sit, or whatever else I needed. A special thanks to Becky Carlson at Agassiz NWR, Karen Kyle at Gaylord Memorial Lab, and Terri Symens, Di Drake and Carol Jacobson at SDSU for their patience with my unending questions about funding, time sheets, and the list goes on. I thank my dedicated and hard working field assistants, Ashley Hitt, Jed Blum-Evitts, Stephanie Hanwell, Kate Lowe, Kristen DeJournett, and Hugo Gee for all the hours they willingly spent in waders, tromping through the marsh. I thank all my fellow graduate students, especially Matt Mangan, Adonia Henry, Belinda Ederington, Tandi Perkins, Kari Odefey and Soch Lor for letting me bounce ideas off of them throughout this process. And last, but certainly not least I want to thank my parents, Harry and Claudia Arnold for all the support, encouragement, and love they have provided me with over the years.

Abstract

**The Breeding Ecology of Least Bitterns (*Ixobrychus exilis*) at Mingo National
Wildlife Refuge and Agassiz National Wildlife Refuge**

Karen Elizabeth Arnold

May 2005

Habitat selection and reproductive effort of least bitterns (*Ixobrychus exilis*) were monitored in 2001 and 2002 at Mingo National Wildlife Refuge (Mingo) in southeast Missouri and 2001 through 2004 at Agassiz National Wildlife Refuge (Agassiz) in northwest Minnesota. The main objective was to study variation in the breeding ecology of least bitterns across a broad geographic area. Information gathered from nests included: nest success, egg and clutch measurements, hatchling developmental rates, and habitat measurements. Data suggest geographical variation in clutch size, relative growth patterns of hatchlings, and nest densities.

A total of 74 nests were found at Mingo and 120 nests at Agassiz. Nest success was lower during incubation compared to post hatching at both sites. Data supported a trend toward larger clutches at northern locations. Tarsus and wing development of hatchlings were similar between sites, while, overall mass and culmen development was a few days less at Mingo. Nest diameter and thickness did not differ between the two sites; however, there were differences between nest height and water depth. Giant cutgrass (*Zizianopsis miliacea*) was the only substrate used for nest building at Mingo while

Cattail (*Typha spp.*), sedge (*Carex spp.*), bulrush (*Scirpus spp.*) and common reed (*Phragmites spp.*) were all used as components for nest building at Agassiz. Birds utilized denser habitat at Agassiz. Nests in the smaller habitat patch at Mingo formed a colony while nests were more widely distributed in the larger marshes at Agassiz.

Habitat conditions were variable within and among years at Mingo and Agassiz. Nevertheless, least bitterns adapted to these variable conditions because they successfully nested annually. This adaptability was apparent when bitterns nested in short residual cattail lacking overhead cover after flooding at Agassiz in 2002.

Currently, there is inadequate monitoring of least bittern populations to establish the distribution and abundance in relation to habitat availability. Thus, implementation of standardized monitoring techniques would be valuable in understanding how this species utilizes marsh habitats throughout the breeding range. Standardized call response surveys lasting 5 minutes or more during the peak of nest initiation would be beneficial in gathering accurate distribution, abundance, and population trend data for the entire least bittern breeding range

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Introduction

The least bittern is the smallest and the most secretive heron in North America (Weller 1961, Gibbs et al. 1992b, Ziebell 1990, Bent 1926). Due to their inconspicuous behavior, cryptic coloring, and dense nesting habitat, the casual observer seldom sees these quiet marsh-nesting birds (Bent 1963). Because of their secretive nature, ecological studies of marsh birds such as the least bittern have not been allotted the attention given to species that are generally more visible. Unfortunately, reliable monitoring techniques are still lacking, and the least bittern is being overlooked in surveys of bird populations. Call response techniques have been recently applied to detect least bitterns, but these surveys have produced contradictory results (Manci and Rusch 1988, Gibbs and Melvin 1993, Lor 2000, Bogner 2001). Although quantitative population data are lacking, existing breeding bird surveys and incidental observations suggest the population may be declining. However, with little data available to assess population trends or serve as a baseline for future surveys, the status of the least bittern is uncertain. If the population is declining, habitat loss may be a major limiting factor. Historically, wetland species had many habitat options available to them to assure adequate recruitment to maintain long-term population stability. However, since pre-settlement times, 50% of wetlands in the lower 48 states have been drained or filled, and the hydrology and distribution of remaining wetlands have changed (Dahl 1990). For example, Minnesota and Missouri have lost 42% and 87% of their original wetlands respectively (Dahl 1990). Recovery of rare species in these disrupted environments is currently of critical importance to ensure their long-term survival.

Research on least bittern breeding biology has focused on nest habitat characteristics, reproductive success, and observations of nesting behaviors (Weller 1961, Frederick et al. 1990, Post 1998, Rodgers and Schwikert 1999). However, more information about the breeding biology and habitat requirements of this species is an urgent necessity in designing appropriate management plans. Previous literature illustrates that least bitterns build nests in robust emergent vegetation, yet only a handful of studies have quantified vegetation density at the nest site (Reid 1989, Lor 2000). In addition, only one study monitored hatchling growth rates (Nelson 2003) and only one study has investigated adult home range, movement patterns of adults during the breeding season and juvenile dispersal patterns (Bogner 2001). Information on many other life history aspects is lacking. Some examples include foraging, wintering habitat, migration, dispersal, re-nesting and double-brooding potential. In addition, past studies have focused on specific sites and no information is available comparing conditions across temporal and spatial scales during any of the life history stages. When information on species biology is limited and when a good understanding of variation in species ecology across habitats and geomorphic sites used throughout the annual cycle has not been achieved, the development of successful management strategies is compromised.

In this study I describe variation in habitat conditions between geographically different sites within the same season and within the same site among seasons. This information is important in order to clarify the response of least bitterns to changing nesting habitat conditions in different ecological settings. This type of information is urgently needed because in the recent past, the United States Fish and Wildlife Service

has listed the least bittern as a Species of Management Concern. This secretive species was recently removed from this list in 2003 (U.S. Fish and Wildlife Service 2003). However, the least bittern is considered a Resource Conservation Priority species within FWS Region 3 (U.S. Fish and Wildlife Service 2002). In addition, the least bittern has been identified as a species of concern in the Northern Prairie and Parkland Waterbird Conservation Plan (Prairie Pothole Joint Venture 2004) and the Upper Mississippi Valley/Great Lakes Waterbird Conservation Plan, which is currently under development (Steve Lewis, USFWS Office of Migratory Birds, personal communication). Furthermore, least bitterns have a status of endangered or threatened in many states throughout their range (Gibbs and Melvin 1992a).

Least Bittern Ecology

The Least Bittern

Least bitterns (*Ixobrychus exilis*), the smallest members of the heron family *Ardeidae*, typically range in length from 28 cm to 36 cm and weigh approximately 80 - 100 g (Gibbs et al. 1992b, Bogner 2001, Nelson 2003). The adult wing chord averages 11-13 cm. Males and females are similar in size but can be distinguished by subtle variation in markings. Females have a rich brown or chestnut colored crown and back while those of the male are black. Males have a white neck and under parts with subtle or no streaking while females tend to have darker streaking on the neck (Palmer 1962, Gibbs et al. 1992b). Juveniles also tend to have chestnut colored crown and back and heavier streaking on the neck (Gibbs et al. 1992b).

Distribution

Relatively little information is available concerning the historical distribution of the least bittern. The earliest fossil records were found in California (Wetmore 1956, Brodkorb 1963, Gibbs et al. 1992b) and Missouri (Parmalee and Oesch 1972, Gibbs et al. 1992b) and date back to the late Pleistocene. Fossil records also have been found in Florida from the late Pliocene (Emslie 1992, Gibbs et al. 1992b). No fossil records have been recorded outside the present range of this species.

The current least bittern breeding range extends from the Gulf Coast of Mexico to Canada. Most populations are concentrated in the eastern United States (Figure 1).

Populations are not found at higher elevations, such as the Appalachian highlands or the western mountains (Gibbs et al. 1992b). Western populations tend to be concentrated in low-lying areas as well (Gibbs et al. 1992b).

Least bitterns winter south of areas with prolonged winter frost. They have been reported in the southeast United States from the Atlantic coast to Panama (Gibbs et al. 1992b).

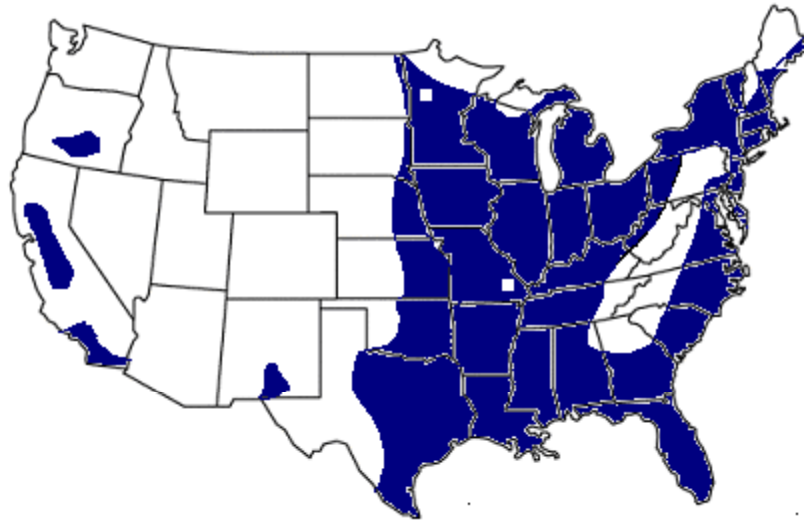


Figure 1. Current U.S. breeding range of the least bittern including study sites

Nesting Habitat

Least bitterns nest in freshwater or brackish marshes with relatively deep water interspersed with dense, tall growths of emergent vegetation (Weller 1961, Gibbs et al. 1992b). Cattail, (*Typha* spp.), sedge (*Carex* spp.), bulrush (*Scirpus* spp.), giant cutgrass (*Zizianopsis miliacea*), and common reed (*Phragmites* sp.), are major components of

preferred nesting habitat (Table 1). Occasionally nests have been found within clumps of woody vegetation such as willow (*Salix* spp.) and buttonbush (*Cephalanthus occidentalis*) interspersed with open water (Gibbs et al. 1992b, Rodgers and Schwikert 1999). Water depths exceeding 30 cm seem to be preferred (Weller 1961, Gibbs et al. 1992b, Rodgers and Schwikert 1999, Lor 2000, Nelson 2003). Nesting platforms are built over water, suspended by weaving vegetation into the surrounding stalks to form a base, then placing pieces of dead plant material in a spoke-like manner to form a platform over the base. A loose canopy, constructed by bending live vegetation over the nest, is often constructed above nests for further concealment. Nests are presumed to be constructed primarily by the male (Weller 1961, Gibbs et al. 1992b).

The vertical height, structure, and robustness of vegetation are all thought to be important characteristics in nest site selection of least bitterns (Weller and Spatcher 1965). Distance to open water and cover/water interspersions may also be important factors in nest location (Weller and Spatcher 1965, Gibbs et al. 1992b). In their assessment of marsh bird populations in midwestern glacial marshes, Weller and Spatcher (1965) found maximum least bittern density and diversity when the cover-water ratio was 50:50. Least bitterns have been classified as a “water’s edge” species, associated with the deeper, more permanent waters at the edge of vegetation (Weller and Spatcher 1965, Frederick et al. 1990, Bogner and Baldassarre 2002).

Table 1. Reported nest characteristics of least bitterns

<i>Location</i>	<i>Nest height (cm)</i>	<i>Nest diameter (cm)</i>	<i>Vegetation used for nest</i>	<i>Vegetation height (cm)</i>	<i>Water Depth (cm)</i>	<i>Source, Year</i>	<i>n</i>
Florida	46.8		bulrush, cattail, maidencane, button-bush, arrowhead		107.2	Rodgers and Schwikert 1999	207
Iowa	15 – 60	12 – 20 (range)	cattail, bulrush, phragmites	-----	8 - 97	Weller 1961	89
Missouri	38.7	14.2	giant cutgrass	145.2		Fredrickson 1996	87
Missouri	28.05	14.99	cattail, bulrush,	158.19	60.99	Nelson 2003	132
New York	60.3	20.2 x 22.1	cattail	132.9	42.4	Lor 1999	
Wisconsin	53.6	16.6	cattail, bulrush	-----	---	Ziebell 1990	37

Marsh size and isolation have been listed as important factors determining bird species richness in wetlands (Brown and Dinsmore 1986, Gibbs et al. 1992b). Brown and Dinsmore (1986) classified the least bittern as a “possibly area dependent species” when 92% of birds observed in their study occurred in marshes greater than or equal to 5 ha. Resource availability cannot be overlooked as a factor in nest site selection, as the least bittern is often associated with nutrient-rich microhabitat (Kushlan 1973, Frederick et al. 1990).

Breeding phenology

The breeding season starts when birds arrive on the breeding grounds from early March in the more southern parts of the range to late May in the northern areas (Bent 1963). Pair formation presumably occurs from late April to early May and may extend into early June. Clutch initiation begins in late May and extends into late June, peaking in early June (Gibbs et al. 1992b). Second broods may occur from late June to early July (Weller 1961). Least bitterns lay between 4-7 pale blue or pale green, non-glossy eggs. Typically, 1 egg is laid per day. Incubation begins with the first or second egg and lasts for approximately 17-20 days. Both sexes are known to incubate, though no information exists in regard to how the attentive period is divided between the two sexes.

Least bitterns are semi-precocial and hatch asynchronously over a 3-4 day period (Weller 1961). Young are either fed regurgitant by gripping the bill of the adult, or grab food that is dropped into the nest (Gibbs et al. 1992b). For the first 2 to 3 days post hatch, young hold their head up briefly and then lay down and appear to sleep. After the third or fourth day, many young begin to assume defensive postures that resemble those used by adults. Young have been observed in the “freeze” posture, which is commonly used as a camouflaging behavior in which the head is pointed vertically with eyes forward, and the body waves back and forth to imitate marsh vegetation blowing in the wind (Weller 1961, and personal observation.). Many bitterns are seen in an aggressive posture with their neck down and wings held wide while the bird is ready to peck repeatedly at any object placed before them. Young begin to leave the nest between 5 and 10 days of age but can often be seen in the vicinity of the nest and probably return to

the nest site to be fed. Hatchlings grow rapidly and are quite mobile within 4 to 5 days post-hatching (Post 1998). By the fifth day after hatch, most young have very well developed leg musculature and coordination that enables them to easily grasp and balance on vegetation. They are excellent climbers and use their feet and bill to grasp and pull themselves upward or through the vegetation. Their mobility aids in avoiding predation because when the young are disturbed they hide in the dense vegetation surrounding nest sites. Young fitted with radio transmitters were located an average of 13.4 m from their nest between 12 and 23 days of age and 29.4 m between 24 and 27 days of age (Bogner 2001). Age of first flight was approximately 29 days (Bogner 2001).

Foraging Strategies

Least bitterns forage from the water's surface along the edge of tall, dense stands of emergent vegetation within deep, open water (Weller 1961). Short, outer toes and long, curved claws aid in clinging to the vegetation along the water's edge. Platform building by bending over vegetation above the water is another method utilized by least bitterns throughout the late stages of incubation through brood-rearing that allows adults and young to forage over deeper water (Reid 1989). Least bitterns use 4 of the 38 techniques described by Kushlan (1978), "standing in place watching for prey", "walking slowly", "neck swaying" (possibly used to help reduce glare, to increase camouflage, or to have muscles in movement when strike begins) and, "wing-flicking", which is thought to startle prey from hiding.

Nesting adults are suspected to forage primarily in the area surrounding their nest, and as a result, may have small home ranges during the nesting season. The mean home range size of nesting adult least bitterns in western New York was 9.7 ha (Bogner and Baldassarre 2002).

Diet

Major food items include small fish, snakes, frogs, tadpoles, salamanders, leeches, slugs, crayfish, insects (mainly Odonata, and Orthoptera), small mammals, and vegetable matter (Gibbs et al. 1992b).

Predators and other factors affecting nest success

Many factors affect the survival rates of adult least bitterns as well as their reproductive success. Predators such as red-tailed hawks (*Buteo jamaicensis*), northern harriers (*Circus cyaneus*), and snapping turtles (*Chelydra serpentina*) prey on adult least bitterns (Weller 1961, Gibbs et al. 1992b). Crows, raccoons, mink and snakes prey upon eggs and young (Weller 1961, Fredrickson 1996). Marsh wrens have been suspected of piercing small holes in eggs, possibly contributing to rates of nest abandonment (Bent 1963, Gibbs et al. 1992b, Lor 2000).

Weather-related conditions such as extreme temperatures, rapidly changing water levels, and strong winds also influence reproductive success of least bitterns (Nero 1950, Paine 1997, Nelson 2003). Nests can be inundated by rising water, causing destruction of

eggs and drowning of hatchlings not yet capable of leaving the nest. In contrast, when water levels recede and leave a nest on dry ground, hatchlings and adults cannot forage near the nest, and they are more susceptible to terrestrial predators. Least bittern nests have a tendency to be weak structures, easily tipped over by strong winds, resulting in the loss of eggs and hatchlings because they fall into the water.

Study Areas

Mingo National Wildlife Refuge (Mingo) and Agassiz National Wildlife Refuge (Agassiz) are part of the National Wildlife Refuge System managed by the United States Fish and Wildlife Service. They represent 2 areas within the least bittern breeding range (Figure 1) that have ecological characteristics that differ (Table 2). Thus, the study provides an opportunity to compare least bittern response to habitat conditions over a large distance.

Table 2. Variations in study sites.

	<i>Location (latitude)</i>	<i>Study plot size</i>	<i>Plant community</i>	<i>Growing season</i>	<i>Hours Daylight (Summer Solstice)</i>
Mingo NWR	South-central (36° N)	< 25 ha	Giant cutgrass (<i>Zizianopsis miliacea</i>)	Long (195 days)	14.82
Agassiz NWR	Northern (48° N)	> 5,000 ha	Cattail (<i>Typha spp</i>) Sedge (<i>Carex spp.</i>) Bulrush (<i>Scirpus spp.</i>) <i>Phragmites</i>	Short (120 days)	16.06

The temperatures and precipitation differ between the two study sites (Figures 2 and 3). Temperature differences between the two sites during the breeding season (May-August) average 6.3° C (Midwestern Regional Climate Center 2005). Average annual precipitation at Mingo (128.9 cm) is more than double the average annual precipitation at Agassiz (55.52 cm). At Mingo, peak precipitation tends to occur in spring (March-May) while at Agassiz, the peak occurs later (May-August). Precipitation tends to be higher at Mingo during the breeding season.

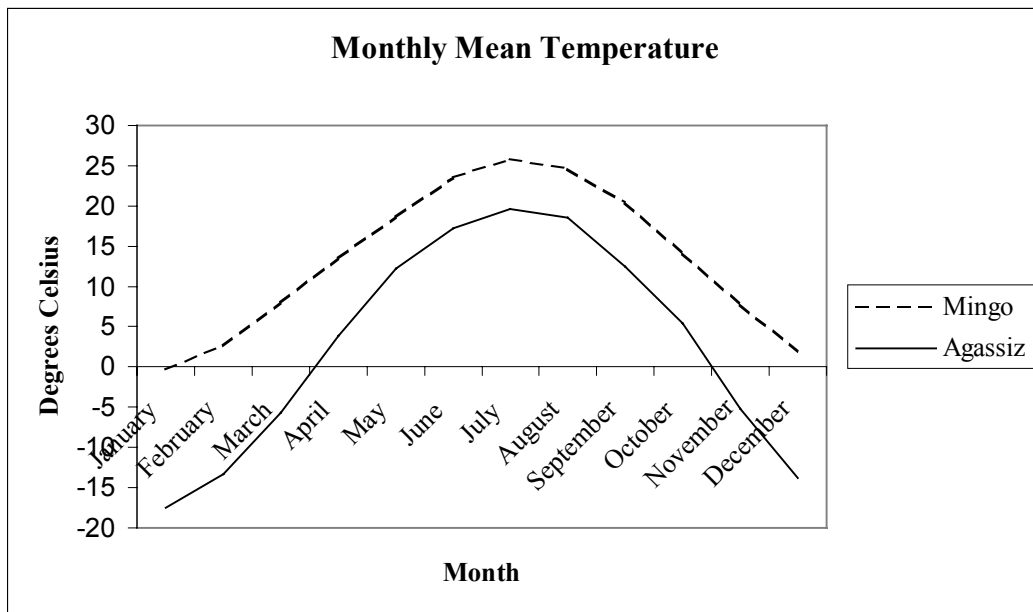


Figure 2. Ten year monthly mean temperature at Mingo NWR and Agassiz NWR

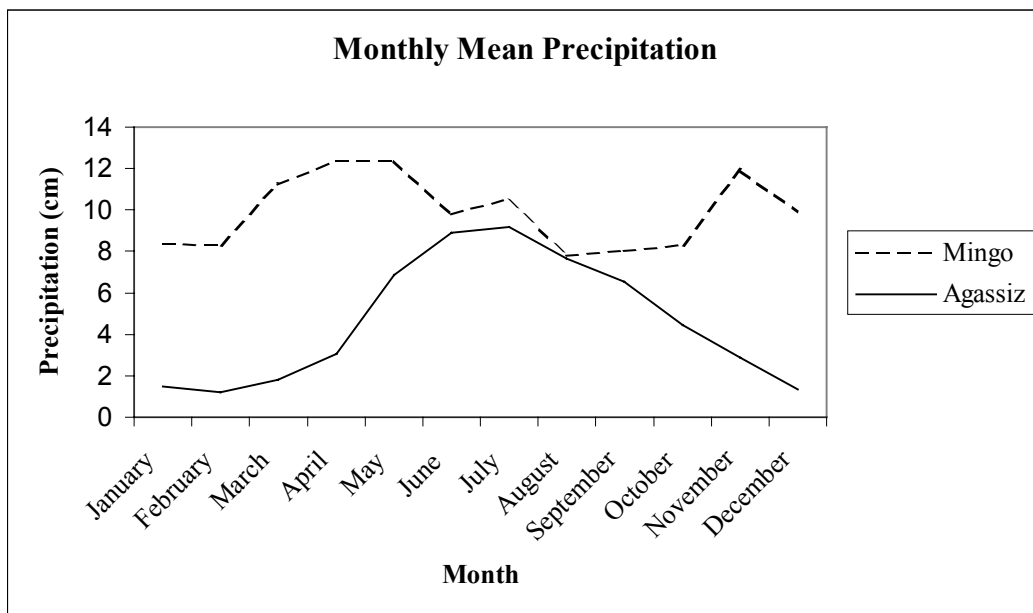


Figure 3. Ten year monthly mean precipitation at Mingo NWR and Agassiz NWR

Mingo National Wildlife Refuge

Mingo is located in southeastern Missouri and is representative of a southern deepwater swamp, with standing water present throughout most or all of the year. The Refuge is located within the Advance Lowlands, which is an abandoned floodplain of the Mississippi River (Leigh Fredrickson, personal communication). This floodplain was abandoned by the Mississippi River about 18,000 years ago. The formation of alluvial fans on the floodplain between the uplifts along Crowley's Ridge and the Ozark Escarpment created a basin with poor drainage, which is known as Mingo Swamp. Mingo is a 9032 ha refuge which consists mainly of bottomland hardwood forests and emergent marsh. One of the two large emergent marshes on the Refuge is Monopoly Marsh, a 1200 ha wetland surrounded by lowland and upland forest. Within Monopoly Marsh, bald cypress (*Taxodium distichum*) trees are interspersed with scattered buttonbush (*Cephalanthus occidentalis*) along the marsh edge. Major aquatic vegetation includes floating leaf species such as American lotus (*Nelumbo lutea*), white waterlily (*Nymphaea tuberosa*), watershield (*Brasenia schreberi*), and emergent water smartweed (*Polygonum coccineum*).

Mingo provides migration and wintering habitat for a number of waterbirds, but nesting is primarily restricted to cavity or forest nesting waterbirds such as wood ducks (*Aix sponsa*), hooded merganser (*Mergus cucullatus*), and various waders. A small number of least bitterns have nested consistently on Mingo since the late 1960's (L. Fredrickson personal communication). During that time, a few stick nests were built in scrub/shrub wetlands dominated by buttonbush. In the late 1970's giant cutgrass became

established in Monopoly Marsh and expanded into a patch approximately 5 ha in size by 1995. In recent years this patch of giant cutgrass has formed a floating mat within Monopoly Marsh and continues to expand in size each year. This original patch (designated as Patch A) has currently expanded into an area encompassing 9.3 ha. Another patch developed on the northeastern edge of the marsh and expanded greatly during 2001-2002. The main part of this patch now encompasses 10.7 ha (designated as Patch B) with two additional smaller areas totaling 0.6 ha. The robust structure of the cutgrass provides ideal nesting habitat for least bitterns and other marsh nesting birds such as American coots, (*Fulica Americana*), common moorhens (*Gallinula chloropus*), and red-winged blackbirds (*Agelaius phoeniceus*).

Nesting effort and nest success of least bitterns has been monitored at Mingo since 1995. Predation, environmental conditions, and weather patterns have influenced nest success each year, and nest success has been highly variable. Predation by mink (*Mustela vison*) was extremely high in 1995 and 1996. An abandoned beaver lodge located near the center of the cutgrass patch provided secure cover for a family of mink, allowing them to exploit least bittern nests within the cutgrass patch. Probability for nest success in 1995 was 3.2%. Nesting effort during 1996 was lower than in 1995 due to cool spring temperatures in combination with high water levels and the restricted re-growth of the cutgrass (L. Fredrickson personal communication). Nonetheless, the probability of a nest surviving from initiation to fledging increased to 17.4%. In 1997, the beaver lodge was removed in order to reduce mink predation. In addition, the structure of the cutgrass was more robust because of lower water levels. Consequently,

probability of survival increased to 63.9% that year. Sites where mink could survive and produce young were removed from the cutgrass patch in 1998 and 1999 as well.

However, nest survival from incubation to fledging was only 23.8% in 1998 and 6.5% during 1999. Predation and weather related events such as thunderstorms were presumed to be the primary causes of nest failure in 1998 and 1999.

Agassiz National Wildlife Refuge

Agassiz is located in Marshall County, northwestern Minnesota, in the aspen/parkland transitional zone between the coniferous forest, and the prairie pothole region of the United States. The Refuge was established in 1937 with the primary objective of providing habitat for migratory birds. The area was formed by the Wisconsin glacier, which created Glacial Lake Agassiz over 10,000 years ago, resulting in a very flat terrain varying only 30 to 60 cm in elevation per km. Wetlands on Agassiz are large freshwater systems with a semi-permanent water regime. In contrast to Mingo, Agassiz has large, emergent herbaceous marsh systems, which provide extensive habitat for breeding marsh birds.

After refuge establishment, wetland habitats were re-established through a system of dikes and water control structures. Twenty pools were developed ranging from 42 to 4200 ha in size. Cattail is the dominant emergent plant in the wetlands. Bulrush, reed canary grass, spike rush and sedges (*Carex* spp.) represent other common emergent vegetation. The dominant submergent vegetation includes water milfoil (*Myriophyllum* spp.), muskgrass (*Chara* spp.), sago pondweed (*Potamogeton pectinatus*), bladderwort

(*Utricularia* spp.), and coontail (*Ceratophyllum demersum*). Duckweeds (*Lemna* spp.) are common free-floating aquatic plants.

Least bittern ecology at Agassiz is not well known compared to Mingo.

Monitoring of nesting least bitterns began in 2001 and continued until 2004. Prior to this study, least bittern numbers and distribution among habitats were poorly documented.

Methods

Nest Site Characteristics

I recorded nest site characteristics including dominant vegetation species, average vegetation height (cm), and water depths (cm) at Mingo in 2001 and 2002, and at Agassiz during 2001-2004. I used a digital photo frame (measuring 1 m [height] x 0.65 m [width] x 0.31 m [depth]) to determine vegetation density (Griffith and Youtie 1988). A black backdrop served as a neutral setting to measure the vegetation coverage of 1 m³. The open face of the frame allowed the vegetation to maintain a natural upright position. Within 1 m of the frame, vegetation was held down or out of the way of the camera (Smith et al. 2000). In order to minimize disturbance to the nesting habitat, I selected the most open route to the nest. I used an Olympus C-3020 digital camera for a digital image of the vegetation within the frame. The camera resolution and quality was set at SQ1, 1600 x 1200, normal. I then cropped and enhanced the image to calibrate the number of pixels represented by the vegetation within the 1 m³. The living plant material was shaded a single green color. The dead plant material was altered to a single red color. The backdrop contained black pixels (Smith et al. 2000). This technique produced a quantitative measure of the proportion or density of vegetation at the nest site within a given area of the frame by counting the proportion of green, red, and black pixels.

This methodology captured a digital obstruction value, the type and height of the vegetation, and the water depth. These measurements were taken in the four cardinal directions at distances of 2, 4, 6, or 8 m from each nest. For every nest found, I selected a

random non-nest plot, and recorded the same measurements as at nest sites. The measurements between the nest sites and the random sites were compared. I recorded GPS coordinates for each nest. I then used this information to determine the placement of each nest within the contiguous habitat patch and to examine nearest neighbor differences.

Vegetation densities were compared between sites and among years and between successful and unsuccessful nests using a t-test. Variances were assumed to be equal.

Nest Characteristics

Data collected at the nest included: nest diameter, nest thickness, height of nest above the water, and water depth at the nest. I kept additional records of nest material (dominant species, fresh vs. residual), and average vegetation height within 1 m of the nest. Nest characteristics were compared between sites and between successful and unsuccessful nests using a t-test. Variances were assumed to be equal.

Clutch and Growth Rate Characteristics

I conducted nest searches starting mid-to late May and continued until mid-to late August 2001 and 2002 at Mingo, and 2001-2004 at Agassiz. Both cutgrass patches at Mingo were searched on a continual basis from a kayak or by wading. Agassiz pools that were not in drawdown or were not burned were searched systematically by airboat and/or by wading. I marked nests using willow sticks or wooden posts that were labeled with

the nest number, number of eggs present, and nest status (nest building, egg laying, or incubating). The status of the nest at the time of discovery was used to determine nest initiation dates. If eggs were present, the relative temperature of each egg was noted (whether an egg was warm or cold). In addition, each egg was floated to estimate the stage of incubation (Hays and Lecroy 1971). The presence of adult least bitterns was recorded to determine whether the eggs were being incubated. The date of nest initiation is the day on which egg laying began. I estimated age of initiation for nests in which egg laying began before the nest was located. If the laying date of the last egg was known, the date of nest initiation was calculated by subtracting one day for each egg laid. Each egg was numbered with a permanent marker, measured (length and width to the nearest mm) with calipers and weighed with a 10 g Pesola scale. Eggs that remained viable throughout the entire incubation period were reweighed within a few days of hatching to determine changes in mass during incubation. Egg measurements were recorded at Mingo and Agassiz in 2001 and 2002. Egg characteristics and clutch sizes were compared between sites using a t-test. Variances were assumed to be equal.

Marking Young

After hatching, I marked the nails of the young with fingernail polish to identify individuals. Until they became too mobile, I measured the young every 2 to 3 days. To record mass (g), I used a 100 g Pesola scale. Culmen and tarsus measurements (to the nearest 0.01 cm) were obtained with calipers and wing length was measured with a

metric ruler. Hatchling measurements were taken in 2001 and 2002 at Mingo and Agassiz.

Nest and Fledging Success

I considered a nest successful if one or more eggs hatched. For nests that failed, I made an effort to determine the cause of failure as either predated or abandoned. This determination was based on the condition of eggs, nest, and surrounding vegetation. Predated nests were those that were tipped with either eggshells or remains of hatchlings in the nest bowl. Abandoned nests were still intact, but eggs were cold for several days.

I often located nests at Agassiz after the clutch was complete and incubation had begun. In contrast, it was much more likely to find the nests at Mingo at or near the time when the first egg was laid. Thus, because the area of good nesting habitat was small, Mingo nests were monitored more often throughout the entire breeding season. The method I used to determine nest success (Mayfield 1961, 1975) calculates a mortality rate by dividing the number of nests lost by the number of days that the nest or young were under observation. This factor combined with the fact that unsuccessful nests were less likely to be found, creates concern that nest success may be biased upward, especially at Agassiz. I calculated nest and fledging success rates separately for three time periods: incubation, the first week after hatching, and the second week after hatching. I calculated mortality rates by dividing the number of nests lost during each time period by the number of exposure days (number of days which the nest or young were under observation). These mortality rates were then used to calculate the probability of survival

during each period. Success rates for incubation were calculated based on an incubation period of 20 days. I calculated standard errors and 95% confidence intervals using methods developed by Johnson (1979).

Philopatry and Re-nesting

In addition to culmen, tarsus, and wing measurements, hatchlings were captured by hand and banded before they left the nest. Banding was dependent on a tarsus length of at least 2.3 cm to ensure the leg was of sufficient size to prevent band loss.

I also captured and banded adult least bitterns. All adult birds were captured with mist nets, hand held nets, or by hand. I placed mist nets around nests with incubating adults, and then the birds were flushed off the nest into the nets. Mist nets also were used in conjunction with a tape recorder broadcasting the male vocalization. Vocalizations were recorded from *Peterson's Field Guides, More Birding by Ear: Eastern/Central* (Nature Sounds Studio, Ithaca NY and the Borror Laboratory of Bioacoustics, The Ohio State University 1994). I made one-minute continuous loop tapes of a male calling with alternating periods of 10-15 seconds of silence. I then placed mist nets around patches of vegetation where males were heard calling and played the tapes to attract birds into the nets. When possible, incubating birds were captured on the nest with hand-held nets or picked from the nest by hand. Attempts were made to capture both members of a pair. Once captured, birds were sexed, weighed, and measurements were taken of the culmen, wing, and tarsus. Birds were banded with size 4 aluminum United States Geological

Survey Bands. All trapping and handling of birds followed American Ornithologists Union guidelines (American Ornithologists' Union 1988).

Nest Measurements

I used Arc View (ESRI 1998) and the Nearest Neighbor extension to determine distances between nests and calculate average distance between nearest neighbor and farthest neighbor.

Growth Curves

I averaged hatchling growth measurements for all individuals per year and site and used an estimated final weight (asymptote) to create growth curves (Ricklefs 1968). These curves were transformed into linear patterns using either a Logistic, Gompertz, or von Bertalanffy equation, depending on which equation gave the best fit.

Results

Habitat Conditions

Habitat conditions varied between the two sites and among years due to the effects of changing weather conditions and water management. At Mingo, the water levels within Monopoly Marsh have been maintained in a consistent pattern of gradually decreasing water level from May to August during most years since 1995 (Figure 4). The exception was 2000, when the marsh was drawn down in an effort to inhibit the growth of American lotus (*Nelumbo lutea*), which is intolerant to dry conditions. This draw down also stimulated new growth of giant cutgrass in 2001.

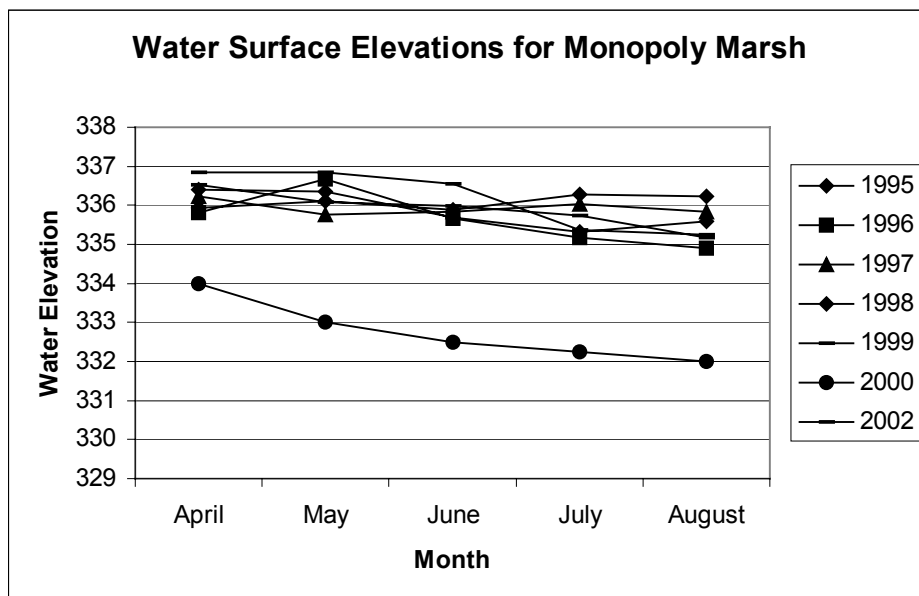


Figure 4. Average water surface elevations for Monopoly Marsh 1995-2002 (2001 data missing)

Conditions at Agassiz varied from year to year, however, the large amount of available habitat and the capability of maintaining a variety of hydrologic regimes between the many pools made it possible to continually provide suitable least bittern habitat within the Refuge, despite these variations. Weather had the most adverse influence on least bittern productivity in 2002. The initial phase of the breeding season was dry, however, on 9 and 10 June, 18.8 cm of precipitation fell in a 24-hour period. As a result, flooding occurred throughout the entire Refuge. Agassiz and Farmes pools were the only pools where least bittern activity had been observed by 9 June. Water levels in Agassiz pool rose 0.94 m, and Farmes pool increased 0.83 m as a result of the 18.8 cm of precipitation.

Vegetation Density

Vegetation density at nest sites and random non-nest sites as determined from digital images was quantified using digital image analysis presented in Table 3. Vegetation density at nests did not differ between Mingo 2002, and Agassiz 2003 ($P = 0.58$). However, there was a significant difference in vegetation density between years at Agassiz ($P < 0.05$), and Mingo 2002 and Agassiz 2002 ($P < 0.05$). Vegetation densities at random, non-nest sites were denser than nest sites at Mingo, and less dense than nest sites at Agassiz ($P < 0.05$). Vegetation density between successful and unsuccessful nests was not different at Agassiz ($P = 0.35$) or Mingo ($P = 0.72$).

Table 3. Vegetation densities at nests sites and random non-nest sites at Mingo NWR and Agassiz

	% fresh vegetation	SE	% residual vegetation	SE	% total vegetation	SE
Mingo nests 2002	9.0	0.010	1.05	0.001	10.2	0.013
Mingo random 2002	12.8	0.012	0.76	0.000	13.6	0.012
Agassiz nests 2002	7.1	0.007	11.1	0.006	17.4	0.015
Agassiz nests 2003	6.1	0.006	8.2	0.010	11.6	0.023
Agassiz random 2003	5.4	0.007	4.06	0.007	9.5	0.013

Nest substrate

All nests at Mingo in 2002 were constructed of giant cutgrass. Fresh giant cutgrass was the primary material used for all nests, but residual giant cutgrass was the second most common substrate (Table 4). Average height of the fresh material was 67.3 cm while average height of the dead material was only 4.94 cm.

The majority of Agassiz nests from all four years (86%) had cattail as the primary substrate. The use of cattail for nests at Agassiz was consistent with vegetation used in Iowa, Florida, and New York (Weller 1961, Ziebell 1990, Lor 2000, Bogner 2001). Phragmites (10%) and bulrush (4%) also were used as the main material for nests, but these species were always used to a lesser extent than cattail. Sedge was present as a secondary material in 3% of nests. Forty-eight percent of nests consisted of one type of vegetation, whereas 44% of the nests had two different materials, 8% had three different substrates, and less than 1% used four different materials.

Table 4. The frequency of specific materials used for nest building by least bitterns and average vegetation heights during the 2001-2004 field seasons at Agassiz NWR

	2001		2002		2003		2004	
	<i>N</i>	<i>Average height (cm)</i>	<i>N</i>	<i>Average height (cm)</i>	<i>N</i>	<i>Average height (cm)</i>	<i>N</i>	<i>Average height (cm)</i>
<i>Cattail (live)</i>	20	171.6	7	133.9	11	175.2	12	143.8
<i>Cattail (residual)</i>	4	142.8	20	58.2	12	84.2	12	92.7
<i>Bulrush (live)</i>	5	146.8	-	-	2	170.5	-	-
<i>Bulrush (residual)</i>	-	-	-	-	-	-	-	-
<i>Phragmites (live)</i>	-	-	2	182.0	6	212.6	1	107.0
<i>Phragmites (residual)</i>	1	263.0	3	82.6	3	170.0	1	200.0
<i>Sedge (live)</i>	3	75.5	-	-	-	-	1	56.0
<i>Sedge (residual)</i>	-	-	-	-	-	-	-	-

Breeding Phenology

Nest initiation dates, median hatch dates, and fledging dates were calculated for all sites/years (Figure 5). Nest initiation dates were calculated by backdating one day for each egg found in the nest if the clutch was not complete at the time of discovery. If the nest was found with a complete clutch, date of nest initiation was calculated by subtracting 20 days from the hatch date, plus 1 day for each egg in the clutch. Fledging dates were calculated by adding 29 days onto the hatch date of the last nest known to hatch.

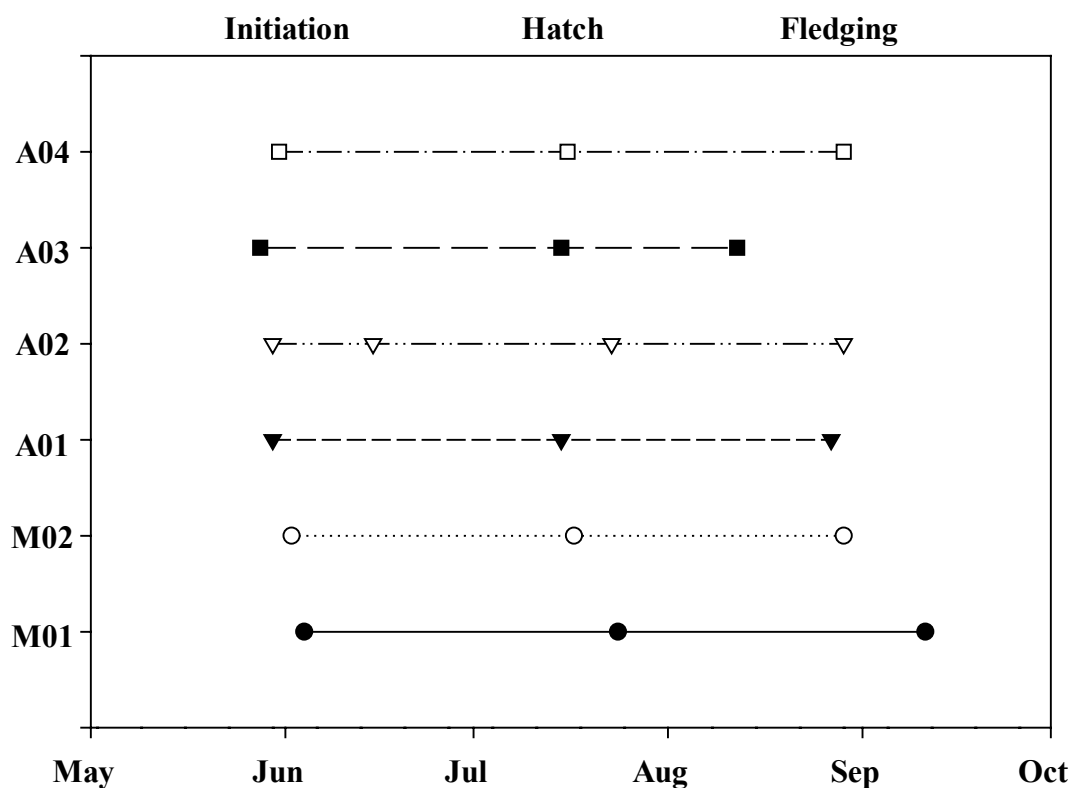


Figure 5. Nest initiation dates, median hatch dates, and nest termination dates for all active nests at Mingo NWR (2001-2002) and Agassiz NWR (2001-2004)

Nest initiation occurred between 28 May and 4 June at both sites within all years that nest searching took place.

In 2002, nesting was initiated on 30 May. None of the nests found at Agassiz before 9 June survived to hatch, because all nests were destroyed by flood conditions in Agassiz and Farmes pools. Eleven days later (21 June), 6 nests with complete clutches of 5 eggs were found that suggested new nests were initiated 5 days after the flood. Therefore, the onset of egg laying for successful nests was delayed by approximately 15 days. The flooding delayed the date of the first hatch by 17 days compared to 2001.

Unfortunately, no adults were banded in 2002, therefore it was not possible to determine with certainty whether re-nesting occurred or if birds were able to go from incubation to egg laying in 5 days.

Nesting Effort

At Mingo, 38 nests were found within the original cutgrass patch in 2001. Of the 38 nests, 27 survived until hatching, and 20 fledged young. Of the nests that failed, 11 were lost to predators, 1 was abandoned, and 6 were lost for unknown reasons. In 2002, 36 nests were found at Mingo. Of these nests, 27 were located in the original cutgrass patch (A), and 9 were located in the newly established patch (B). Twenty-eight of these nests survived until hatching and all produced fledglings. Of the 8 nests that failed, 5 were lost to predators, and 3 were lost because of inclement weather.

A total of 21 nests was found at Agassiz in 2001. Of these 21 nests, 17 hatched, and 13 fledged young. Of the 8 nests that failed, 4 were lost to predators, 2 were abandoned, and 2 were lost for undetermined reasons.

Fifty nests were found during the 2002 field season at Agassiz. Twenty-two of those nests were initiated before the flooding occurred, and 28 were initiated post-flooding. All nests initiated before the flood were lost. Three nests were abandoned, 1 was lost to a predator, and the other 18 were lost due to flooding. Active nests were checked immediately after the water levels increased and each of the 18 nests was completely submerged. Of the 28 nests initiated after the flood event, 10 survived to hatching. Of the 14 that failed, 10 were lost to predators, 2 were abandoned, and 2 were

lost to inclement weather. An additional 4 nests were not monitored long enough to determine the final outcome. Twenty-six nests were found at Agassiz in 2003. Of those nests, 12 survived until hatching, but all young in 4 nests were lost to predators after hatching. Twelve of the unsuccessful nests were lost to predators, 4 were lost for unknown reasons, and 2 nests had an unknown outcome. Twenty-three nests were found in 2004. Nineteen of those nests survived until hatching, but young in 2 nests were lost to predators after hatching. Three nests were lost to a predator prior to hatching, and one was lost to weather. Nest outcomes are summarized in Table 5.

Table 5. Nest success and sources of loss for least bitterns nesting at Mingo NWR, 2001-2002 and Agassiz NWR 2001-2004

<i>Nest outcome</i>	<i>Mingo</i>		<i>Agassiz</i>			
	2001	2002	2001	2002	2003	2004
Successful	20	28	13	10	8	17
Lost to Predator	11	5	4	11	12	5
Abandoned	1	0	2	5	0	0
Weather/Exposure	0	3	0	20	0	1
Lost-Unknown	6	0	2	0	4	0
Unknown Outcome	0	0	0	4	2	0
Total	38	36	21	50	26	23

Nest and Fledging Success

In all years, probability for survival was lowest during incubation, and the probability for survival increased as the season progressed (Tables 6 and 7). These lower survival rates for eggs could be attributed to the length of time eggs were exposed (approximately 20 days) as compared to the exposure period for young. In addition, the

rapid development of the hatchlings enabled them to be mobile soon after hatching which enhanced their ability to avoid predation.

Table 6. Daily survival and success for incubation, hatchlings 0-7 days old, and the entire nesting period at Mingo NWR for the nesting season of 2001 and 2002.

<i>Nesting period</i>	<i>Year</i>	<i>survival</i>	<i>SE</i>	<i>Success estimate</i>	<i>Lower 95% CI</i>	<i>Upper 95% CI</i>
<i>Incubation</i>	2001	0.984	0.006	72.0%	57.4%	90.5%
<i>Hatchling 0-7 days</i>	2001	0.971	0.013	81.0%	67.2%	97.5%
<i>Entire period</i>	2001	0.981	0.005	58.0%	43.5%	78.8%
<i>Incubation</i>	2002	0.983	0.007	72.0%	53.5%	93.8%
<i>Hatchling 0-7 days</i>	2002	0.990	0.007	93.0%	83.6%	100%
<i>Entire period</i>	2002	0.985	0.005	67.0%	50.3%	89.1%

Table 7. Daily survival and success for incubation, hatchlings 0-7 days old, and the entire nesting period at Agassiz NWR for the nesting season 2001-2004.

<i>Nesting period</i>	<i>Year</i>	<i>Daily survival</i>	<i>SE</i>	<i>Success estimate %</i>	<i>Lower 95% CI</i>	<i>Upper 95% CI</i>
<i>Incubation</i>	2001	0.975	0.012	60.0%	36.1%	99.4%
<i>Hatchling 0-7 days</i>	2001	0.971	0.017	81.0%	63.5%	100%
<i>Entire period</i>	2001	0.973	0.009	48.2%	27.5%	83.2%
<i>Incubation</i>	2002	0.973	0.011	57.8%	36.7%	90.0%
<i>Hatchling 0-7 days</i>	2002	0.961	0.019	75.0%	65.0%	86.0%
<i>Entire period</i>	2002	0.968	0.010	42.0%	24.2%	70.6%
<i>Incubation</i>	2003	0.961	0.019	45.0%	20.2%	98.0%
<i>Hatchling 0-7 days</i>	2003	0.964	0.035	77.0%	45.7%	100.0%
<i>Entire period</i>	2003	0.953	0.034	27.6%	10.3%	71.7%
<i>Incubation</i>	2004	0.986	0.010	75.3%	67.3%	100%
<i>Hatchling 0-7 days</i>	2004	0.983	0.016	89.0%	70.0%	100%
<i>Entire period</i>	2004	0.985	0.009	66.0%	44.4%	100%

In 2002, the timing of flooding at Agassiz resulted in loss of nests soon after they were initiated. Therefore, these nests were only observed for a very short period and resulted in a probability of 0.001 for pre-flood nest survival. Only post-flood nest probabilities are shown in Table 4 because exposure days were too few to calculate probabilities for the pre-flood nests.

Nest Distribution

At Mingo, the 35 nests located in 2001 were all within the 9.3 ha original cutgrass patch (patch A) on Monopoly Marsh. In 2002, 34 nests were located within 21 ha of giant cutgrass habitat. Twenty-seven of these nests were located within the original patch (A), and 9 nests were located within the newly established 10.7 ha cutgrass patch (B). Nearest neighbor distances at Mingo were slightly larger in 2002, perhaps because both patches were available to nesting least bitterns (Table 8).

Table 8. Spatial distribution of nests at Mingo NWR

	<i>2001</i>	<i>2002</i>	
	<i>Patch A</i>	<i>Patch A</i>	<i>Patch B</i>
<i>Average (m)</i>	44.7	63.5	60.1
<i>Range</i>	2.2-591.5	3.0-379.0	30.0-112.0
<i>SE</i>	16.8	19.9	12.6
<i>N</i>	35	25	9

The distribution of nests among the different pools at Agassiz varied among years (Table 9) because of water management regimes. The majority of nests (81 out of 120 nests) were found in Headquarters and Agassiz pools. In May 2001, Headquarters pool was being drawn down and therefore conditions for nesting were poor as the water receded from the cattail. In 2002, Headquarters and Madsen pools were two of the few pools with suitable water conditions for least bittern nesting whereas the other pools were being drawn down.

Table 9. The distribution of nests within different pools at Agassiz NWR 2001-2004.

	<i>Pool</i>					
	<i>Headquarters</i>	<i>Farmes</i>	<i>Agassiz</i>	<i>Kelly</i>	<i>Madsen</i>	<i>Parker</i>
<i>2001</i>	-	8	11	1	1	-
<i>2002 (pre-flood)</i>	-	14	8	-	-	-
<i>2002 (post-flood)</i>	14	-	2	-	12	-
<i>2003</i>	3	-	23	-	-	-
<i>2004</i>	15	-	5	-	-	3
<i>Total</i>	32	22	49	1	13	3

Nest distribution within individual pools varied among years (Table 10).

Sometimes nests were clumped within a patch of habitat within a pool, in other instances nests tended to be more dispersed or occurred as a solitary nest. In order to examine the spacing pattern of least bitterns by pool and habitat type, I used nearest neighbor distances within the groups by pool or habitat, but solitary nests were excluded from the analysis

Table 10. Spatial distribution of least bittern nests at Agassiz NWR

	<i>2001</i>	<i>2002 pre-flood</i>	<i>2002 post-flood</i>	<i>2003</i>	<i>2004</i>
<i>Average (m)</i>	214.9	104.3	158.9	111.9	210.8
<i>Range</i>	49.7-729.7	53.3-185.1	20.6-660.5	5.4-763.7	32.3-1091.3
<i>SE</i>	46.9	9.4	31.2	36.3	69.7
<i>n</i>	15	17	26	24	15

Nest metrics

Measurements of nest structure were only recorded at Mingo in 2002 whereas measurements at Agassiz are available from 2001-2004 (Figures 6 and 7). When nest structure characteristics were compared between the two sites, there were no differences between nest diameter ($P = 0.24$) and thickness ($P = 0.15$) (Figure 5). However; nest height and water depth were different between Mingo and Agassiz ($P < 0.05$) (Figure 6).

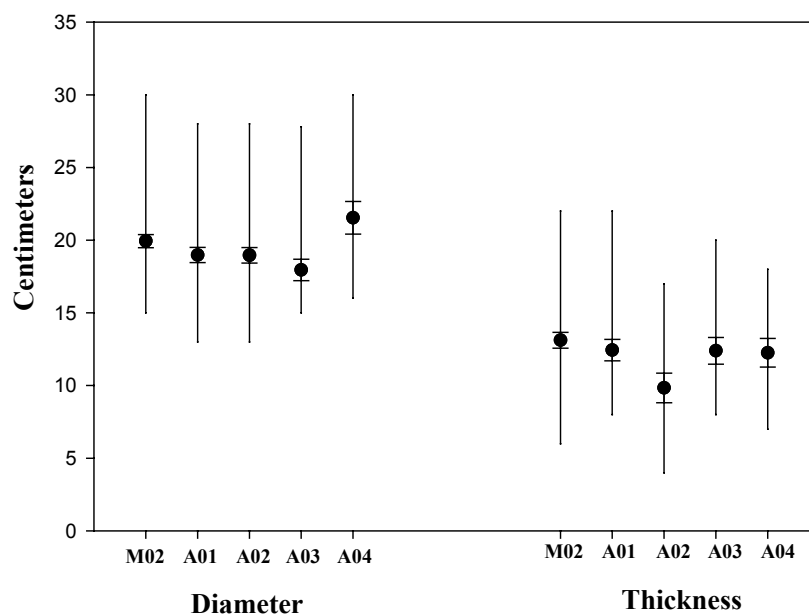


Figure 6. Comparison of diameter and thickness of least bittern nests at Mingo NWR (2002) and Agassiz NWR (2001-2004)

Nest characteristics from both sites were compared with nest fate to determine whether there were any correlations between nest structure and nest success. There were no differences between diameter ($P = 0.52$), thickness ($P = 0.13$), height ($P = .09$), or water depth ($P = 0.55$) of successful versus unsuccessful nests.

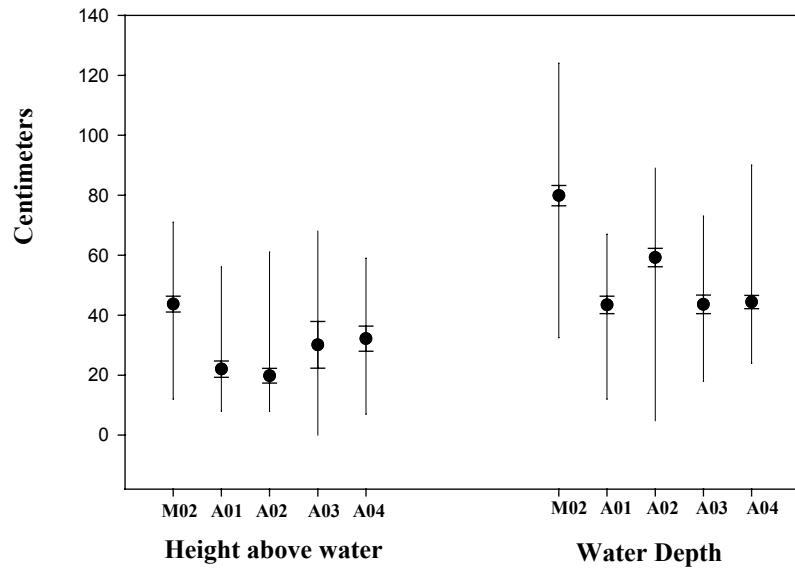


Figure 7. Comparison of averaged height above water and water depth of least bittern nests at Mingo NWR (2002) and Agassiz NWR (2001-2004)

Egg metrics

Egg measurements (length, width and mass) were recorded at Mingo in 2001-2002, and Agassiz in 2001-2003 (Table 11). There was no difference in egg length ($P = 0.37$) or width ($P = 0.06$) between the two sites.

Table 11. Least bittern egg characteristics from Mingo NWR and Agassiz NWR

Year/Site	Characteristic	Mean	Range	SE	N
Mingo 2001	Mass (g)	8.8	2-12	0.133	260
	Length (cm)	30.5	19.5-33.4	0.085	146
	Width (cm)	23.2	16.7-25.0	0.040	146
Mingo 2002	Mass (g)	8.9	1.50-12.5	0.111	1071*
	Length (cm)	30.5	19.1-33.7	0.079	158
	Width (cm)	23.6	15.8-25.8	0.068	158
Agassiz 2001	Mass (g)	10.0	6.5-12.0	0.114	140
	Length (cm)	31.2	29.0-33.4	0.075	80
	Width (cm)	23.8	22.3-25.8	0.114	80
Agassiz 2002	Mass (g)	9.6	23.0-33.0	0.091	140
	Length (cm)	30.6	22.2-25.6	0.048	147
	Width (cm)	23.8	7.0-12.0	0.094	147
Agassiz 2003	Mass (g)	10.0	8.0-12.0	0.266	66
	Length (cm)	30.7	20.0-35.4	0.162	67
	Width (cm)	23.9	21.6-31.1	0.117	67

* Eggs were weighed repeatedly

Egg mass varied depending on the stage of incubation when the egg was weighed. Eggs gradually lose mass during incubation due to water loss and growth of the air cell inside the egg (Westerkov 1950). Slight variation in mass was apparent when eggs from Mingo and Agassiz were separated into 2 groups based on the time of measurement (early-mid vs. late) during development (Table 12). Eggs measured within the first 10 days of incubation were considered early - mid incubation, while those measured between the tenth day of incubation and hatching were considered late incubation. The

masses of eggs weighed during early-mid incubation were different from the masses of eggs weighed during late incubation ($P < 0.05$).

Table 12. Comparison of early-mid vs. late incubation egg mass (g) of least bitterns in Missouri and Minnesota.

<i>Site and Year</i>	<i>Early-mid incubation</i>	<i>Range</i>	<i>SE</i>	<i>Late incubation</i>	<i>Range</i>	<i>SE</i>
<i>Mingo 2001</i>	9.2	7.0 - 12.0	0.12	8.1	7.0 - 10.0	0.09
<i>Mingo 2002</i>	9.5	4.5 - 12.5	0.05	8.7	1.5 - 11.5	0.05
<i>Agassiz 2001</i>	10.9	10.0 - 12.0	0.10	10.6	9.0 - 12.0	0.10
<i>Agassiz 2002</i>	9.5	7.0 - 11.5	0.10	8.6	7.0 - 9.5	0.10

Clutch size varied among locations and years (Table 13). Clutch sizes were significantly larger at Agassiz than at Mingo ($P < 0.05$). There was no difference between clutch sizes of successful vs. unsuccessful nests ($P = 0.49$).

Table 13. Least bittern clutch size variation at Mingo NWR and Agassiz NWR

	<i>Mingo NWR</i>		<i>Agassiz NWR</i>		
	<i>2001</i>	<i>2002</i>	<i>2001</i>	<i>2002</i>	<i>2003</i>
<i>Clutch size</i>	4.2	4.8	5.1	5.1	5.0
<i>Range</i>	3-5	3-6	3-6	3-7	4-6
<i>Standard error</i>	0.10	0.10	0.20	0.14	0.20
<i>N</i>	34	32	19	27	14

The number of hours of daylight on the day of clutch initiation accounted for 25% of the variation in clutch size when a linear regression was adjusted for phenology during the breeding season (Figure 8). It was interesting that only 3 out of 66 broods at Mingo

contained 6 eggs, and all 3 were located within the newly established patch (B) of cutgrass in 2002.

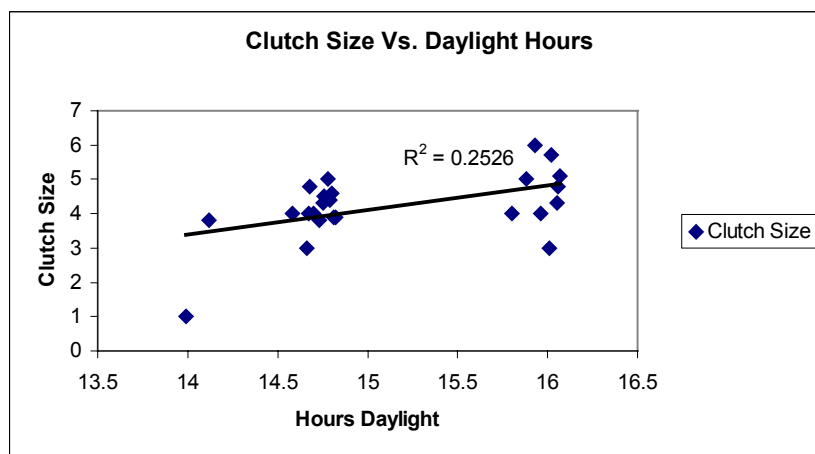


Figure 8. Linear regression demonstrating clutch size variation with day length

Hatchling Metrics

Least bitterns start incubation before the clutch is complete. Asynchronous hatching occurred over a period of 3 to 4 days at most nests, which was similar to previous reports (Weller 1961, Fredrickson 1996). Asynchronous hatching favors the survival of young from first hatched eggs compared to young from eggs hatched later. At Agassiz, some observations indicated that incubation was sometimes ended before the last egg in the nest hatched. In 2001, this was observed twice, and in 2002, four nests were observed with 1 un-hatched egg remaining after the rest of the clutch was hatched successfully. Starvation also may have mediated brood survival because the last one or two young that hatch in a nest frequently died.

I used Ricklefs's (1967, 1968) methods to determine the growth form of the variables. Gompertz and Logistic equations accounted for over 97% of the variation in the daily means (Figure 9). Asymptotes for the curves were determined by averaging adult measurements taken at the Minnesota and Missouri sites (Table 14). These equations were then used to estimate the number of days for a hatchling to develop between 10-90% of the size of an adult least bittern (Table 14). Least bittern development is rapid, and hatchlings are near full adult size within 28 days after hatching. These developmental rates were similar to those found in the literature. Similar time for development estimates occurred at Squaw Creek National Wildlife Refuge in northwest Missouri (Nelson 2003). A study in western New York showed the average age of first flight to be approximately 29 days (Bogner 2001).

Table 14. Growth of young least bitterns (2001-2002) at Mingo NWR and Agassiz NWR calculated according to Ricklefs's methods (1967).

Variable	Asymptote	Growth rate (rate/estimated days to adult size)	
		Agassiz	Mingo
Mass	90 g	0.27 / 16.3 days	0.33 / 13.4
Tarsus	4.49 cm	0.23 / 18.4 days	0.24 / 19.5 days
Wing	12.0 cm	0.22 / 19.8 days	0.22 / 19.78 days
Culmen	4.31 cm	0.04 / 27.4 days	0.05 / 24.0 days

Logistic equations explained the growth form of the tarsus, wing, and weight. The culmen developed the slowest, and was best represented by the Gompertz equation, demonstrating that there was a prolonged growth of the culmen later in development (Ricklefs 1967). Culmen development took 24.0 days at Mingo compared to 27.4 days at Agassiz (Figure 9). Tarsus and wing development were similar between the two refuges,

and both demonstrated rapid development. The rapid development of the tarsus may be related to the foraging techniques used by least bitterns that require well-developed leg muscles to enable young to escape predators or to forage before they can fly (Ricklefs 1968). Mingo hatchlings attained adult mass at around 13 days compared to 16.3 days at Agassiz. This response may be related to availability of food resources in southern environments where permanent water has a great variety of fishes. Variations in body mass of hatchlings also may be related to the amount of ingested food at the time of weighing. Some hatchlings regurgitated as many as three or four minnows during a visit to a nest, making comparison of weights problematic.

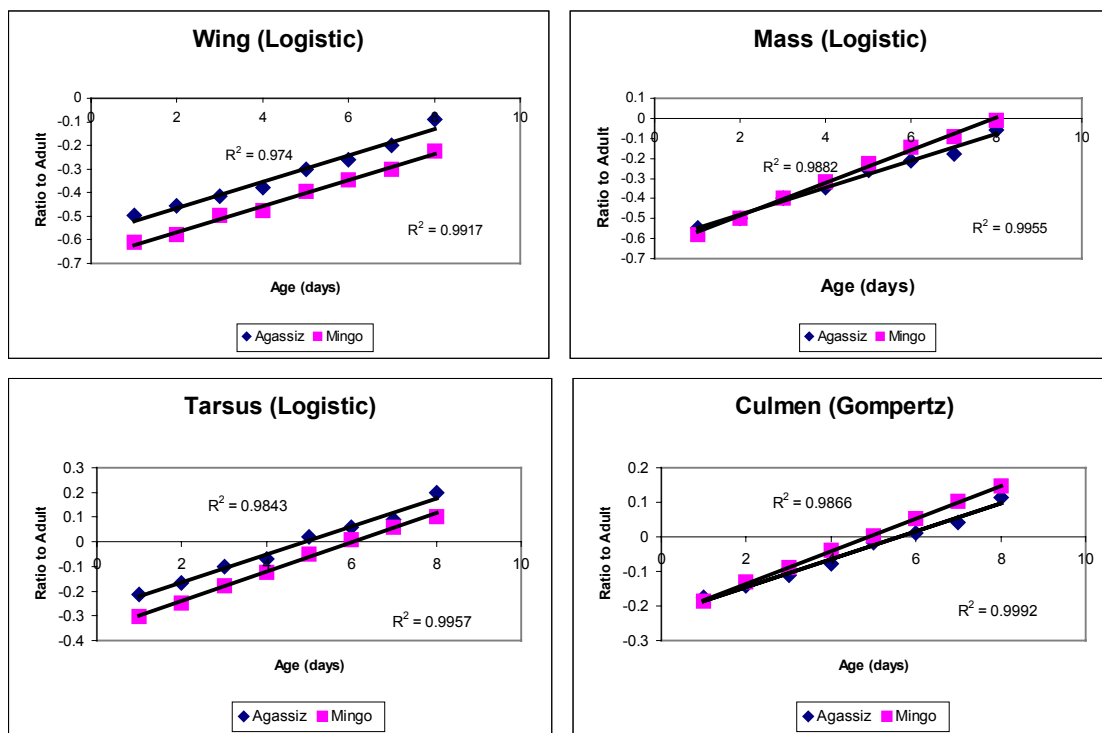


Figure 9. Growth comparisons of least bittern hatchlings at Mingo NWR and Agassiz NWR using Ricklefs's (1967) methods.

Adult metrics

During the 2001 season, 61 birds were banded at Mingo with USGS bands plus color leg bands. A total of 57 hatchlings were banded before they left the nest. Four adults were captured (3 females, 1 male). In 2002, 105 hatchlings were banded and 5 adults (2 females, 3 males).

Adult birds were captured and banded at Agassiz in 2003 and 2004. In 2003, 8 adult birds were captured and banded. In 2004, 14 adult birds were captured and banded. Hatchlings were not banded at Agassiz.

Adult measurements taken at both sites fell within the ranges reported in the literature (Tables 15 and 16) (Bogner 2001, Nelson 2003).

Table 15. Average adult measurements from Mingo NWR

	<i>2001</i>				<i>2002</i>			
	<i>Mean</i>	<i>S.E.</i>	<i>Range</i>	<i>N</i>	<i>Mean</i>	<i>S.E.</i>	<i>Range</i>	<i>N</i>
<i>Culmen</i>	44.4	0.44	43.9-45.3	3	41.8	2.8	27.8-46.5	6
<i>Tarsus</i>	39.7	0.55	38.8-40.7	3	41.0	1.1	37.3-44.1	6
<i>Wing</i>	11.9	0.26	11.5-12.4	3	12.0	0.27	11.3-12.8	5
<i>Mass</i>	86.3	5.4	71-96	4	89.0	3.5	76-97	5

Table 16. Average adult measurements from Agassiz NWR

	<i>2003</i>				<i>2004</i>			
	<i>Mean</i>	<i>S.E.</i>	<i>Range</i>	<i>N</i>	<i>Mean</i>	<i>S.E.</i>	<i>Range</i>	<i>N</i>
<i>Culmen</i>	43.14	1.82	31.4-48.8	8	45.22	0.37	42.6-47.5	14
<i>Tarsus</i>	44.7	1.29	36.11-48.32	8	47.64	0.31	45.4-49.5	13
<i>Wing</i>	13.1	9.79	11.1-19.9	8	11.95	0.12	11.18-13	13
<i>Mass</i>	-	-	-	-	93.49	2.78	76.9-108	13

Behavioral Observations

Throughout the past 4 years, I have had various opportunities to observe least bittern behavioral responses to the various methods employed in this study. One of the main concerns with continual visits to the nest was that adult birds would be more likely to abandon the nest. Throughout the course of my study, only 8 out of 194 nests were classified as abandoned. Out of these 8 nests, several were found with small punctures in the eggs, thought to be damage incurred by marsh wrens. As a result, I do not consider abandonment by the adults to be a common result of nest visitations by observers.

Hatchling disturbance as a result of repeated measures taken every 2 to 3 days at each nest was also a concern. Hatchlings that were measured from the time of hatch tended to flee the nest when disturbed at an earlier age than those that were not disturbed. Hatchlings that were repeatedly measured were likely to flee from the nest at about 5 to 6 days of age, and were quite difficult to capture after 8 to 9 days of age. I noted significant behavioral differences at nests that were discovered post-hatching. On several

occasions I came across a nest with hatchlings that appeared to be 8 or more days old and the entire brood would remain inside the nest bowl when I approached the nest.

I observed various responses when using broadcast tapes of a male least bittern calling in order to capture adults. For example, on numerous occasions when I played a vocalization, I observed both male and female least bitterns respond immediately by positioning themselves closer to the tape recorder that was broadcasting the call rather than responding vocally. Females were likely to be responding to a potential mate, while males were probably defending their nesting territory. Males did respond vocally on numerous occasions, however, the response time often took several minutes. It may have been possible that some of these birds were moving closer to the tape recorder before giving a vocal response.

Discussion

Vegetation Density

The vegetation density estimates at Agassiz suggest that least bitterns were selecting nesting habitat with a higher vegetation density than the Mingo least bittern population. A possible explanation for this is that the water levels at Mingo in Spring 2002 completely covered any residual cutgrass from the previous season. As a result, birds could not nest until fresh growth reached a height suitable for nest attachment. In contrast, birds at Agassiz used a higher percentage of residual vegetation during nest site selection in the spring because fresh vegetation was just beginning to grow. The majority of the fresh vegetation had probably not yet reached heights sufficient for nest attachment at this time.

The characteristics of the dominant vegetation at nest sites between the two sites were different. Cattail has a thick robust stem that often extends above the water, while giant cutgrass has a somewhat less robust stem. The upper portions of cattail and giant cutgrass leaves are easily moved by the wind, but they are more likely to bend and sway back and forth in the wind than they are to break.

Nest Substrate

The dominance of giant cutgrass as tall emergent vegetation at Mingo dictated that this vegetation was the dominant nesting material at this site. In contrast, nests at

Agassiz were widely dispersed across a range of plant types because of an abundance of suitable nesting habitat within different plant communities.

The height of the giant cutgrass on Monopoly Marsh in 2002 was shorter than the height of vegetation used in nest construction in the past (Fredrickson 1996). In 1996, average vegetation height for nests built early (May and June) in the nesting season was 134.8 cm while the average height of vegetation in which nests were built later (July and August) in the season was 162.8 (Fredrickson 1996). This difference in height is most likely associated with the growth form of the vegetation, as water levels recede growth continues late in the growing season.

Habitat conditions were variable within and among years at Agassiz. Nevertheless, least bitterns seemed adapted to exploit whatever habitat conditions were available because they nested annually. Because the least bittern nest is elevated above the water surface in emergent vegetation, the presence of tall robust plants seems essential. The dominance of cattail at Agassiz resulted in its wide use as a nest substrate in 2001. The species' adaptability was apparent because least bitterns nested in short residual cattail lacking overhead cover following the flooding in 2002. The least bittern's exceptional camouflage allows the exploitation of a variety of nesting substrates such as the residual cattail that was the dominant vegetation present after the flood in June. A similar response to limited robust emergent vegetation was noted on Squaw Creek National Wildlife Refuge in Northwest Missouri (Nelson 2003). In this case least bitterns nested in cattail with an average height of 158 cm.

Breeding Phenology

Twelve degrees of latitude did not affect breeding phenology. Egg laying began between 28 May and 4 June at both locations in all years. Whether the breeding phenology identified at Agassiz reflects the normal annual nesting chronology is unknown because the capability of searching the entire refuge thoroughly was compromised by my ability to determine nesting response because of refuge size. Because of the large area of robust emergent vegetation at Agassiz, nests found may not represent the earliest or latest nesting attempts and may only represent a small fraction of the total nesting effort. Therefore, the nest searching effort was likely insufficient to determine the chronology or the duration of the nesting effort. In addition, in 2003 and 2004, tracking marked birds was the main focus at Agassiz, therefore less time was committed to nest searching and following the success of nests and the survival and growth of hatchlings, which may have influenced dates within which nests were thought to be active.

Nest initiation at Mingo was later in 2001 and 2002 than in previous years (Fredrickson 1996). The timing of nest initiation at Mingo may have been delayed in 2001 because conditions in the cutgrass patch were less than ideal for nesting early in the spring. The cutgrass patch was sparse and contained significantly less residual and newly developing robust vegetation during spring 2001 than in previous years (L. Fredrickson, personal communication). This less suitable structural condition was at least in part related to a drawdown during the 2000 growing season. The residual cutgrass structure

was less robust thus suitable structure for nest placement did not occur until the newly developing cutgrass was of sufficient height and density to support nests in late May.

In 2002, water levels remained high in Monopoly Marsh at Mingo until late June. These conditions resulted in poor nesting habitat conditions similar to those in 2001 (Fredrickson 1996).

At Agassiz in 2002, birds began constructing nests and laying eggs at approximately the same time as in other years (30 May). The flooding that occurred in early June prevented significant new vegetation growth until early July. As a result, only residual vegetation was available as nesting habitat. The vegetation structural conditions for least bittern nesting were not ideal, and the nests were exposed. However, these water level conditions provided insights into least bittern response to flooding. If the nests found on 21 June at Agassiz represent re-nests, the females had a body condition sufficient to initiate laying immediately following the flood event. These observations suggest that birds may be maintaining the physiological and hormonal condition required for egg laying throughout the early portion of the nesting period. Thus females have the potential to nest successfully despite environmental conditions that may cause nest failures (e.g., wind storms).

The ultimate factor influencing the initiation of the least bittern-breeding season is still unknown. Daylight is an important factor that stimulates reproduction in birds (Hammond 1953). Furthermore, the day length influences vegetation response and determines the length of time daily when foraging is possible for a sight feeder. For example, breeding birds benefit from a longer day length because foraging hours/day are

maximized. Availability of food resources and nesting habitat are certainly important biotic factors associated with habitat conditions in emergent marshes (Weller and Spatcher 1965, Weller and Fredrickson, 1974). Age or experience of the nesting birds may also influence the timing of nest initiation. Older birds may be in better body condition or perhaps more experienced at selecting suitable habitat.

Consistency of nesting chronology among sites may be related to the fact that both sexes incubate. If only one bird incubated, inattentive periods would likely be longer and more frequent, thus more time would be required for incubation in the colder, more northern climate. Likewise when more time is required for foraging to maintain body mass this activity may compromise hatchling growth and result in prolonged brood rearing.

Nest Success

The influence of weather and predators between sites and among years on nest success was variable. Predation caused approximately 22% of nest failures at Mingo and 27% of nest failures at Agassiz. Loss to a predator was presumed if nests were structurally intact but the eggs or young were missing. At Mingo, snakes such as the Western Cottonmouth (*Agkistrodon piscivorous leucostoma*) and Yellowbellied water snake (*Nerodia erythrogaster flavigaster*) were observed frequently swimming in the cutgrass patch or basking on abandoned nests or beaver lodges in the vicinity of active nests.

Mammalian predators were observed at both sites. Mink (*Mustela vison*) and raccoons (*Procyon lotor*) were seen on the roads and dikes surrounding all pools. Occasionally, the entire brood was killed but left on or near the nest. In some instances tooth marks were visible as well. In these instances, mink was the suspected predator due to the fact that they often engage in killing more victims than they are able to consume. At Agassiz, some of the nests that were abandoned consisted of only one egg with a small puncture. In these cases, marsh wren predation was suspected.

The flood event at Agassiz in 2002 was an example of weather conditions having a direct influence on nest outcomes. Eighteen nests were lost when rapidly rising water levels, completely submerged all eggs and hatchlings. Later in the season, 2 nests were abandoned when water levels decreased rapidly. The flooding event demonstrated that least bitterns were incapable of building their nests up quickly enough to prevent inundation. Other species such as Franklin's Gulls (*Larus pipixcan*) and American Coots (*Fulica Americana*) that nested in the same pools during the flood collected additional nesting material and added these quickly enough to maintain their nests above the surface of the rising water. In 2002 and 2003, the probability of survival was lower for Agassiz hatchlings compared to 2001 and 2004. Lower survival probability may be attributed to several factors. First, any of the nests found after the flood in 2002 were likely to be second nest attempts for most pairs. Second, because of flooding in 2002, all new vegetation growth was greatly inhibited, resulting in birds building nests in very short, residual vegetation that provided less secure cover. Lack of newly developing vegetation may have resulted in limited food resources as well. The stems and leaves of submergent

and emergent vegetation provide materials for the detrital-based food web that eventually nourishes least bitterns (Fredrickson and Laubhan 1994). Observer influences may have affected nest success in 2002 and 2003 as well. A new method of vegetation sampling employed in those two years required the use of canoes to transport equipment to the nest site. Once at the nest site, pictures were taken from the 4 cardinal directions. These movements further disrupted the vegetation surrounding the nest. This method of assessing vegetation density was much more destructive to the vegetation surrounding the nest site than during the other years and may have contributed to decreased nest survival. Adult birds were captured and fitted with radio transmitters in 2003 and 2004. The activities associated with catching and marking adults increased the amount of disturbance near the nest sites.

Nest success generally fell within the ranges reported in the literature with the exception of 2003 at Agassiz (30%). Other studies of least bittern nest success reported Mayfield nest success of 43.8% (n = 38) and 52.5 % (n = 35) in western New York (Bogner and Baldassarre 2002), 54.9% (n = 159) in South Carolina, and 47.5% (n = 126) and 39.1% (n = 6) in northwest Missouri (Nelson 2003).

Nest Distribution

Comparison of the least bittern nesting ecology at Mingo and Agassiz suggests differences in nest density and distribution in relation to habitat conditions. The restricted availability of tall, emergent vegetation at Mingo influences nesting density because suitable nesting habitat was restricted to a small patch (9.3 ha) of giant cutgrass

in 2001, and 2 small patches (9.3 and 10.7 ha) in 2002. In contrast, least bitterns are more widely distributed in the larger marshes at Agassiz where there are extensive stands of robust emergent vegetation available as suitable nesting habitat. Nearest neighbor distances among least bittern nests in previous studies had a tendency to be much lower than the nearest neighbor distances at Mingo and Agassiz (Kushlan 1973, Post 1998, Weller 1961). For example, in the Florida Everglades, Kushlan found 11 nests in 1 of 5 stands of sawgrass (*Mariscus jamaicensis*). The mean distance between each active nest and the closest neighbor was 2.7 m. The average distance between nearest neighbor least bittern nests in South Carolina (Post 1998) was 9 m, however, in this study, any nest over 25 m from another nest was considered solitary and excluded from the analysis. In Iowa, nests were 5 to 6 m apart (Weller 1961). When densities of active nests were compared using the size of the habitat patch they were located in, nesting densities reported in several studies were similar to nest densities at Mingo (Table 17).

Table 17. Nesting densities reported in the literature

Location	Nest per hectare	Source, Year
<i>Missouri</i>	0.8	<i>Present Study, 2002 (patch B)</i>
Iowa	1.8	Kent, 1951
<i>Missouri</i>	2.7	<i>Present Study, 2002 (patch A)</i>
Florida	2.9	Post and Seals, 1993
Florida	3.2	Rodgers and Schwikert, 1999
<i>Missouri</i>	3.8	<i>Present Study, 2001 (patch A)</i>
Florida	4.23	Kushlan, 1973
Iowa	5.1	Weller and Spatcher, 1965

Possible explanations as to why some least bitterns nest in a semi-colonial situation and others choose to nest solitarily have not been fully explored. One of the major advantages of nesting colonially with conspecifics is improved resource acquisition (Burger 1984, Post and Seals 1993). Individuals nesting in colonies have the potential to forage more effectively due to information transfer among colony residents. Because least bitterns rely on stealth to forage, they are more likely to forage alone; however, it is possible that individuals are able to learn about the foraging sites from other birds within the breeding colony (Ehrlich et al. 1988).

The other advantage to nesting colonially relates to predation. In the case of least bitterns, nesting within colonies of mixed species seems to be the most beneficial. Timid species such as the least bittern may gain a protective advantage from nesting with more aggressive species. Nesting least bitterns at both sites were often found nesting in conjunction with red-winged black birds (*Agelaius phoeniceus*) (personal observation). At Agassiz, the nests of other aggressive species such as yellow-headed blackbirds (*Xanthocephalus xanthocephalus*), black terns (*Chlidonias niger*) and marsh wrens (*Cistothorus palustris*) were commonly found near least bittern nests. In South Carolina, least bitterns were commonly associated with boat-tailed grackle (*Quiscalus major*) colonies (Post and Seals 1993). Defense behaviors such as early warning calls, mobbing, and attacking of predators by these more aggressive species may provide early warning signals to least bitterns, therefore providing more time for both young and adults to hide in the vegetation surrounding the nest. In addition, species such as black terns are usually

hovering above the colony and can detect approaching predators much sooner than incubating or foraging bitterns.

Within the boat-tailed grackle colonies studied by Post and Seals (1993), least bittern nests were found closer to boat-tailed grackle nests than to other bittern nests. Possibly, least bitterns exhibit a higher tolerance for other species than for members of their own species. At both study sites, male least bitterns exhibited territorial behavior by responding to call-playback tapes of a male calling.

Nest Metrics

The flooding that took place at Agassiz in 2002 likely explains the lowest heights of nests above water and the deepest water depths, which occurred that year. Water depths remained quite deep within Monopoly Marsh in 2002, which was reflected in the water depths at nests and the nest heights (Figure 6). Nest height differences between the two sites may also be attributed to differences in vegetation structure.

Egg Metrics

Differences in clutch sizes showed a trend toward larger clutches at northern locations as well as differences in ranges among years. Increasing clutch size with latitude is a pattern first reported by Lack (1954). Comparison of clutch sizes from previous studies also supports this trend. Clutches containing 6 eggs were reported in Iowa (Weller 1961) and New York (Lor 2000), whereas, studies in South Carolina (Post

1998), and Florida (Rodgers and Schwikert 1999), reported the largest clutch as 5 (Table 18). It is not clear, however, if larger clutches reflect a genetic difference between these populations, or whether females could be laying more eggs in response to better foraging conditions during the egg laying period, and therefore clutch size corresponds with the number of young that parents are able to nourish adequately within the specific habitat patch or season in question. If better foraging conditions exist at sites further north, the question becomes whether the larger clutch size results from more available prey or the additional foraging time because of a longer day length.

Table 18. Geographical comparison of least bittern clutch sizes

<i>Area</i>	<i>Average clutch size</i>	<i>Source, Year</i>
Florida	4.1	Rodgers and Schwikert, 1999
South Carolina	3.8	Post, 1998
Missouri	4.6	Present study
Iowa	4.1	Weller, 1961
New York	5.2	Lor, 2000, Bogner 2001
Minnesota	5.0	Present study

Hatchling metrics

Differences in growth rates between sites may be genetically or environmentally controlled, however the influence of these factors on growth rate and development require further investigation. Few studies have identified genetic control of growth in relation to patterns of size variation (James 2001). It may be overly simplistic to assume that there would only be one cause of intraspecific growth variation because of the complexity of environmental and genetic factors. Abiotic and biotic factors that may

effect growth include: 1) timing when hatchlings begin to forage, and how long they are fed by the adults; 2) timing/chronology of food abundance and availability; 3) warmer temperatures allow hatchlings to invest in development rather than thermoregulation; 4) longer day length that allows adults and hatchlings more time for foraging each day; and 5) size of the brood, mediating the parents ability to gather enough food for all the young.

Least Bittern Information Needs and Management Strategies

Conservation Issues and Threats to Least Bitterns

This study has provided information on habitat selection and reproductive effort of least bitterns across a broad geographic scale. Comparative studies across large scales have the potential to further enhance our understanding of least bittern ecology. Understanding habitat availability and food resources is one of the critical aspects where information is lacking. Wetland loss and deterioration seems the most imminent threat to least bittern populations (Gibbs et al. 1992a). Even though wetlands are recognized as among the most productive ecosystems globally, wetland acreage continues to be lost and degraded (Dahl 1990). For example, Minnesota continues to lose thousands of acres of wetlands due to drainage or filling despite laws designed to achieve “no net loss” of those lands (The Conservation Foundation 1988). In addition, Minnesota currently has no comprehensive method for tracking wetland gains or losses. Degradation of upland habitats surrounding wetlands has potential to negatively impact least bittern populations as well. Erosion in agricultural and industrial areas causes siltation and run-off into adjacent wetlands. These conditions can lead to reductions in fish and invertebrate populations because of turbidity that impacts submergent vegetation and foraging conditions.

Additional threats to least bittern populations include global climate change and the introduction of invasive species (Gibbs et al. 1992a, The Wildlife Society 2004). Many changes are expected in the earth’s environment as a result of the accumulation of greenhouse gases. Predicted changes such as rising sea levels and

increasing aridity in the continental interiors could ultimately decrease the amount of quality wetland habitat available to wetland dependent species such as the least bittern (Poiani and Johnson 1991). Wetlands such as Mingo and Agassiz that are dependent on an interaction of groundwater and precipitation as the main source of water may be the most vulnerable to changes in climate. In addition, a number of exotic plants also have invaded many wetlands due to their ability to adjust to a wide range of environmental conditions. Eventually, these exotics can create dense monotypic stands, which reduce biotic diversity and eliminate open water habitat.

Habitat management for least bitterns

Determining how to promote the appropriate distributions and densities of vegetation for least bittern habitat may require some experimentation within a site (Fredrickson and Laubhan 1994). In order to manage an area effectively, it is necessary to understand how various impoundments with unique topographies and soils will respond to various management regimes. Timing and duration of an impoundment's hydroperiod will influence the plant species composition and densities within that pool. In areas where tall emergent vegetation is too sparse for nesting bitterns, a late spring draw down exposing bare mudflats during warm temperatures will provide ideal conditions for germination of emergent vegetation such as cattail or giant cutgrass (Fredrickson and Laubhan 1994). Once germination occurs, maintaining water depths greater than 30 cm throughout the growing season will prevent drying and allow for further growth of the newly established vegetation. Further growth will promote thicker

rhizomes, and higher plant survival over the winter, which will in turn establish a thicker residual structure for the following spring. Patches of residual emergent vegetation can provide least bitterns with nest-building material and cover early in the breeding season prior to the establishment of fresh vegetation. On the other hand, patches of emergent vegetation such as cattail or giant cutgrass may become too thick and create dense stands of monotypic vegetation which could lead to declines in waterbird use (Weller and Spatcher 1965). Controlling dense stands of emergent vegetation is problematic at many locations because of nutrients (especially Phosphorus) and sediments. The site must be dried to enhance the decomposition of the residual above and below ground vegetation. Drawdowns are only effective if they are implemented for a sufficient period to reduce the residual biomass. Herbivores such as muskrats can also have an influence on the vegetation structure within an impoundment. Where marshes have not been filled with the organic matter from cattail, deeper water might allow muskrats to overwinter. Muskrats use cattail for food and for building houses in the fall. When the cattail stalks are cut during the characteristic low water in the fall, the cut stems are submerged in the spring and “suffocate”, resulting in openings in the marsh.

Water levels greater than 30 cm should be maintained throughout the breeding season in order to maintain sufficient water depths for least bittern foraging and nest building. It is important to maintain water levels at a fairly stable depth from the time of nest initiation (early –mid May) through the end of breeding season (late August). Rapid decreases could increase the risks of predation, while rapid increases could result in inundation of nests or young. Maintaining water depths greater than 30 cm through the

fall and winter is also beneficial to other wildlife species that are important for least bittern habitat conditions. Fish and muskrat populations require high winter water levels to insure their survival in more northern locations that become ice covered.

Some invasive plant species have characteristics unfavorable for least bittern nesting. Biological methods of control are preferred on refuges but in some cases chemical treatments may be required. Because predation has been noted as a common reason for nest failure, predator management may be beneficial at some sites. Removal of structures (such as beaver lodges) from impoundments may be beneficial to least bitterns by reducing the proximity of predators such as mink or raccoons from nesting colonies.

Monitoring the distribution of habitats for least bitterns

There is still a need for a better understanding of movement patterns and habitat requirements during nesting, migration, and over-wintering at local and landscape scales (Gibbs et al. 1992a, Bogner 2001). For example, information on important sites during migration and wintering is lacking. Until the location and distribution of these sites is identified, conserving populations of least bitterns will be problematic.

Current conservation strategies for least bitterns include the preservation, protection, and improvement of large, shallow (10-30 cm.) wetlands with dense growth of robust emergent vegetation. However, little is known about how the size, juxtaposition, and successional stage of these wetlands influences survival and breeding success.

Federally supported restoration and enhancement programs to preserve existing wetland habitat are of great importance. Programs such as the Conservation Reserve Program (CRP), Wetland Reserve Program (WRP) and Partners for Wildlife assist private landowners with habitat restoration, development, and management (Prairie Pothole Joint Venture 2004). If wetlands important to least bitterns were identified, these lands could be enrolled in conservation programs to protect and enhance available habitats. In addition, more standardized inventories would identify wetlands that provide suitable habitat.

Wetlands should be managed in a dynamic state to lengthen the period of time that provides suitable least bittern habitat. Groups of wetlands could be managed as complexes to ensure that suitable habitat is available within close proximity each year.

Monitoring Programs

At the present time, there is a need for accurate distribution, abundance, and population trend data across the entire least bittern breeding range. As long as this information is lacking, it is impossible to set population goals for the future. It may be more appropriate to set “no net loss” goals for critical habitat for least bitterns at this time. Currently, there is a lack of standardized monitoring techniques for least bitterns because regular monitoring is either limited or the sites selected for monitoring do not have suitable characteristics for nesting bitterns. In some areas, the only source of standardized monitoring of least bittern populations is the North American Breeding Bird Survey (BBS). Unfortunately, it is unclear how effectively this survey detects secretive

marsh birds for at least three reasons. First, this secretive species is seldom seen or heard. This behavior further compromises effective monitoring because the distribution of BBS routes are not related to the distribution of habitat suitable for least bitterns. In addition, most BBS routes are not monitored in late May and early June, when the peak of the least bittern vocalization occurs.

In order to overcome this deficiency in monitoring, the Biological Resources Division of the United States Geological Survey has recently initiated standardized monitoring of marsh birds using call-response surveys. Currently, approximately 70 National Wildlife Refuges are participating in this survey (Soch Lor, USFWS, personal communication). Information on the effectiveness of call response surveys to detect least bitterns is still inconclusive because studies investigating least bittern responses to call surveys have produced inconsistent results (Manci and Rusch 1988, Gibss and Melvin 1993, Lor 2000, Bogner 2001). This is probably related to varying methods used in individual surveys. My observations indicate that least bitterns may not respond to calls immediately but are more likely to position themselves closer to the source of the call before responding. For example, Bogner (2001) found only 22% of radio marked male least bitterns responded to a call within the first minute of broadcast in New York. Lor (2000) and Bogner (2001) likewise, noted that least bitterns approached the source of the call before responding vocally.

Monitoring/Population Assessment Recommendations

Implementation of regional monitoring programs that employ the same techniques on wetlands or habitat outside United States Fish and Wildlife Service refuges and a common spatial database is needed urgently. Due to the slow response time of this species to call surveys, a more suitable monitoring strategy for least bitterns should include a broadcast of a male call that lasts for at least 4-5 minutes in order to increase detection rates. Recommendations have been made to use 15-second recordings of vocalizations interspersed with at least 15 seconds of silence (Bogner 2001). Timing of surveys can also significantly impact detection rates. It is important to conduct surveys early in the breeding season between mid-May and mid-June during nest initiation when the peak in vocalization occurs. In addition, surveys for least bitterns should be performed from within the marsh when feasible rather than from roadsides or dikes.

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