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EVALUATION OF A BEHAVIORAL INDEX FOR ESTIMATING REPRODUCTIVE
SUCCESS OF GRASSLAND BREEDING BIRDS

A Thesis

presented to the Graduate Faculty of the Department of Biological Sciences
of the State University of New York College at Brockport
in partial fulfillment for the Degree of
Master of Science

By

Michael R. Morgan

26 October 2007

THESIS DEFENSE

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ABSTRACT

Declining populations of grassland breeding birds have generated considerable concern from biologists and managers, and an increased understanding of the habitat preferences of grassland breeding birds and improved management techniques are being used to guide planning and conservation efforts. The success of these efforts is often determined by the collection of data on bird response, primarily changes in occupancy or abundance as determined by point counts or similar techniques. However, anthropogenic grasslands in the Northeast may serve as ecological traps when mature birds choose fields that appear to be suitable breeding habitat, but intensive agricultural practices or other detrimental management occurs prior to the successful fledging of young. Therefore, merely quantifying the presence or abundance of adult birds does not indicate the quality of a field as breeding habitat, and impacts to productivity should be quantified as the true measure of grassland bird response.

The traditional metric for productivity has been nest searching and monitoring. However, due to the challenge of locating well camouflaged nests, along with the potential to unnecessarily disturb nesting attempts while searching for nests, interest is mounting in developing methods that involve indirect estimates of productivity. A potentially valuable method was introduced by Vickery et al. (1992); this combines territory mapping (from which density can be calculated) with observations of behaviors associated with stages in the breeding cycle to create an index of productivity for each territory. Estimates of rates of breeding success (productivity) can then be calculated, although this method does not provide any information on the number of young fledged. In addition, the estimated rates

can be artificially inflated by misclassifications of breeding failure as successes due to nest parasitism by Brown-headed Cowbirds (*Molothrus ater*).

Before this method should be widely implemented, its accuracy and suitability as a substitute for nest searching and monitoring should be assessed. The research presented in this thesis expands upon a preliminary effort by Rivers et al. (2003) that compared results from the reproductive index and nest searching and monitoring for Dickcissels (*Spiza americana*) in Kansas. The authors found that the reproductive index may be unsuitable substitute when studying Dickcissels, and concluded that the method should not be implemented for other species without further assessment.

This thesis presents the results of a rigorous assessment of the reproductive index using Savannah Sparrows (*Passerculus sandwichensis*) in western New York during the 2002 and 2003 breeding seasons. I found a weak correlation in classification of the breeding stages of the monitored territories among multiple observers ($r=0.398$), as well as large differences between plot-level success rates estimated by the reproductive index and modified nest success rates using data from standard nest searching and monitoring (9.8% and 41.7%, respectively). Most importantly, I made territory-level comparisons of reproductive index estimates of success with actual fate as observed through detailed nest monitoring, and found the reproductive index correctly predicted actual nest fates for only 43% of the monitored nests. When treated as a continuous predictor of nest success, the reproductive index rank did have a positive slope (odds ratio 1.55, $P = 0.09$), but treated as a categorical predictor, predicted nest success did not increase smoothly with increasing index rank. In short, the reproductive index exhibited neither internal consistency, nor the ability to

predict nest fate at the plot or territory level, and functioned poorly as a substitute for traditional nest searching and monitoring for Savannah Sparrows in my study.

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CHAPTER 1 - An introduction to the conservation of grassland birds in the northeast United States and the need for a new technique for assessing avian productivity.

HABITAT LOSS AND DECLINING GRASSLAND BIRD POPULATIONS

For nearly 400 years the land cover of the northeast United States has been altered dramatically by European colonists and their descendants (Askins et al. 2007). The primary change has been in the distribution of land cover in the categories of forest, previously the dominant land-cover type, and agricultural lands (Stanton and Bills 1996, Foster et al. 2002). As settlers moved into the Northeast, forests were gradually lost as land was cleared for farms. However, with advances in technology and increased demand for crops grown at industrial scales, the amount of land dedicated to farming has declined over the last 100 years, and abandoned farmland is gradually reverting to forest (Figs. 1 and 2; Stanton and Bills 1996, Foster et al. 2002).

More recently, urban development has also begun to replace a large amount of farmland, and to a lesser extent forest land and wetlands (USDA 2000, Hasse and Lathrop 2003). Although vast amounts of wetlands have been drained to create farmland, and many are now threatened by development, their rate of loss has slowed somewhat due to the regulatory effort of the US Army Corps of Engineers and state environmental quality agencies (Gibbs 2000).

As forests were cleared for settlement, populations of the habitat/species suite referred to as obligate grassland breeding birds, or those that are “adapted to and reliant on some variety of grassland habitat for part of all of its life cycle” (Vickery et al. 1999), undoubtedly flourished and colonized much additional acreage beyond the previously

available grasslands (Foster et al. 2002). Prior to European settlement, most grassland habitats were maintained by either natural geological processes or soils that retarded colonization by woody species, or disturbances that maintained open areas including fire, flooding (particularly from beaver activities), and wind (Askins et al. 2007). The hayfields and pastures common to the typical farms of the period simulated the natural habitat required by the grassland birds, and the regular mowing and harvesting replicated natural disturbances (Bollinger 1995, Stanton and Bills 1996, Foster et al. 2002). However, Breeding Bird Survey (BBS) monitoring data from 1966 to the present has demonstrated serious declines in populations of obligate grassland birds (Table 1, created by Morgan and Burger 2007 with data from Sauer et al. 2005), with a higher percentage of those species showing declining trends than any other species/habitat suite (Samson and Knopf 1994; Herkert 1995).

The consensus among experts is that the loss of suitable agricultural grasslands and their replacement by inhospitable early-successional shrublands, forests, or development is the leading cause of declines in the populations of obligate grassland birds in the Northeast (Foster et al. 2002, Norment 2002). For example, New York, Massachusetts, and Vermont have each lost 50% or more of the farmland that was present when agriculture was at its peak in the Northeast (Stanton and Bills 1996, Foster et al. 2002).

The remaining agricultural land is also now much less hospitable to breeding grassland birds due to the development of modern agricultural techniques, further amplifying the habitat-loss crisis. Changes in farming techniques that impact grassland birds include early and frequent mowing that directly impacts nests and conversion of hayfields and pastures to cropland (Bollinger et al. 1990, Jones and Vickery 1997, Perlut et al. 2006, Askins et al. 2007).

Unfortunately, these declines in grassland bird populations are occurring not only in the Northeast, but also across the entire range of the full suite of grassland birds (Sauer et al. 2005). In contrast to the loss of suitable agricultural habitat as a major factor in population declines in the Northeast, population declines in other regions of North America are linked to the loss or fragmentation of the dominant land cover (native grasslands or prairie) (Samson and Knopf 1994, Herkert 1997, Vickery et al. 1999, Herkert et al. 2003) which is caused primarily by the conversion of grasslands to agricultural land uses (Noss et al. 1995).

THE VALUE OF GRASSLAND BIRD HABITAT IN THE NORTHEAST

The link between anthropogenic grasslands (e.g., hayfields and pastures) and grassland birds in the Northeast may lead some to conclude that their population declines are an indication of a “failed experiment” on the part of the bird species, and therefore may not warrant expenditure of limited resources for conservation efforts (Whitcomb 1987).

However, there are several arguments for supporting their conservation in the Northeast. First, grasslands in the Northeast host important populations of some grassland bird species such as Upland Sandpiper (*Bartramia longicauda*) and Henslow’s Sparrow (*Ammodramus henslowii*), along with as much as 17% of the global population of Bobolinks (*Dolichonyx oryzivorus*) (Rosenberg 2000). Apparently low rates of nest predation and parasitism of grassland bird nests by Brown-headed Cowbirds (*Molothrus ater*) occur much less frequently in the Northeast than in the Midwest, contributing to relatively high nest success rates of grassland birds in properly managed habitats in the Northeast (Norment et al. 1999). This indicates that efforts to conserve grassland birds in the Northeast may be a relatively efficient expenditure.

In addition, severe declines in the populations of grassland birds across their entire ranges demand conservation efforts wherever the birds are found. Though declines in agriculture land uses are likely the primary cause of the declines of grassland birds in the Northeast, agricultural land uses will likely persist as the predominant source of grassland habitat throughout the region, and significant potential exists to partner with landowners to modify practices and maintain suitable habitat (Askins et al. 2007).

Another factor supporting the conservation of grasslands in the Northeast is the variety of organisms that benefit from maintaining grasslands as a component of the landscape in the Northeast, including several federally-listed threatened or endangered species such as the karner blue butterfly (*Lycaeides melissa samuelis*), sandplain gerardia (*Agalinis acuta*), bog turtle (*Clemmys muhlenbergii*), and others.

Finally, the impacts of European colonists on the landscape are possibly irreversible. Ecosystem impacts (e.g., habitat fragmentation, introduction of invasive species and pathogens, and suppression of natural disturbance regimes), altered soils (including homogenization of upper soil horizons and the effects on the organic component of soils by introduced earthworms), and modified dynamics between carbon and nitrogen availability (from nitrogen amendments provided by farmers and varying ratios in the tissues of exotic plant species) are just a few of the factors that dictate that wholesale reversion of the landcover of the Northeast to some pre-colonial, “natural” state may be impractical (Foster et al. 2003).

GRASSLAND BIRD CONSERVATION PRACTICES

Once conservationists realized the unique nature of the dependence of grassland birds in the Northeast on anthropogenic grasslands and the need for regionally relevant conservation efforts and monitoring in response to the declining populations, research on management techniques and habitat requirements became a high priority (Mitchell et al. 2000, Norment 2002, Askins et al. 2007). The need to consider habitat factors at both local and landscape level scales also began to influence management efforts (Norment 2002).

Among the early actions performed at the local scale for conserving grassland birds were many plantings of native, warm-season grasses (WSG) (Dickerson et al. 1998) whose growth habits resemble those occurring in Midwestern prairies, which were often considered to be ideal grassland bird habitat. However, some scientists questioned if preferences of grassland birds in the Northeast differed from those in the Midwest and found that some grassland birds may be more likely to be found in fields planted with introduced cool-season grasses (CSG) than WSG in the Northeast (Bollinger 1995, Norment et al. 1999, Runge et al. 2004).

As it is commonly accepted that native species are more desirable and “natural” than introduced species (Gumbine 1994, Vitousek et al. 1997), the US Department of Agriculture’s New York Plant Materials Specialist is maintaining a list of experimental native CSG species that some partners in the New York grassland bird conservation partnership have begun to utilize (Paul Salon, pers. comm.). These native CSG provide height and density characteristics more similar to those of the introduced species, and hopefully will prove to be equally attractive to grassland breeding birds, although further research is needed.

Some research has also been done on various techniques for managing grassland bird habitat, including grazing, burning, and mowing/haying (Sample and Mosman 1997, Smith 1997, Zuckerberg and Vickery 2006). Burning is particularly suited for management of native WSG, as the tall, dense stands of vegetation typical of WSG provide sufficient fuel to maintain combustion, and the timing of peak growth (during the summer) allows the grass to easily out-compete undesirable forbs following a spring burn (MacDonald et al. 2007).

Emphasis has recently been given to the role of landscape-level effects when modeling the suitability of grassland bird habitat, as well as the strong correlation between field size and occupancy by grassland breeding birds (Bakker et al. 2002, Murphy 2003, Lazazzero and Norment 2006). In response, Audubon New York coordinated the identification of grassland Focus Areas in which the limited resources available could be concentrated to provide the landscapes needed to sustain populations of grassland birds, and similar efforts are being considered across the Northeast (Morgan and Burger 2007).

THE NEED FOR A NEW METHOD FOR ASSESSING GRASSLAND BIRD PRODUCTIVITY

As various management techniques are developed to maintain habitat for grassland birds, such as species mixes for re-vegetating grasslands or timing of harvest for agricultural grasslands, and their value is assessed, or when modeling grassland bird habitat preferences, the response variable has traditionally been relative abundance, occupancy, or density (Diefenbach et al. 2003, Royle and Nichols 2003, Mattice et al. 2005, Diefenbach et al. 2007). Issues of observer bias and detectability of the populations of interest have led to a rapid growth in the number of techniques for minimizing variability and standardizing effort,

particularly for trend monitoring using occupancy or relative abundances (Sauer et al. 1994, Johnson 1995, Rosenstock et al. 2002).

However, these measures may not be suitable for studying grassland breeding birds in the Northeast, as agricultural grasslands may function as ecological traps (Schlaepfer et al. 2002; Shochat et al. 2005) when haying or intensive grazing occur in fields that originally appeared to be suitable habitat, and nests or fledglings are destroyed or abandoned. Therefore, measures of density or abundance alone may provide misleading information about habitat quality or suitability (Van Horne 1983, Vickery et al. 1992). A more suitable approach may be to evaluate reproductive success or productivity (Hughes et al. 1999) in conjunction with density to determine if the habitats being considered should be designated as population sources or sinks (Watkinson and Sutherland 1995, Runge et al. 2006)

The most commonly used technique for collecting productivity data has been nest searching and monitoring (McCoy et al. 2001, Perlut et al. 2006) when the results are adjusted to account for the difference in probabilities of locating successful versus unsuccessful nests (Mayfield 1975, Hazler 2004). However, searching for and monitoring grassland bird nests is particularly challenging, given the cryptic nature of the nests and the potential to adversely impact nests while attempting to find their locations (Gotmark 1992, Mayer-Gross et al. 1997). The use of indirect estimators of productivity is becoming more common in an effort to mitigate for these concerns and to develop efficient monitoring programs (Vickery et al. 1992, Powell and Collier 1998, Gunn et al. 2000).

The use of indirect techniques to estimate waterfowl productivity was evaluated by Serie and Cowardin (1990) using previously described "social indices" (Serie and Cowardin 1990, Hochbaum et al. 1987) for Canvasbacks (*Aythya valisineria*). These indices are

calculated when censusing numbers of paired ducks along with number of males and females in social groups to determine the approximate numbers of nesting females, as is commonly used to estimate waterfowl production during breeding censuses (Dzubin 1969, Ball et al. 1995). Conducting these censuses over several survey periods allows the observer to estimate the onset of egg laying and incubation. Serie and Cowardin (1990) found that the indices were highly correlated with actual hen nesting success ($r^2 = 0.69-0.93$).

A NEW REPRODUCTIVE INDEX FOR GRASSLAND BREEDING BIRDS

Vickery et al. (1992) described a reproductive index for grassland breeding birds that combines territory mapping (IBCC 1970) with observations of breeding behaviors to assign a reproductive "rank" to each territory (ranks listed in Table 2). The ranks for all mapped territories are pooled to estimate overall success rates for study plots. Vickery et al. (1992) compared the results of the index to traditional nest searching and monitoring conducted in the same study areas in Maine, and considered the success rates derived from the two methods sufficiently close to validate the approach (25% from the index and 42% from nest searching and monitoring). They also found the index to be useful in distinguishing between habitat characteristics of successful versus unsuccessful territories.

Powell and Collier (1998) utilized this reproductive index to assess reproductive success of Belding's Savannah Sparrows (*Passerculus sandwichensis beldingi*) in coastal California. Gunn (2000) used a similar technique with playback calls of mobbing Black-capped Chickadees (*Poecile atricapilla*) to assess reproductive success of forest birds, but Doran et al. (2005) concluded that the modified technique held limited value for distinguishing differences in reproductive success between territories of forest birds.

Rivers et al. (2003) paired the reproductive index with nest searching and monitoring to compare plot-level estimates of breeding success for Dickcissels (*Spiza americana*) in Kansas. The authors found that the index underreported actual breeding success in most plots, but also indicated breeding success in three plots where no successful nests were found. In addition, the index lacked the ability to indicate the large number of nests that failed due to brood parasitism by Brown-headed Cowbirds. Rivers et al. (2003) concluded that the index was a poor substitute for nest searching and monitoring for Dickcissels in Kansas, and suggested that preliminary trials be conducted to determine the index's suitability prior to employing the technique elsewhere.

Obviously, additional assessment of this technique is needed before it becomes accepted or rejected as a substitute for traditional nest searching and monitoring. The research reported here builds upon these preliminary assessments of the reproductive index, and is a rigorous examination of the suitability of using the reproductive index as a substitute for nest searching and monitoring for Savannah Sparrows (*Passerculus sandwichensis*) in western New York. My research is presented in Chapter 2, and is formatted in preparation for submission to *The Auk*.

Table 1. Population trends and estimated percent population remaining from the start of the Breeding Bird Survey in 1966 at two scales for grassland birds common to the Northeast.

Species	USFWS Region 5		Survey-wide	
	trend (%/year)	population remaining (%)	trend (%/year)	population remaining (%)
Northern Harrier	1.1	153.2	-1.7	51.2
Upland Sandpiper	-0.7	76.0	0.5	121.5
Short-eared Owl	--	--	-4.6	15.9
Sedge Wren	0.5	121.5	1.8	200.5
Henslow's Sparrow	-12.6	0.5	-7.9	4.0
Grasshopper Sparrow	-5.2	12.5	-3.8	22.1
Bobolink	-0.3	88.9	-1.8	49.2
Loggerhead Shrike	-11.4	0.9	-3.7	23.0
Horned Lark	-2.1	43.7	-2.1	43.7
Vesper Sparrow	-5.4	11.5	-1.0	67.6
Eastern Meadowlark	-4.3	18.0	-2.9	31.7
Savannah Sparrow	-2.3	40.4	-0.9	70.3

Background colors indicate data quality and sufficiency. Blue indicates no deficiencies in the data, (yellow) indicates a deficiency, and Red indicates an important deficiency. **Bold** indicates significant trends ($P < 0.05$).

Created by Morgan and Burger 2007 with data from the Breeding Bird Survey provided by Sauer et al. 2005.

Table 2. Ranks indicated by Vickery et al.'s (1992) reproductive index for behaviors associated with stages of the breeding cycle for Savannah Sparrows.

Rank	Breeding Stage	Indicative Behavior
1	Establish a territory	Territorial behaviors (e.g., singing, defending from intruders) > time needed to produce 1 successful clutch (23 d for Savannah Sparrow)
2	Attract a mate	Non-agonistic behavior toward conspecific of opposite sex
3	Building nest, laying and incubating eggs	Difficult to establish (varies with species, often given by carrying nest material, distraction displays, or direct observation of laying or incubating eggs)
4	Feeding nestlings	Adults carrying food (rather than immediate consumption)
5	Feeding fledglings	Adults carrying food longer than nestling stage (10 d for Savannah Sparrow)

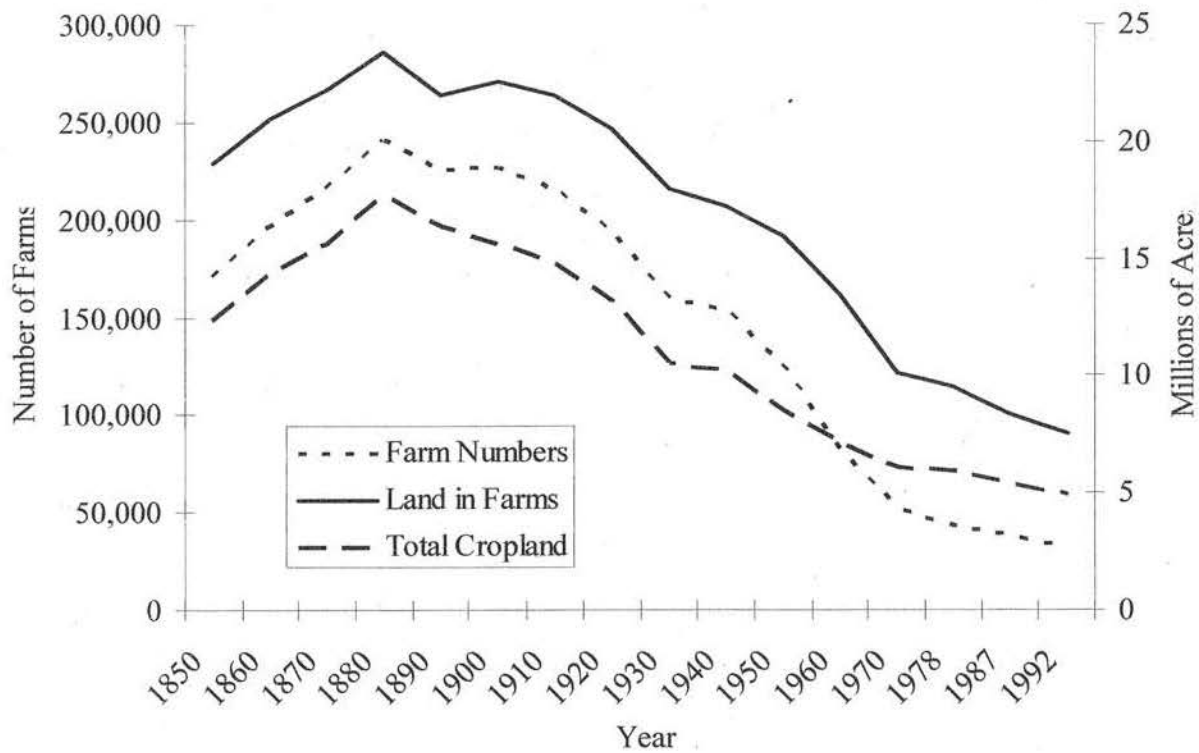


Fig. 1. Trends in land use and ownership for agricultural land in New York (from Stanton and Bills 1996).

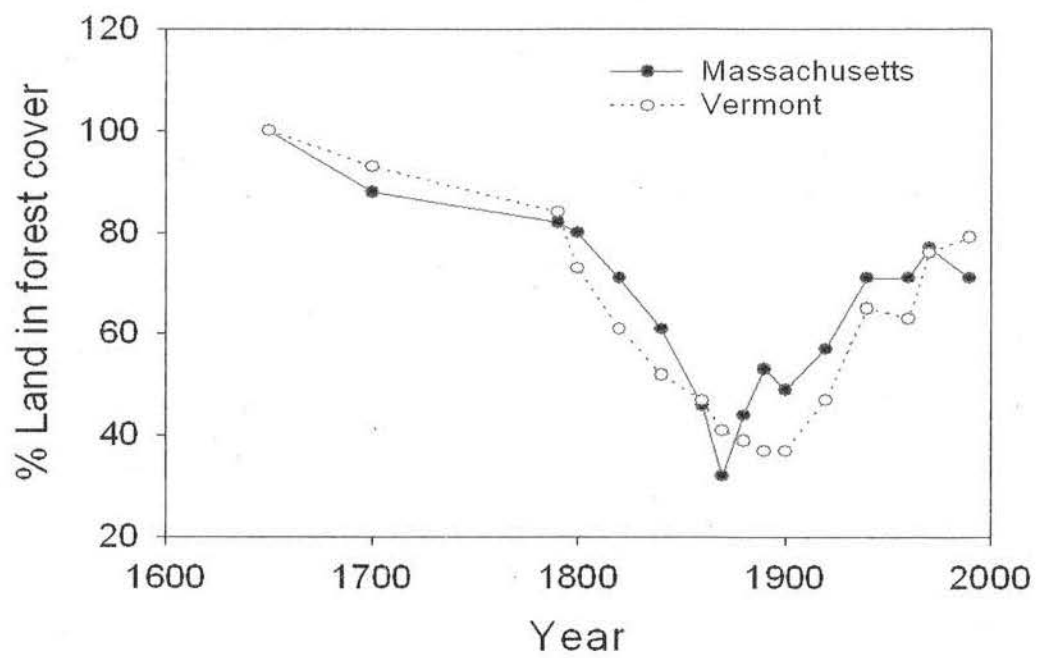


Fig. 2. New England forest cover from 1650-1990 (data from Foster 1995).

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CHAPTER 2 – Evaluation of a reproductive index for estimating productivity of grassland breeding birds.

Stabilization of rapidly declining populations of grassland breeding birds (GBB) has become a priority for many conservation groups and agencies (Askins et al. 2007). Data from the Breeding Bird Survey (BBS) indicate that many populations of GBB have declined precipitously since the start of the BBS in 1966. For example, in the US Fish and Wildlife Service's Region 5 (the northeastern United States), Henslow's Sparrow (*Ammodramus henslowii*) populations have declined more than 12% per year, and Eastern Meadowlarks (*Sturnella magna*) have declined more than 4% percent per year (Sauer et al. 2005).

The primary cause of these declines is thought to be habitat loss and degradation including widespread farmland abandonment and rural development in the Northeast (Norment 2002, Murphy 2003). The causes of the population declines in the Northeast contrast with intensification of agriculture and grazing which, along with development, have caused the loss of prairie habitat throughout the Midwest (Samson and Knopf 1994, Herkert 1997, Vickery et al. 1999).

As conservation efforts, which commonly involve habitat management through mowing, prescribed fire, and grazing continue to intensify, the need exists for meaningful assessment of their effectiveness. This can be done simply by documenting presence or absence of the target species in managed parcels, or more rigorously by also correlating measurements of controllable habitat variables with relative abundance of target species determined using point counts or other standardized techniques (Ralph et al. 1995) to provide

feedback through an adaptive management process (Schreiber et al. 2004, McCarthy and Possingham 2007),

However, measures of density or abundance can provide misleading information about habitat quality or suitability (Van Horne 1983, Vickery et al. 1992). For example, agricultural land may act as an ecological trap for GBB (Schlaepfer et al. 2002; Shochat et al. 2005) when fields are hayed or grazed prior to fledging, or if adjoining land cover types attract high numbers of predators or brood parasites (Bollinger et al. 1990, Frawley and Best 1991). The potentially misleading nature of density or abundance metrics necessitates a more rigorous approach to quantifying habitat suitability, such as a method which assesses and quantifies productivity within the targeted habitat patch.

For GBB, the traditional method for collecting productivity data has been nest searching and monitoring (Nur and Geupel 1993), along with a statistical analysis that takes observer effort into account (Mayfield 1975; Hensler and Nichols 1981; Johnson and Shaffer 1990). However, searching for nests of GBB is at best difficult for some species, and nearly impossible for others. In addition, this method, which relies on repeated examinations of the nest to document hatching and fledging, may affect success rates, although data documenting this effect is fairly equivocal, possibly due to the variety of nesting behaviors exhibited by different avian species (Gotmark 1992, Martin and Geupel 1993, Hoi and Winkler 1994, Mayer-Gross et al. 1997, Westemeier et al. 1998). To mitigate for these concerns, or in efforts to develop improved monitoring techniques, the use of indirect estimators of productivity is becoming more common (Vickery et al. 1992, Powell and Collier 1998, Gunn et al. 2000).

Serie and Cowardin (1990) evaluated the use of indirect observations to estimate productivity for waterfowl by testing previously described social indices (Serie and Cowardin 1990, Hochbaum et al. 1987) to predict reproductive success for Canvasbacks (*Aythya valisineria*). This technique evaluates the numbers of paired ducks along with number of males and females in social groups to determine the approximate numbers of nesting females, as is commonly used to estimate waterfowl production during breeding censuses (Dzubin 1969, Ball et al. 1995). When conducted over several survey periods to track changes in these social groups, scientists can estimate initiation dates of egg laying and incubation. Serie and Cowardin (1990) found that hen breeding success determined independently by nest searches correlated well with three calculated behavioral indices ($r^2 = 0.69-0.93$).

In 1992, Vickery and colleagues (Vickery et al. 1992) described a new reproductive index for territorial songbirds, particularly GBB, which uses indirect observations of behaviors associated with stages of the breeding cycle to score reproductive success for mapped territories. They reported an overall breeding success rate of 25% for territories monitored using this index for several species across many areas in Maine, while nest searching and monitoring provided a 42% success rate for nests monitored in the same areas. They also found significant differences in vegetation characteristics between successful and failed territories, as identified by their index. However, as Vickery et al. (1992) indicated, their method required "further field testing" before the method is broadly applied, although it has seen some use with grassland birds (Powell and Collier 1998)

Rivers et al. (2003) compared productivity estimates from the reproductive index and nest searching and monitoring using Dickcissels (*Spiza americana*) in Kansas. When

comparing methods at the plot level they found that the index underestimated the final reproductive rank for most observed territories, and reported successful nests on three plots where no young fledged. Also, the index failed to indicate nest failure from Brown-headed Cowbird (*Molothrus ater*) parasitism. While Rivers et al.'s (2003) research indicated that the reproductive index may not be reliable for estimating overall nest success at the plot level, further analysis at different scales (i.e. individual territories and their associated nesting attempts), and with additional species may demonstrate if the reproductive index remains a potentially useful tool for estimating reproductive success.

In the present study, I gathered productivity data on an obligate grassland breeding bird, the Savannah Sparrow (*Passerculus sandwichensis*), using both Vickery et al.'s (1992) reproductive index and traditional nest searching and monitoring. My approach was unique in that I linked the fate of individual nests to data on the reproductive index collected in the same territories. This allowed me to analyze how well the reproductive index functioned as a predictor of individual nest fates, which I consider to be the true measure of the accuracy of the reproductive index. I also compared estimates of productivity from the two methods at the plot level, to determine if my results were comparable to those of Rivers et al. (2003). In addition, I determined whether values for the reproductive index were consistent among multiple observers. If different observers monitoring the same territories obtain different values for the reproductive index, the usefulness of the method should be suspect.

Two other key aspects of my study allow me to build on the study of Rivers et al. (2003). First, I conducted the study in the northeastern United States, where parasitism of ground-nesting grassland birds by Brown-headed Cowbirds is infrequent (Norment et al. 1999). Second, I focused on Savannah Sparrows instead of Dickcissels. By evaluating the

index with a different species, I can better understand how the index performs across the guild of grassland breeding birds.

METHODS

I conducted my study during the 2002 and 2003 breeding seasons (approximately 15 May to 15 July) at Iroquois National Wildlife Refuge in Shelby, NY (43.145N, 78.386W). My study site was a 98 ha grassland dominated by introduced cool season grasses such as timothy (*Phleum pratense*) and orchardgrass (*Dactylis glomerata*), as well as a variety of forbs and shrubs, including goldenrod (*Solidago* spp.), milkweed (*Asclepias* spp.), and spirea (*Spiraea alba*). Historically the field was used as pasture, but more recently has been managed primarily by summer mowing (every 3 or 4 yr) after most birds have completed breeding (Paul Hess, INWR, pers. comm.). Bobolinks (*Dolichonyx oryzivorous*) and Savannah Sparrows are numerous in the field (Norment et al. 1999), and they are the only obligate grassland breeding birds found there in large numbers. Eastern Meadowlarks (*Sturnella magna*) are less common; Upland Sandpipers (*Bartramia longicauda*), Grasshopper Sparrows (*Ammodramus savannarum*), and Henslow's Sparrows are occasionally spotted in some years (Norment unpubl. data).

I limited the project scope to breeding Savannah Sparrows because their nests are relatively easy to locate, and they demonstrate the territorial behavior necessary for the territory mapping required by the reproductive index (Vickery et al. 1992, Wheelwright and Rising 1993). In contrast, Bobolinks are not territorial during the breeding cycle (Martin and Gavin 1995).

At the study site, I established three 12 ha plots (Appendix A) in which multiple observers gathered productivity data using either the reproductive index or nest searching and monitoring. Savannah Sparrow territories range in size from 0.05 ha in New Brunswick (Wheelwright and Rising 1993) to 1.25 ha in sparse habitat in Nova Scotia (Stobo and McLaren 1975), so plots were located nearly 100 m from adjacent plots to prevent double counting territories that might overlap multiple plots. Within each plot I set a grid of plastic flags on wire stakes placed every 25 m. The flags were numbered using a coordinate system that allowed accurate transcription of each territorial bird's location to a map of the plot for use with the reproductive index. The observers also used the flags to monitor nests found while nest searching, as the flags provided reference points for relocating the nests without marking each nest location.

Four observers collected data used for estimating Vickery reproductive index ranks and searched for and monitored nests to calculate Mayfield daily survival rates in the three plots during the breeding seasons of 2002 and 2003 (two observers participated in both years, while the other two participated in separate years). Each observer independently gathered data for the reproductive index in two plots, while visiting each plot between 0600 and 1000 on alternate days. During afternoons, each observer searched for and monitored nests in a third plot (Table 1). This avoided biasing the data collected for the reproductive index by ensuring that observers were unaware of nest locations and status in the other plots, forcing them to rely solely on behavioral observations to calculate the index. Observers did not discuss their observations from time spent collecting data for the reproductive index with one another during the field season.

Nests were located by tracking females as they made repeated trips to nest sites. Rope dragging or other methods of nest searching by disturbing the vegetation to flush females were considered unnecessarily disruptive to both vegetation and nest sites and were not used. Once nests were located, observers attempted to minimize any disturbance to concealing vegetation and varied the direction from which they approached and departed from the nests to avoid providing any indications of nest locations to other observers or to potential nest predators. To track survival, nests were visited every two or three days, and data gathered on number of eggs or nestlings, as well as approximate age of nestlings using descriptions in Wheelwright and Rising (1993). Visitation rates increased to once a day or more as time of fledging neared.

When collecting data for the reproductive index, the observers spot-mapped (International Bird Census Committee [IBBC] 1970) each territorial Savannah Sparrow and recorded behavioral data as described by Vickery et al. (1992) that indicate the breeding stage (1-establishing territories, 2-attracting mates, 3-nest-building/egg-laying/incubating, 4-feeding nestlings, and 5-feeding fledglings). Each observer visited their plots either two or three times per week during the breeding season, providing data from 20 visits per plot per year, which was greater than the ten to 17 visits/plot employed by Vickery et al. (1992). Each visit lasted approximately 4 h from sunrise, during which time observers attempted to gather behavioral data for each territory within the plot. The entry point for each visit varied around the plot perimeters to randomize the path the observers traveled in the plots. Observers walked so that they came within 50 m of every point in the plot, in contrast to the IBBC (1970) protocol for spot mapping, which states that for open areas, the maximum viewing distance should be ≤ 100 m. I felt that the observers would be unable to observe

birds carrying small prey items at distances ≥ 50 m, and that it would be difficult to accurately map sparrow locations at greater distances due to their high density.

Data analysis.— From the nest searching and monitoring (NSM) data I used Program Mayfield (Hines 1989) to calculate modified daily survival rates (DSR) for each plot in each year, accounting for exposure days (Mayfield 1975). I compared DSRs using Program Contrast (Hines and Sauer 1989) which facilitates multiple non-orthogonal comparisons of rate estimates and allowed me to examine patterns among various intersecting plot and year combinations.

After each field season, I superimposed the territory maps created by paired observers allocated to each plot to determine how consistently the observers identified and mapped individual territories. Territories were deemed to match if they showed $\geq 50\%$ overlap of the mapped area. I calculated Spearman rank correlation coefficients (r) for the reproductive index ranks given by paired observers to matching territories for each plot and year as well as the combination of all paired observers. I felt that rotating observers between plots in different years, along with the independence of Savannah Sparrow breeding efforts between years, mitigated concerns about pseudo-replication when pooling results from both years of the study.

Index ranks also were plotted to visually examine distribution of paired ranks. Since index ranks are discrete, the results were plotted so that the dot size indicates the number of matches for that rank combination. A perfect correlation would provide a graph with all points occurring on a line of slope $x=y$. In addition, the distribution of point sizes along the line would indicate the proportion of territories reaching a particular stage, but not progressing any further.

Nest locations were plotted on the territory maps to determine which nests and territories corresponded, which allowed me to compare predictions of nest fate derived from the reproductive index and actual nest fate as determined by NSM, using both naïve (unmodified) nest success (defined as a nest that fledged at least one nestling) and nest success modified using Mayfield daily survival rates. I used Mayfield logistic regression, which incorporates the number of observation days to determine the daily survival rate and avoids the bias associated with monitoring nests for unequal lengths of time (Hazler 2004), to assess the ability of the reproductive index to predict nest success.

RESULTS

During 2002 and 2003, one or both observers paired to each plot mapped 190 unique territories (approximately 2.6 territories ha^{-1}); observers also located and monitored 76 Savannah Sparrow nests (31 in 2002, and 45 in 2003). Observers spent an average of c. 11 h locating and gathering data on each nest while nest searching and monitoring, and an average of c. 2.5 h gathering data on each territory used for deriving the reproductive index.

Sixteen non-orthogonal contrasts were examined for patterns in the daily survival rate by year and plot (Table 2). Nest survival differed significantly among plots (plot A had higher nest survival than plots B and C), but there were no year effects. Further, no contrasts indicated an observer effect; these would have appeared as significant plot X year interactions in those situations in which different observers monitored the same plot in different years (Table 2).

Of the 190 unique spot-mapped territories, 143 (75.3%) were independently identified by observers mapping the same plot. On these 143 matched territories, there was a weak

positive correlation between the reproductive index values assigned by the independent observers (Table 3). The paired ranks given to these territories were plotted for all observers combined (Fig. 1) and for each observer pair (Fig. 2). The size of the circles indicates the approximate proportion of territories given that paired ranking. The generally even distribution of the circles on each side of the diagonal fails to indicate any bias in the rankings, but the wide dispersion of the circles indicates that concordance in ranks was relatively low (Figs. 1 and 2).

Although the number of territories assigned to each rank was not expected to be equal, only four territories were given a terminal rank of 3 (nest-building and laying eggs), and received this rank after observations of active nests. Observers conducting the reproductive index in the morning never observed Savannah Sparrows carrying nesting material, although this behavior was observed several times while nest searching and monitoring during the afternoon. Three additional territories were temporarily classified with rank 3 after observations of active nests, but then received higher rankings following the observation of behaviors from advanced stages of the breeding cycle.

Reproductive indices were also compared to nest fates for 76 territories in which a nest was found. Despite the poor association between mapped territories by the paired observers, joining nests locations with the independently mapped territories was relatively simple, as the boundaries of the spot-mapped territories often gradually shifted to center on locations of established nests. One or both observers were correct in assigning a reproductive index matching the actual nest fate for only 33 (43%) of the 76 nests (Table 4). The reproductive index calculated a 9.8% overall success rate (the number of territories successfully fledging young), while the actual success rate of territories that reached the nest-

building and egg-laying stage or higher was 15.9%. The overall naïve (unmodified) rate of nest success determined by NSM, was 69.7% (53 of 76 nests fledged young), although the modified success rate was 41.7% when calculated using the DSR (0.9627). Most importantly, 77% of the successful nests were in territories ranked by both observers as having failed (Table 4). At the plot level (assuming independence of success rates within plots between years), there was no significant correlation between the modified nest success rate and the reproductive index estimate of territory success ($r^2 = 0.115$, $P = 0.511$; Table 5 and Fig. 3).

I used Mayfield logistic regression to explore whether the reproductive index rank for a territory could be used as a predictor of nest success, controlling for plot and year differences. When HiRank (the higher of the two ranks assigned by the paired observers of a territory) was treated as a categorical predictor, only rank 4 (hatching young, but not fledging young) showed a strong positive correlation with nest fate. The odds of nest success for territories given rank 4 was 4.5 times greater than the odds for territories with the lowest rank (rank 2 was the basis for comparison to other ranks in the output, see Table 6). When HiRank was treated as a continuous predictor, the slope was positive, such that a 1 unit increase in the reproductive index corresponded to a 55% increase in the odds of nest survival (odds ratio 1.55, $P = 0.091$, Table 7).

DISCUSSION

The success rates I observed for monitored nests were relatively high compared with studies from other regions in North America (Best et al. 1997, Davis 2003), and together with the high density of territorial males observed during the project (approximately 2.6 territories

ha⁻¹) indicate the potential value of properly managed “non-native” cool season grasslands in the Northeast for conserving important populations of grassland breeding birds (Norment 2002). However, additional research on conservation strategies, management techniques, and the potential benefit of native grass varieties is required, particularly in the Northeast (Morgan and Burger 2007), and an efficient, non-intrusive technique for quantifying reproductive success as a response (such as the reproductive index) would strengthen any analyses of grassland bird response to these actions.

I found the index to be fairly efficient to implement, and it allowed the observers to quickly collect a larger sample size than nest searching and monitoring (approximately 2.5 h spent per territory vs. 11 h locating and monitoring each nest). Unfortunately, 25% of territories mapped by one observer did not match territories mapped by a second observer, which together with a low degree of correlation in ranks assigned by observers to matching territories, indicates the potential for a wide range of variation in results from multiple observers. This variation suggests an important weakness of the reproductive index’s ability to meet the requirement for a standardized technique for estimating grassland bird breeding productivity.

Furthermore, failure of the reproductive index to accurately predict nest fate for 57% of the monitored nests demonstrates that the reproductive index fails as a substitute for nest searching and monitoring at the territory level, despite the time saved by using the reproductive index. Even at the plot level, there was a very low degree of correlation between the two methods ($r^2=0.115$), as previously was reported by Rivers et al. (2003).

While it is tempting to limit my comparison of the territory success rate provided by the reproductive index (9.8%) to the nest success rate calculated using the DSR obtained

from nest searching and monitoring (41.7%), such a comparison may be misleading. The success rate derived from the reproductive index estimates the percentage of territories that complete the entire breeding cycle by successfully fledging young. However, the DSR and associated nest success rate estimate the success of territories at least reaching the nest-building stage, and ignore those territories in which males failed to attract a mate or pairs failed to initiate nest building. A more accurate comparison would be between the nest success rate derived from the DSR (41.7%) and the success rate for only those territories that reached the nest-building stage or higher (15.9%). However, given the disparity in success rates, and the fact that plot-level comparisons only provide a limited amount of information regarding the usefulness of the reproductive index, a rigorous assessment would include a detailed analysis at the territory/nest level.

I incorporated a Mayfield logistic regression into the analysis, which measured the ability of the reproductive index to accurately predict nest survival. The results demonstrate some unexpected patterns, particularly a large odds-ratio associated with rank 4 (presence of nestlings, which generally was documented by observing adult birds carrying food items towards a presumed nest), relative to rank 5 (successful fledging of young, documented by parents carrying food for a period of time longer than the nestling stage or rarely by observations of local birds). Under the assumption that the reproductive index is tightly correlated with nest success, I expected a smooth increase in the odds ratios as the index rank increased. The different odds-ratios for ranks 4 and 5 along with the much larger number of territories classified as rank 4 than rank 5 (in contrast with the high success rate of monitored nests) suggests a possible difficulty in assigning rank 5. Treating the reproductive index rank as a continuous predictor, rather than categorical factor, allows the model to smooth over

noise in the effects of ranks. This model (Table 7) does estimate a positive, but non-significant ($p=0.091$), slope for the VRI predictor.

One assumption of the reproductive index is that human observers will be able to observe breeding behaviors. The lack of observations of Savannah Sparrows carrying nest material while mapping territories may be a result of their skill at avoiding detection by predators while establishing a nest site, as befits a species adapted for breeding in an open habitat such as grasslands (Repasky 1996, Devereux et al. 2005). The skills that grassland birds must possess to conceal their breeding activity, and particularly nest locations from visual predators (such as Savannah Sparrow use of nest canopies and their avoidance of nest sites when observers are near, Wheelwright and Rising 1993), conceivably also reduces the probability that conspicuous human observers will detect behaviors associated with stages of the breeding cycle and may cause observers to underestimate breeding success.

Observations of Savannah Sparrows carrying nesting material that occurred while observers were searching for and monitoring nests in the afternoons could also indicate variation in the probability of detection for certain breeding behaviors as a function of time of day, e.g., females foraging during the morning, but selecting a nest site during the afternoon. However, observers expended more time searching for individual nests than observing behaviors in each territory, and perhaps this difference increased the probability of observing secretive behaviors while nest searching in the afternoon.

The high density of Savannah Sparrows in the study plots may have also compromised the ability of the observers to detect certain behaviors, thus affecting the assignment of ranks. For example, almost all locations to which the observers traveled within the plot were located within the territorial boundaries of a Savannah Sparrow. The

observers' presence often elicited defensive behaviors from the territorial male (and possibly a female if a nest site was nearby), which commonly alerted other, nearby Savannah Sparrows, causing them to temporarily abandon behaviors associated with breeding until the perceived threat (the observer) moved away. This effect may have caused observers to fail to identify sufficient instances of adults carrying food to make the distinction between nests that failed during the nestling stage versus successful nests.

Additionally, the large number of territories within the plot, and the need to map as many territories as possible, made it challenging to spend sufficient time at each territory to observe behaviors associated with the breeding cycle. On an operational basis, however, I do not think that these challenges could be overcome through increased effort, especially since one of the intents of the reproductive index is to reduce monitoring costs.

Potential proponents of the reproductive index may contend that its use will strengthen the assessment of reproductive potential on a wide range of habitats, and that it need not be used as a surrogate for nest searching and monitoring. However, collecting presence/absence or density data remains more efficient than conducting the reproductive index, particularly at large scales, and is likely sufficient for a first-order assessment of habitat quality. Collection of productivity data (second-order assessments) is necessary when evaluating potential ecological traps, which are most alarming at high-density sites. My research demonstrates that the reproductive index functions poorly in predicting breeding success at a high-density site.

In summary, I consider the reproductive index method to be inadequate for estimating the reproductive success of Savannah Sparrows in western New York grasslands for several reasons. First, spot-mapping of territories was not reliably repeatable among different

observers. Second, there was a low correlation among the ranks assigned by different observers to the same territories. Third, at the plot level there was little correlation between the success rate determined from the reproductive index and the nest success rate derived from Mayfield DSRs. Fourth, the reproductive index was a poor predictor of nest success at the territory level. Although my study focused on one species at one locality during a two-year period, I intensively examined many assumptions underlying the reproductive index; my results, as well as those of Rivers et al. (2003) suggest that researchers should use substantial caution before employing the reproductive index as a surrogate for estimating reproductive success.

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Table 1. Allocation of observer effort per plot in each year. RI refers to the reproductive index (Vickery et al. 1992), and NSM refers to nest searching and monitoring.

	Obs 1	Obs 2	Obs 3
Plot A	RI	RI	NSM
Plot B	RI	NSM	RI
Plot C	NSM	RI	RI

Table 2. Contrasts among Mayfield daily survival rates for various plot and year combinations. "A02", for example, refers to the daily survival rate estimated in plot A in 2002. Significant differences are shown in bold. Asterisks (*) indicate comparisons involving different observers in different years. Contrasts and their p-values were estimated using Program Contrast (Hines and Sauer 1989).

Plot/Year Comparison	Chi ² value	Probability
A02 to B02	4.324	0.0376
A02 to C02	2.847	0.0916
B02 to C02	0.942	0.3318
A03 to B03	7.859	0.0051
A03 to C03	3.813	0.0508
B03 to C03	2.027	0.1556
A02,03 to B02,03	11.810	0.0006
A02,03 to C02,03	6.567	0.0204
B02,03 to C02,03	2.880	0.0897
ABC02 to ABC03	0.7332	0.3919
A02 to A03*	0.1490	0.6995
B02 to B03*	0.4102	0.5219
C02 to C03*	0.1818	0.6698
A02B03 to A03B02	0.1693	0.6807
A02C03 to A03C02	4.2164	0.9444
B02C03 to B03C02	0.1258	0.7228

Table 3. Spearman rank correlation coefficients (r) for reproductive ranks assigned individually by paired observers. Significant differences shown in bold. A, B and C = plot. 02 = 2002, 03 = 2003.

Plot	r-value	df (n-2)	critical value (p=0.05)	p-value (2-tailed)	p-value (1-tailed)	Observer
All	0.398	141	0.195	<0.001	<0.001	All
A02	0.449	21	0.413	0.031	0.016	GL,CW
B02	0.327	15	0.482	0.200	0.100	MM,GL
C02	0.361	30	0.349	0.042	0.021	MM,CW
A03	0.349	24	0.388	0.081	0.041	MM,SL
B03	0.323	15	0.482	0.207	0.103	MM,CW
C03	0.522	26	0.374	0.004	0.002	CW,SL

Table 4. Number of correct predictions of nest fate (survival or failure) made by observers using the reproductive index. The true nest fate was determined by the nest searching and monitoring method.

Nest Fate	Observers		
	Both Correct	One Correct	Neither Correct
Failed	15 (65%)	6 (26%)	2 (9%)
Success	4 (8%)	8 (15%)	41 (77%)
Overall	19 (25%)	14 (18%)	43 (57%)

Table 5. Daily survival rate (DSR), the associated modified nest success rate, and reproductive index estimate of territory success rate for each plot/year combination.

Plot/Year	DSR	Modified Nest Success Rate	Reproductive Index Estimate
A02	0.9708	0.5058	0.0870
B02	0.9017	0.0926	0.1154
C02	0.9333	0.2044	0.0588
A03	0.9632	0.4222	0.1765
B03	0.8753	0.0467	0.0938
C03	0.9236	0.1607	0.0714

Table 6. Mayfield logistic regression (Hazler 2004) of nest success, using Plot and HiRank as factors.

Predictor	Coefficient	SE Coefficient	Z	P	Odds Ratio	95% CI
Constant	3.21542	0.601358	5.35	0.000		
Plot						
A03	0.638214	0.971842	0.66	0.511	1.89	0.28-12.72
B02	-1.21338	1.05257	-1.15	0.249	0.30	0.04-2.34
B03	-0.781745	0.971247	-0.80	0.421	0.46	0.07-3.07
C02	-0.706388	0.861360	-0.82	0.412	0.49	0.09-2.67
C03	-1.30960	0.914654	-1.43	0.152	0.27	0.04-1.62
HiRank						
3	-0.0925373	0.971083	-0.10	0.924	0.91	0.14-6.12
4	1.50442	0.715267	2.10	0.035	4.50	1.11-18.29
5	1.02830	0.778280	1.32	0.186	2.80	0.61-12.85

Table 7. Mayfield logistic regression of nest success using Plot as a factor and HiRank as a continuous predictor.

Predictor	Coefficient	SE Coefficient	Z	P	Odds Ratio	95% CI
Constant	2.48614	0.887493	2.80	0.005		
Plot						
A03	0.623352	0.935498	0.67	0.505	1.87	0.30-11.67
B02	-0.878228	0.991020	-0.89	0.376	0.42	0.06-2.90
B03	-1.21080	0.800775	-1.51	0.131	0.30	0.06-1.43
C02	-0.548147	0.814893	-0.67	0.501	0.58	0.12-2.85
C03	-1.09324	0.833380	-1.31	0.190	0.34	0.07-1.72
HiRank	0.437697	0.258680	1.69	0.091	1.55	0.93-2.57

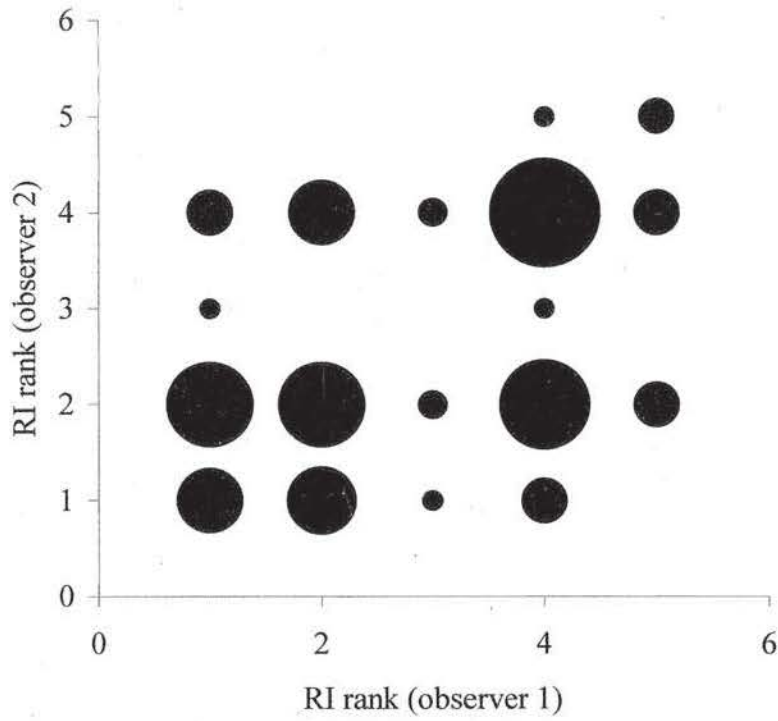


Fig. 1. Correlation between reproductive index ranks given individually to matching territories by paired observers (for all plots and years). The area of each circle is proportional to the number of nests with that pair of rankings.

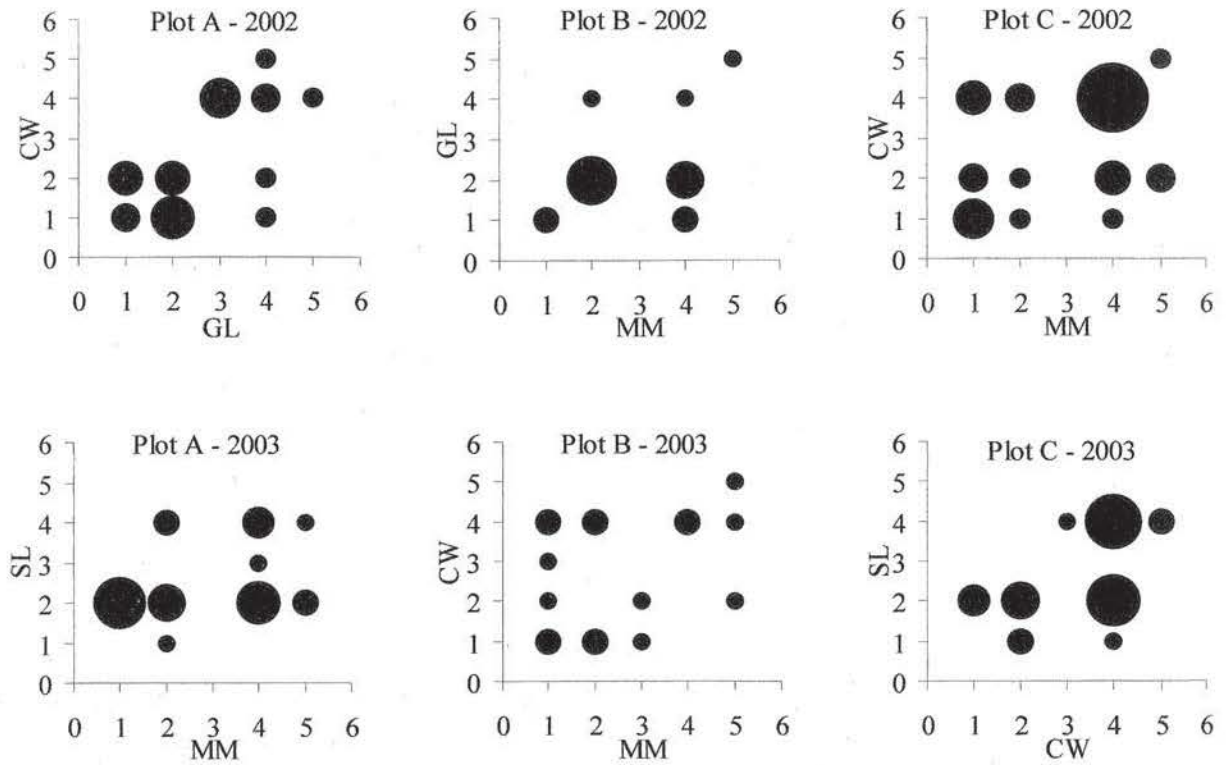


Fig. 2. Correlation between reproductive index ranks given individually to matching territories by paired observers (for each plot and year combination). The area of each circle is proportional to the number of territories given that pair of rankings. The initials on each axis indicate the observers who assigned the ranks in each plot and year.

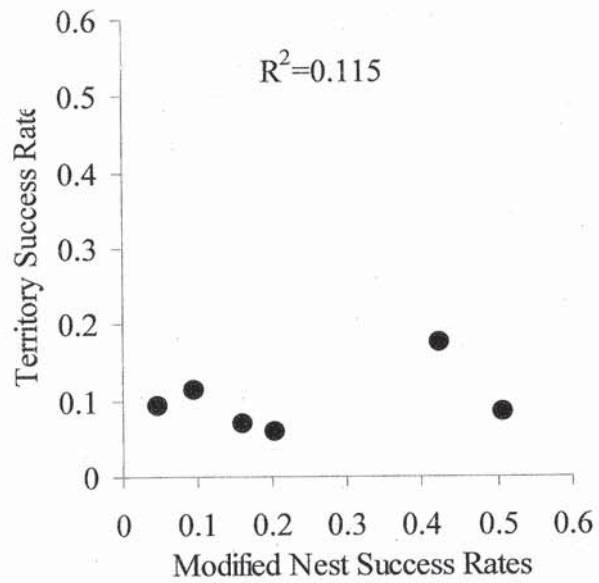


Fig. 3. Correlation between plot-level estimates of territory success from the reproductive index and nest success determined by nest searching and monitoring.

APPENDIX A – Map of study plots in Grazing Unit I, Iroquois National Wildlife Refuge, Shelby, NY.

