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REPORTING RESULTS OF DATA ANALYSIS, PREPARING SCIENTIFIC MANUSCRIPTS, AND WEBSITE DEVELOPMENT EFFORTS

Preparation of scientific manuscripts and use and presentation of statistics have been topics of several commentaries from previous journal Editors-in-Chief, and have been submitted as invited papers, so I would like to share my perspective as the current Editor-in-Chief (Editor) of *The Prairie Naturalist* (Journal). Because there is not complete consensus among the experts about when hypothesis testing versus information theoretic methods, or Bayesian versus frequentist methods are suitable, previous Editors have avoided presenting their perspectives (Thompson 2010). I also will avoid presenting my perspective as Editor. I will, however, present my perspective on several of these approaches and then offer some guidelines for presenting results of some commonly used statistical methods in the Journal. Further, I will also highlight several recurring issues related to improper manuscript formatting that I continue to encounter and then provide several potential solutions to minimize future occurrences and in turn, expedite the peer-review process.

Previous Editors have addressed the importance of exploratory analyses and descriptive statistics and the need to keep statistical analyses as simple as possible, all while keeping the focus on biology and management (Thompson 2010). Another recurring theme has been to focus on effect sizes rather than P-values for statistical tests. I think few people would disagree with this advice if kept in the proper context. The Journal publishes a wide range of Articles and Notes; some will require nothing more than simple models (e.g., means and confidence intervals), but others will require more complex models and model selection approaches. There has been considerable commentary in professional wildlife journals concerning the increased use of information theoretic (I-T) approaches, including concerns that it has become a widely misused statistical ritual in scientific journals (Thompson 2010). Most any statistical approach can be misused but all have value when used properly and in the proper context. There is a place for exploratory analyses and descriptive work in the Journal; descriptive statistics may be all that is necessary for some Research Notes and provide useful background before presenting results from more complicated statistical models (Thompson 2010). I firmly believe, however, that throughout the wildlife profession, our focus should be centered on rigorous studies that address a priori hypotheses through appropriate manipulative and observation study designs. Ideally, conducting simple experiments to directly evaluate research hypotheses is preferred. However, most of our research is exploratory (observational) because of its scale or context and information theoretic approaches can help provide stronger inference in these cases (Thompson 2010).

As Editor I will not insist on any particular approach because one size does not fit all. However, I will point out, with the help of reviewers and Associate Editors, when methods and interpretation are inappropriate. In the case where multiple approaches are acceptable, I am unlikely to request that an author change their approach to data analyses unless the current approach results in misleading conclusions or is overly complex and lengthy. Through the review and content editing processes, our Editorial Staff will try to make sure results are reported appropriately with a focus on wildlife biology and management. Problems with presentation of analyses in scientific papers often begin in the introduction section of a paper (Thompson 2010). At the end of the Introduction authors should clearly present their objectives, as well as a limited number of a priori hypotheses if applicable. On the other hand, lengthy lists of hypotheses tied to models in an information theoretic approach should instead be presented in the Methods section (Thompson 2010). It is surprising to me how many authors do not clearly state their study objectives. A statement of objectives is not the place to demonstrate creative writing; authors should simply state "our objectives were to ..." or "we evaluated support for the following hypotheses...." (Thompson 2010). These should be stated as scientific or research hypotheses, not statistical or null hypotheses (Thompson 2010). In the Methods section authors can justify how analyses will support or refute these hypotheses based on appropriate statistical approaches (Thompson 2010). When using information theoretic approaches or any approach based on a priori hypotheses authors should present evidence that these are valid hypotheses. Authors should clearly describe the extent to which the study was exploratory or confirmatory.

Traditional frequentist approaches like t-tests and analysis of variance test null hypotheses. Although results of these tests should usually be reported (test statistic value, df, and P-value) the primary focus should be interpretation of effects (Thompson 2010). Presenting treatment means, or their differences, and confidence intervals are effective ways to present effect sizes (Thompson 2010). For more complicated analysis of variance models authors should generally present model based means, such as least-squared means, rather than simple arithmetic means (Thompson 2010). Authors should emphasize estimated effects or parameters and their biological interpretation, and report test statistics and P-values in tables whenever possible or else parenthetically. Authors should try to avoid stand-alone, often meaningless, P-values by being specific about how things differed (e.g., parameter X was 10 % smaller than parameter Y [$P < 0.001$]; Thompson 2010). In the case of numerous comparisons that are presented graphically or in tabular format, citation of the figure or table is appropriate.

Many submitted papers continue to confuse the meaning of a P-value. As researchers, we should wonder why conditioning on the null hypothesis is desirable. Importantly, we also should note that the alternative hypothesis is never tested. The alternative gets support only by default – when the null is “rejected” or “significant” (Anderson 2010). The usual t-tests and analysis of variance (ANOVA) models are still useful in the analysis of experimental data. Results ruled “nonsignificant” in a null hypothesis testing (NHT) framework should not be taken to mean there is no effect or no difference (Anderson 2010). This is a very common mistake. A parallel issue exists when a simple model (e.g., one with only a few parameters) is selected by AIC_c and assigned a high weight (model probability). This result should not be taken to mean that larger models with additional effects and parameters are unimportant (Anderson 2010). With small samples only dominate effects can often be supported. As sample size increases, smaller effects can be identified (Anderson 2010).

Because information theoretic or other model selection approaches involve multiple models, presenting and interpreting results is a little more challenging (Thompson 2010). Key to an information theoretic approach is identification of a limited set of interpretable models that represent valid a priori hypotheses (Thompson 2010). While many researchers are trying to limit the number of models by carefully considering and reconsidering alternatives; there are others that seemingly give this little thought and hope the computer will sort out the important variables and relationships (Anderson 2010). As researchers, we should continue to encourage hard thinking about *plausible* alternatives. This focus should be on the science and alternatives that seem worthy of study. Then, the focus shifts to the *evidence* for each alternative (Anderson 2010). I contend that authors should think about alternative hypotheses more than the number of potential models to include in analyses. While most statistical software packages are capable of running hundreds (if not thousands) of models, I would contend that as researchers we would find it very challenging to develop hundreds or thousands of plausible scientific hypotheses. Further, there are cases where none of the models have merit. This can often be checked by an evidence ratio of a model with only an intercept vs. a global model or the AIC_c -best model (Anderson 2010).

Model selection approaches can be exploratory and use Akaike’s Information Criteria (AIC) but should be clearly differentiated from an information theoretic approach to a priori hypothesis-based inference (Thompson 2010). Authors should clearly articulate the candidate models considered, preferably by presenting a limited number of models (e.g., the top models) in the results tables; when many models are considered, authors should list these in tables, appendices, or supplemental material or describe in text how variables were combined to form the candidate models (Thompson 2010). Authors should present support

for the models, typically in a table that includes model name or description, the log-likelihood value, number of model parameters, selection criteria (e.g., AIC), differences from the top model (Δ_i), and Akaike weights (Thompson 2010). If there are many models, authors may consider presenting these results only for the competing models with some support. In almost all cases in addition to evaluating support for these hypotheses, authors should interpret effects in the supported model or use model averaging if there is model selection uncertainty (Thompson 2010). Interpretations of regression coefficients, odds ratios, and plots of predicted responses as a function of covariates are effective ways to evaluate model selection uncertainty. Authors should be clear about what they did and why. Interpretation of effects from supported models should focus on the biological significance of estimated effects and treat confidence intervals as measures of precision of the effects, not null hypothesis tests of no effect (Thompson 2010). Authors should interpret model support, or lack of support, to evaluate their hypotheses (Thompson 2010).

When using information-theoretic (I-T) approaches there are no “tests” and no dichotomous decisions concerning “significant” or “nonsignificant.” However, Anderson (2010) noted that there are substantial advantages of I-T approaches over NHT. For example, the use of NHT and its P-values leaves an analyst without ways to (1) rank models, (2) treat observation studies, (3) model average effect size, (4) incorporate model selection uncertainty into estimates of precision, or (5) lessen model selection bias. Classic ANOVA tables have been used for the past 70–80 years; it is not surprising that better approaches have been discovered. Outside of one’s “comfort zone” why would an analyst prefer an F-statistic and a P-value over an array of evidential quantities available under an I-T approach? There is no “power” of the test as there are no tests nor is there a valid concept of “power” following an analysis where the P-value is ruled “nonsignificant” (Anderson 2010). Statistical power should be reserved as a planning device for experiments.

Confidence intervals often are misused as if they can be used as a binary “test.” That is, if the intervals “overlap” then “nonsignificant” is ruled; such judgments are incorrect (Anderson 2010). The correct approach is to examine the confidence interval of the *difference* between two estimates. Such intervals are often easy to interpret; however, a more rigorous measure of evidence can be had using simple evidence ratios. Some authors continue to use AIC_c to rank models and then “test” to see if the best model is “significantly” better than other models in the candidate set. Such mixing of test statistics and their P-values with I-T approaches is inappropriate and leads to serious inferential problems (Anderson 2010). Thus, one should use NHT tests or I-T methods throughout rather than mixing the two approaches. Importantly, “testing” or reporting null hypotheses that are obviously uninteresting or trivial (“silly nulls”).

Akaike's Information Criterion should be used only when the sample size (n) is substantially larger than the number of parameters in the global model (K). Generally, one should usually use AIC_c unless $n/K > 40$ (or in the case of overdispersion, use $QAIC_c$; Anderson 2010). Many papers use AIC_c only to rank models; inference is then made from this estimated "best" model. While this strategy is not incorrect, it fails to use the power of making formal inference from multiple models and the hypotheses they represent (Anderson 2010). Some authors use NHTs to assess the "significance" of a β -coefficient representing an interaction term in a linear or nonlinear regression analysis or an ANOVA model. A simple alternative is to compute an evidence ratio between 2 models: one with the interaction term and one without. This simple procedure avoids assumptions about the distribution of the test statistic under the null, the multiple testing problem, and the fact that the alternative (the importance of the interaction term) is never "tested" (Anderson 2010).

In the case where the top models are nearly tied in terms of empirical support and your goal is prediction, predictions should be made from each of the top models to calculate a weighted model-averaged prediction (Anderson 2010). In this case, the fact that one or two of the models does not contain a particular variable is immaterial. When trying to understand effects or relationships, and some variables don't appear in some of the top models, the answer is more difficult to determine with any generality (Anderson 2010). This being said, Anderson (2010) suggests focusing not on model averaging, but instead on the use of various evidence ratios. For example, he suggested considering the case where you believe that X_1 and X_4 are important and your attention is focused on X_3 where you would like more evidence concerning its worth. Further, Anderson (2010) suggested examining 2 models: one with only X_1 and X_4 and the second model with X_1 and X_4 AND X_3 and subsequently computing the model likelihoods for both models and take a ratio of these. He also noted that this evidence ratio gets directly at the importance of X_3 , given that X_1 and X_4 are in the model. Unlike the usual t-test of the regression coefficient for X_3 , the evidence ratio makes no assumption about the distribution of the test statistic being t-distributed, no concept of alpha (e.g., 0.05), and not worry that other tests have been performed on the data (the multiple testing problem; Anderson 2010). The evidence ratio is nice for exploring relationships with both variables and interaction terms.

In summary, authors should begin by clearly stating their study objectives. Authors should then report a priori hypotheses, and the Introduction should provide background as to why these are valid hypotheses (Thompson 2010). Authors should indicate if their approach is exploratory and explain the experimental design. Adequate explanations of experimental designs are often lacking from submitted manuscripts, but this is perhaps a topic for another column. Authors should use appropriate statistics and models and

present some assessment of model plausibility and fit (beyond relative comparisons of model support; Thompson 2010). Authors should focus on the biological interpretation of effect size with test statistics and P-values reported in tables or parenthetically (Thompson 2010).

For the benefit of our members and future authors, we have developed a revised version of the manuscript submission guidelines, which are available as a PDF file on the website (<http://www.sdstate.edu/wfs/GPNSS/TPN/submission-guidelines.cfm>) and as a published manuscript in Volume 41, Issue 3/4. Our intention was to develop a detailed, consistent set of manuscript submission guidelines for the benefit of all potential authors in the future. I am surprised, however, at the number of improperly formatted manuscripts that I continue to receive. Fortunately, most of the "problems" I encounter are easily corrected by our Editorial Staff. Spending additional time addressing these issues, however, contributes to a delayed peer-review process. I believe strongly that properly formatting manuscripts prior to submission is the sole responsibility of the authors. I would encourage future authors to pay particular attention to formatting tables and figures, especially being mindful to use consistent font type/size throughout. Authors also should provide our Editorial Staff with an original version of all figure files (jpeg, tiff, bitmap formats) or Excel files of raw data to ensure that we can properly manipulate files as needed during latter stages of the peer review process (e.g., preparation of galley proofs). Future authors also are encouraged to thoroughly review the current submission guidelines to ensure that *all sections* of their manuscripts (including headings, subheadings, running heads, page numbering, title page, literature cited, list of figure files, table titles, etc.) strictly adhere to our formatting guidelines.

Though we have seen a slight increase in our 2010 manuscript submission rate, the current manuscript submission rate remains insufficient to support a quarterly publication of the Journal. Importantly, the future publication schedule of the Journal will continue to occur biannually (June and December) until manuscript submission rates can once again support a quarterly publication schedule. Our Editorial Staff will continue to work on restoring the quarterly publication schedule of the Journal, which will require increasing current manuscript submission rates. Additionally, increasing manuscript submission rates will aid in accomplishing our long-term objective of recognition and indexing of the Journal on the Intercollegiate Studies Institute (ISI) Web of Knowledge. We would encourage researchers throughout the Great Plains to submit their work for possible publication in the Journal. Importantly, I have been in communication with ISI Web of Knowledge to identify future efforts that our Editorial Staff can work on to aid in eventual ISI recognition and indexing of the Journal, including improving the timeliness of publication and providing greater access to information via our website

(<http://www.sdstate.edu/wfs/GPNSS/TPN/index.cfm>). We have minimized our peer review process to 2–3 months and have developed our new website, which provides access to previous publications and other GPNSS/Journal information. The Editorial Staff will continue to develop the website and will revisit the ISI Web of Knowledge during Fall 2011 in an effort to gain recognition and indexing of the Journal. We will continue to develop an electronic version of the quarterly Newsletter, which will be available to our members on the website. Further, we will continue to explore options that will allow GPNSS members to establish or renew existing memberships electronically.

We are pleased to inform our members that *The Prairie Naturalist* now offers an online publication option to manuscripts published in the Journal. Authors have the option of choosing to publish their work Open Access in addition to traditional print. Open Access Research Articles and Notes will be found in *The Prairie Naturalist* Current Publications or *The Prairie Naturalist* Archives. Open access will allow authors to have their work digitally downloaded directly from our website and made available to a larger audience. We have published our most recent Journal issue (Volume 42, Issue 1/2) as Open Access to provide authors with opportunities to examine the current format. Our Editorial Staff members are working to allow free access to abstracts of all Research Articles published in the Journal. The fee schedule for Open Access can be found in *The Prairie Naturalist* Page Charges (<http://www.sdstate.edu/wfs/GPNSS/TPN/upload/Page-Charges-for-Publishing-in-The-Prairie-Naturalist.pdf>).

Finally, I am pleased to announce the addition of several new members of our Editorial Staff, including Associate Editors Drs. Gary Larson, Lawrence Igl, and Kurt VerCauteren. We are seeking additional Associate Editors to serve on our Editorial Staff. Interested persons should forward a letter of interest and curriculum vitae directly to me. I am most easily reached via email (prairie.naturalist@sdstate.edu). As always, we will continue to provide our members with information updates in future issues of the Journal. I'm excited about the future of the Journal. Thanks everybody and I hope you enjoy this issue.

—Christopher N. Jacques
Editor-in-Chief

LITERATURE CITED

- Anderson, D. R. 2010. Some important considerations when reporting the results of data analysis. 3 pp.
- Thompson, F. R., III. 2010. Editor's Message – Application and Presentation of Statistics. *Journal of Wildlife Management* 74:617–619; 2010; DOI: 10.2193/2010-045

Current Distribution of Rare Fishes in Eastern Wyoming Prairie Streams

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ABSTRACT Distributions of native fishes have declined throughout the Great Plains region. Over 50% of native fishes within the Missouri River drainage in Wyoming have experienced declines in distributions. Thus, the primary goal of our study was to assess current distribution of rare native fishes in eastern Wyoming prairie streams. Of the 10 rare fishes sampled, goldeye (*Hiodon alosoides*), western silvery minnow (*Hybognathus argyritis*), plains minnow (*H. hankinsoni*), and Iowa darter (*Etheostoma exile*) have experienced declines in distribution over the last decade. Plains topminnow (*Fundulus sciadicus*) appears to be expanding to areas outside their historical distribution, while pearl dace (*Margariscus margarita*), hornyhead chub (*Nocomis biguttatus*), suckermouth minnow (*Phenacobius mirabilis*), finescale dace (*Phoxinus neogaeus*), and orangethroat darter (*Etheostoma spectabile*) distributions appear stable. Our study has increased knowledge of current distribution and status of rare fishes in eastern Wyoming prairie streams.

KEY WORDS fish distributions, Missouri River drainage, prairie fishes, Wyoming

Freshwater systems are among the most imperiled ecosystems worldwide (Leidy and Moyle 1998). As sentinels for these fragile aquatic ecosystems, North American freshwater fish populations have been in decline since the early 20th century (Williams et al. 1989, Moyle and Leidy 1992). Over the past 30 years, the number of imperiled freshwater fish taxa has increased 179 fold (Jelks et al. 2008).

Similar declines are apparent in prairie stream systems within the Great Plains region (Patton 1997, Hoagstrom et al. 2006b, Fischer and Paukert 2008). North American prairie ecosystems are among the most threatened biomes in North America (Samson and Knopf 1994). As most of the remaining fragments of the Great Plains ecosystem are not large enough to support naturally-functioning watersheds (Dodds et al. 2004), those that persist require dedicated conservation efforts to support viable aquatic resources for future generations.

Prairie streams have been described as harsh and fluctuating systems due to their variable hydrologic regimes and physicochemical conditions (Matthews 1988, Fausch and Bestgen 1997). Prairie stream fishes have evolved adaptations to these natural processes and environmental extremes. Prairie streams are of ecological importance due, in part, to their highly-adapted native fish assemblages (Cross et al. 1986, Rabeni 1996).

Considerable changes to prairie stream systems have occurred throughout the Great Plains. Water development activities, irrigation practices, and livestock grazing have altered these systems and impacted native fish communities (Rabeni 1996, Fausch and Bestgen 1997, Nesler et al. 1997). In Wyoming, Patton et al. (1998) found that over 50% of the native fish species in prairie streams of the Missouri River drainage had experienced reduced distributions.

Little is known about the current distribution, ecology, and status of prairie fishes as these fish have historically been considered species of low conservation and management need by managers and researchers (Fausch and Bestgen 1997). The Wyoming Game and Fish Department (WGFD) is charged with conserving and managing all fish species throughout the state. However, funding in the state has historically been lacking for nongame fish management and conservation. In 2000, the United States Congress established the Federal State Wildlife Grants Program, which created funding sources for states to support projects that focus on the management of all fish and wildlife species (WGFD 2005). With this new program, the WGFD identified native fish species with conservation need. Declines in native fish distributions combined with the inception of the Federal State Wildlife Grants Program have led to increased efforts by resource managers to expand fisheries evaluations, particularly throughout Wyoming prairie streams (Barrineau et al. 2007, Bear and Barrineau 2007). Thus, the primary goal of our study was to assess the status of rare native fishes in eastern Wyoming prairie streams in accordance with the goals of the WGFD conservation strategy (WGFD 2005). Our specific objective was to document the current distribution of rare native fishes in eastern Wyoming prairie streams.

STUDY AREA

Our study sites were located within the Missouri River drainage, east of the Continental Divide in Wyoming, USA. We selected study watersheds identified as priority areas for aquatic species within the eastern Wyoming short-grass prairie ecosystem (Patton 1997, WGFD 2001). Surveyed watersheds included the Little Powder, Little Missouri, Cheyenne, Niobrara, North Platte, and South Platte rivers

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(Fig. 1). Study area streams typically originated as high-gradient, headwater systems before transitioning to intermittent, prairie streams. Detailed descriptions of these watersheds have previously been described (Snigg 1999, Barrineau et al. 2007, Bear and Barrineau 2007). While native cyprinids and catostomids dominated fish communities, rare fishes in our study area include goldeye (*Hiodon alosoides*), western silvery minnow (*Hybognathus argyritis*), plains minnow (*H. hankinsoni*), pearl dace (*Margariscus margarita*), hornyhead chub (*Nocomis biguttatus*), suckermouth minnow (*Phenacobius mirabilis*), finescale dace (*Phoxinus neogaeus*), plains topminnow (*Fundulus sciadicus*), Iowa darter (*Etheostoma exile*), and orangethroat darter (*E. spectabile*; Table 1).

METHODS

We conducted fish surveys from April through October 2004–2007 following the collection methods used by Patton (1997), with the exception that electrofishing and seining were seldom used at the same site. Our sample site selection criteria targeted (1) larger mainstem streams located upstream and downstream of major tributary confluences, (2) tributary streams near the mainstem confluence, (3) sites where rare fishes were previously found, (4) sites surveyed by Patton (1997) and sites upstream and downstream of these sites, and (5) site accessibility. At each site, we selected a sampling reach and marked the upstream and downstream boundaries. Sampling reaches measured at least 200 m (Patton et al. 2000) and encompassed multiple habitat units (pools, riffles, runs, backwaters, and side channels) to capture all species present.

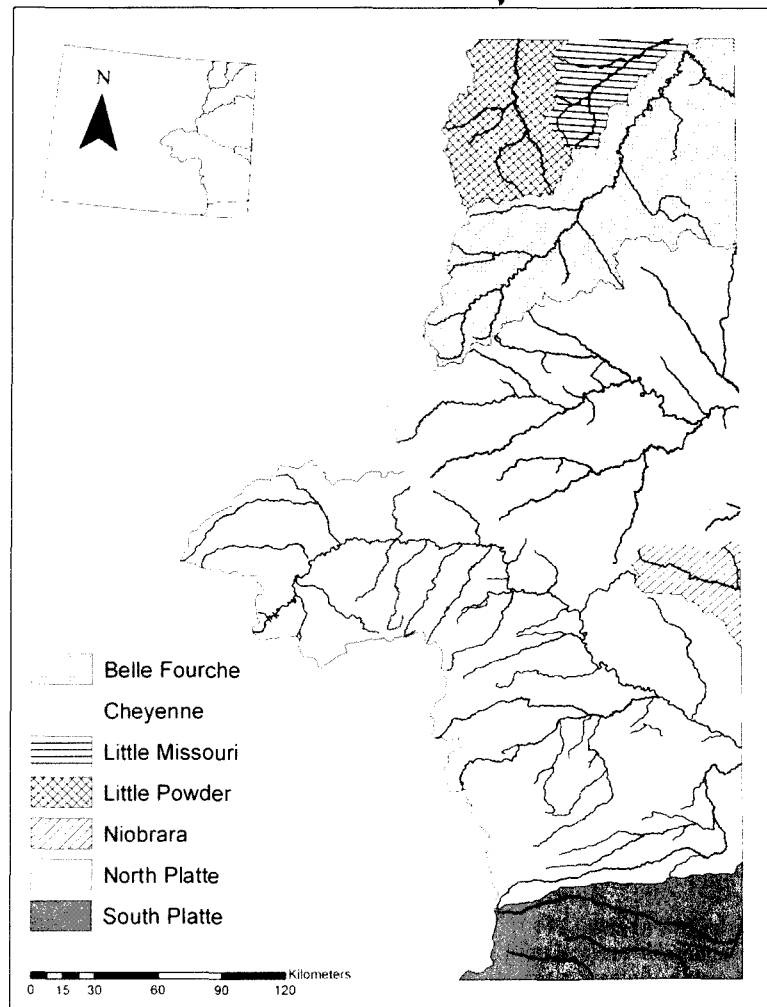


Figure 1. Location of watersheds surveyed within the Missouri River drainage in eastern Wyoming, 2004–2007. No surveys were conducted in the Belle Fourche watershed.

Given the inefficiency of electrofishing in turbid, high conductivity water, our sampling efforts consisted largely of seining (6, 4.6, or 7.6 m long with a 1.2 × 1.2 m bag and 4.8-mm mesh). In addition to seining, we used a pulsed DC backpack electrofishing unit (Smith-Root LR 24 or Coffelt Model Mark-10) to collect fish in low conductivity waters.

Captured fish were identified to species, counted, and returned to the stream. We preserved unidentified fish in 10% formalin for later identification by personnel at the Larval Fish Laboratory at Colorado State University in Fort Collins.

Table 1. Fish fauna of eastern Wyoming prairie streams by watershed, 2004–2007.

Family	Scientific name	Common name	Watershed ^a					
			LP	LM	C	N	NP	SP
Hiodontidae	<i>Hiodon alosoides</i> ^b	Goldeye	x	x				
Cyprinidae	<i>Campostoma anomalum</i>	Central stoneroller				x	x	x
	<i>Cyprinella lutrensis</i>	Red shiner					x	
	<i>Cyprinus carpio</i>	Common carp	x ^c	x ^c	x ^c		x ^c	
	<i>Hybognathus argyritis</i> ^b	Western silvery minnow		x				
	<i>Hybognathus hankinsoni</i>	Brassy minnow				x	x	x
	<i>Hybognathus placitus</i> ^b	Plains minnow			x			
	<i>Luxilus cornutus</i>	Common shiner					x	x
	<i>Margariscus margarita</i> ^b	Pearl dace				x		
	<i>Nocomis biguttatus</i> ^b	Hornyhead chub					x	
	<i>Notropis atherinoides</i>	Emerald shiner					x ^c	
	<i>Notropis dorsalis</i>	Bigmouth shiner					x	
	<i>Notropis stramineus</i>	Sand shiner	x	x	x	x	x	
	<i>Phenacobius mirabilis</i> ^b	Suckermouth minnow					x	
	<i>Phoxinus neogaeus</i> ^b	Finescale dace				x		
	<i>Pimephales promelas</i>	Fathead minnow	x	x	x	x	x	x
	<i>Platygobio gracilis</i>	Flathead chub	x		x			
<i>Rhinichthys cataractae</i>	Longnose dace	x		x		x	x	
<i>Semotilus atromaculatus</i>	Creek chub	x	x		x	x	x	
Catostomidae	<i>Carpiodes carpio</i>	River carpsucker		x	x			
	<i>Carpiodes cyprinus</i>	Quillback					x	
	<i>Catostomus catostomus</i>	Longnose sucker					x	
	<i>Catostomus commersoni</i>	White sucker	x	x	x	x	x	x
	<i>Catostomus platyrhynchus</i>	Mountain sucker			x			
	<i>Moxostoma macrolepidotum</i>	Shorthead redhorse	x		x			

Table 1. Continued.

Family	Scientific name	Common name	Watershed ^a						
			LP	LM	C	N	NP	SP	
Ictaluridae	<i>Ameiurus melas</i>	Black bullhead	x ^c	x ^c	x ^c			x	
	<i>Ictalurus punctatus</i>	Channel catfish		x	x			x	
	<i>Noturus flavus</i>	Stonecat	x					x	
Fundulidae	<i>Fundulus sciadicus</i> ^b	Plains topminnow			x ^c	x	x	x	
	<i>Fundulus kansae</i>	Northern plains killifish			x ^c	x ^d	x	x	
Gasterosteidae	<i>Culaea inconstans</i>	Brood stickleback			x ^c			x ^c	
Centrarchidae	<i>Lepomis cyanellus</i>	Green sunfish	x ^c	x ^c	x ^c			x ^c	x ^c
	<i>Micropterus dolomieu</i>	Smallmouth bass						x ^c	
	<i>Micropterus salmoides</i>	Largemouth bass			x ^c				
	<i>Pomoxis annularis</i>	White crappie						x ^c	
	<i>Pomoxis nigromaculatus</i>	Black crappie			x ^c			x ^c	
Percidae	<i>Etheostoma exile</i> ^b	Iowa darter				x	x	x	
	<i>Etheostoma nigrum</i>	Johnny darter					x		
	<i>Etheostoma spectabile</i> ^b	Orangethroat darter						x	
	<i>Perca flavescens</i>	Yellow perch			x ^c			x ^c	
Clupeidae	<i>Dorosoma cepedianum</i>	Gizzard shad						x ^c	
Salmonidae	<i>Oncorhynchus mykiss</i>	Rainbow trout						x ^c	
	<i>Salmo trutta</i>	Brown trout						x ^c	

^a Watersheds LP, LM, C, N, NP, SP refer to the Little Powder, Little Missouri, Cheyenne, Niobrara, North Platte, and South Platte River drainages, respectively; ^b rare species; ^c introduced species; ^d the native status of Northern plains killifish in these watersheds is questionable (Hoagstrom et al. 2009).

We determined percent relative abundance for each rare species within a watershed by dividing the number of each rare species by the total number of fish captured in that watershed. We calculated watershed-specific percent occurrence for rare fish by dividing the number of sites at which a species was collected by the total number of sites sampled within a given watershed.

RESULTS

We collected 58,350 fish from 100 sites across 6 watersheds. We surveyed 3 sites and collected 4,218 fish

within the Little Powder River drainage. Within the Little Missouri River drainage, we sampled 8 sites and collected 1,603 fish. Within the Cheyenne River drainage, we sampled 28 sites and collected 20,669 fish. We surveyed 5 sites and collected 5,768 fish within the Niobrara River drainage. We sampled 51 sites and collected 25,673 fish in the North Platte River drainage. Lastly, in the South Platte River drainage we surveyed 5 sites and collected 419 fish. Rare species represented 8% of the total catch and were collected from 25 sites across 5 watersheds. We collected no rare species from the Little Powder River drainage. The Niobrara and North Platte River drainages each yielded 4

rare species, the most of any watershed surveyed. Rare species relative abundance was generally less than 10% of the total catch from each watershed. Only 1 rare species, goldeye, was not documented during our survey.

Fish Species Collections

We collected western silvery minnow from the Little Missouri River drainage. Relative abundance of western silvery minnow in the Little Missouri River was <1% and the species was documented at 13% of sampled sites. We collected plains minnow in the Cheyenne River drainage. Relative abundance of plains minnow in the Cheyenne River drainage was 1% and the species was collected at 36% of sites surveyed in the drainage. We collected pearl dace from the Niobrara River drainage. Relative abundance of pearl dace in the Niobrara River was 8%. Pearl dace were collected from 60% of sampled sites in the Niobrara River drainage. We collected hornyhead chub from the North Platte River drainage. Hornyhead chub relative abundance was 2%, and we sampled the species at 8% of surveyed sites in the North Platte River drainage. We collected suckermouth minnow from the North Platte River drainage. Relative abundance of suckermouth minnow in the North Platte River drainage was <1%. Six percent of the sites we surveyed in the North Platte River drainage had suckermouth minnow. We collected finescale dace from the Niobrara River drainage. The relative abundance of finescale dace was 1% in the Niobrara River drainage, and we documented the species at 40% of our sampled sites. We collected plains topminnow from the Cheyenne, Niobrara, North Platte, and South Platte drainages. Relative abundance of plains topminnow in the Cheyenne River drainage was 9%, and we collected the species at 36% of our sites sampled. Within the Niobrara River drainage, plains topminnow relative abundance was 7%, and we collected the species at 100% of sites sampled. Relative abundance of plains topminnow in the North Platte River drainage was 4%, and we collected the species at 18% of sites sampled. Within the South Platte drainage, plains topminnow relative abundance was 15%, and we collected the species at 40% of our sites sampled. We collected Iowa darters in the Niobrara, North Platte, and South Platte drainages. Relative abundance of the species in the Niobrara River drainage was 3% and we documented them at 20% of our sites sampled. Iowa darter relative abundance in the North Platte River drainage during this survey was <1% and we documented them at 4% of our sites. Relative abundance of Iowa darters in the South Platte River drainage was 4%, and we documented them at 20% of our sites sampled. We collected orangethroat darters in the South Platte River drainage. Relative abundance of the species was 13%, and we collected orangethroat darters at 22% of our sites sampled in the South Platte River drainage.

DISCUSSION

Of the rare fish species documented, 4 were noted to have declined and 6 were stable or increasing since previous surveys were conducted in the mid-1990s survey (Patton 1997). Rare species which appear to have declined include goldeye, western silvery minnow, plains minnow, and Iowa darter. In contrast, the observed range of plains topminnow has expanded. Species with minimal changes in distribution over the last decade include: pearl dace, hornyhead chub, suckermouth minnow, finescale dace, and orangethroat darter. Changes in the distribution of these rare fishes can be attributed to habitat degradation, introduced species, range expansions, and in the case of goldeye, variable sampling efficiency.

Goldeye

While Patton (1997) found goldeye distributions had increased since the 1960s, we observed a decreasing distribution trend for this species. We expected to collect goldeye in the Little Powder and Little Missouri drainages based on the findings of Baxter and Simon (1970) and Patton (1997). However, it is possible that putative declines are artifacts of ineffective sampling. We used seining to capture fish in the Little Powder and Little Missouri drainages and others have found this method to be ineffective at capturing goldeye (Hoagstrom et al. 2006a, WGFD 2007). In addition, adult goldeye are thought only to enter the Little Powder and Little Missouri rivers in Wyoming for spawning (Barrineau et al. 2007). These watersheds were sampled in late-July and August, after goldeye had likely completed spawning migrations (Pflieger 1997). Given the need to sample many species across multiple drainages, sampling efforts were not tailored around the unique life-history characteristics of goldeye. As a result, observed declines may be related to the sampling gear used and timing of the survey.

Western Silvery Minnow

Since the 1960s, Patton (1997) reported that western silvery minnow distributions had declined. Our survey results point to further distributional declines for this species. Patton (1997) sampled western silvery minnow from both the Little Missouri and Little Powder River drainages. We sampled the species from the Little Missouri River drainage alone. Declines in western silvery minnow in eastern Wyoming prairie streams can be attributed to changes in habitat conditions, introductions of non-native, piscivorous fishes, and natural drought cycles (Quist et al. 2004, Hoagstrom et al. 2006a, Bear and Barrineau 2007). Western silvery minnow are often found in the backwaters and pools of large prairie rivers (Baxter and Stone 1995, Pflieger 1997). This species is associated with silt and sand substrates and is tolerant of high turbidity (Baxter and Stone

1995, Pflieger 1997). Impoundments and reservoirs on prairie streams have altered river morphology, thus have affected water depth, substrate, and turbidity levels (Patton and Hubert 1993, Quist et al. 2004). Additionally, presence of introduced, piscivorous fishes in these reservoirs is inversely related to native fish abundances, suggesting the potential for predation and competition to reshape native fish assemblages (Quist et al. 2004, Hoagstrom et al. 2006b). Compounding these factors, recent drought conditions have likely exacerbated the apparent range constriction of the western silvery minnow (Hoagstrom et al. 2006a).

Plains Minnow

Patton (1997) indicated that plains minnow had declined since the 1960s and our findings suggest that this trend is continuing. Patton (1997) sampled plains minnow from the Cheyenne and Little Powder River drainages. However, we were only able to sample the species from the Cheyenne River drainage. Similar to the western silvery minnow, plains minnow is associated with slow water, pool habitats in turbid streams (Baxter and Stone 1995, Pflieger 1997, Hoagstrom et al. 2006a). Given the two species' overlap in habitat, the mechanisms driving plains minnow declines are likely the same as those which have caused range reductions in western silvery minnow (Hoagstrom et al. 2006b).

Pearl Dace

Currently, the distribution of pearl dace in Wyoming is stable. Pearl dace were documented in the Niobrara River drainage both in our survey and by Patton (1997). This species is commonly found in clear, cool streams (Baxter and Simon 1995). Habitat in the Niobrara River consists of clear, deep-pools with an abundance of aquatic vegetation (Bear and Barrineau 2007). If current habitat conditions persist throughout this watershed, the Niobrara River will likely remain a stronghold for pearl dace in Wyoming.

However, several potential threats to pearl dace persistence exist. If aquifer recharge requirements are not factored into current water withdrawal practices, available habitat for Niobrara River pearl dace may be limited in the future (Cunningham 2006). Another potential threat to pearl dace in the Niobrara River is the introduction of non-native piscivores (Weitzel 2002a, Cunningham 2006). While we did not collect any non-native piscivores from the Niobrara River drainage during our survey, brown trout (*Salmo trutta*) and green sunfish (*Lepomis cyanellus*) have been documented in the past (Mueller and Rockett 1966, Baxter and Simon 1970).

Hornyhead Chub

Patton (1997) found that hornyhead chub distributions had declined since the 1960s. Our survey indicates that no

further declines have occurred since the 1960s and that the species is stable. We collected hornyhead chub from two locations in the North Platte River drainage not previously sampled by Patton (1997). Hornyhead chub are found in clear, small streams with persistent flow and coarse substrate (Pflieger 1997, Weitzel 2002b, Bear and Barrineau 2007). Preferred streams throughout the species' Wyoming range are influenced primarily by water development activities including local and transbasin diversions, reservoir construction, and groundwater withdrawals (Bear and Barrineau 2007). These activities likely threaten the persistence of hornyhead chub throughout the North Platte River drainage by fragmenting habitats and creating physical barriers to movement (Miller et al. 2005).

Suckermouth minnow

Although sampled, changes in distribution of suckermouth minnow in the North Platte River drainage were not assessed by Patton (1997) due to differences between his and the previous (Baxter and Simon 1970) survey. Like Patton (1997), we also documented suckermouth minnow in Horse Creek, a tributary to the North Platte River. While the number of individuals collected was low compared to other rare species, suckermouth minnow appears stable throughout the North Platte River drainage. Suckermouth minnow prefer clear streams with riffle habitats and substrates composed of sand, gravel, or rubble (Baxter and Stone 1995). Future persistence of suckermouth minnow in the North Platte drainage may be limited by water development and introductions of non-native piscivores (Quist et al. 2003). Many small impoundments and diversion structures occur along Horse Creek. Water development activities such as these impede movements of suckermouth minnow and reduce available habitat through periodic stream channel dewatering. Additionally, introduced piscivores, including green sunfish, yellow perch (*Perca flavescens*), and largemouth bass (*Micropterus salmoides*) have been collected from Horse Creek in reaches not occupied by suckermouth minnow (Quist et al. 2003).

Finescale Dace

Patton's (1997) surveys documented declines in finescale dace. However, our findings do not support these trends. Although few individuals were collected, our survey suggests that the species is stable throughout the Niobrara River drainage. Finescale dace inhabit small, cool, spring-fed streams with aquatic vegetation (Baxter and Stone 1995, Stasiak and Cunningham 2006). If current habitat conditions continue, the Niobrara River should remain an important stronghold in the persistence of finescale dace in Wyoming. However, as with pearl dace, the introduction of non-native piscivores is a potential threat (Weitzel 2002a, Stasiak and Cunningham 2006).

Plains topminnow

Patton (1997) found that plains topminnow distributions had declined since the 1960s. Based on our survey, its distribution has remained stable over the last decade in the Niobrara, North Platte, and South Platte drainages. However, we believe the species has expanded its range within the Cheyenne River drainage. While we found plains topminnow to be widely distributed throughout the Cheyenne drainage, Patton (1997) collected no individuals from this area. Previous to Patton's (1997) sampling, Baxter and Simon (1970) found the species at one site in the watershed and suggested that it was likely introduced. Plains topminnows have been incidentally released when stocking waters with non-native warmwater game species in the past (Simon 1946).

Habitat degradation and competition with nonnative species likely limit plains topminnow distribution within its native range. Plains topminnows inhabit pool habitats in clear streams with aquatic vegetation (Baxter and Stone 1995, Pflieger 1997). Many of the stream systems the species occupies in Wyoming are influenced by natural and anthropogenic dewatering (Weitzel 2002a). For instance, several of the streams within the Cheyenne River drainage follow natural cycles of periodic intermittency (Barrineau et al. 2007), while streams within the North Platte River drainage have intermittent reaches due to irrigation water withdrawals (Bear and Barrineau 2007). Stream dewatering limits the amount of available pool habitat for plains topminnow (Weitzel 2002a). Additionally, introductions of western mosquitofish (*Gambusia affinis*) have been implicated in restricted distributions of plains topminnow in Nebraska and also may be affecting Wyoming populations (Rahel and Thel 2004).

Iowa Darter

Patton (1997) found that Iowa darter distributions had been stable since the 1960s. Based on our survey, Iowa darter distributions appear to have declined in the North Platte River drainage, but remain stable in the Niobrara and South Platte drainages. Iowa darters are found in clear, cool streams with aquatic vegetation (Baxter and Stone 1995). Declines in this species can be attributed to habitat degradation and interspecific competition (Baxter and Stone 1995). Increasing turbidities have degraded Iowa darter habitat and may have contributed to range retractions in Wyoming. Range expansions of Johnny darter (*E. nigrum*) are implicated in Iowa darter declines. Increases in spatial overlap between the two darter species may result in greater competition for resources and consequently may contribute to localized reductions in native darter abundances (Baxter and Stone 1995).

Orangethroat Darter

As with suckermouth minnow, changes in distribution of orangethroat darter in the South Platte drainage were not assessed by Patton (1997). Nevertheless, our results are consistent with previous findings by Patton (1997), indicating that orangethroat darter continue to persist in Lodgepole Creek, a tributary to the South Platte River. We found no evidence for distributional changes in orangethroat darter; the species appears to be stable. Orangethroat darter are typically associated with small, clear streams with sand or gravel substrates (Baxter and Stone 1995, Pflieger 1997). Habitat in the tributary stream where orangethroat darter were collected consisted of clear pools with abundant aquatic vegetation. Drought and habitat degradation associated with water withdrawals and land use practices are threats to the persistence of orangethroat darter in the South Platte watershed (Weitzel 2002b).

MANAGEMENT IMPLICATIONS

Our survey has increased the knowledge of the current distribution of rare fishes in eastern Wyoming prairie streams. In light of current rare species' distribution information, streams previously identified as high conservation priorities for native Wyoming fishes should remain as such. Implementing conservation efforts and monitoring programs for rare fishes in eastern Wyoming prairie streams is warranted. Additionally, sampling methods to target large-bodied, migratory fishes, such as drifting trammel nets to capture goldeye should be incorporated with other sampling techniques to monitor prairie stream assemblages (WGFD 2007).

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Diets of Nesting Swainson's Hawks in Relation to Land Cover in Northwestern North Dakota

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ABSTRACT Relationships between land use practices and types of prey used by Swainson's hawks (*Buteo swainsoni*) in the Northern Great Plains is of increasing interest as the quantity and quality of habitat in the region declines. I recorded 1,284 prey items at 18 Swainson's hawk nesting areas throughout northwestern North Dakota during summer 1986–1987. After correcting for detectability biases and food needs of adults, I estimated (90% CI) 2,087–2,859 total prey individuals and 138.3–206.7 kg of prey biomass (\bar{X} = 69.8 g/item) were consumed by adult and nestling Swainson's hawks during my study. Major prey (>10% overall frequency or biomass) were small (<50 g) rodents, ground squirrels (*Spermophilus* spp.), juvenile ducks (Anatinae), juvenile galliforms, and amphibians. Wetland-dependent species composed nearly 50% of all identified prey items based on frequency and biomass though wetlands averaged only 18% of land cover in Swainson's hawk nesting areas (i.e., within 1 km of nests). Compared to previous studies in the region, I documented a greater diversity of prey items, with a lower proportion of Richardson's ground squirrels (*S. richardsonii*) and higher proportions of small rodents, avian prey, and amphibians. Relationships between land cover in Swainson's hawk nesting areas and composition of prey items used by nesting pairs indicated that fragments of grazed prairie, hayland, and especially wetland may enhance future conservation efforts for the hawk in intensively farmed landscapes throughout the Northern Great Plains.

KEY WORDS *Buteo swainsoni*, diet, habitat, land use, North Dakota, Northern Great Plains, predator-prey relationships, wetlands

Swainson's hawks (*Buteo swainsoni*) nest mainly throughout the midcontinent prairies and western intermountain grasslands of North America (England et al. 1997). In the Northern Great Plains, distribution of nesting pairs of Swainson's hawks is related mainly to extent of cultivated land. In southeastern Alberta, for example, Swainson's hawks nested most often where cropland for grain production covered a low (11–30%) proportion of the landscape or, to a lesser degree, a high (71–90%) proportion (Schmutz 1984, 1987). Nesting by the species in southeastern Saskatchewan followed a similar bimodal pattern (Groskorth 1995). In southcentral North Dakota, cropland composed less than one-fourth of the land cover within 1 km of Swainson's hawk nests (Gilmer and Stewart 1984).

Knowledge of Swainson's hawk diets remains fundamental to their management and conservation (Giovanni et al. 2007). Influences of land use practices and vegetation conditions on nesting and reproductive success of Swainson's hawks in the Northern Great Plains are of increasing interest as the quantity and quality of habitat in the region declines for this and many other species of grassland birds (Houston and Schmutz 1999, Schmutz et al. 2001, Higgins et al. 2002). Aside from impacts on nest site availability, mechanisms by which rural land use and landscape composition influence types and availability of prey and, ultimately, the reproductive success of Swainson's hawks nesting in the region are poorly understood. Schmutz

(1987) hypothesized the hawk shifted from its main prey, Richardson's ground squirrel (*Spermophilus richardsonii*), to mice and voles (species unspecified) as landscapes changed from grassland to cropland. Schmutz et al. (2001) also hypothesized that Swainson's hawks may broaden their diets in years when Richardson's ground squirrels are scarce. However, published reports of diets of nesting Swainson's hawks in the Northern Great Plains do not address variation in use of prey types among nesting pairs. Such knowledge could elucidate relationships between land cover composition and Swainson's hawk occurrence and reproductive success, and advance its conservation. My primary objective was to assess the relationship between composition of summer diets of the Swainson's hawk and that of land cover surrounding its nest sites in a varied landscape in the Northern Great Plains. My secondary objective was to compare and contrast diversity of Swainson's hawk diets in northwestern North Dakota with diets of Swainson's hawks nesting elsewhere in the region.

STUDY AREA

I studied diets of nesting Swainson's hawks during mid-June to early August 1986–1987 on Lucy Township (93 km²; about 48°40'N;102°35'W) in Burke County, northwestern North Dakota, and on adjoining area of similar land use up to 10 km north, south, and east of the township. The study area was within the Missouri Coteau, a rolling to

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hilly moraine. Annual precipitation was 46 cm in 1986 and 31 cm in 1987 compared to a 42-cm average, and water levels in local wetlands were average and below average in respective years (Murphy 1993:155). Land use was dryland grain farming and cattle ranching. Land cover composition was 41% native (*Stipa-Agropyron*) prairie (approximately 50% grazed heavily by domestic livestock and 50% grazed lightly or idle) with scattered tall shrubs especially hawthorn (*Crataegus* spp.) and chokecherry (*Prunus virginiana*); 31% cropland, a third of which annually was fallow; 19% seasonal, semi-permanent, and permanent wetlands (classification per Cowardin et al. 1979); 5% tame hay; 2% small (< 1 ha), scattered patches of quaking aspen (*Populus tremuloides*) trees, and 2% roads, farmsteads, and tree shelterbelts (Murphy 1993:109). The area was sparsely inhabited by humans (10 farmsteads/100 km²). Common species of nesting raptors were red-tailed hawk (*B. jamaicensis*), Swainson's hawk, northern harrier (*Circus cyaneus*), and great horned owl (*Bubo virginianus*; Murphy 1993:111).

METHODS

Data Collection and Interpretation

Each spring I systematically searched the study area and located occupied nests of Swainson's hawks; nearly all were in aspen trees. I visited nests daily to record fresh (i.e., edible) prey items when nestlings were 1–3.5 weeks old. Visits lasted 5–10 min and nest trees were left undisturbed by viewing prey through a mirror on an extendable pole or by using mountaineer's ascenders on fixed ropes to quickly reach tops of nearby trees and look into nests, often with binoculars. When nestling hawks were about 3.5 weeks old, I used falconry jesses and swivels to tether them on platforms 1.5 m above ground in sites sheltered from wind and sun, 0–8 m from nest trees, following published guidelines (Petersen and Keir 1976). My research activities were conducted under the auspices of U.S. Fish and Wildlife Service Master-station banding permit number 5890 and a special purpose salvage permit issued by North Dakota Game and Fish Department to national wildlife refuges in North Dakota; permits for animal care and use in research were unavailable and not required at the time of this work. I visited each tether platform daily for 2.5–3 weeks, weighed all hawks each day to ensure they were maintaining or gaining mass, then released young hawks when they reached fledging age. At each visit, I identified every fresh prey item, marked it by cutting off a foot and subsequently left it on the platform, and identified and removed all discarded (inedible) remains. I avoided duplicating my count of any prey item by conservatively choosing the lowest number of items represented by discarded remains and fresh items, including fresh items noted at the previous visit (Craighead and Craighead 1956). I excluded regurgitated pellets from my analysis after finding they added negligibly to quantity

of prey used (7.1% increase for small [<50 g] rodents; none for other vertebrate species).

I assessed efficacy of using discarded remains and fresh items to reveal prey delivered by adult Swainson's hawks at 25% of tether platforms by using direct observation from 1 × 2 × 1.5-m blinds placed 4–8 m away. I stratified the sample based on the number of nestlings, however, the sample was not entirely random because I omitted from consideration 2 sites that were devoid of shrubs to conceal blinds. During my daily visit to a given platform at midday, an assistant entered the blind to observe until approximately 15 min after sunset then returned to the blind just before dawn the next day and remained until my midday visit. Two consecutive half-days of platform observation comprised a period of approximately 15 hr for comparing numbers of prey delivered by adult hawks to those revealed by fresh items and discarded remains on the platform. I used these results to correct data from all platforms for detectability biases.

I report overall dietary makeup in terms of relative (percentage) frequency and biomass. After correcting for detectability bias, I calculated percentage frequency by dividing the number of individuals in each prey species category by the total number of prey items. I estimated percentage biomass by multiplying the number of individuals of each prey category by their respective mean mass, then dividing the subtotal of each prey category by the total prey mass (Marti et al. 2007). For each prey category composing more than 1% frequency of prey pooled from all hawk tether platforms, I estimated the mean biomass (g) of prey killed daily by each nesting pair of Swainson's hawks and defined this as daily biomass consumption rate (DBC). I estimated DBC by multiplying the percentage biomass of each prey category by daily food needs of adults and young combined (Craighead and Craighead 1956:312). I assumed that composition of prey consumed by adults resembled that delivered to their tethered young, and each adult and young Swainson's hawk required a mean of 150 g of prey daily (Craighead and Craighead 1956, Kirkley and Gessaman 1990). My assumption of similar diets was supported by observations from blinds of partially consumed prey delivered by adults. Last, I assumed biomass of prey killed by adult Swainson's hawks approximated that consumed by adults and young.

I assigned mass values to prey from specimens collected from my study area and published literature (Jones et al. 1983, Dunning 1984). I assigned mass values to juvenile prey relative to those of adults of same species: (1) large juvenile (adult mass × 0.75), (2) two-thirds grown (× 0.66), and (3) one-half grown (× 0.5). For prey of undetermined age, I assigned the mean mass of conspecific or congeneric prey for which age could be determined. I estimated mass values of undetermined species of juvenile duck (Anatinae) prey by comparing tarsus lengths to a composite curve of tarsus length versus mass for small, medium, and large species of ducks common on my study area (Murphy

1993:196). I assigned each invertebrate prey (all Orthoptera) a mass of 1 g.

Land Cover Measurements

I defined nesting area as the land within 1 km of a Swainson's hawk nest; 1 km was approximately 50% of the mean distance between Swainson's hawk nests on my study area and in most studies reviewed by England et al. (1997). I classified land cover within each nesting area using 8 categories: aspen tree patch, seasonal wetland, semi-permanent wetland, cropland, hayland (tame hay), grazed native prairie (moderate to heavy annual grazing), idle prairie (infrequent or light grazing to no grazing), or miscellaneous (farmstead, road right-of-way; Murphy 1997). I measured area (ha) of each land cover type using aerial photographs (1:15,840). Within every nesting area I also measured area of each land cover type within 100 m of a tall (>6 m high) perch because Swainson's hawks sometimes hunt from elevated perches (Janes 1984). I also measured distance (m) from a given nest to nearest seasonal wetland, semi-permanent wetland, cropland, hayland, grazed prairie, idle prairie, and to the next nearest aspen patch (hereafter referred to as e.g., distance or proximity to cropland).

Statistical Analyses

I assessed relationships between Swainson's hawk diets and land cover using ANOVA (Sokal and Rohlf 1981). I tested frequency and biomass data for normality and homogeneity of variances using the Kolmogorov-Smirnov and F -tests in BMDP statistical software (Dixon 1992). I used multivariate ANOVA to test for between-year differences in frequency proportions of prey used by Swainson's hawks. I used linear regression models (Neter et al. 1985) to explore variation in DBC of important prey categories among Swainson's hawk families. I used biomass in this analysis because it may better convey relative importance of prey to raptors than frequency of occurrence (Marti et al. 2007). To maintain independence, I randomly omitted 1 season's data for each of 2 nesting areas monitored in 1986 and 1987. I used an index of the local abundance of meadow voles (Murphy 1993) as an independent variable to account for a possible year effect. Number of tethered young also was included as an independent variable. I used the stepwise regression procedure in BMDP (Dixon 1992) with DBC of prey as the dependent variable to select 5 to 8 biologically meaningful independent variables then explored all possible 2- and 3-variable models to find the most parsimonious (Neter et al. 1985). Additionally, I log transformed all independent variables not normally distributed. I referenced correlation matrices to avoid multicollinearity among independent variables and examined residual plots to meet an assumption

of homogeneity of variance (Neter et al. 1985). To convey the relative importance and validity of independent variables in each model, I reported standardized regression coefficients and associated P -values (probability of t in a reduced model test for coefficient; Neter et al. 1985). Throughout, I conveyed exact probability levels for test results where $P > 0.001$ and considered $P < 0.1$ to indicate statistical significance.

RESULTS

Detectability Corrections

I obtained 15 observation periods from 4 tether platforms, during which 141 prey were delivered ($\bar{X} \pm SD = 0.66 \pm 0.33$ items/hr; Table 1). Differences in handling by tethered young of 2 prey types led to a contrast in detectability between types. Excluding avian prey, I detected 43% of small (<50 g) prey items delivered to platforms (Table 1). Young Swainson's hawks swallowed these prey items whole or otherwise consumed them entirely, leaving minimal discarded remains. This low detectability (LD) group included meadow voles, deer mice, tiger salamanders, and northern leopard frogs, and comprised 91% of prey delivered to platforms during observations. In contrast, I detected 79% of birds and large (≥ 50 g) mammals (Table 1). Juvenile passeriforms, juvenile ducks, Richardson's ground squirrels, and thirteen-lined ground squirrels comprised this high detectability (HD) group. Based on mean detectability of LD prey and HD prey, I used correction factors of $1/0.43 = 2.3$ for LD prey and $1/0.79 = 1.3$ for HD prey.

Generalized Diet of Swainson's Hawks

During July through mid-August 1986 and 1987, I recorded 1,284 prey items (fresh and discarded remains) at 20 Swainson's hawk tether platforms (10 platform sites each year). Eighteen nesting areas were represented in this sample; 2 nesting areas were sampled both years. I tethered 29 young on platforms ($\bar{X} = 1.5$ and 1.4 in 1986 and 1987, range = 1–3 young/platform each year), 1 of which was killed by a raccoon (*Procyon lotor*) despite erecting metal guards to deter mammalian predators, and another was killed by a great horned owl. After correcting for detectability and food needs of adults, food items I recorded at daily visits to tether platforms represented 2,087–2,859 (90% CI) total prey individuals and 138.3–206.7 kg of prey biomass consumed by Swainson's hawk families. Mean prey mass was 69.8 g. I detected no overall year effect in prey use by Swainson's hawks ($F_{1,17} = 1.14$, $P = 0.42$), although numbers of meadow voles killed daily by hawk pairs seemed greater in 1987 (3.6 ± 1.5) than in 1986 (1.5 ± 1.1).

Table 1. Numbers of low detectability (LD) and high detectability (HD) prey items noted during daily visits to 4 Swainson's hawk nest sites at which juvenile hawks were placed on tether platforms to determine diet composition. Numbers of prey represented by fresh and discarded remains noted on platforms are compared with total numbers of prey delivered by adult hawks, based on direct observation from blinds.

Site	Young	Observation periods (hr)	LD ^a items		HD ^b items	
			Detected/delivered	Detected (%)	Detected/delivered	Detected ^d (%)
A	2	3 (41.5)	24/45	53.3	0/0	
B	3	5 (73.5)	19/43	44.2	5/5	
C	1	3 (40.3)	6/18	33.3	0/1	
D	2	4 (59.0)	9/21	42.9	6/8	
Total		15 (214.3)	58/127	43.4 ± 8.2 ^c	11/14	78.6

^a Low detectability items included meadow vole, deer mouse (*Peromyscus maniculatus*), tiger salamander (*Ambystoma tigrinum*), and northern leopard frog (*Rana pipiens*); ^b High detectability items included juvenile passeriforms, juvenile ducks, Richardson's ground squirrel, and thirteen-lined ground squirrel (*S. tridecemlineatus*); ^c $\bar{X} \pm SD$; ^d Number of HD items from individual sites insufficient to warrant percentage breakdown and variance estimate; overall percentage for HD items based on total derived from all sites.

Major prey (>10% frequency or biomass) were Richardson's and thirteen-lined ground squirrels, small rodents (nearly all of which were meadow voles and deer mice), juvenile ducks, juvenile galliforms (sharp-tailed grouse [*Tympanuchus phasianellus*] and gray partridge [*Perdix perdix*]), and amphibians (tiger salamander and northern leopard frog). Mammals and birds dominated dietary biomass of Swainson's hawks (55% and 36%) and mammals were the most frequently delivered prey (Table 2). Richardson's ground squirrel contributed 18.2% of dietary biomass, more than any other single species. Overall, 49% frequency and 42% biomass of prey items represented species associated directly with wetlands (muskrat [*Ondatra zibethicus*], American coot, [*Fulica americana*], sora [*Porzana carolina*], juvenile ducks, wetland-dwelling species of shorebirds, yellow-headed blackbird [*Xanthocephalus xanthocephalus*], red-winged blackbird [*Aegialius phoeniceus*], and amphibians), even though wetlands averaged only 18.1% (SD = 5.2%) of land cover within nesting areas. Amphibians were detected at all but 1 tether platform (Table 2). Tiger salamanders comprised 77% frequency and 86% biomass of this prey type.

I noted 207 fresh prey at visits to 27 Swainson's hawk nests during mid-June through early July, 1986 and 1987. Compared to data from tether platforms, frequency of occurrence of major groups of prey based on nest visits suggested greater use of ground squirrels (6.5% at platforms and 20.8% at nest visits) and birds (12.8% and 29.4%) and

less use of small rodents (63.3% and 48.8%). Amphibians composed 15.3% of prey at tether platforms but I did not detect them among fresh prey at nests.

Variation in Diet among Hawk Families

Composition of land cover and prey items varied among individual nesting areas (Fig. 1, Fig. 2). I did not detect each major prey species or species group at 1 to 5 nesting areas except for voles and mice (Table 2), which comprised >50% of all prey delivered at each of 13 (72%) nesting areas. Richardson's and thirteen-lined ground squirrels were primary ground squirrel prey (Fig. 2). Two models with 2 and 3 variables, respectively, explained approximately 50% of the variation in DBC of Richardson's ground squirrels among Swainson's hawk nesting areas (Table 3). Both models indicated greater use of Richardson's ground squirrels when nests were closer to grazed prairie and, to a lesser extent, with increased cropland area within 100 m of hunting perches. Best supported models for DBC of meadow voles (Table 3) suggested Swainson's hawks preyed more on voles as area covered by hayland increased and area covered by semi-permanent wetland decreased. A contrast in local abundance of voles between 1986 and 1987 (0.1 and 12.4 captures per 100 trap-nights; Murphy 1993) and idle prairie near perches also helped explain variation in use of this prey (Table 3).

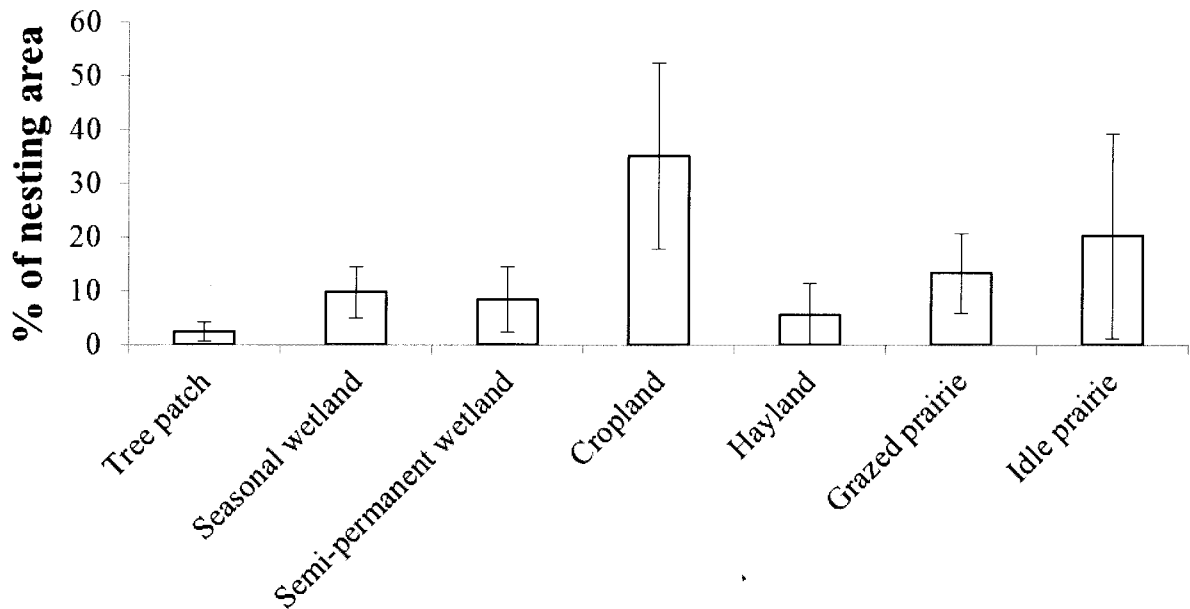


Figure 1. Variation (± 1 SD) in land cover within 1 km of Swainson’s hawk nests during summer 1986 and 1987 in northwestern North Dakota. Data are from 18 nesting areas; nests examined 1 year are exclusive (>2 km from) of those in the other year.

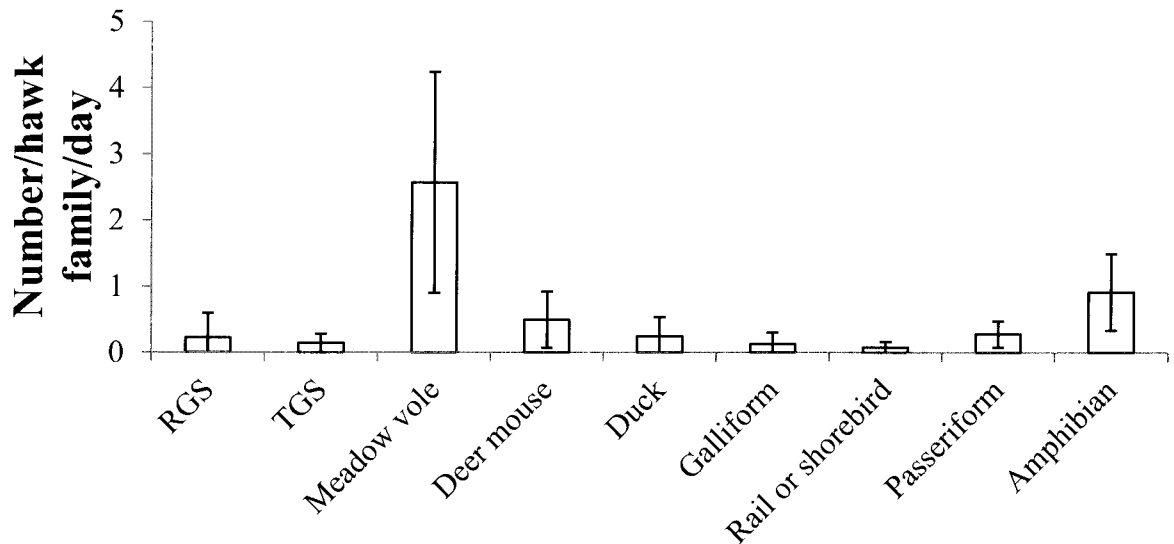


Figure 2. Variation (± 1 SD) in estimated mean daily intake of numbers of prey among Swainson’s hawk nests, i.e., families, during summer 1986 and 1987 in northwestern North Dakota. Excludes prey species or prey species groups that composed less than 1% of dietary composition by frequency. Data are from 18 nesting areas; nests examined 1 year are exclusive (>2 km from) of those in the other year. RGS = Richardson’s ground squirrel and TGS = thirteen-lined ground squirrel.

Several 2- and 3-variable models explained most (65–69%) of the variation in DBC of juvenile ducks among Swainson’s hawk nesting areas. Hawks preyed on ducks in proportion to amount (ha) or proximity of brood-rearing habitat (e.g., seasonal or semi-permanent wetland cover) surrounding hawk nests (Table 3). Models also suggested predation on ducks increased with greater area of wetland near tall perches and with area of idle prairie, and decreased in a year with elevated vole abundance. Nearly all (97.5%)

duck remains were of juveniles, most less than 2.5 weeks old; 2 female blue-winged teal (*Anas discors*) were the only adult ducks represented. I estimate Swainson’s hawk pairs preyed on about 2.6 and 1.5 juvenile ducks/week/nesting area in 1986 and 1987. Adjusting for local Swainson’s hawk breeding density (7.5 occupied nests/100 km²), this translates to a predation loss of 0.1–0.2 juvenile ducks/week/km².

Table 2. Percentage composition of prey used by nesting Swainson's Hawks in northwestern North Dakota during summer 1986–1987, based on prey items pooled from all hawk families^a.

Prey category	Frequency		Biomass		% nesting areas where recorded ^e
	<i>n</i> ^b	%	kg ^b	%	
Mammals					
White-tailed jackrabbit ^c	12	0.5	7	4.1	33.3
Ground squirrel ^d	160	6.5	42.1	24.4	88.9
Vole and mouse ^e	1566	63.3	44	25.5	100
Miscellaneous ^f	8	0.3	1.5	0.9	
Subtotal		70.6		54.9	
Birds					
Duck ^g	103	4.2	27.3	15.8	88.9
Galliform ^h	57	2.3	20.5	11.9	38.9
Rail and shorebird ⁱ	30	1.2	7.9	4.6	38.9
Passeriform ^j	122	4.9	5	2.9	88.9
Miscellaneous ^k	5	0.2	0.9	0.5	
Subtotal		12.8		35.7	
Amphibians ^l	378	15.3	15.4	8.9	94.4
Reptiles ^m	12	0.5	0.9	0.5	16.6
Insects ⁿ	20	0.8	<0.1	<0.1	22.2
Total	2473	100	172.5	100	

^a Ten nesting areas monitored in 1986 and 1987, 2 of the nesting areas were monitored both years; ^b Sample and biomass are point estimates based on corrections for size-related biases; ^c *Lepus townsendii*; ^d Richardson's, thirteen-lined, and Franklin's (*S. franklinii*) ground squirrels; ^e Meadow and southern red-backed voles (*Clethrionomys gapperi*), deer, western or meadow jumping (*Zapus* spp.), and olive-backed pocket mice (*Perognathus fasciatus*); ^f Muskrat, Norway rat (*Rattus norvegicus*), short-tailed shrew (*Blarina brevicauda*), least weasel (*Mustela nivalis*); ^g Mallard, northern pintail (*A. acuta*), blue-winged teal, American wigeon (*A. americana*), lesser scaup (*Aythya affinis*), unknown duck species; ^h Sharp-tailed grouse, gray partridge; ⁱ American coot, sora, killdeer (*Charadrius vociferus*), lesser yellowlegs (*Tringa flavipes*), upland sandpiper (*Bartramia longicauda*), willet (*Catoptrophorus semipalmatus*), marbled godwit (*Limosa fedoa*); ^j Eastern (*Tyrannus tyrannus*) and western kingbird (*T. verticalis*), horned lark (*Eremophila alpestris*), tree swallow (*Tachycineta bicolor*), black-billed magpie (*Pica pica*), Sprague's pipit (*Anthus spragueii*), vesper (*Pooecetes gramineus*), Savannah (*Passerculus sandwichensis*) and unknown sparrows (Emberizinae), red-winged blackbird, western meadowlark (*Sturnella neglecta*), yellow-headed blackbird, Brewer's blackbird (*Euphagus cyanocephalus*), common grackle (*Quiscalus quiscula*), brown-headed cowbird (*Molothrus ater*), unknown blackbird (Icterinae); ^k Mourning dove (*Zenaida macroura*), short-eared owl (*Asio flammeus*), yellow-shafted flicker (*Colaptes auratus*); ^l Tiger salamander, northern leopard frog; ^m Plains garter snake (*Thamnophis radix*), smooth green snake (*Opheodrys vernalis*); ⁿ Grasshopper (Orthoptera: Oedipodinae).

Table 3. Most parsimonious linear regression models that best explain variation in daily biomass consumption (g/day) of major prey items by nesting Swainson's hawks in northwestern North Dakota, summer 1986 and 1987.

Model and independent variables ^a	Coefficient		Model fit		
	β	P^b	R^2	F	P
RGS I			0.425	5.55	0.016
Distance to grazed prairie	-0.48	0.027			
Cropland near perches	0.37	0.080			
RGS II			0.556	5.85	0.008
Distance to grazed prairie	-0.52	0.012			
Distance to hayland	0.37	0.062			
Cropland near perches ^c	0.32	0.100			
Vole I			0.466	6.55	0.009
Year (vole abundance)	0.54	0.013			
Idle prairie near perches	0.48	0.022			
Vole II			0.569	6.17	0.007
% semi-permanent wetland	-0.55	0.012			
% hayland	0.55	0.011			
Idle prairie near perches	0.39	0.053			
Duck I ^e			0.686	10.21	0.001
% semi-permanent wetland	0.83	0.001			
% idle prairie (log transformed)	0.38	0.027			
Distance to seasonal wetland	-0.34	0.045			
Duck II			0.651	8.72	0.002
% semi-permanent wetland	0.93	<0.001			
Seasonal wetland near perches ^d	0.48	0.031			
Year (vole abundance)	-0.34	0.058			

^a RGS = Richardson's ground squirrels; ^b Probability of t in reduced model test for coefficient; ^c Total area (ha) within 1 km of nest that was ≤ 100 m from any perch > 6 m tall (e.g., utility poles, trees); ^d Year effect: 1986 and 1987 vole abundance index, 0.1 and 12.4 captures/100 trap-nights (Murphy 1993); ^e Approximately 98% of duck prey were juveniles ≤ 6 weeks old.

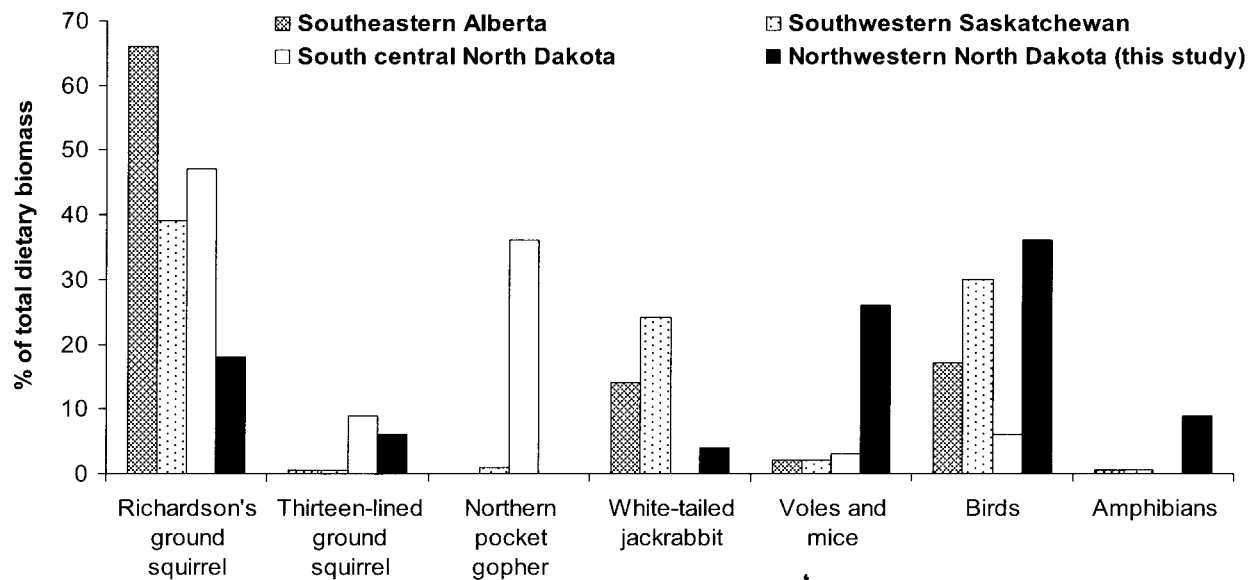


Figure 3. Percentage composition of diets of nesting Swainson's hawks in 4 areas of the Northern Great Plains in terms of biomass of major categories of prey (e.g., excludes prey groups that comprised <1% frequency in all studies). Biomass percentages for southeastern Alberta and southeastern Saskatchewan are approximated from 1983–1996 data presented in Appendix 1 of Schmutz et al. (2001) and those for south central North Dakota are from Gilmer and Stewart (1984). Data for these 3 areas were collected by noting prey items in nests. Percentages for northwestern North Dakota (this study) are based on items observed at tether platforms corrected for detectability biases via direct observation.

DISCUSSION

Tethering of Young

For several decades, which include this study, large nestling raptors sometimes were tethered on the ground (Craighead and Craighead 1956) or on raised platforms (Peterson and Keir 1976) beneath nests often beyond the normal fledging period, so prey delivered to them by adults could be recorded. When tethered, however, young raptors could be more vulnerable to predators, be fed or protected less by adults, or exhibit delayed physical and behavioral development (Marti et al. 2007). Depredation of 2 young Swainson's hawks on tether platforms in this study may have been less likely had they been in their respective nests. Except in unusual circumstances, use of tether platforms is no longer warranted with recent advances in videography for study of raptor diets (Giovanni et al. 2006, Marti et al. 2007) and may be considered unacceptable by modern institutional animal care and use committees.

Relationships Between Land Cover and Diet

Variation in avian diets is of greater ecological interest than what the average bird eats (Wiens 1989). My models performed well in predicting influences of land cover attributes on Swainson's hawk use of species with specialized habitat needs (e.g., juvenile ducks versus ha of semi-permanent wetland). The extent that Richardson's

ground squirrels occur in Swainson's hawk diets was explained in my models mostly by proximity to grazed prairie, the preferred habitat of this rodent (Jones et al. 1983). Richardson's ground squirrels also use annually tilled cropland; my models suggested vulnerability of the ground squirrel to Swainson's hawk predation increases when it inhabits growing grain near elevated perches. Swainson's hawks generally underuse croplands until harvest (Bechard 1982), but might exploit rodents in croplands earlier when suitable hunting perches are present.

Use of meadow voles by Swainson's hawks related directly to spatial extent of hayfield within nesting areas, which likely related to altered vulnerability of voles during cutting of hay in midsummer. Swainson's hawks characteristically catch prey flushed by hay-harvesters and other farm machinery (Schmutz 1987, England et al. 1997), and such vegetation disturbance may be an important aspect of the hawk's foraging and evolutionary ecology (Bechard 1982, Janes 1985, Murphy and Smith 2007). Additionally, Swainson's hawks may have used voles less as wetland cover in nesting areas increased, in part because wetland-associated prey items (such as juvenile ducks and amphibians) were readily available.

Use of juvenile ducks by Swainson's hawks related mostly to extent of semi-permanent wetlands within nesting areas. Other land cover variables such as percentage cropland or hayland could be important because, even if relatively few juvenile ducks occurred, they may have been particularly vulnerable in these habitats. This hypothesis

was not supported by my models, although juvenile ducks (e.g., their brood hens) may have avoided these areas. In 1987, all seasonal wetlands and small (<1 ha) semi-permanent wetlands were dry by late July. This likely triggered extensive overland movement by duck broods, making them more vulnerable to predation and other causes of mortality (Rotella and Ratti 1992). The role of raptors in mortality of nesting ducks and their young in the northern Great Plains is poorly understood (Sargeant and Raveling 1992). This study occurred during the nesting season in good waterfowl habitat, yet Swainson's hawks preyed on relatively few juvenile ducks/km² and rarely preyed on adult ducks.

Comparison to Swainson's Hawks Elsewhere

My data indicate diets of Swainson's hawks in northwestern North Dakota are more diverse and include a greater proportion of wetland-dependent prey species than reported elsewhere in the Northern Great Plains. I found biomass contributed by small rodents and amphibians more important and biomass by Richardson's ground squirrel less important than previous researchers in the region (Fig. 3). Avian prey also were more important to Swainson's hawks I studied. However, I assessed Swainson's hawk diets during what likely was a period of low abundance of Richardson's ground squirrels in much of the region. In southeastern Alberta and southern Saskatchewan, a substantial decline in Richardson's ground squirrel abundance was apparent in the late 1980s and early 1990s and coincided with poor reproductive success among Swainson's hawks (Houston and Schmutz 1995, Houston and Zazelenchuk 2004). Scarcity of Richardson's ground squirrel in my study likely explained, in part, increased use of alternative prey items by Swainson's hawks as noted in Alberta and Saskatchewan (Schmutz et al. 2001). Northern pocket gopher (*Thomomys talpoides*), a major, widespread prey species of Swainson's hawks in southcentral North Dakota (Gilmer and Stewart 1984), did not occur on my study area.

Greater dietary diversity of Swainson's hawks relative to reports elsewhere in the Northern Great Plains also may have been influenced by differences in diet study methods. Gilmer and Stewart (1984) relied solely on fresh prey items observed in nests. Schmutz et al. (2001) apparently also used fresh remains of prey at nests. I increased detection rates of small rodents and amphibians by using tether platforms combined with direct observation to correct for biases, an assertion supported by comparing data from tether platforms with those based on fresh prey observed at nests just before I tethered young. At nests I observed no amphibian prey but amphibians comprised 15% of the total number of prey items at platforms, whereas ground squirrels occurred 3 times more frequently at nests than at platforms. Some differences between composition of fresh prey at nests and of prey at tether platforms could be related to time of data collection, although time periods overlapped (mid-

June through early July versus July through mid-August).

Wetland-dependent species represented nearly 50% of the frequency and biomass of prey used by hawk families. In contrast, at least 90% of the frequency and biomass of prey used by Swainson's hawks in other areas of the Northern Great Plains were associated with uplands (Gilmer and Stewart 1984, and calculated from 1983–1996 data in Appendix 1 of Schmutz et al. 2001). Relatively high importance of amphibians in diets of nesting Swainson's hawks in my study has not been reported previously (England et al. 1997), perhaps in part because of biases discussed above (e.g., see relevant note in Gilmer and Stewart [1984]). Most amphibian prey items in my study were tiger salamanders, despite noxious secretions from skin granular glands being exuded by this species (Hamning et al. 2000).

MANAGEMENT IMPLICATIONS

I found relationships between components of Swainson's hawk diets and variation in land cover attributes that characterized northwestern North Dakota. Though prairie wetland habitats comprised a relatively small portion (19%) of the study area, wetland-dependent prey items were an important food source for Swainson's hawks. To help facilitate adequate reproductive success by Swainson's hawks, maintenance of seasonal and semipermanent wetlands is recommended, particularly given the increasing emergence of agricultural monotypes throughout the Northern Great Plains.

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Resource Selection of Greater Prairie-Chicken and Sharp-Tailed Grouse Broods in Central South Dakota

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ABSTRACT Habitat use of sympatric greater prairie-chicken (*Tympanuchus cupido*) and sharp-tailed grouse (*T. phasianellus*) broods during the brood-rearing season has not been quantified for stable prairie grouse populations in large contiguous grassland landscapes in the Northern Great Plains. Characteristics of habitats used by prairie grouse broods were described based on data collected from 35 broods (18 greater prairie-chicken and 17 sharp-tailed grouse) during the breeding seasons of 2004 and 2005. Greater prairie-chicken and sharp-tailed grouse broods used vegetation with visual obstruction heights ≥ 26 cm and 37 cm, respectively. Greater prairie-chicken broods selected western wheatgrass (*Pascopyrum smithii*), green needlegrass (*Nassella viridula*) and Japanese brome (*Bromus japonicus*) dominated habitats. Sharp-tailed grouse broods selected sweet clover (*Melilotus spp.*), mixed forb-dominated vegetation, and green needlegrass dominated habitats. Both grouse species avoided habitats dominated by smooth brome (*B. inermis*). Knowledge of brood habitat use will provide information on suitable brood habitat resources needed to sustain prairie grouse populations in South Dakota.

KEY WORDS brood resource selection, Fort Pierre National Grassland, greater prairie-chicken, prairie grouse, sharp-tailed grouse, South Dakota, *Tympanuchus cupido*, *Tympanuchus phasianellus*

Greater prairie-chickens (GPC; *Tympanuchus cupido*) and sharp-tailed grouse (STG; *T. phasianellus*) populations have been declining since the early 1900s (Hillman and Jackson 1973, Houston 2002); habitat loss is the primary reason for these population declines. To better understand what resource requirements are needed to sustain and grow prairie grouse populations, we studied one of the last remaining (and possibly the most productive) sympatric prairie grouse populations in North America.

Vegetation characteristics can limit brood survival and is considered to be one of the most important factors related to prairie grouse population levels (Hamerstrom et al. 1957, Kirsch 1974, Svedarsky et al. 1999). Vegetation characteristics must accommodate chick movement at ground level, provide adequate abundance and diversity of insects, concealment from predators, protection from weather elements, openings for sun exposure and dusting, and be accessible from nest sites (Svedarsky et al. 2003). Fredrickson (1996) recommended that vegetation height be 25 to 51 cm for nesting, brood-rearing and escape cover for greater prairie-chickens (*T. cupido*). Newell et al. (1988) found that during summer months (June–August), GPC broods primarily used vegetation that was 26 to 50 cm in height on the Sheyenne National Grassland in North Dakota. Resource selection by GPCs and STG broods varies

spatially throughout their current geographic ranges. However, previous studies of habitat use have documented the importance of grassland, savannah, and grassland-low shrub transition zones to GPC and STG broods (Hamerstrom 1963, Moyles 1981, Rice and Carter 1982, Horak 1985, Manske and Barker 1988). Although previous studies have provided general descriptions of the types of grasslands used by prairie grouse, to our knowledge no studies have quantified vegetation at the species-specific level. Further, most previous research on prairie grouse has been conducted on declining populations in fragmented landscapes where grassland habitats were not the dominant vegetation cover type. Thus, our objective was to quantify and compare resource selection by GPC and STG broods in grassland dominated habitats in central South Dakota.

STUDY AREA

Our study occurred during summer (June–August) 2004–2005 on a 19,500 ha portion of the Fort Pierre National Grassland (FPNG) west of US highway 83 in central South Dakota (44° 14' N, 100° 39' W), centered approximately 27 km south of Pierre, South Dakota. The FPNG is a restored mixed-grass prairie and is currently managed for wildlife production and outdoor recreation by

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the United States Forest Service (USFS; Nebraska National Forest 1998). Rotational cattle grazing occurred throughout FPNG whereby a maximum of 33% was stocked with cattle at any one time; cattle stocking rates ranged from 0.44–2.63 animal unit months (AUM)/ha. An AUM is defined as the amount of forage (800 lbs of air-dried forage) that an animal weighing 1,000 lbs will eat in one month (Gum et al. 1993).

Western wheatgrass (*Pascopyrum smithii*) and green needlegrass (*Nassella viridula*) were the dominant grass species on the flats and ridges, whereas big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), and side oats grama (*Bouteloua curtipendula*) were predominant species on the slopes (Faulkner 1999). Overstory vegetation was sparse and included plains cottonwoods (*Populus deltoides*) found near stock ponds. Private land primarily composed of pasture land and limited cultivated fields of alfalfa, sunflower, and wheat were interspersed throughout the FPNG. Long term average annual precipitation on FPNG was 43.2 cm and occurred mainly from April through June (U.S. Forest Service 2001). Daytime high temperatures in July and August often exceeded 38° C, while summer and winter temperatures average 24.2° C and –7.9° C, respectively (National Weather Service 2003).

METHODS

We captured GPC and STG hens on display grounds (leks) using walk-in traps (Schroeder and Braun 1991) during April 2004–2005. We also used nest dragging and bow nets to capture hens using methods previously described by Higgins et al. (1969). Upon locating incubating hens, we flushed them from their nests and subsequently placed a bow net with a 15 m trigger rope (Slayer 1962) within 40 cm of the nest. We placed a flag at the end of the rope and returned to the flag the following day to deploy bow nets.

We aged (immature or adult), weighed, radio-marked and released all GPC and STG females on leks where they were captured. We marked each female with a necklace-mounted transmitter (Holohil Systems Ltd., Carp, Ontario, Canada) and leg banded each male captured. We determined sex of prairie grouse using field criteria previously developed by Bihrlé (1993).

Two to three weeks post hatch, we flushed each radio-marked hen to determine presence or absence of chicks. If chicks were present or hens moved short distances (< 0.8 km) from their nests, we captured broods that night between 2300 and 0500 hours. We approached marked hens on foot using standard radiotelemetry techniques, circled each hen's position, and marked the position with 3 to 5 Garrity fun-tastick glow sticks; the mean area marked was approximately 175 m². We used and subsequently dropped a 2.4 cm mesh net (15 m × 15 m) over radio-marked hens and their broods. We used spotlights to capture and suture small (<2 g) radio transmitters to the dorsal surface of each

chick (Burkpile et al. 2002); radio-marked broods were released within 25 m of the capture site. All animal handling protocols used during our study were approved by the South Dakota State University Institutional Animal Care and Use Committee (Approval 00-A039).

We determined resource selection of broods by sampling vegetation around 2-day-old triangulated locations from radio-marked females that had radio-marked chicks. We located radio-marked females with radio-marked chicks a minimum of 3 times per week from the time chicks were marked at 2 to 3 weeks of age through the end of August by triangulation of directional signals using a truck-mounted null-peak radio telemetry system. We did not sample vegetation around a location if radio-marked chicks were not located with radio-marked hens. We equipped our pickup truck with a Global Positioning System (Garmin GPSMAP® 76S) and a laptop computer for subsequent use in triangulating brood positions.

We established 2, 50-m perpendicular line-transects in each of the 4 cardinal directions, with the estimated location used as the center point for both transects. We collected plant species composition data at 1 m intervals along established transects. We used a Robel pole (Robel et al. 1970) at 10 m intervals along each transect to measure horizontal visual obstruction from the 4 cardinal directions. At 4 m to each side of the point where the visual obstruction was measured we used 2, 0.5 × 0.25 m modified Daubenmire plots (Daubenmire 1959) to estimate vegetation canopy cover. We ocularly estimated percent vegetation canopy coverage for grasses, forbs, and shrubs within each plot using the following cover categories. 0 = none, 1 = 1–5%, 2 = 6–25%, 3 = 26–50%, 4 = 51–75%, 5 = 76–95%, and 6 = 96–100%. We used midpoint values of the cover categories to estimate average cover. We sampled randomly selected points in the same manner to measure resource availability. We quantified resource availability using 37 and 86 random locations during 2004 and 2005, respectively. We sampled the same number of brood locations and random locations each day and selected the closest random points to the brood location for sampling. Plant nomenclature followed the United States Department of Agriculture plants website (USDA, Natural Resource Conservation Service 2005). We clipped United States Geological Survey Digital elevation model 10 m data to 21 GPC brood home ranges and 16 STG brood home ranges to determine percent of each species home range that was composed of 3 slope categories: 0–0.50%, 0.51–1.0%, and > 1.01%. We compared differences in mean composition percentages between species using program CONTRAST (Sauer and Williams 1989).

We determined home range size of hens with broods (Gabbert et al. 1999) during the breeding season (1-day post-hatch through August) using a minimum of 20 locations for each hen and brood. Additionally, we buffered radiolocations by 200 m and overlaid buffered locations in a GIS to generate home range polygons. We determined the

200 m buffer by looking at average daily movements and adjusting for days during this same period by multiplying the average daily movement by the number of days between radiolocations. This allowed us to encompass the average area that a hen and brood would have used while moving between locations taken on different days.

We analyzed brood resource selection using compositional analysis (Aebischer et al. 1993), which generates resource use scores based on the difference between use and availability. For instance, selection for a habitat category was indicated if the confidence interval for the selection ratio did not contain the value 1 and the lower

limit was >1 . A habitat category was avoided if the confidence interval for w_i did not contain the value 1 and the upper limit was <1 . Use in proportion to availability was indicated if the confidence interval for w_i contained the value 1 (Manly et al. 2002, Grovenburg et al. 2010). We compared use scores using ANOVA and Bonferroni multiple pair-wise comparisons in SYSTAT (SPSS 2000). We compared visual obstruction heights and canopy cover estimates using ANOVA and Bonferroni pair-wise comparisons in SYSTAT; we determined significance using an α value <0.05 .

Table 1. Mean vegetation visual obstruction heights with standard error (SE) at locations used by greater prairie-chicken (GPC) and sharp-tailed grouse (STG) broods in relation to mean vegetation heights with standard error (SE) at random locations on the Fort Pierre National Grassland, South Dakota, USA, summer 2004–2005.

Year	Species	Habitat Use					Habitat Availability				
		Mean height (cm)	SE	LCL ^a	UCL ^b	n ^c	Mean height (cm)	SE	LCL ^a	UCL ^b	n ^c
2004	GPC	32.1	2.8	26.6	37.5	8	29.4	1.7	26.1	32.7	37
	STG	43.1	2.6	37.9	48.2	8					
2005	GPC	37.9	2.1	33.8	41.9	10	35	1.4	32.3	37.7	86
	STG	42.8	2.3	38.3	47.4	9					

^a 95% lower confidence limit; ^b 95% upper confidence limit; ^c sample size. Blank cells represent no data.

RESULTS

We determined habitat use by prairie grouse during the brood-rearing season using habitat data collected from 16 broods (8 GPC and 8 STG) in 2004 and 19 broods (10 GPC and 9 STG) in 2005. During 2004 and 2005, we marked a mean of 4 and 3 chicks per brood, respectively. The average polygon size of triangulated locations was 952 m² and ranged from 0.1 m² to 2000 m². Greater prairie-chicken brood locations were sampled for brood habitat use a mean of 1.9 (SD = 1.0) times/brood and STG brood locations were sampled a mean of 2.0 (SD = 0.8) times/brood in 2004. In 2005, GPC brood locations were sampled a mean of 3.5 (SD = 0.7) samples/brood and STG brood locations were sampled a mean of 3.9 (SD = 1.7) times/brood.

Visual obstruction of habitats used by GPC broods ranged from 19–53 cm (Table 1). Habitats used by GPC broods were comprised of 9–24% grasses and 1–33% forbs (Table 2). Sharp-tailed grouse broods used vegetation with visual obstruction heights that ranged from 31–55 cm, which in 2004 averaged 9 cm taller than vegetation used by

GPC broods ($F_{1,14} = 8.9, P < 0.01$) and 14 cm taller than the mean available vegetation on the FPNG ($F_{1,37} = 12.9, P < 0.01$; Table 1). Areas used by STG had canopy cover comprised of 5–24% grasses and 2–32% forbs (Table 2). Forb canopy coverage was 15% less in 2005 than in 2004 on sites used by STG broods ($F_{1,15} = 47.0, P < 0.01$). Vegetation height ranged from 5–77 cm and grasses and forbs covered 3–74% and 0.1–28% of the ground, respectively.

Available resources were similar ($P > 0.05$) in 2004 and 2005 except for sweet clover ($F_{1,37} = 11.3, P < 0.01$), porcupine grass ($F_{1,37} = 13.4, P < 0.01$), Kentucky bluegrass ($F_{1,37} = 8.2, P < 0.01$), and bare ground categories ($F_{1,37} = 10.4, P < 0.01$; Fig. 1). During 2004 and 2005, sweet clover comprised 16.1 and 2.5% of the study area, respectively. Larger portions of the FPNG were comprised of porcupine grass, Kentucky bluegrass, and bare ground in 2005 than in 2004 (Fig. 1). We documented 53 different species of vascular plants and bare ground while sampling prairie grouse brood use locations, of which 8 plant species and

bare ground accounted for an average of 87% of the use areas (Fig. 1).

Brood habitat use scores differed ($F_{8,145} = 7.2, P < 0.01$) among different habitats for both GPCs and STG. Sweet clover ranked highest and was significantly higher than bare ground ($P < 0.04$), smooth brome ($P < 0.03$), and Japanese

brome ($P < 0.01$) on locations selected by STG broods (Table 3). Mixed forb-dominated vegetation habitat and green needlegrass habitats ranked significantly higher ($P < 0.02$) than Japanese brome for STG broods.

Table 2. Mean estimated vegetation canopy cover and standard error (SE) for grasses, forbs, and shrubs at locations used by greater prairie-chicken (GPC) and sharp-tailed grouse (STG) broods in relation to mean estimated canopy cover and standard error (SE) at random locations on the Fort Pierre National Grassland, South Dakota, USA, summer 2004–2005.

Year	Species	Habitat Use					Habitat Availability				
		Grass (%)	SE	LCL ^a	UCL ^b	n ^c	Grass (%)	SE	LCL ^a	UCL ^b	n ^c
2004	GPC	17.9	0.9	16.1	19.8	8	17.4	0.9	15.6	19.1	37
	STG	13.8	1.9	10.0	17.6	8					
2005	GPC	17.8	1.4	15.2	20.5	10	19.3	0.4	16.9	21.8	86
	STG	17.2	1.2	14.8	19.6	9					

Year	Species	Habitat Use					Habitat Availability				
		Forb (%)	SE	LCL ^a	UCL ^b	n ^c	Forb (%)	SE	LCL ^a	UCL ^b	n ^c
2004	GPC	10	3.5	3.1	16.8	8	7.7	1.1	5.6	9.8	37
	STG	19.3	2.7	13.9	24.6	8					
2005	GPC	4.6	0.9	2.9	6.3	10	3.9	1.3	3.2	4.6	86
	STG	4.4	0.8	2.7	6.0	9					

^a 95% lower confidence limit; ^b 95% upper confidence limit; ^c sample size. Blank cells represent no data.

Brood habitat use differed ($F_{16,137} = 5.9, P < 0.01$) between 2004 and 2005 for GPC broods. During 2004, western wheatgrass ranked highest and was significantly higher ($F_{7,56} = 2.9, P < 0.02$) than Kentucky bluegrass (Table 4). Smooth brome, bare ground, and Kentucky bluegrass were avoided by GPC broods during 2004. In 2005, GPC broods selected (in order of most to least important) green needlegrass, western wheatgrass, Japanese brome, and mixed forb-dominated vegetation, which all ranked significantly higher ($P < 0.03$) than smooth brome, sweet clover, and porcupine grass (Table 4).

Sweet clover ($F_{1,33} = 11.8, P < 0.01$) and porcupine grass ($F_{1,17} = 13.4, P < 0.01$) habitat use scores for STG broods were higher than the scores for GPC broods (Table 3). The GPC brood use scores for western wheatgrass ($F_{1,33} = 7.0, P < 0.02$) and Japanese brome ($F_{1,33} = 15.3, P < 0.01$)

communities were higher than for STG broods (Table 3). Greater prairie-chicken ($F_{1,16} = 5.3, P < 0.04$) and STG ($F_{1,15} = 7.1, P < 0.02$) brood use of sweet clover habitats were higher in 2004 than in 2005 (Fig. 2). Use of sweet clover by STG broods was higher than GPC brood use during 2004 ($F_{1,14} = 3.7, P < 0.08$) and 2005 ($F_{1,17} = 14.5, P < 0.01$; Fig. 2).

Topography of areas used by GPCs and STG broods differed by slope category (Fig. 3). A greater percentage of GPC brood home ranges were composed of slopes $< 0.5\%$ ($\chi^2_1 = 12.8, P > 0.01$) than home ranges of STG broods (Fig. 3). Conversely, a greater percentage of STG brood home ranges were composed of slopes $> 1.01\%$ ($\chi^2_1 = 20.06, P > 0.01$). We documented no differences ($\chi^2_1 = 1.13, P = 0.29$) in prairie grouse home range use composed of slopes between 0.51 and 1.0 % (Fig. 3).

Table 3. Mean scores (Aebischer et al. 1993), standard error (SE), and confidence intervals for vegetation communities selected by sharp-tailed grouse and differently ($P < 0.05$) by greater prairie-chicken broods in relation to habitats available during summer 2004–2005 on the Fort Pierre National Grassland, South Dakota, USA.

Habitat	Sharp-tailed Grouse				Greater Prairie Chicken			
	Mean score	SE	LCL ^a	UCL ^b	Mean score	SE	LCL ^a	UCL ^b
Sweet Clover	1.74	0.43	1.71	1.76	-0.77	0.58	-0.80	-0.73
Other ^c	0.90	0.43	0.87	0.93				
Green Needlegrass	0.80	0.41	0.78	0.83				
Western Wheatgrass	0.42	0.55	0.39	0.46	1.53	0.25	1.52	1.55
Porcupine Grass	-0.33	0.24	-0.34	-0.31	-3.24	0.34	-3.29	-3.20
Kentucky Bluegrass	-0.34	0.59	-0.38	-0.31				
Bare Ground	-0.60	0.29	-0.63	-0.57				
Smooth Brome	-0.66	0.54	-0.69	-0.62				
Japanese Brome	-1.53	0.75	-1.58	-1.48	1.08	0.28	1.07	1.10

^a 95% lower confidence limit; ^b 95% upper confidence limit; ^c forb-dominated vegetation. Blank cells represent no differences.

Table 4. Mean scores (Aebischer et al. 1993), standard error (SE), and confident intervals for vegetation communities selected by greater prairie-chicken (GPC) broods during summer 2004–2005 in relation to availability during the breeding season on the Fort Pierre National Grassland, South Dakota, USA.

Habitat	2004				2005			
	Mean score	SE	LCL ^a	UCL ^b	Mean score	SE	LCL ^a	UCL ^b
Western Wheatgrass	1.82	0.42	1.79	1.85	1.31	0.30	1.29	1.32
Japanese Brome	0.92	0.52	0.89	0.95	1.21	0.31	1.19	1.23
Other ^c	0.65	0.86	0.59	0.70	1.07	0.25	1.05	1.08
Sweet Clover	0.57	0.94	0.51	0.63	-1.84	0.57	-1.88	-1.80
Green Needlegrass	0.57	0.28	0.55	0.59	1.38	0.18	1.35	1.37
Smooth Brome	-0.45	1.20	-0.52	-0.37	-1.24	0.81	-1.29	-1.19
Bare Ground	-1.55	0.58	-1.59	-1.51	0.50	0.31	0.48	0.52
Kentucky Bluegrass	-2.53	1.06	-2.60	-2.47	0.88	0.75	0.83	0.93
Porcupine Grass					-3.24	0.72	-3.29	-3.20

^a 95% lower confidence limit; ^b 95% upper confidence limit; ^c forb-dominated vegetation. Blank cells represent no data.

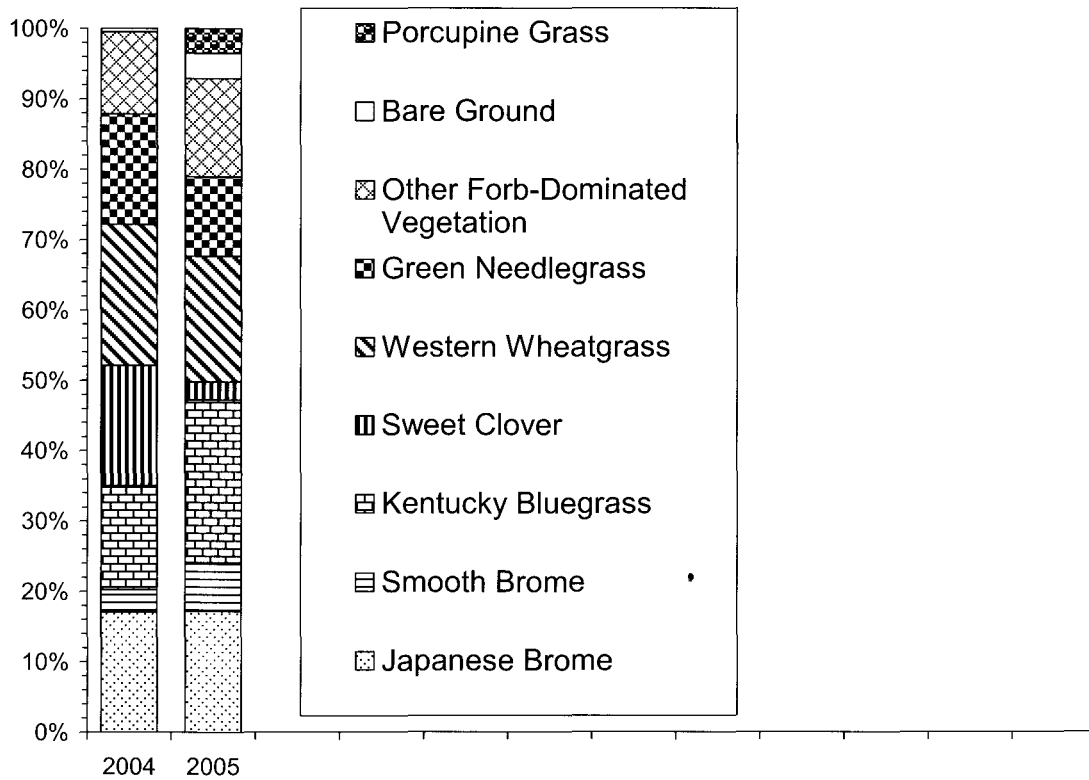


Figure 1. Resource availability for prairie grouse broods on the Fort Pierre National Grassland, South Dakota, USA, summer 2004–2005.

DISCUSSION

Sharp-tailed grouse broods selected vegetation communities primarily composed of sweet clover, mixed forb-dominated vegetation, and green needlegrass. These habitats contained taller vegetation than was randomly found on the FPNG. Greater prairie-chicken and STG broods used areas with abundant forbs, which often contain more insects than other habitats (Jones 1963, Manske and Barker 1988). Sweet clover and mixed forb-dominated vegetation communities likely produced more invertebrates than other habitats and also provided protective cover.

Greater prairie-chicken broods selected vegetation communities primarily composed of western wheatgrass, Japanese brome, green needlegrass and mixed forb-dominated vegetation. Western wheatgrass and green needlegrass often were interspersed with the mixed forb-dominated vegetation community. We hypothesize that mixed forb communities provided more abundant food for broods (invertebrates) whereas adjacent grassy cover with open understory provided easy travel routes. Use of sweet clover, green needlegrass and western wheatgrass by broods of both species of prairie grouse supports the findings of Rice and Carter (1982). However, we did not find any support for use of snowberry, prairie cordgrass, and

bulrushes by broods of either prairie grouse species. Drought conditions during 2004 may have resulted in greater use of sweet clover by STG broods, presumably because it provided the most effective hiding cover compared to other herbaceous vegetation. With more abundant moisture in 2005, overhead cover from other vegetation was more abundant and grouse made less use of sweet clover.

Greater prairie-chicken broods selected Japanese brome vegetation communities whereas STG broods selected sweet clover. Sweet clover was primarily located on the tops and sides of hills while Japanese brome was primarily located on flat areas. Western wheatgrass also was used more ($P = 0.01$) by GPC broods than STG broods, and also occurred primarily in swales and on flat areas. Observed differences in habitat use and landscape position suggested that GPC and STG broods partially segregated by landscape features. For instance, GPC broods used flat areas ($< 0.5\%$ slope) more ($P < 0.01$) than STG broods. Newell et al. (1988) also found that GPC broods spent most of their time in lowland communities. Moreover, sweet clover and porcupine grass grew taller than other vegetation on the FPNG, which likely accounted for observed differences in mean visual obstruction height of vegetation used by STG and GPC broods.

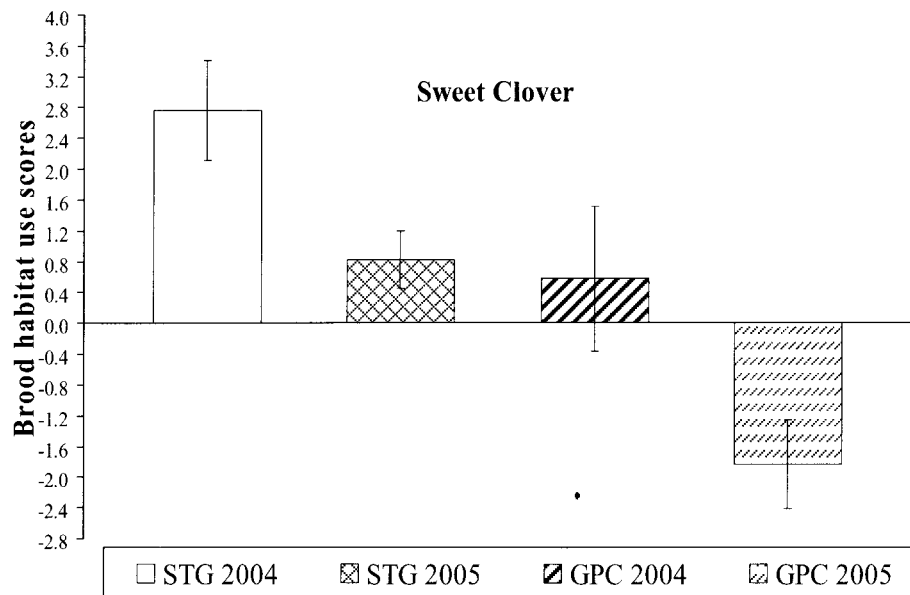


Figure 2. Mean scores (Aebischer et al. 1993) and standard errors for sweet clover habitat use by sharp-tailed grouse (STG) and greater prairie-chicken (GPC) broods in relation to availability on the Fort Pierre National Grassland, South Dakota, USA, summer 2004–2005.

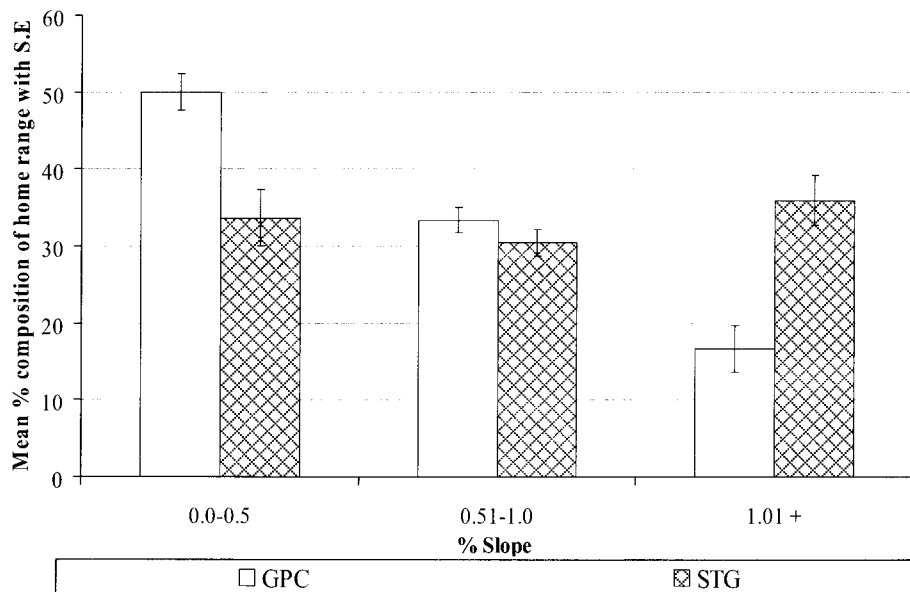


Figure 3. Home range topography of greater prairie-chicken (GPC) and sharp-tailed grouse (STG) hens with broods during the breeding seasons of 2004 and 2005 on the Fort Pierre National Grassland, South Dakota, USA.

Prairie grouse broods of both species exhibited avoidance of smooth brome. Smooth brome occurred in dense monotypic stands on the FPNG. A single species stand of vegetation may not provide as diverse or abundant invertebrate community as plant communities with multiple species (Koricheva et al. 2000). Smooth brome often provided little overhead protective cover from avian predators, especially if it was in an allotment that was actively grazed by cattle, as cattle often graze smooth brome patches before grazing other species of vegetation (A. J. Smart, South Dakota State University, personal communication). Consequently, prairie grouse broods may have avoided smooth brome patches of grassland dominated habitats.

Sharp-tailed grouse broods used taller vegetation than GPC broods during our study. Sweet clover accounted for approximately 95% of the taller vegetation in 2004 on STG brood locations, but the mean vegetation visual obstruction height was only 1 cm shorter in 2005 when sweet clover availability was significantly less ($P < 0.01$) on the landscape. Sharp-tailed grouse broods used habitats that provided adequate protective cover. Greater prairie-chicken broods did not use habitats with vegetation as tall as those used by STG broods (> 37 cm), but used habitats with vegetative visual obstruction height > 26 cm. Newell et al. (1988) and Fredrickson (1996) similarly reported minimum vegetation height in habitats used by GPC broods to be 26 cm and 25 cm, respectively.

MANAGEMENT IMPLICATIONS

In restored grassland across the Northern Great Plains, exclusive planting of sweet clover to improve STG habitat or Japanese brome to improve GPC habitat is not recommended. Segregation of the two prairie grouse species suggested that habitat managers could manage slopes for taller vegetation species, like sweet clover, porcupine grass, and green needlegrass for STG broods, and valleys and flats for shorter vegetation like western wheatgrass for GPC broods. Habitats that provide a diverse community of forbs were important to both species of prairie grouse in this study. Managers should incorporate a diverse herbaceous component into both upland and lowland settings of grasslands managed for prairie grouse broods. These habitats provide an open understory for ease of movement by chicks and overhead cover from avian predators and prolonged exposure to solar radiation.

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Population Characteristics of Central Stonerollers in Iowa Streams

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ABSTRACT The central stoneroller (*Campostoma anomalum*) is a herbivore that can have substantial effects on algal communities, nutrient dynamics, and energy flow in streams. Despite its importance in lotic ecosystems, little is known about its population dynamics in streams of the Great Plains. Our objective was to describe age structure, age-specific mortality, and growth rates of central stonerollers in three Iowa streams. We sampled fish from 41 reaches during June–August 2007. We sampled 466 central stonerollers, of which we aged 192. Fish varied in length from 32 to 130 mm and in age from age 0 to 4 years. Over 75% of the central stonerollers were age 2 or younger. Total annual mortality varied from 53.5 to 65.5% across the 3 streams and averaged 64.4% for all streams. Age-specific mortality was approximately 35% between ages 1 and 2, but increased to approximately 50% and above for older ages. Central stonerollers grew approximately 75 mm during their first year and approximately 10–20 mm per year in subsequent years. Size structure, age structure, mortality, and growth were similar to other central stoneroller populations in the Great Plains. Our results provide important insight for the management and conservation of streams, and provide a foundation for future research on factors influencing small-bodied, nongame fishes in stream ecosystems.

KEY WORDS central stoneroller, fish population dynamics, growth, Iowa, mortality

The central stoneroller (*Campostoma anomalum*) is a widely-distributed species in North America; it occurs throughout central and eastern regions of the United States and Canada (Lee et al. 1980). Central stonerollers are often most abundant in small streams with moderate to high channel gradients, well-defined riffle habitats with large rocky substrate (e.g., gravel, cobble), and permanent flow (Pflieger 1997). The trophic ecology of central stoneroller has been extensively studied. Central stonerollers are herbivorous and may consume up to 27% of their body weight in benthic algae per day (Fowler and Taber 1985). In addition to algae, a variety of food items often are consumed by central stonerollers. For instance, Evans-White et al. (2003) found that algae contributed most (47%) to the diet of central stonerollers in a Kansas stream, followed by detritus (30%), animal matter (21%), and terrestrial vegetation (2%).

Most studies on central stonerollers have primarily focused on their role in aquatic food webs. Specifically, central stonerollers can significantly reduce algal biomass (Power et al. 1985, Stewart 1987, Power et al. 1988, Gelwick and Matthews 1992), decrease algal spatial and temporal variability (Gelwick and Matthews 1997), and may alter algal community composition (Power and Matthews 1983, Power et al. 1988). Consequently, the central stoneroller is a primary driver of ecosystem processes (e.g., benthic community composition, nutrient and energy dynamics) in streams where they occur (Power et al. 1988, Matthews 1998). Despite their importance to the structure and function of lotic food webs, little research has been conducted on their population dynamics.

Understanding the population dynamics of central stonerollers is critical for effective management and

conservation, and for predicting the potential consequences of biotic interactions (e.g., introduction of nonnative species) and environmental alterations (e.g., climate change, changes in land use). In particular, growth and mortality are important population-level dynamics that influence the structure and function of central stoneroller populations. Growth provides an integrated evaluation of environmental conditions (e.g., prey availability, thermal conditions, habitat suitability) and genetic factors, and has direct and indirect effects on recruitment dynamics, trophic interactions, and mortality (DeVries and Frie 1996). An understanding of mortality also is critical for management and conservation. Mortality results from factors such as predation (Brant et al. 1987), disease (Post 1987), and starvation (Chick and Van Den Avyle 1999). As such, knowledge of mortality rates is critical for understanding the influence of abiotic and biotic mechanisms on central stoneroller populations. Due to their importance in stream ecosystems and lack of information on their population dynamics, our objective was to describe growth and mortality of central stonerollers in three Iowa streams.

STUDY AREA

Watershed areas of all study streams were approximately 70 km² and typical of most streams in central Iowa. Land use in the watersheds was dominated by row crop agriculture (Isenhardt et al. 1997). Bear Creek has undergone extensive riparian habitat enhancement since 1990; primarily plantings of multi-species riparian buffers along more than 23 km of stream (see Schultz et al. 1995 and Isenhardt et al. 1997 for a detailed description of conservation buffer practices on Bear Creek). Adjacent

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watersheds and streams, including Keigley Branch and Long Dick Creek, were nearly identical to Bear Creek except that they were not the focus of riparian restoration prior to (since 1990) or during our study. Despite focused restoration on portions of Bear Creek, all 3 streams were characterized by natural and artificial riparian buffers with similar instream physical habitat (see Fischer et al. 2010).

METHODS

We sampled central stonerollers from 41 reaches in three streams located in central Iowa during June–August 2007; we sampled 20 reaches from Bear Creek, 10 reaches from Keigley Branch, and 11 reaches from Long Dick Creek. We sampled central stonerollers using a Smith-Root Model LR-20 backpack-mounted DC electrofisher (Smith-Root, Inc., Vancouver, Washington, USA). At each reach, we made 1 upstream pass with 2 netters using dip nets with 6-mm ace mesh. Sample reach length was 35 times the mean stream width (Lyons 1992; Simonson et al. 1994) or 300 m, whichever was longer. We measured central stonerollers to the nearest mm (total length) and removed asterisci otoliths from 10 fish per cm length group for age and growth analysis. We placed otoliths in microcentrifuge tubes and subsequently transported samples to the Iowa State University fisheries laboratory for processing. Once in the laboratory, we mounted otoliths on glass slides (i.e., convex or distal-side facing up) with thermoplastic cement and read samples under a microscope equipped with a digital camera linked to an image analysis system (Image-Pro Plus, Media Cybernetics, Silver Spring, Maryland, USA). We aged otoliths using a single reader; however, we read a random subsample of otoliths ($n = 30$) using 2 readers to assess accuracy of our aging technique. We measured annuli and radii from all otoliths using the image analysis system. We estimated mean back-calculated lengths at age (MBCL) using the Dahl-Lea method (DeVries and Frie 1996): $L_i = L_c \times (S_i/S_c)$, where L_i was the length at annulus i , L_c was the length at capture, S_i was the otolith radius at annulus i , and S_c was the otolith radius at capture.

We compared size structure of central stonerollers using a Kolmogorov-Smirnov two-sample test (Neumann and Allen 2007). We estimated age structure of central stoneroller populations at each reach using an age-length key (DeVries and Frie 1996; Bettoli and Miranda 2001). We estimated total annual mortality using a weighted catch curve (Miranda and Bettoli 2007). We estimated mortality for each stream and also by pooling age structure data across streams (Ricker 1975; Miranda and Bettoli 2007). We estimated age-specific mortality rates (e.g., mortality between age 1 and age 2, mortality between age 2 and age 3) by calculating changes in the relative frequency of individuals in successive age groups for each reach (Ricker 1975). We estimated average MBCL at age and age-specific mortality rate across reaches for each stream. The standard error and 95% confidence interval for MBCL at

age were estimated using pooled variance. Our study was conducted with the approval of Iowa State University's Institutional Animal Care and Use Committee (project identification #4-06-6109-I).

RESULTS

Central stonerollers varied in length from 32 to 130 mm ($n = 466$) across all reaches and length-frequency distributions were similar among streams (Fig. 1). Specifically, central stoneroller length distributions were similar between Bear Creek and Keigley Branch (Kolmogorov-Smirnov, $D_{\max} = 0.18$, $P = 0.31$, $n = 52$ and 74), Bear Creek and Long Dick Creek (K-S, $D_{\max} = 0.14$, $P = 0.59$, $n = 52$ and 66), Keigley Branch and Long Dick Creek (K-S, $D_{\max} = 0.10$, $P = 0.87$, $n = 74$ and 66). Age and growth were estimated from a subsample of 192 central stonerollers, including 52 from Bear Creek, 74 from Keigley Branch, and 66 from Long Dick Creek. Central stonerollers varied in age from 0 to 4 years (Fig. 2). No age-0 fish were collected from Keigley Branch, a single age-0 fish was sampled in Bear Creek, and 13 were sampled from Long Dick Creek. Only 7 age-4 central stonerollers were sampled; 2 from Keigley Branch and 5 from Long Dick Creek. Approximately 75% of the fish were age 1 and 2 across all streams.

Total annual mortality of age-1 and older central stonerollers was 50.3% in Bear Creek, 55.0% in Keigley Branch, and 61.7% in Long Dick Creek. When streams were pooled, total annual mortality was 64.4%. Age-specific mortality averaged approximately 35% between age 1 and 2 for all streams (Fig. 2). Age-specific mortality increased to 50% between age 2 to 3 across all streams and approximately 85% for age 3–4 for Keigley Branch and Long Dick Creek. Mean back-calculated length at age was similar across streams (Table 1). Growth was fastest during the first year of life where fish grew approximately 75 mm. Annual growth increments declined thereafter to approximately 20 mm per year for all but the oldest central stonerollers.

DISCUSSION

Use of population characteristics (i.e., age, growth, mortality) obtained from age determination has been critical to the management and conservation of sport fishes and large-bodied species of conservation concern. However, small-bodied fish research has commonly focused on assemblage characteristics (e.g., richness, composition) due to lack of techniques or the high cost and labor intensive methods associated with collecting age data from individual fish. As such, the description of small-bodied fish population characteristics is important to understanding stream ecosystems. Our study demonstrated that central stoneroller size structure, mortality, growth were similar to other Great Plains populations.

Reported maximum lengths of central stonerollers vary considerably among studies. For instance, Lennon and Parker (1960) reported that the maximum length of central stonerollers in streams from Great Smoky Mountains National Park (GSMNP) was 226 mm. Moreover, Gunning and Lewis (1956) reported a maximum length of

approximately 170 mm in Roaring Springs Creek, Illinois. Our results are most similar to those of Quist and Guy (2001) and Evans-White et al. (2003), who reported a maximum length of approximately 140 mm in Kansas streams.

Table 1. Mean (SE, 95% confidence limits) back-calculated length (mm) at age of central stonerollers sampled from three streams in central Iowa, 2007.

Stream	n	Age (years)			
		1	2	3	4
Bear Creek	52	77 (1.8, 74–81)	97 (1.8, 93–100)	112 (2.2, 107–116)	
Keigley Branch	74	74 (2.5, 69–79)	95 (2.1, 91–99)	113 (2.3, 108–117)	120 (7.3, 101–138)
Long Dick Creek	66	75 (1.3, 72–78)	95 (1.7, 92–98)	103 (1.6, 100–106)	108 (4.6, 97–121)

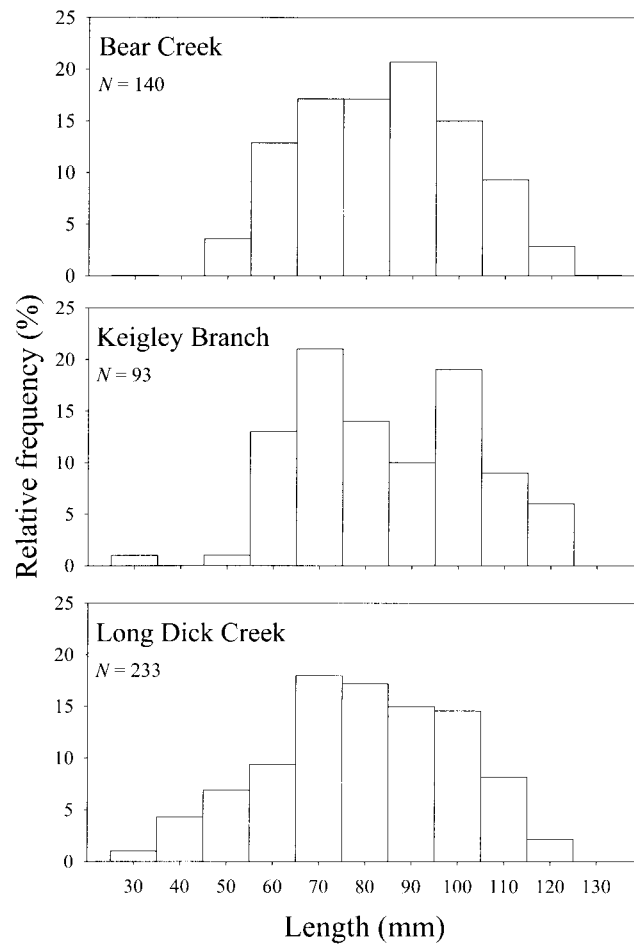


Figure 1. Length-frequency distributions of central stonerollers sampled from three streams in central Iowa, 2007.

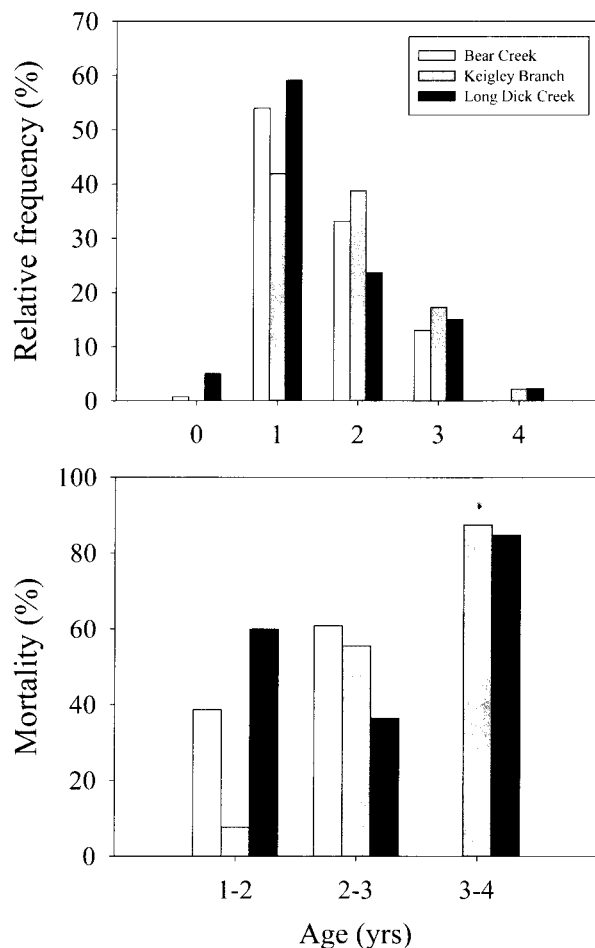


Figure 2. Relative frequency of different ages (top panel) and age-specific mean (SE) total annual mortality (lower panel) of central stonerollers sampled from three streams in central Iowa, 2007.

Similar to maximum length, age structure varies among studies. Quist and Guy (2001) reported central stonerollers up to age 3 in Kansas streams with 97% of the fish less than age 2. Gunning and Lewis (1956) reported that central stonerollers in an Illinois stream varied from age 0 to 3 and that 77% were age 1 and 2. While the age structure of central stoneroller populations in the current study is similar to that reported in Quist and Guy (2001) and Gunning and Lewis (1956), it is most similar to the age structure of populations reported by Lennon and Parker (1960). The authors reported that central stonerollers varied in age from 0 to 5 and that most fish (55–87% depending on stream) were less than age 3.

Although the mortality estimate of 61% by Quist and Guy (2001) is similar to that observed in the current study, patterns of age-specific mortality were quite different. Specifically, Quist and Guy (2001) found that age-specific

mortality increased from approximately 80% between age 1 and 2 to nearly 100% for subsequent age intervals. Thus, once central stonerollers live past age 1 in central Iowa streams, survival is higher than for central stonerollers in Kansas streams. The streams studied by Quist and Guy (2001) were located on Fort Riley Military Reservation and experience high levels of anthropogenic and natural disturbance (e.g., high sediment delivery, highly variable discharge, low instream cover; Quist et al. 2003). While the mechanisms related to the observed patterns in age-specific mortality are unknown, one possibility is that environmental conditions in Iowa streams are not as deleterious to the survival of central stonerollers (i.e., at least those older than age 1) as those studied by Quist and Guy (2001) in Kansas. Specifically, increased sediment delivery coupled with high canopy coverage (i.e., > 80%) and increased abundance of creek chubs (*Semotilus atromaculatus*) in the streams

studied by Quist and Guy (2001) may have increased mortality of adult central stonerollers by reducing the quality and quantity of food resources and predation.

Growth of central stonerollers in Iowa streams was similar to that of fish in Roaring Springs Creek, Illinois (Gunning and Lewis 1956) and Kansas streams (Quist and Guy 2001; Fig. 3). In contrast, growth of central stonerollers in GSMNP was higher than other central stoneroller populations, particularly at older ages (Lennon and Parker 1960). Few studies have described factors (e.g., habitat characteristics) contributing to growth of central stonerollers. However, the importance of benthic algae in their diet (e.g., Fowler and Taber 1985; Evans-White et al. 2001) suggested that any factor resulting in high production of benthic algae should result in fast growth rates of central stonerollers. Recent research suggests that stream reaches in Iowa without extensive riparian vegetation have low canopy cover and high nutrient delivery to streams (e.g., Isenhart et al. 1997; Fischer et al. 2010). These areas also appear to result in fast growth of herbivorous fishes;

presumably through increased algal production (e.g., increased nutrient availability and solar irradiance). However, the faster growth for all ages of central stonerollers observed by Lennon and Parker (1960) in Tennessee streams suggested that other factors (e.g., climate) may have been important to small-bodied fish population characteristics. For instance, Marsh-Matthews and Matthews (2000) found latitudinal gradients (e.g., annual temperature, bank stability, terrestrial vegetation type) were important determinants of fish assemblage composition in Midwestern streams. As such, the observed growth of central stonerollers in central Iowa streams may be conducive to faster rates of growth and lower mortality associated increased food availability compared to Kansas (Quist and Guy 2001) and Illinois (Gunning and Lewis 1956) populations. However climatic conditions (e.g., growing degree days) may be responsible for the reduced rate of growth compared to those observed in Tennessee stream central stoneroller populations (Lennon and Parker 1960).

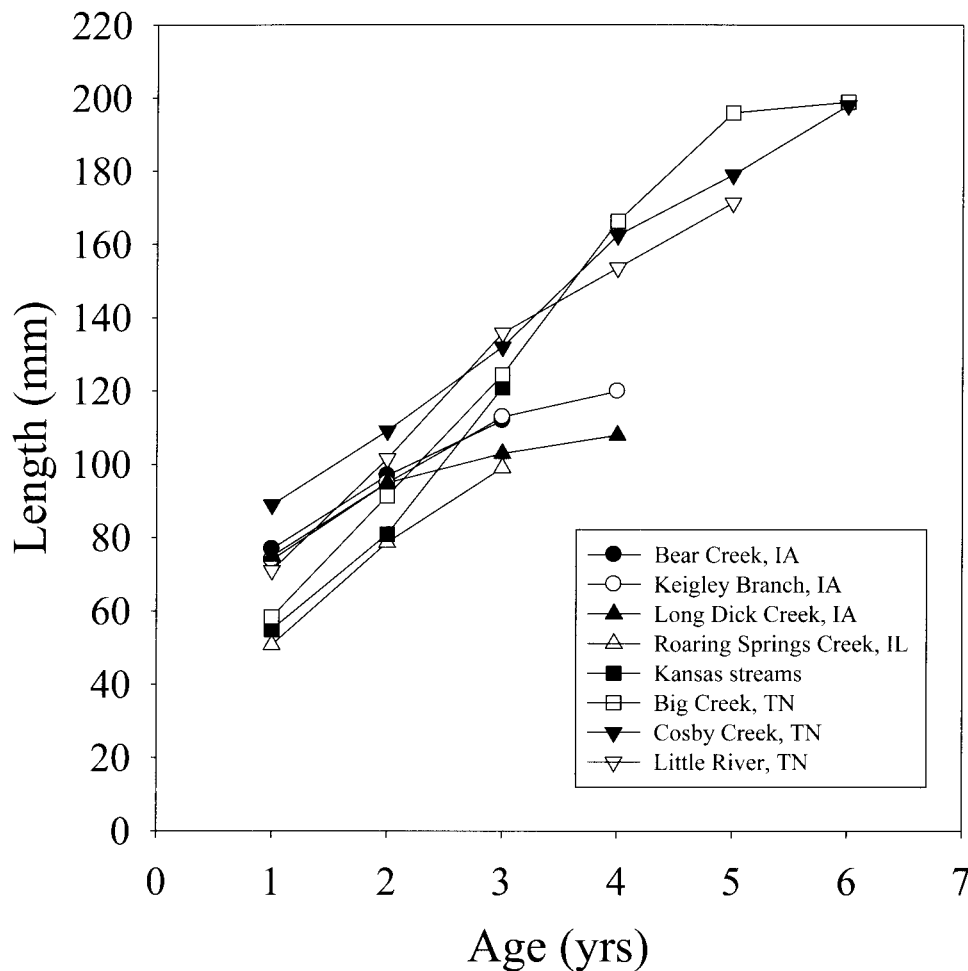


Figure 3. Mean total length at age (mm) for central stonerollers sampled from central Iowa (current study), Illinois (Gunning and Lewis 1956), Kansas (Quist and Guy 2001), and Tennessee (Lennon and Parker 1960).

MANAGEMENT IMPLICATIONS

Given the importance of central stonerollers to stream ecosystem function, understanding their population dynamics should be a high priority in systems where they are abundant. For instance, coupling age-structured population models with food web models is becoming more common because they can provide insight on ecosystem impacts of nonnative species, climate change, or alterations to important system inputs (e.g., nutrient delivery). Consequently, the availability of data on age structure, mortality, and growth of fishes (particularly small-bodied, nongame fishes) will be increasingly important to aquatic ecologists and management biologists. Our study provides such data as well as a foundation and framework for further observational and experimental research on the mechanistic processes influencing stream fish populations.

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Seasonal Yellow Perch Harvest in Two Dissimilar South Dakota Fisheries

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ABSTRACT Angler effort and fish harvest in South Dakota have historically been quantified through summer and winter creel surveys. However, the late-summer, pulsed recruitment of yellow perch (*Perca flavescens*) into a fishery combined with an increase in fall movement and feeding activity suggested September and October could be significant periods of perch harvest in South Dakota lakes. Seasonal trends in angler effort and yellow perch harvest during 2005–2007 were compared for high- and low-quality yellow perch fishery types commonly found in eastern South Dakota glacial lakes. High-quality yellow perch fisheries are characterized by fast growth (mean total length at age-3 greater than 200 mm), low density and inconsistent recruitment. Low-quality fisheries are characterized by slow growth (mean total length at age-3 less than 200 mm), high density and consistent recruitment. Angler effort directed at yellow perch ($F_{9,20} = 6.59$, $P < 0.001$) and the percentage of anglers targeting perch ($F_{9,20} = 3.82$, $P = 0.006$) were highest during the winter, but perch harvest ($F_{9,47} = 2.75$, $P = 0.012$) was highest during the summer on the low-quality fishery. Angler effort ($F_{9,20} = 6.59$, $P < 0.001$), percentage of anglers targeting yellow perch ($F_{9,20} = 3.82$, $P = 0.006$), and harvest of perch ($F_{9,47} = 2.75$, $P = 0.012$) were highest during the fall in the high-quality yellow perch fishery. High angler effort and yellow perch harvest during the fall in the high-quality fishery suggests that this period should be sampled to avoid underestimation of effort and harvest. Conversely, exclusion of the fall sampling period in low-quality yellow perch fisheries would likely not bias annual perch harvest estimates.

KEYWORDS angler effort, harvest, *Perca flavescens*, pulse recruitment, yellow perch

Yellow perch (*Perca flavescens*) are an important component of recreational fisheries throughout their range (VanDeValk et al. 2002, Su et al. 2007, Brooks and Hiltner 2008) and are the most widespread and sought-after panfish species in South Dakota (Gigliotti 2004). Researchers have documented two distinct but common yellow perch fisheries in South Dakota glacial lakes. Yellow perch fisheries classified as high-quality are typically found in lakes having simple basin morphometry with limited submersed vegetation. High-quality fisheries also are characterized by yellow perch populations with fast growth (mean total length at age-3 greater than 200 mm), large size structure, low abundance and variable recruitment (Lott et al. 1996, Isermann 2003, Schoenebeck and Brown 2010). Conversely, low-quality yellow perch fisheries are generally found in lakes with complex basin morphometry, abundant submersed vegetation, and perch populations characterized by slow growth (mean total length at age-3 less than 200 mm), small size structure, high abundance and relatively consistent recruitment (Lott et al. 1996, Isermann 2003, Schoenebeck and Brown 2010).

Differences in fish growth characteristics may contribute to differences in the timing and duration of recruitment into a fishery (Grant et al. 2004) and therefore, may potentially influence angler effort and harvest. Fast growth of high-quality yellow perch populations may lead to pulsed recruitment into the fishery while slow growth of low-quality populations often results in protracted recruitment into the fishery. Year classes in high-quality perch

populations commonly reach an acceptable size to anglers (180–200 mm; Isermann 2003) following the third season of growth (i.e., during late summer as age-2+). Late-summer, pulsed recruitment in fast growing populations could mean that August, and subsequently fall, would present the first opportunity for anglers to potentially harvest recently recruited yellow perch. In this type of fishery, anglers may respond with increased angling effort during late summer and fall.

A typical South Dakota Department of Game, Fish and Parks creel survey, which routinely quantifies the fishery only during summer (May – August) and winter (December – March), may underestimate annual harvest and exploitation for high-quality yellow perch fisheries. Conversely, year classes in low-quality perch populations usually reach an acceptable size to anglers throughout the growing season (protracted recruitment) and at older ages (Grant et al. 2004), thereby reducing the potential for high harvest during the fall and the need for a fall creel survey.

Fall months are rarely sampled during standard creel surveys. Assessment of previous studies failed to reveal any consistent seasonal trend in yellow perch harvest (VanDeValk et al. 2002, Su et al. 2007). A better understanding of the relationship between yellow perch population types and the resulting fishery would enable fisheries managers to schedule creel surveys during periods of high angler effort, resulting in more accurate estimates of angler effort and harvest that could potentially facilitate better management of the perch fishery. Thus, our objective

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was to describe differences in seasonal trends in yellow perch angler effort and harvest between a high- and low-quality perch fishery.

STUDY AREA

We selected study populations to represent low-quality and high-quality yellow perch fisheries that are common to natural lakes in eastern South Dakota (Lott et al. 1996, Isermann 2003, Schoenebeck and Brown 2010). We used mean total length at age-3 to classify population types as either high (greater than 200 mm) or low (less than 200 mm) quality yellow perch fisheries. We selected Lake Cochrane (Deuel County) to represent a low-quality fishery due to its relatively slow yellow perch growth (mean length at age 3 was 182–187 mm total length (TL) during 2005–2007) and low population size structure (< 3% of sampled yellow perch larger than 130 mm TL exceeded 250 mm during 2005–2007), moderate submersed vegetation coverage (31.0%) and low productivity (total phosphorus 0.03 ppm; Stukel 2003, Schoenebeck and Brown 2010). We selected Lake Madison (Lake County) to represent a high-quality fishery due to its relatively fast yellow perch growth (mean length at age 3 was 231 to 242 mm TL during 2005–2007) and high population size structure (4 to 39% of the sampled yellow perch larger than 130 mm TL exceeded 250 mm during 2005–2007), low submersed vegetation coverage (<0.1%) and high productivity (total phosphorus 0.27 ppm; Stukel 2003, Schoenebeck and Brown 2010). Lake Cochrane had a maximum depth of 7.3 m, mean depth of 4.0 m, surface area of 144 ha, and Secchi depth (i.e., measure of water transparency) of 2.18 m (Stukel 2003). Lake Madison had a maximum depth of 4.9 m, mean depth of 2.4 m, surface area of 1,069 ha, and Secchi depth of 0.81 m (Stukel 2003). The fish community in Lake Cochrane contained slow growing populations of yellow perch, bluegill (*Lepomis macrochirus*), and hybrid sunfish (bluegill × green sunfish *L. cyanellus*). Black crappie (*Pomoxis nigromaculatus*), largemouth bass (*Micropterus salmoides*), walleye (*Sander vitreus*), northern pike (*Esox lucius*), white sucker (*Catostomus commersonii*), and common carp (*Cyprinus carpio*) also were present. The Lake Madison sport fish community was primarily comprised of walleye and yellow perch, but black crappie, smallmouth bass (*M. dolomieu*), and northern pike also were present. Lake Madison contained a higher abundance of white sucker, common carp and bigmouth buffalo (*Ictiobus cyprinellus*) than Lake Cochrane.

METHODS

We conducted creel surveys from May 2005 through March 2008 on both lakes to evaluate seasonal trends in yellow perch angler effort and harvest. We conducted a stratified-random, access-point creel survey on both study

lakes to estimate month-specific yellow perch angler effort (h ha⁻¹) and harvest (fish ha⁻¹) from 1 May to 31 August (summer), 1 September to 31 October (fall) and 1 December to 31 March (winter; Pollock et al. 1994, Soupir and Brown 2002). We did not conduct creel surveys during November or April of any study year due to the absence of anglers because of unsafe ice conditions. We conducted open-water creel surveys (summer and fall) at 50–60 h lake⁻¹ month⁻¹ and 40–50 h lake⁻¹ month⁻¹ during the winter when angler effort was lower. We stratified creel survey sampling effort by day type (60 % weekday, 40% weekend and holiday) and time period (50% morning, 50% afternoon). The lengths of morning and afternoon periods were proportionally adjusted according to hours of available daylight (Isermann et al. 2005). We estimated angler effort using two or three instantaneous angler counts per sample with 12 to 15, 4- to 6-h shifts occurring each month. We classified anglers as either shore or boat anglers during open-water periods and as either open-ice or ice-shack anglers during winter. We calculated angler effort (h ha⁻¹) for fishing by boat or ice shack in the same manner as for shore or open-ice fishing except that boats or occupied ice shacks were counted instead of individual anglers and then expanded to angler hours by multiplying by the mean number of anglers per boat or ice shack (Ryckman 1981). Information gathered from anglers during interviews included the number of anglers in each group (per boat or shack), time of day when the anglers began fishing, if their trip was complete at the time of the interview, which species the anglers were targeting, the number of each species caught, the number of each species harvested, and lengths (TL, mm) of harvested fish.

All angler effort directed at yellow perch and perch harvest estimates (fish ha⁻¹) were calculated using Creel Application Software, Version 2.2 (Soupir and Brown 2002). Differences in angler effort directed at yellow perch, the average percentage of anglers targeting perch, and perch harvest from May 2005 to March 2008 between study lakes (not replicated), years and months were evaluated using a repeated measures ANOVA (Hansen et al. 2007) with statistical significance set at 0.05 (Littell et al. 1996). We used the distribution of lengths at age-3 (TL, mm; Schoenebeck and Brown 2010) between each population to diagnose recruitment as either pulsed (< 50 mm) or protracted (> 50 mm) using a Kolmogorov-Smirnov two sample test.

RESULTS

Interactions between year and month ($F_{18,20} = 3.32$, $P = 0.006$) and lake and month ($F_{9,20} = 6.59$, $P < 0.001$) were significant for yellow perch angler effort. Yellow perch angler effort was highest during September in 2005 and highest during January of 2006 and 2007 on Lake Cochrane (Fig. 1). Yellow perch angler effort was highest from August to October on Lake Madison.

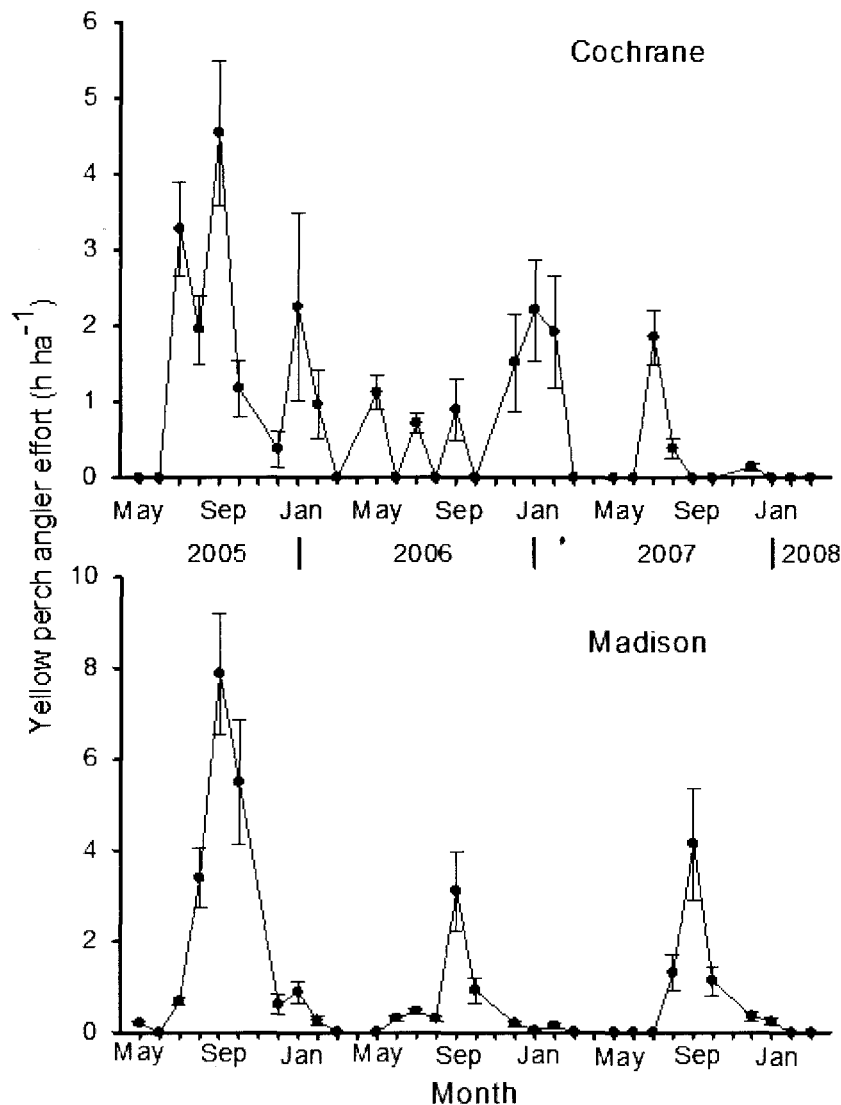


Figure 1. Yellow perch angling effort (h ha^{-1}) on Lake Cochrane and Lake Madison, South Dakota, May 2005–March 2008. Error bars represent standard error.

The interaction between year and month ($F_{18,20} = 0.61$, $P = 0.855$) was not significant while the interaction between lake and month ($F_{9,20} = 3.82$, $P = 0.006$) was significant for the percentage of anglers targeting yellow perch indicating that more anglers targeted yellow perch on Lake Madison than Lake Cochrane. Further, effort aimed at yellow perch was higher during the fall months on Lake Madison (Fig. 2). The percentage of anglers targeting yellow perch on Lake Madison decreased from the fall throughout the winter. Conversely, the percentage of anglers targeting yellow perch on Lake Cochrane was highest during the winter months.

Interactions between year and month ($F_{18,20} = 1.52$, $P = 0.183$) and lake and month ($F_{9,20} = 1.90$, $P = 0.110$) were

not significant for yellow perch harvest and thus were not included in further analyses. Yellow perch harvested per hectare did not differ between lakes ($F_{1,47} = 1.00$, $P = 0.322$) or years ($F_{2,47} = 1.60$, $P = 0.212$), but differed among months ($F_{9,47} = 2.75$, $P = 0.012$). Yellow perch harvest per hectare was highest from June through August during 2005 and 2006 on Lake Cochrane (Fig. 3). Yellow perch harvest was highest during September in all three years of the study on Lake Madison. During September and October 2005, 2006, and 2007 (e.g., months that are not normally surveyed in South Dakota), 74%, 79%, and 83%, respectively, of the annual yellow perch harvest occurred on Lake Madison.

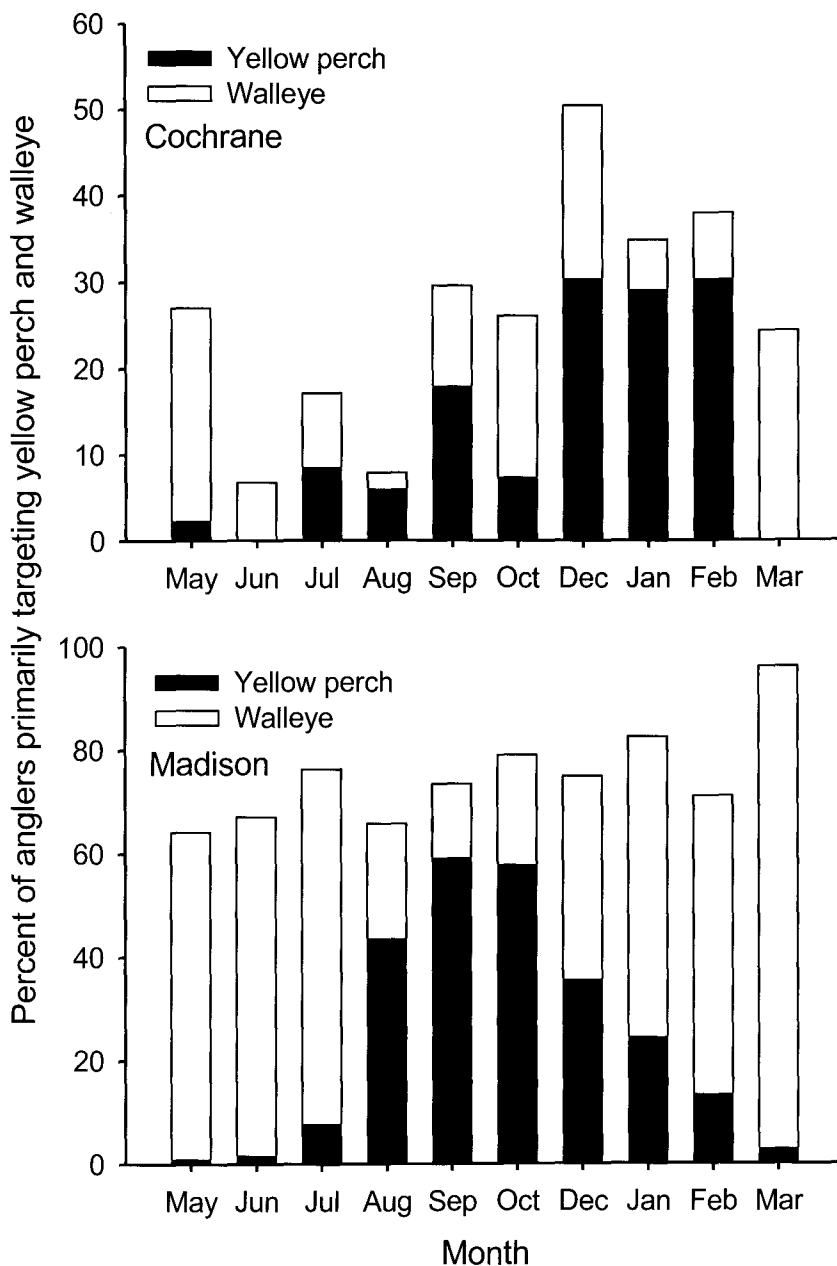


Figure 2. The average percentage of anglers targeting yellow perch (solid bars) and walleye (open bars) for Lake Cochrane and Lake Madison, South Dakota, May 2005–March 2008.

Yellow perch recruitment to the fishery differed ($D = 1.00$, $P < 0.001$) between the two lakes. Recruitment was pulsed at Lake Madison as the mean length of harvested yellow perch decreased from June through September and the range of lengths within an age group was narrow (age-3 total lengths ranged from 231 to 261 mm) during 2007 (Fig. 4). Recruitment of the 2005 yellow perch year class into the Lake Madison fishery during the late summer and fall of

2007 coincided with a decrease of 81 mm in mean total length of harvested yellow perch from 299 mm in June to 218 mm in October (Schoenebeck and Brown 2010). Conversely, recruitment was protracted at Lake Cochrane as the mean total length of harvested yellow perch remained relatively unchanged with only an 8 mm difference from May to October 2007. Total lengths within the age-3 cohort ranged from 121 to 204 mm during 2007 (Fig. 4).

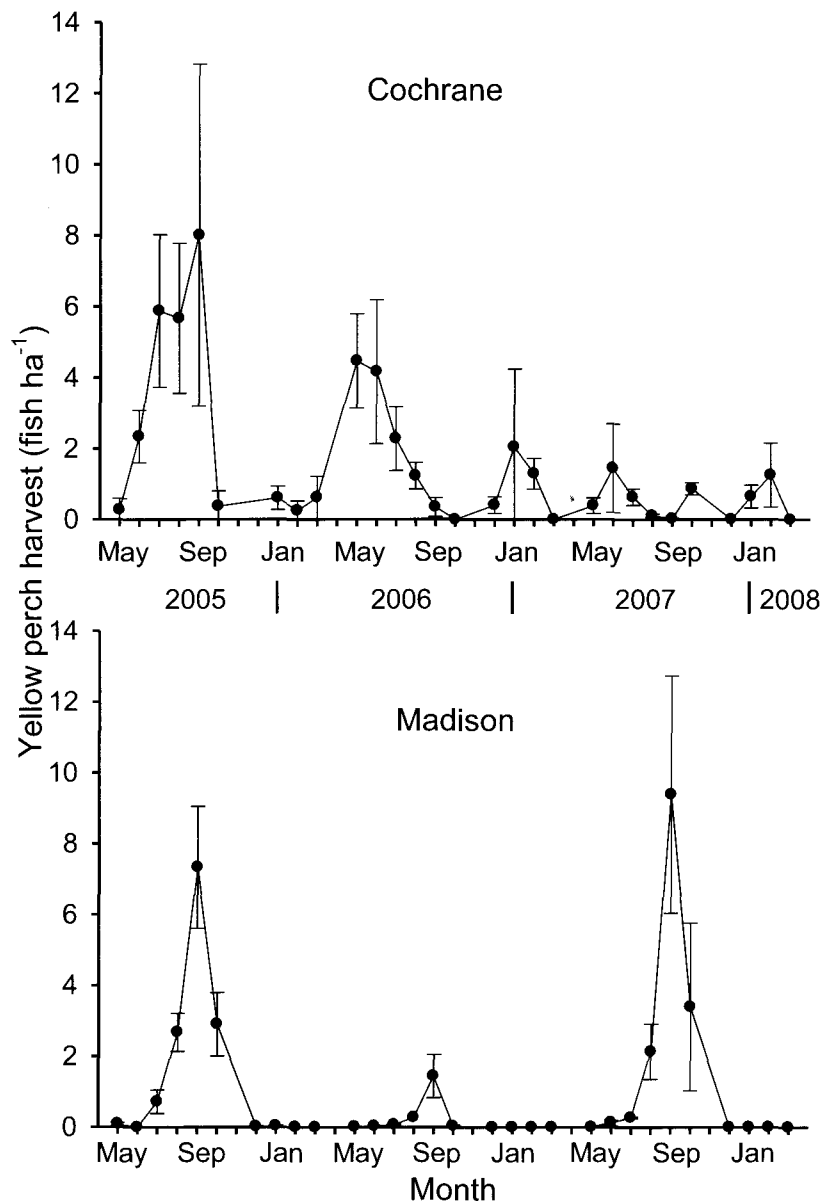


Figure 3. Yellow perch harvest (fish ha⁻¹) from Lake Cochrane and Lake Madison, South Dakota, May 2005–March 2008. Error bars represent standard error.

DISCUSSION

Seasonal trends in yellow perch angler effort and harvest varied between the two fisheries. Angler effort directed at yellow perch and perch harvest were variable for the low-quality yellow perch fishery, whereas yellow perch angler effort and harvest were highest during the fall for the high-quality fishery. Differences in the time of recruitment may account for some of the temporal differences in yellow perch angler effort and harvest. Fast growth and a narrow range of lengths within an age group exhibited by high-

quality yellow perch fisheries can result in fish of a particular age group reaching an acceptable size to anglers (180–200 mm; Isermann 2003) in a short time period (e.g., during the fall), thereby concentrating angler effort directed at yellow perch harvest during this time period. Conversely, slow growth and a wider range of lengths within an age group of yellow perch in the low-quality population suggest protracted recruitment and subsequently, a more uniform distribution in monthly angling effort and harvest would be anticipated as fish would reach an acceptable size to anglers throughout the growing season.

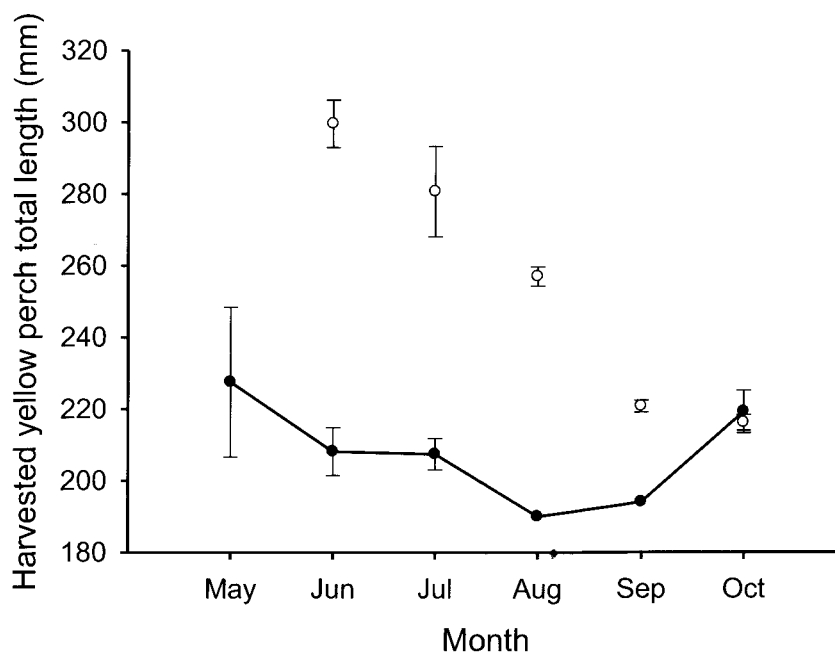


Figure 4. Mean total length (mm) of yellow perch harvested from Lake Cochrane (solid line) and Lake Madison (dotted line), South Dakota, May 2007–October 2007. Error bars represent standard error.

Differences in fish communities between fishery types may explain differences in the percentage and timing of anglers targeting yellow perch. Anglers on Lake Madison primarily target yellow perch and walleye throughout the year in this relatively simple fish community. During this study, a higher percentage of anglers targeted yellow perch than any other species during the months of August, September, and October on Lake Madison. In comparison, anglers on Lake Cochrane tend to be generalists targeting a variety of species available in that complex fish community. Anglers did not target yellow perch on Lake Cochrane even when yellow perch harvest was at its highest during the summer and fall of 2005.

Seasonal changes in yellow perch behavior may have influenced seasonal trends in harvest between fishery types. Increases in fall movement have been documented for adult yellow perch in Lake Madison and Lake Sinai, another high-quality South Dakota yellow perch population (Radabaugh et al. 2010). Increases in fall movement are likely associated with increased feeding activity and could have translated into higher susceptibility and increased angler catch rates during this time period (Costa 1973, Radabaugh et al. 2010).

Peak angling effort and harvest of yellow perch during fall has been documented for Lake Madison and has previously been observed for other high-quality perch fisheries. For instance, yellow perch harvest from private (60%) and charter (83%) boat anglers in the Ohio waters of Lake Erie occurred during September and October 2007 (Ohio Division of Wildlife 2008). Despite small sample

sizes, Radabaugh (2006) also reported high (37%) fall harvest of yellow perch in Lake Madison in eastern South Dakota. Although not documented, substantial harvest of yellow perch has occurred during September and October on Waubay Lake and Big Stone Lake, other high-quality yellow perch fisheries in South Dakota (B. Blackwell, South Dakota Department of Game, Fish and Parks, personal communication).

MANAGEMENT IMPLICATIONS

Not sampling angler use and harvest of a yellow perch fishery during the fall months could potentially underestimate harvest estimates, consequently rendering creel survey estimates biased and unreliable for directing management decisions. Conversely, exclusion of the fall yellow perch harvest for low-quality fisheries may not bias annual harvest estimates allowing personnel to be redirected to high-quality fisheries during the fall. Pulsed recruitment of a yellow perch year class into the fishery should result in a decreased mean length of harvested fish. Given this information, a fisheries managers who typically samples the recreational creel only during the summer months could schedule a fall creel survey for a high-quality population if a decrease in mean total length of yellow perch harvested is observed or if summer netting data indicate that fall recruitment of a year class is likely. Scheduling a fall creel survey under these circumstances would help ensure the most accurate information on angler effort and yellow perch harvest was collected and used to manage the fishery.

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Cropland Nesting by Long-billed Curlews in Southern Alberta

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ABSTRACT Long-billed curlews (*Numenius americanus*) are described primarily as a grassland nesting species. However, no studies to date have quantified nest habitat selection among available habitats. During a study of waterfowl nest habitat selection and success in landscapes ranging from cropland to grassland-dominated, we found 9 curlew nests of which 8 were located in active cropland within cropland-dominated landscapes. Cropland nests occurred in fall-seeded winter wheat and spring-seeded barley and nests were clumped in distribution. Four cropland nests and 1 nest in native grass pasture hatched young. Further research is needed to characterize nesting habitat selection and reproductive success for this species.

KEY WORDS Alberta, cropland, long-billed curlew, nesting habitat, *Numenius americanus*, winter wheat

Long-billed curlews (*Numenius americanus*; hereafter, curlews) are the largest North American shorebird and breeding populations were once abundant over most of the shortgrass and mixed-grass prairies of the northern Great Plains. Significant population declines since the late 1800s have been attributed to overharvest (prior to 1918) and loss of breeding habitat, particularly the loss of grasslands to cultivation (Dugger and Dugger 2002). Curlews are listed nationally in the United States as a U.S. Fish and Wildlife Service “Bird of Conservation Concern” (Fellows and Jones 2009), and in Canada they are listed as a species of “Special Concern” indicating that it may become threatened or endangered as a result of biological characteristics and identified threats (COSEWIC 2009). In Alberta, the curlew is presently found in isolated populations in the Grassland Natural Region of southeastern Alberta; breeding densities there are thought to be some of the highest within their remaining range (Hill 1998). Curlews are a “Blue List” species in Alberta, indicating that the species may be at risk of declining to non-viable population levels (Alberta Environment 2001). Despite their population status, curlews remain a relatively “underemphasized” species in studies of breeding shorebirds (Dugger and Dugger 2002: 23).

Based on surveys of territorial males and pairs, breeding curlews typically settle in landscapes characterized by large, open expanses of grassland pasture. While proximity to water is likely an important factor in settling, pairs often occur in dry grasslands (Dugger and Dugger 2002, reviewed in Dechant et al. 2003). Cultivated lands adjacent to grasslands often were used by breeding curlews, but extensively cultivated landscapes were generally avoided (Dugger and Dugger 2002, Foster-Willfong 2003, Ackerman 2007). Knopf (1994) listed curlews as a primary grassland endemic species. In systematic range-wide surveys of breeding pair habitat associations in southern Alberta, Saunders (2001) indicated that native grasslands in

Alberta were preferred habitat for breeding pairs, cultivated lands were used in proportion to availability, and tame pastures were avoided. Saunders also noted that relatively large numbers of breeding curlews in Alberta occurred in intensively cultivated landscapes. In a similar range-wide survey in the United States, Saalfeld et al. (2010:153) found “curlews were most frequently observed in low stature (i.e., 4–15 cm), shortgrass prairie and pasture grasslands as well as cultivated crops”.

Nesting habitat is typically characterized as grazed grasslands with rare occurrences of nesting in haylands and cultivated lands (Dugger and Dugger 2002, Dechant et al. 2003, Hartman and Oring 2009). Whereas several sources indicate that curlews may nest in croplands or cultivated land (e.g., Pampush 1980, Renaud 1980), documented first-hand accounts are rare. Shackford (1994:19) found two nests in Oklahoma, both in recently plowed wheat fields that were “essentially bare except for an occasional weed or two”. He further stated “this was the first confirmed nesting of curlews in a cultivated field in Oklahoma and, to the best of our knowledge, no other exists elsewhere”. More recently, Foster-Willfong (2003:37) “found one nest and it was located in a crop field” and Ackerman (2007) reported one nest in spring-seeded wheat and one nest in fallow crop (of four nests found) in North Dakota. It is important to note that these reports are incidental encounters and not the result of systematic nest searching activity and therefore, the potential relative use of cropland habitat for nesting remains unknown. Our objective was to report the extent of cropland nesting by curlews from a study where a range of habitats were systematically searched for nests.

STUDY AREA

Our study was conducted near the town of Hussar, Alberta (51° 2' 27" N, 112° 40' 57" W; Fig. 1). This area is within the Moist Mixed Grassland Ecoregion of southern

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Alberta and is characterized by flat to hummocky or kettled topography formed by deposition of lacustrine deposits and glacial till (Ecological Stratification Working Group 1995). Wetlands, in the form of prairie potholes, comprised approximately 7.6% of the area (J. Devries unpublished data). The regional climate was cold continental with a mean annual temperature of 4.1°C (January–July range: –8.9 – 16.2 °C) and a mean annual precipitation of 320 mm (at Calgary; Environment Canada 2000). Primary land uses in the area included cropland (predominantly for cereal grain and oil-seed production), and introduced and native grassland pasture and hayland for beef cattle.

Native grasslands were dominated by spear grass (*Stipa comata*), western porcupine grass (*S.curtiseta*), western wheat grass (*Agropyron smithii*), northern wheatgrass (*A. dasystachyum*), June grass (*Koeleria macrantha*), western snowberry (*Symphoricarpos occidentalis*), and prickly rose

(*Rosa acicularis*; Alberta Environmental Protection 1997). Tame grasslands and haylands typically were seeded to alfalfa (*Medicago* spp.) in combination with crested wheatgrass (*A. cristatum*), smooth brome (*Bromus inermis*), or Russian wild rye (*Elymus junceus*). Approximately 99 and 92% of native and tame grasslands, respectively, were used as pasture and generally provided sparse cover throughout the nesting season. Haylands provided sparse cover early in the season but dense cover by early June. Idle native and tame grasslands provided dense cover throughout the nesting season. Croplands included standing stubble of cereal crops (e.g., wheat, barley) and canola or bare dirt (previous year's fallow land). All cropland provided sparse nesting cover early in the nesting season although winter wheat became relatively tall and dense by early June (Devries et al. 2008).

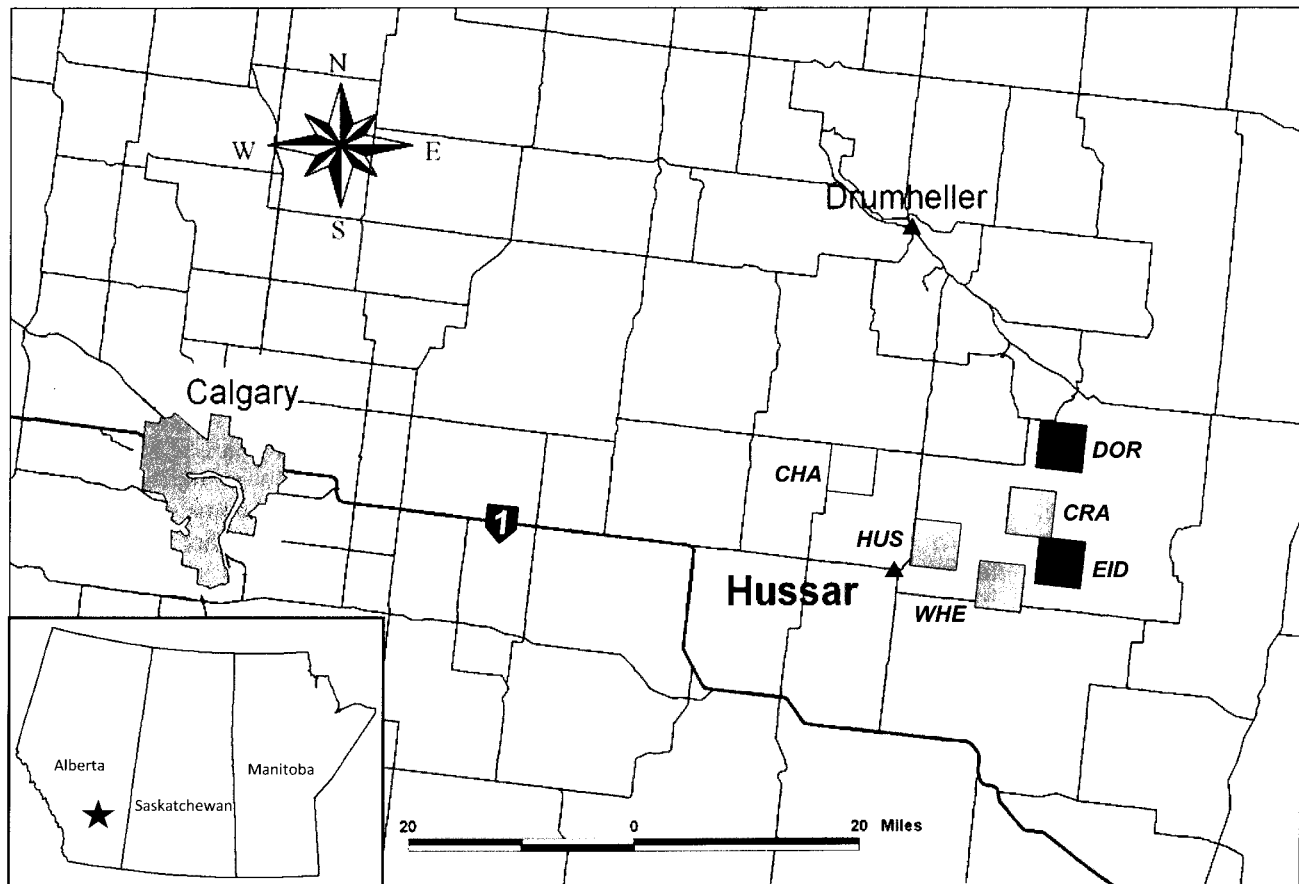


Figure 1. Location of 6, 41km² study sites containing habitats searched for waterfowl and shorebird nests near Hussar, Alberta, 2007. Light-gray sites contain <40% grassland cover (CHA, CRA, HUS, WHE), and dark-gray sites contain >60% grassland cover (DOR, EID). CHA = Chancellor, CRA = Crawling Valley, HUS = Hussar, WHE = Wheatland, DOR = Dorothy, and EID = Eastern Irrigation District study sites.

METHODS

We conducted nest searches for waterfowl and shorebirds during April–June 2007 and we sampled most nesting habitats available. Our study examined the influence of landscape composition on waterfowl nesting; hence, we selected 6, 6.4 x 6.4-km (41 km²) landscapes of which 2 represented high (>60%) levels of grassland cover (i.e., tame and native grassland and hayland), and 4 represented low (<40%) levels of grassland cover. Our study sites were 41 km² in size because previous research indicated that grassland amount at this scale affected waterfowl nest survival (Stephens et al. 2005). The 6 study sites were a stratified random sample from 2,000 random sites generated in ArcMap and stratified by land use as determined from classified Landsat-TM data (Agriculture and Agri-Food Canada 2001). The 2 high-grassland site replicates were dominated by intact native prairie with minimal cropland (Dorothy [DOR] and Eastern Irrigation District [EID]), 2 low-grassland replicates were composed of tame and native pastures and hayland with some spring-seeded cropland (Hussar [HUS] and Crawling Valley

[CRA]), and the remaining 2 low-grassland replicates were dominated by spring-seeded cropland (Chancellor [CHA] and Wheatland [WHE]; Table 1, Fig. 1).

Because use of cropland habitat, especially winter wheat, for nesting was of interest, we contracted seeding of 111–124 ha of winter wheat (473 ha total) on the 4 low grassland sites (i.e., CHA, HUS, WHE, CRA) during September 2006. Agreements with landowners ensured that we could nest search these areas as well as an equal area of their spring-seeded cropland and/or chemical fallow cropland. Exact location of crop fields within the study site was constrained by landowner willingness to be involved in our study. Because we could not nest search entire study sites, we identified other habitats of interest (native grassland, tame [seeded] grassland, hayland) on all quarter sections (65 ha legal subdivisions) within a study site and we randomly selected a minimum of 2 quarters containing each habitat for nest searching. We searched non-flooded wetland vegetation on all quarters.

Table 1. Study sites, location, percent of study sites in grassland and cropland, and habitat area (ha) systematically searched for waterfowl and shorebird nests in southern Alberta, 2007.

Study site	% grassland, cropland ^a	Area searched						Total area searched
		Native grass	Tame grass	Hayland	Spring-crop / Chemical fallow	Winter wheat	Wetland	
Chancellor	21, 68	72.6	15.8	0.0	234.1	110.0	7.2	439.7
Crawling Valley	31, 55	182.4	127.5	24.7	203.0	118.3	3.7	659.6
Dorothy	61, 29	243.3	115.3	114.8	52.2	0.0	2.8	528.4
E. Irrigation District	94, 0	304.9	0.6	0.0	0.0	0.0	4.7	310.2
Hussar	41, 52	191.8	95.4	0.0	160.9	120.7	4.3	573.1
Wheatland	4, 87	0.0	4.9	50.0	235.4	124.0	4.7	419.0
Total area searched		995.0	359.5	189.5	885.6	473.0	27.4	2,930.0

^a Percent grassland (native and tame grassland and hayland) and cropland (annually cultivated lands) within the 41-km² study site boundaries reflecting criteria used to select sites.

We found nests using all-terrain vehicle (ATV) cable-chain drags (Higgins et al. 1977) and ATV rope drags (2.5-cm diameter rope used in growing cropland), by walking and dragging a rope between 2 observers, or by walking and striking the vegetation with willow switches (‘beat-outs’). We conducted 4 nest searches on each quarter section

beginning approximately 26 April, 15 May, 3 June and 27 June. We conducted searches between 0730 and 1300 MST each day. We searched all habitats including croplands but excluded trees and flooded wetland vegetation. When a nest was discovered, we identified the nest habitat, species, number of eggs in the nest, and incubation status. We

recorded nest locations using a Global Positioning System (GPS; Garmin Model 76) for later analyses in a Geographic Information System (GIS; ArcMap, ESRI, Redlands, California, USA), and marked with a willow stake 4 m north of the nest. Following discovery, we checked nests every 7–10 days to track number of eggs and incubation status until final nest fate was determined (hatched, destroyed, or abandoned). For shorebird nests, we determined incubation status by flotation in water (C. Gratto-Trevor, Environment Canada, personal communication; Liebezeit et al. 2007). In the absence of evidence of curlew chicks, we determined nest fate based on condition of the nest bowl (tiny shell chips from pipping, flattened nest bowl; C. L. Gratto-Trevor, Environment Canada, personal communication).

To characterize the landscape surrounding nests, we used classified Landsat-TM digital landcover (Agriculture and Agri-Food Canada 2008) in ArcMap to estimate the percent grassland (all types) within a composite 1.6-km radius buffer landscape (hereafter, landscape) around curlew nests at each study site. We used classified landcover as well to estimate mean distance from cropland nests to the nearest large (>65 ha) patch of grazed grassland.

RESULTS

We searched a total of 2,930 ha of 6 habitats of which 1,544 ha were grassland types (native/tame pastures and haylands), and 1,386 ha were cropland types (spring-seeded

wheat and barley, chemical fallow, and winter wheat; Table 1). We found 9 curlew nests; 3 each on the CHA and CRA sites (low-grassland), 2 on WHE (low-grassland), and 1 on EID (high-grassland). Eight of 9 nests were in active cropland, including 5 in winter wheat and 3 in spring-seeded barley. The remaining nest was in native grassland pasture (Table 2). Nests in winter wheat were distributed among 2 fields; 3 nests in one 126-ha field and 2 nests in one 124-ha field. The 3 nests in spring-seeded barley also were together in 1, 125-ha field. The nest in native prairie was 1,560 m into a large contiguous block of native grassland pasture (i.e., > 41 km² in size) that comprised the EID site. All nests were concurrently active and hence represented separate breeding females. Distances among 3 nests in winter wheat were 805, 780, and 395 m in 1 field and 340 m between 2 nests in the other. Distances among nests in the spring-seeded barley field were 910, 640, and 540 m.

Percent grassland comprised approximately 99, 16, 7, and <1% of the landscape surrounding nests at the EID, CRA, CHA, and WHE study sites, respectively. Median distance from cropland nests to the nearest large block of grazed grassland was 1,475 m (range: 690–3,270 m). We were able to estimate incubation for 6 nests and these were backdated to initiation dates between 8 May and 27 May (Table 2). Seven of 8 nests for which we determined full clutch contained 4 eggs and the remaining nest contained 3 eggs (Table 2). Five of the nests hatched and the remainder were presumed lost to predation.

Table 2. Characteristics of nine long-billed curlew nests found during systematic nest searches in southern Alberta, 2007.

Nest	Study site	Nest habitat ^a	Nest initiation		Full clutch	Exposure days	Fate
			date				
LBCU01	CRA	Barley	8-May		4	22	Hatched
LBCU02	CHA	Winter Wheat	8-May		4	20	Hatched
LBCU03	CHA	Winter Wheat			4	11	Destroyed
LBCU04	CHA	Winter Wheat				4	Destroyed
LBCU05	CRA	Barley			3	13	Destroyed
LBCU06	CRA	Barley	13-May		4	27	Hatched
LBCU07	WHE	Winter Wheat	13-May		4	13	Hatched
LBCU08	WHE	Winter Wheat	13-May		4	4	Destroyed
LBCU09	EID	Native Grass	27-May		4	3	Hatched

^a Barley was seeded on 2 May 2007; winter wheat was seeded in September 2006. Blank cells represent no data.

DISCUSSION

Dechant et al. (2003) and Fellows and Jones (2009:8) report that curlews “nested in the simplest, most open habitat available”. Saunders (2001) speculated that, based on the presence of pairs and courtship activity in intensively cropped landscapes, nesting in croplands was likely. Moreover, early spring croplands with standing stubble from previous year’s crop may provide the open, sparsely vegetated structure preferred by nesting curlews (Saunders 2001).

Our study is the first to report a higher proportion of curlew nests in croplands when compared to previous research. Despite opportunities to nest in nearby expanses of grazed native grasslands, most (8 of 9) curlew nests we observed were in cropland. Saalfeld et al. (2010) indicated that in landscapes with 0–5% grassland, curlew tended to avoid grassland fragments and speculated that minimum breeding area requirements may make these unsuitable breeding habitats. Because we only searched a relatively small set of landscapes within the curlew range in Alberta, we are limited in our inference regarding nest habitat selection. Observed use of croplands in our study could easily result from a unique concurrence of curlews and highly cropped landscapes.

In our study, curlews initiated nests in spring-seeded cropland 6 days after seeding operations had occurred in early May and hence avoided disturbances which would have destroyed established nests. This may have been an artifact of suitable weather for early crop seeding in 2007; nests would commonly be at risk in this habitat in many years when seeding occurs well into May. In contrast, winter wheat is seeded in August–September and remains relatively undisturbed through the following breeding season prior to harvest. Lack of a seeding disturbance in winter wheat could enhance both initial nest success and re-nesting success relative to croplands cultivated during spring (Hartman and Oring 2004, Devries et al. 2008). Nest success is a primary factor determining the population growth potential of many bird species and is often a vital rate targeted by conservation efforts (e.g., Hoekman et al. 2002, Mattson and Cooper 2007).

The clumped distribution of nests in our sample is striking and supports the observation of Allen (1980) and Saunders (2001) that curlews tend to occur, and may nest, in loose social aggregates. This attribute also may enhance the risks or benefits to a nesting population when making habitat selection decisions. Curlew are known for vigorous defense of nests and young (Dugger and Dugger 2002) and the effectiveness of this behavior is likely enhanced if nests are semi-colonial (e.g., Berg 1996). When nests are aggregated in cropland, however, the benefit of this behavior may be lower, and risk higher, if cultivation is the primary source of nest destruction.

Our study was not designed to examine curlew breeding habitat association or nest habitat selection; however, our

observations suggest that nesting of curlews in croplands may be more common than previously believed. Given low nest success reported for birds nesting in croplands (Lokemoen and Beiser 1997, Best 1986, Devries et al. 2008), the extent and implications of this behavior to curlew population demography requires further study.

MANAGEMENT IMPLICATIONS

Conservation planning and habitat management for the curlew requires that nesting habits and habitats are well understood, and plausible conservation options are available. We recommend that where curlew and highly cropped landscapes overlap, agricultural producers incorporate fall-seeded crops into their rotations to potentially reduce disturbance of nesting curlew. Fall-seeded crops such as winter wheat and fall rye are examples of low disturbance crops already being planted in the region.

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Population and Diet Assessment of White Bass in Lake Sharpe, South Dakota

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ABSTRACT White bass (*Morone chrysops*) have been introduced into all 4 South Dakota Missouri River reservoirs and compose a substantial proportion of the annual recreational harvest. To date, limited studies have examined white bass population dynamics and food habits in South Dakota Missouri River reservoirs. Our objective was to examine population dynamics and food habits of white bass in Lake Sharpe, a South Dakota mainstem Missouri River reservoir. White bass consistently consumed invertebrates during May but switched to a more piscivorous diet later in the growing season; most of the fish consumed were gizzard shad (*Dorosoma cepedianum*). Information from this study adds to the body of knowledge of white bass population dynamics and their role in fish communities that is necessary for successful management of those communities.

KEY WORDS food habits, *Morone chrysops*, population dynamics, white bass

White bass (*Morone chrysops*) are native to the Minnesota and Big Sioux drainages in South Dakota, the latter of which is nested within the Missouri River drainage (Bailey and Allum 1962). However, white bass are not native to the Missouri River mainstem in South Dakota and have been introduced into all four South Dakota Missouri River reservoirs (Bailey and Allum 1962, Ruelle 1971). White bass compose a seasonal but substantial portion of the recreational fish harvest in all four reservoirs (Willis et al. 1996, 2002).

To date, limited studies have examined white bass population dynamics and food habits in South Dakota Missouri River reservoirs (see Ruelle 1971, Willis et al. 1996, Beck et al. 1997, Beck 1998). Information on recruitment, growth, and mortality is necessary for effective management. Further, the potential exists for white bass to compete with other recreationally important species in these reservoirs such as walleye (*Sander vitreus*; Beck et al. 1998, Starostka 1999) and smallmouth bass (*Micropterus dolomieu*; see Wuellner et al. 2010a). Our objective was to examine population dynamics and food habits of white bass in Lake Sharpe, a mainstream Missouri River reservoir.

STUDY AREA

Lake Sharpe is located in central South Dakota. This reservoir extends from Oahe Dam to Big Bend Dam with a surface area of ~25,000 ha (Stueven and Stewart 1996). Maximum and mean depths are 23.5 m and 9.5 m, respectively, and the bottom substrate is classified as sand, gravel, shale, and silt (Stueven and Stewart 1996). Lake Sharpe experiences relatively small annual water level fluctuations (<1.1 m) and is operated primarily for water

control and hydropower purposes (Stueven and Stewart 1996). Fisheries management classification of this reservoir is cool and warm water permanent (Lott et al. 2006).

METHODS

We sampled white bass throughout Lake Sharpe from May through August 2006 and 2007 using short-term (i.e., ≤4 hr) and overnight experimental monofilament gill net sets. We sampled fish during the last 2 weeks of every month. Though we did not standardize sampling locations, fish were sampled throughout the reservoir. Experimental gill nets were 91.4 m long and 1.89 m deep; bar mesh sizes of the six panels were 12.7, 19.1, 25.4, 31.8, and 50.8 mm. Fish collection was conducted under South Dakota State University Institutional Animal Care and Use Committee Approval Number 03-E007.

We measured total length [(TL); mm] and weighed (g) each white bass collected. We calculated proportional size distribution (PSD) values by year to index size structure; PSD is defined as the percentage of stock-length fish that exceed quality length; proportional size distribution of preferred-length (PSD-P) fish is the percentage of stock-length fish that also exceed preferred length, and proportional size distribution of memorable-length (PSD-M) fish is the percentage of stock-length fish that also exceed memorable length (Anderson and Neumann 1996, Guy et al. 2007). Minimum stock, quality, preferred, and memorable lengths for white bass are 150, 230, 300, and 380 mm TL, respectively (Gabelhouse 1984). We indexed fish condition using mean relative weight values (W_r ; Murphy et al. 1990). We calculated mean W_r by length group (e.g., stock-quality, quality-preferred, preferred-memorable) and month to avoid

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length-related bias and to reflect changes in prey availability throughout the growing season. We used analysis of variance (ANOVA) to determine differences in mean W_t between length groups, months and years. Statistical significance was determined at $\alpha = 0.05$.

We removed sagittal otoliths from each white bass collected to determine ages of individuals. At least 1 otolith from each fish was cracked, sanded, and viewed in section independently by two readers; initial readings were done blindly and any discrepancies in age were settled by a third reader. We plotted age-frequency histograms by year. We noted several missing year classes in our plots; thus, we used the recruitment variability index (RVI) to assess relative recruitment variation among years (Guy 1993, Guy and Willis 1995). We calculated the index as:

$$RVI = [S_N / (N_m + N_p)] - N_m / N_p$$

where S_N is the sum of the cumulative relative frequency distribution based on the number of fish in each age group; N_m is the number of missing year-classes in the sample (excluding those year-classes older than the oldest fish collected in the sample); and N_p is the number of year-classes present in the sample. The RVI ranges from -1 to 1, with values close to 1 indicating relatively stable recruitment (Guy 1993, Guy and Willis 1995). We combined age data with length data to assess growth. We calculated and plotted mean TL per cohort by year and fit a von Bertalanffy (1938) growth model to data collected in each year.

We excised whole stomachs in the field from each white bass collected and individual stomachs were stored in a 90% ethanol solution. Our goal was to collect 60 fish with food in their stomachs at both the upper and lower ends of the reservoir; however, our goal was rarely reached due to difficulty in catching fish during some months. In the laboratory, we identified, enumerated, and weighed (wet weight; g) stomach contents. We indexed food habits as percent composition by weight (Bowen 1996) by individual fish. We calculated a mean diet composition for all white bass by month and year. We made no attempts to calculate food habits by length categories due to the inadequate numbers of fish collected for some length groups in some months. Additionally, we made no comparisons of food habits between white bass collected in upper and lower Lake Sharpe

RESULTS

More than twice as many white bass were collected in 2006 ($n = 313$) than in 2007 ($n = 126$). In both years, the greatest number of white bass was collected in August ($n = 147$ and 63, respectively) compared to the other three months (May = 47 and 15, June = 66 and 12, July 53 and 36, respectively). Proportional size distribution indices were higher in 2007 than 2006 (Table 1); all white bass

collected in 2007 exceeded quality length. Condition values were higher for smaller length categories in both 2006 ($F_{2,310} = 62.47, P < 0.001$) and 2007 ($F_{2,123} = 13.58, P < 0.001$). Condition generally increased throughout the growing season in both years (2006: $F_{2,309} = 52.60, P < 0.001$; 2007: $F_{3,122} = 21.97, P < 0.001$) and was generally higher among all length categories in 2006 compared to 2007 ($F_{1,437} = 10.26, P < 0.001$; Fig. 1).

Table 1. Proportional size distribution (PSD), proportional size distribution of preferred-length (PSD-P), and proportional size distribution of memorable-length (PSD-M) white bass collected in Lake Sharpe, South Dakota, in 2006 and 2007. Numbers in parentheses represent the 95% confidence interval.

Year	PSD	PSD-P	PSD-M
2006	85 (±7)	60 (±10)	9 (±6)
2007	100 (±5)	86 (±7)	20 (±8)

The range in white bass ages was similar during both years of this study (Fig 2). Ages-1 and -5 fish were equally more prevalent than other year classes in 2006. As expected, age-2 white bass dominated catches in 2007, followed by age-6 fish (Fig. 2). In 2006, the 1996, 2000, and 2002 year classes were not represented in the sample (Fig. 2). In 2007, individuals from the 1998 and 1999 year classes were not sampled (Fig. 2). Recruitment variability index values indicated somewhat erratic recruitment each year (Fig. 2).

Growth rates for white bass were relatively similar between 2006 and 2007, particularly for older (≥ 5 years) fish (Fig. 3). Growth was relatively rapid between ages-1 and -5 but slowed thereafter (Fig. 3). Growth rates of younger fish appeared to be more rapid in 2006 compared to 2007. Mean TL of Lake Sharpe white bass was larger or similar than back-calculated TL reported in other South Dakota Missouri River reservoirs, eastern natural lakes, and throughout Minnesota through age-5 (Fig. 3; Willis et al. 1997). However, mean back-calculated TL of white bass was larger in eastern natural lakes at age-6 than mean TL of Lake Sharpe white bass in 2006 and 2007 (Fig. 3).

White bass food habits were more diverse later in the growing season compared to the early season (Fig. 4). In May of both years, invertebrates composed the entire diets of collected white bass. In 2006, all invertebrates consumed were ephemeropterans, but dipterans were consumed in addition to ephemeropterans in 2007. Odonates were the only insects consumed in July 2006. Diets were not analyzed in June 2006 as no white bass that were collected had food in their stomachs. Prey fish were prevalent in white bass diets during the latter months of the growing season (June – August) in both years. The most common

identifiable prey fish was gizzard shad (*Dorosoma cepedianum*). Other prey fishes consumed included emerald shiner (*Notropis atherinoides*), johnny darter (*Etheostoma nigrum*), rainbow smelt (*Osmerus mordax*), and yellow

perch (*Perca flavescens*). One white bass was consumed in 2006. Unidentifiable larval fish were consumed in June 2007; otherwise, all prey fishes appeared to be juveniles or adults.

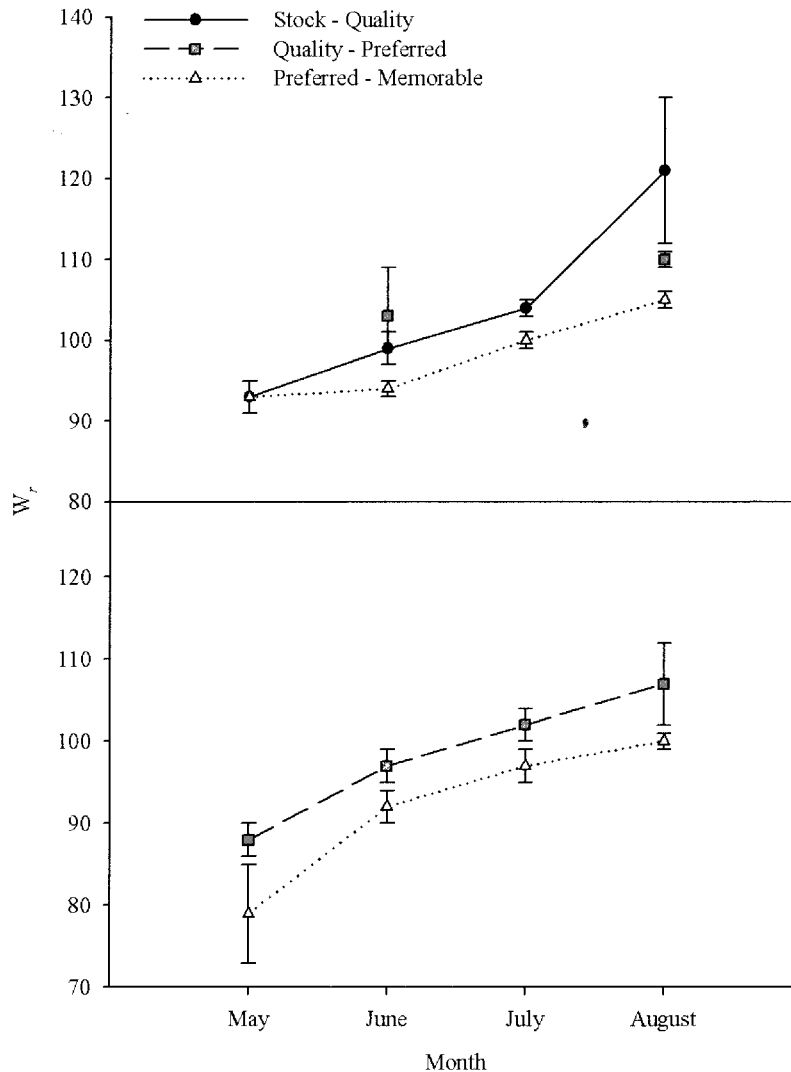


Figure 1. Mean relative weight (W_r) by month, length category, and year (2006: top panel; 2007: bottom panel) for white bass collected from Lake Sharpe, South Dakota. Error bars represent \pm one standard error.

DISCUSSION

White bass are an important recreational species in South Dakota (Willis et al. 2002); information gleaned from this study adds to the body of knowledge of white bass population dynamics and their role in fish communities that is necessary for successful management of the communities. Size structure of Lake Sharpe white bass indicated a quality fishery. Proportional size distribution indices equaled or exceeded those of four Missouri reservoirs (Pomme De Terre Lake, Lake of the Ozarks, Table Rock Lake, and Bull Shoals Lake; Colvin 2002a) and 23 Nebraska reservoirs

(Bauer 2002). Size structure may be related to year-class stability (Bauer 2002) or strength (Colvin 2002a). Bauer (2002) found a larger proportion of white bass >300 mm TL in Nebraska reservoirs that were characterized by less stable recruitment than those with more stable recruitment; the Lake Sharpe white bass population appears to have erratic recruitment. Proportional size distribution values were often <50 in years when age-0 catch rates were high and older age-groups were not abundant in four Missouri reservoirs (Colvin 2002a). High population size structure may also be related to growth or prey availability. Colvin (2002a) found that two reservoirs with faster white bass

growth rates had consistently higher size structure than two reservoirs with slower growth rates. Bauer (2002) reported higher PSD but lower PSD-P values in Nebraska reservoirs

with a gizzard shad prey base than those with a primarily alewife (*Alosa pseudoharengus*) prey base.

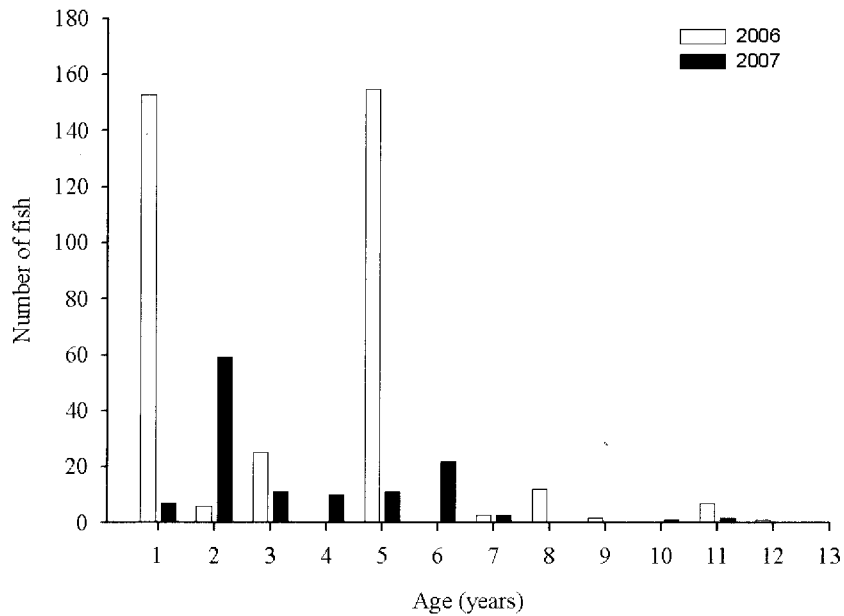


Figure 2. Age structure and recruitment variability index (RVI; 2006 = 0.56, 2007 = 0.54) for white bass collected from Lake Sharpe, South Dakota, 2006–2007.

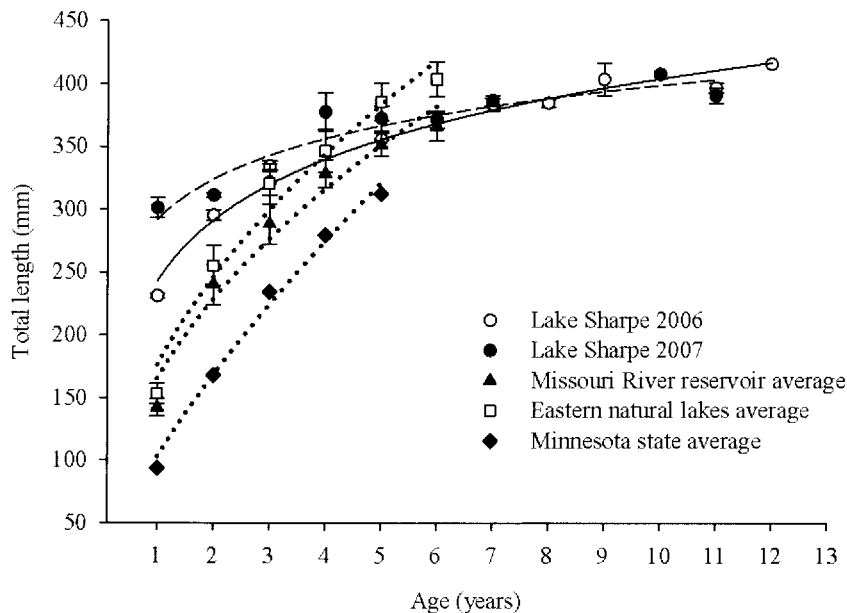


Figure 3. Mean total length (TL; mm) at time of capture by age group for white bass sampled in Lake Sharpe, South Dakota, 2006 (open circles) and 2007 (filled circles) and mean back-calculated total length averages for South Dakota Missouri River reservoirs excluding Lake Sharpe (filled triangles), eastern natural lakes (open squares), and Minnesota state averages (filled diamonds) adapted from Willis et al. (1997). Error bars represent \pm one standard error. Equations (2006: $l_t = 388[1 - e^{-0.42(t + 1.18)}]$; 2007: $l_t = 413[1 - e^{-0.24(t + 3.81)}]$) represent the von Bertalanffy (1938) growth model fit to the data.

Growth of Lake Sharpe white bass often equaled or exceeded that of southern populations. In both years, many white bass reached quality length by age-1, and most were preferred length by age-2, similar to that observed in four Alabama reservoirs (Lovell and Maceina 2002) and 54 Texas reservoirs (Wilde and Muoneke 2001). Preferred sizes were attained within three years in Table Rock and Bull Shoals Lakes, Missouri (Colvin 2002a). Willis et al. (1997) found that growth of white bass \leq age-6 in two eastern South Dakota natural lakes exceeded that of South Dakota Missouri River reservoirs. However, length-at-age data obtained in our study equaled or exceed those reported by Willis et al. (1997) for both eastern natural lakes and Missouri River reservoirs at most ages. These differences may be related to methodology; Willis et al. (1997) back-calculated length-at-age using scales, whereas otoliths were used to determine mean length-per-cohort in this study, which should provide more accurate and precise data. If Lake Sharpe white bass do grow faster than those in eastern natural lakes, growth may be related to differences in prey availability. White bass in eastern South Dakota natural lakes tended to be less piscivorous compared to other populations (Starostka 1999, Blackwell et al. 1999) and consumption of prey fish (particularly gizzard shad) has been linked to faster growth (Lovell and Maceina 2002, Colvin 2002b).

Lake Sharpe white bass tended to be older than those in more southern U.S. populations. Longevity of white bass may be related to latitude (Willis et al. 2002). White bass rarely exceeded age-4 in the Brazos River and Lake Whitney, Texas (Muoneke 1994) or age 3 in Nebraska reservoirs (Bauer 2002). Age-6 white bass were reported in Lake McConaughy, Nebraska (McCarraher et al. 1971), and age-7 bass were reported in Lake Winnebago, Wisconsin (Priegel 1971). Among eastern South Dakota natural lakes, maximum ages of white bass reported in Lakes Kampeska and Poinsett were 12 and 14, respectively (Soupir et al. 1997, Willis et al. 1998). Shorter growing seasons and lower overall mortality rates at northern latitudes may contribute to the longevity of those white bass populations relative to their southern counterparts (Willis et al. 2002).

Condition of Lake Sharpe white bass was generally high throughout the growing season among all size categories. Mean W_r values of 93 to 107 were reported for Nebraska reservoirs for all size categories of white bass collected from late summer to late autumn (Bauer 2002). Relative weight values were >90 for all length groups in 4 Missouri reservoirs (Colvin 2002a). Condition of Lake Sharpe white bass generally increased throughout the growing season, likely reflecting changes in availability of different prey types. White bass consumed more invertebrates in the early part of the growing season but became more piscivorous after June, primarily consuming gizzard shad. Similar increases in condition during the growing season have been

observed for Lake Sharpe walleyes and smallmouth bass as a result of changing prey availability (Wuellner et al. 2010a). Higher condition also may be related to fast growth rates. Lovell and Maceina (2002) found higher condition values of white bass in Alabama reservoirs with faster growth rates; it was thought that both condition and growth may be related to productivity and the availability of gizzard and threadfin shad (*Dorosoma petenense*) in these reservoirs.

Recruitment of white bass in Lake Sharpe appeared to be erratic (i.e., $RVI < 1$), which is common among white bass populations within South Dakota (Soupir et al. 1997) and throughout their range (Colvin 1993). Climate, hydrology, and prey availability have been linked to white bass year-class strength in southern reservoirs (DiCenzo and Duval 2002, Schultz et al. 2002), but variation in bass recruitment exists on regional and local levels (Schultz et al. 2002). Abundance of age-0 white bass in Lake Sharpe was higher in years when January, April, and May air temperatures were cooler and July inflow and discharge were lower (Beck et al. 1997). However, other factors were related to age-0 white bass abundance in the other three South Dakota Missouri River reservoirs (Lakes Oahe and Francis Case and Lewis and Clark Lake; Beck et al. 1997). Pope et al. (1997) reported that white bass recruitment was synchronous between two South Dakota natural lakes. To date, no studies have examined the influence of prey availability on white bass recruitment in South Dakota waters. We did not attempt to relate prey availability to white bass year-class strength due to the erratic nature of the age structure of the Lake Sharpe white bass population. However, we suggest that monitoring of age-0 white bass abundance should be coupled with climate, reservoir operation, and prey availability data to better understand population dynamics of this species in reservoirs.

Food habits of Lake Sharpe white bass were similar to those reported in reservoirs with a gizzard shad prey base (Lovell and Maceina 2002, Colvin 2002b) and to walleye and smallmouth bass in the same system (Wuellner et al. 2010a). Invertebrates, particularly ephemeropterans, composed most of the diets of Lake Sharpe walleye during May and June in 2006 and 2007, but gizzard shad were consumed almost exclusively from July through October (Wuellner et al. 2010a). Smallmouth bass in Lake Sharpe consumed a wider variety of invertebrates in May and June but also fed largely on gizzard shad later in the growing season (Wuellner et al. 2010a). Based on this information, the potential for competition among white bass, walleye, and smallmouth bass exists. However, competition cannot exist without prey limitation (Crowder 1990). Evidence suggests that gizzard shad are abundant in Lake Sharpe (Wuellner et al. 2008, 2010a, 2010b) and thus competitive interactions are mitigated.

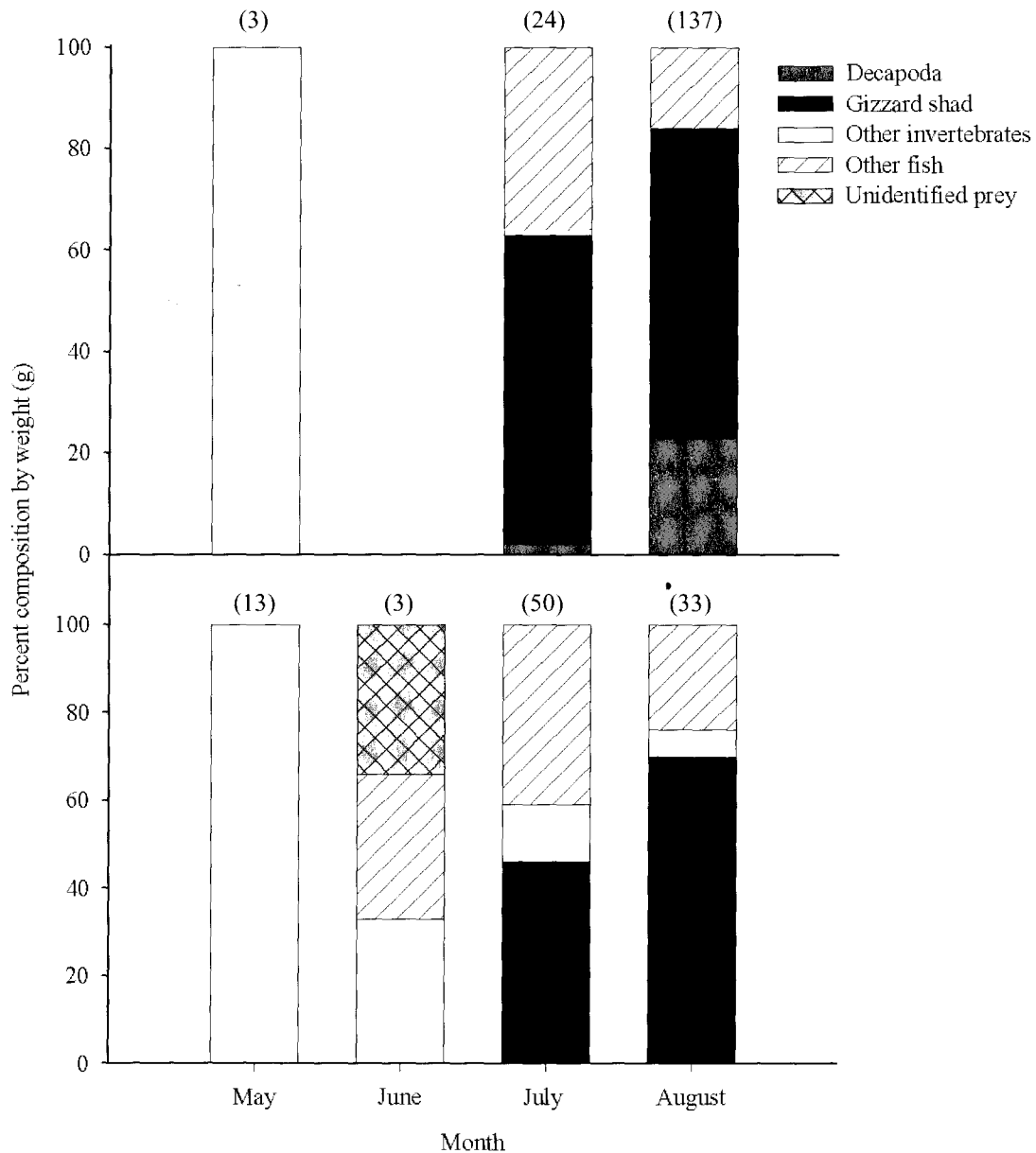


Figure 4. Monthly food habits summarized as percent composition by weight for white bass in Lake Sharpe, South Dakota, in 2006 (top panel) and 2007 (bottom panel). A food habits analysis was not completed in June 2006 as no fish were collected. Numbers in parentheses above the bars represent the number of stomachs analyzed each month.

MANAGEMENT IMPLICATIONS

The white bass population in Lake Sharpe commonly produces a quality fishery with relatively high size structure and condition and fast growth despite erratic recruitment patterns. White bass likely do not compete with other Lake Sharpe predators at present due to abundance in prey and do serve as a prey source for walleye and smallmouth bass. Future research should focus on elucidating the relationships between climate, reservoir operation and prey availability on white bass recruitment dynamics in Lake Sharpe.

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NOTES

EXAMINATION OF OWL PELLETS FOR NORTHERN POCKET GOPHERS AT CRESCENT LAKE NATIONAL WILDLIFE REFUGE, NEBRASKA—Analysis of regurgitated pellets from owls is a well-known and nondestructive method that provides useful information regarding diet (Errington 1930). This technique also is used to examine composition of small mammal communities and distribution of prey species (e.g. Kamler et al. 2003, Torre et al. 2004, Poole and Matlack 2007). In western Nebraska, two species of owls that regularly breed in the region are the common barn owl (*Tyto alba*) and great horned owl (*Bubo virginianus*). In the early 1970s, Rickart (1972) studied the diet of both species at Crescent Lake National Wildlife Refuge (CLNWR), Garden County, Nebraska. Rickart (1972) recovered 447 prey items representing 14 taxa of small mammals from regurgitated pellets, including remains of 3 northern pocket gophers (*Thomomys talpoides*) from pellets of great horned owls. Those findings extended the range of *T. talpoides* about 60 km northeast from Cheyenne County into the Sandhill Region of Nebraska, a region and soil type where *T. talpoides* previously has not been documented in the state (Jones 1964). Prior to our study, we attempted to locate voucher material of mammals from Rickart (1972) without success (E. Rickart, Utah Museum of Natural History and R. Timm, University of Kansas, Natural History Museum; pers. comm.). Thus, we initiated our study to determine whether tangible evidence (e.g., a voucher specimen) could be obtained for the presence of *T. talpoides* at the refuge, which may represent an isolated population in need of conservation. We also compared the diet of owls from the refuge in the early 1970s (Rickart 1972) to diets based on recent collections of owl pellets (this study).

In August and October 2008, we collected owl pellets and pellet debris (e.g., bones from crumbling older pellets) at CLNWR. Pellets and pellet debris were collected at the refuge headquarters (41°45.644'N, 102°26.398'W; NAD 83) from underneath several large trees (eastern redcedar, *Juniperus virginiana* and cottonwood, *Populus deltoides*) used by both species, below and inside 3 nest boxes attached to windmills used by barn owls (41°44.046'N, 102°25.022'W; 41°44.524'N, 102°25.577'W; and 41°44.699'N, 102°24.357'W; NAD 83), and from the base of a tree under a nest of a great horned owl (41°44.780'N, 102°23.046'W; NAD 83). In addition to pellets collected in 2008, we also obtained pellets and pellet debris collected from 6 localities throughout the refuge by a previous researcher in 2002 (J. A. White, University of Nebraska at Omaha; 1) tree northeast of Boyd Pond, great horned owl; 2) cottonwoods in wilderness area, 41°41.057'N, 102°13.690'W, unknown species of owl included in “both species” in Table 1; 3) trees at headquarters as described above used by both species; 4) trees southwest of Harrison

Lake, 41°45.040'N, 102°30.883'W, great horned owl; 5) north of Island Lake, 41°45.123'N, 102°23.583'W, barn owl; 6) just off refuge in abandoned house and under eastern redcedars, 41°44.410'N, 102°27.870'W; great horned owl observed but placed in “both species” in Table 1 due to likelihood of barn owls also using site).

To extract identifiable material from pellets, we immersed each pellet in water and allowed it to soak for 1–3 minutes. Pellets were gently pulled apart using forceps, and hair was separated from bones. We kept only cranial and dentary bones of vertebrates, which were dried and originally stored in individually labeled plastic bags for each pellet. To identify prey items to the lowest taxonomic level, we used various taxonomic keys (e.g., Carraway 1995) and comparative voucher material housed at the University of Nebraska at Kearney and University of Nebraska State Museum, Lincoln. Only craniums were tabulated to determine frequency of prey, but some dentary bones were used to positively identify cranial material, such as between *Peromyscus* and *Onychomys*. For 6 species of mammals infrequently documented in diets ($n \leq 6$), we included in tabulations the occurrence of mandibular material that lacked a corresponding cranium. We deposited ≤ 6 cranial and dentary materials of each species in the natural history collections, Division of Zoology, University of Nebraska State Museum, Lincoln, Nebraska, USA.

We identified 1098 vertebrates including 15 taxa of mammals and 5 unidentified craniums of birds in diets of barn and great horned owls at CLNWR (Table 1). The most prevalent prey item recovered in all of the owl pellets was the meadow vole (*Microtus pennsylvanicus*), whereas the second most common prey item recovered was Ord's kangaroo rat (*Dipodomys ordii*; Table 1). Both species of owls consumed small mammals associated with upland (e.g., *D. ordii* and *Microtus ochrogaster*) and lowland habitats (e.g., *M. pennsylvanicus* and *Ondatra zibethicus*) at CLNWR. Prevalence of *Microtus* in pellets of both owls is consistent with previous studies across Nebraska (Jones 1949, 1952, Rickart 1972, Epperson 1976, Gubanyi et al. 1992, Huebschman et al. 2000). The relative frequency of *D. ordii* in the diet of both owls also is consistent with other studies from western Nebraska (Rickart 1972, Huebschman et al. 2000), where kangaroo rats are abundant in sandy habitats (Jones 1964).

We observed a tendency for larger prey to be captured by great horned owls and smaller prey to be captured by barn owls (Table 1). Great horned owls diets were composed of 28.6% large prey items and barn owls had 3.8% large prey items in their diets (Table 1). Large prey items included plains pocket gophers, cottontails (*Sylvilagus* spp.), common muskrats, long-tailed weasels (*Mustela frenata*), and jackrabbits (*Lepus* spp.); whereas all other species were considered small prey items. Huebschman et al. (2000) also

reported great horned owls feeding on large prey in Nebraska, including plains pocket gophers, cottontails, and jackrabbits (*Lepus* spp.). Prey items of barn owls were generally small (<300 g), with the plains pocket gopher (*Geomys bursarius*) being the largest species frequently eaten. One exception was a mandible of a common muskrat

(*Ondatra zibethicus*) discovered in a pellet of a barn owl, but further examination revealed it was a juvenile based on jaw size and cusp wear. Others also have noted that barn owls generally consume smaller-sized prey than the larger great horned owl (e.g., Marti 1974).

Table 1. Total number (*n*) and percentage frequency (%) of individual prey items identified from regurgitated pellets of barn owls (*Tyto alba*) and great horned owls (*Bubo virginianus*) at Crescent Lake National Wildlife Refuge, Garden County, Nebraska in 2002 and 2008.

Species	<i>Tyto alba</i>		<i>Bubo virginianus</i>		Both species ^a		Totals
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	
<i>Microtus pennsylvanicus</i>	135	36.8	12	16.4	249	37.8	396
<i>Dipodomys ordii</i>	85	23.2	26	35.6	148	22.5	259
<i>Microtus ochrogaster</i>	61	16.6	10	13.7	89	13.5	160
<i>Geomys bursarius</i>	13	3.5	15	20.5	80	12.2	108
<i>Reithrodontomys</i> spp.	36	9.8	2	2.7	40	6.1	78
<i>Microtus</i> spp.	9	2.5	1	1.4	18	2.7	28
<i>Perognathus</i> spp.	13	3.5			11	1.7	24
<i>Peromyscus maniculatus</i>	5	1.4			9	1.4	14
<i>Sorex cinereus</i>	1	0.3			5	0.8	6
<i>Cryptotis parva</i>	3	0.8			2	0.3	5
Bird spp.	2	0.5	1	1.4	2	0.3	5
<i>Ondatra zibethicus</i>	1	0.3	2	2.7	1	0.2	4
<i>Sylvilagus</i> spp.			2	2.7	1	0.2	3
<i>Onychomys leucogaster</i>	2	0.5			1	0.2	3
<i>Mustela frenata</i>			2	2.7			2
<i>Scalopus aquaticus</i>	1	0.3			1	0.2	2
<i>Lepus</i> spp.					1	0.2	1
TOTALS	367		73		658		1098

^a Pellets and pellet debris of barn owls and great horned owls mixed under trees at headquarters and other sites at the refuge (see text). Other species of owls might occasionally use such sites, but no other species was observed when collecting pellets. In the headquarters area, refuge personnel occasionally observe eastern screech owls (*Otus asio*) nesting in nest boxes. Long-eared owls (*Asio otus*) and short-eared owls (*A. flammeus*) also are reported a few times during a season annually at the refuge whereas other species are seen even less frequently.

We identified 15 mammalian taxa at the refuge. Rickart (1972) reported 2 species that we did not observe—the hispid pocket mouse (*Chaetodipus hispidus*) and northern pocket gopher. Additionally, we identified 3 species that Rickart (1972) did not report—the least shrew (*Cryptotis parva*), common muskrat, and eastern mole (*Scalopus aquaticus*). Rickart (1972) reported *Reithrodontomys* spp. and *Microtus* spp. as the 2 predominant prey items, whereas we observed *Microtus pennsylvanicus* and *Dipodomys ordii* as the 2 most prevalent (Table 1). During the past 35 years, such differences in prey consumed by owls might reflect changes in habitat and concomitant changes in abundance and distribution of mammals. Differences also might reflect locations of owl roosting sites, composition and abundance of prey items in surrounding habitats, foraging tactics of owls, and timing of our sampling. For the 2 species of prey detected by Rickart (1972) that we did not observe in pellets, a recent survey of mammals at CLNWR reported only the occurrence of the *C. hispidus* but not *T. talpoides* (Bogan et al. 2004). In that survey, pocket gophers were trapped at various locations at the refuge (Bogan et al. 2004, K. Geluso, unpublished data).

We did not document a single *T. talpoides* in the diet of owls at CLNWR but observed 108 *G. bursarius* (Table 1). Imler (1945) first reported the presence of a *T. talpoides* captured in a snake trap at CLNWR, but Jones (1964) discounted the record because of the absence of voucher specimens or other conclusive evidence. Subsequently, Rickart (1972) reported the presence of 3 *T. talpoides* in pellet debris of owls at the refuge. We attempted to repeat Rickart's methods to detect *T. talpoides* at CLNWR but were unsuccessful (Table 1). Thus, our research does not support Rickart's (1972) findings. Lack of voucher materials by both Imler (1945) and Rickart (1972) likely will prevent us from determining whether *T. talpoides* has occurred at CLNWR in the past, especially if the species is now extirpated from the region or currently occurs at the refuge in low abundances or in isolated areas. Such examples stress the need for continued support of natural history collections to house voucher specimens.

Mammalian surveys at CLNWR have not reported the least shrew (*Cryptotis parva*) at the refuge in the past (Gunderson 1973, Bogan et al. 2004). Owl pellets collected at CLNWR in 2002 only contained the masked shrew (*Sorex cinereus*, $n = 5$), but pellets collected in 2008 primarily consisted of *C. parva* ($n = 5$ for *C. parva* and $n = 1$ for *S. cinereus*, this study). In recent decades, least shrews apparently have moved westward across western parts of Nebraska (Geluso et al. 2004), as well as in other regions of the Great Plains (Choate and Reed 1988, Backlund 2002, Marquardt et al. 2006). Least shrews are suspected to have moved westward along riverine corridors in the Great Plains (e.g., Geluso et al. 2004). Our current study documents the occurrence of *C. parva* in Garden County, which indicates an additional range expansion for this species away from the North Platte River. We suspect that if *C. parva* has

followed riverine or stream corridors to CLNWR, individuals advanced via Blue Creek, a tributary of the North Platte River.

We thank M. French and N. Powers at CLNWR for assistance with housing accommodations and permission to conduct research on the refuge; M. French and J. White for assistance locating nests of owls; M. Harner for assistance in the field; J. White for donating owl pellets from an earlier survey at the refuge; R. Timm (University of Kansas) and E. Rickart (Utah Museum of Natural History) for assistance in attempting to track down former voucher specimens; K. N. Geluso and anonymous reviewers for helpful comments on earlier versions of our manuscript; and the Undergraduate Research Fellows Program, University of Nebraska at Kearney for financial support.—*Stacey L. Bonner and Keith Geluso*¹, Department of Biology, University of Nebraska at Kearney, Kearney, NE 68849. ¹Corresponding author email address: gelusok1@unk.edu.

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SUMMER ACTIVITY PATTERN AND HOME RANGE OF NORTHERN POCKET GOPHERS IN AN ALFALFA FIELD

Allocation of time for feeding, resting and reproduction in subterranean animals is difficult to determine. Although pocket gophers (*Thomomys* spp.) are among the most widely studied subterranean rodents, there are conflicting reports on activity measurement in these animals. Activity studies have included opening gopher burrows (Tryon 1947), laboratory studies of activity (Vaughan and Hansen 1961), telemetry studies (Anderson and McMahon 1981, Bandoli 1987, and Cameron et al. 1988), and subcutaneously implanted radioactive gold wires (Gettinger 1984). The diversity of techniques reflects the difficulty of generalizing results from different species of pocket gophers in natural and artificial environments. Patton and Brylski (1987) considered alfalfa fields to be food rich environments based on crop density and food availability; therefore, pocket gophers in an alfalfa field should exhibit decreased activity periods because of a reduced search time for food and smaller home range size. Our objective was to measure daily activity patterns of pocket gophers in a food rich environment.

We conducted our study from May 20, 2005 through July 30, 2005 in an irrigated alfalfa field on the Carnahan Ranches, approximately 9.5 km north of the town of Elbert in Elbert County, Colorado. The project followed ASM guidelines (Gannon et al. 2007) and was approved by the Institutional Animal Care and Use Committee at the University of Colorado at Colorado Springs (Approval Number UCCS-04-001).

We live-trapped 6 northern pocket gophers (*Thomomys talpoides*; 2 males and 4 females) in an irrigated alfalfa field May 20 and 21, 2005. All animals were trapped from separate burrow systems that did not overlap other burrow systems. Because of transmitter size, we selected only animals weighing more than 115 g (mean weight 141.6 g, range 119–169 g), and released 1 animal that weighed less than 115 g; the transmitter weighed 3.9 g and no transmitter exceeded 3.3% of the animal's body mass. While in captivity, animals were housed in cages under local environmental light and temperature conditions and food and water were provided *ad libitum*. On May 24 the transmitters (Advanced Telemetry Systems, Isanti, MN, USA) were implanted in the peritoneal cavity of each animal by a veterinarian at Briargate Veterinary Clinic, Colorado Springs, Colorado with isoflurane as an anesthetic. In case of transmitter failure, a passive integrated transponder (PIT) was implanted subcutaneously for future identification. On May 27 each gopher was released back into the burrow where it had been captured. Wilks (1963) and Proulx et al. (1995) stated that empty burrows were quickly occupied by neighboring animals; however, during our study no vacated burrow was inhabited by another gopher.

Underground animal movement was monitored using a receiver and a hand-held three element yagi antenna. The

animal was considered to be active when it left the nest. Periods of observation were designed to include every hour of a 24-hr day. We obtained at least 72 hr of observation on each animal. We randomly selected each animal to monitor for 3 to 12 hr. We approached each burrow system very quietly to minimize disturbance. When the animal stopped moving a surveyor's flag was planted at that location based on radio signal strength. We determined the location of each animal's nest (e.g., sleeping area) within the burrow by long periods of inactivity. We marked the location by driving a wooden stake into the ground at that site. If the animal emerged above ground, the investigator remained motionless. It was not unusual to watch the gopher harvest plants (e.g., alfalfa, grasses, *Equisetum*) within reach of the burrow entrance and as far as one meter away from the burrow.

We calculated a minimum convex polygon home range for each animal. Based on the small sizes of the individual home ranges, we used direct measurements taken in the field. We calculated home ranges by dividing the area into triangles using the outermost flags as boundaries. We measured the compass direction and distance in meters from the nest stake for each outermost flag and calculated the area for each triangle. The minimum convex polygon home range represented the total area of all the triangles for each animal (Fig. 1).

Gophers were monitored for a total of 21,744 min (362.4 hr) with an average of 4,324 min (range = 2737–5756 min) per animal. Animals were considered to be active for an average of 703 min (range = 159–1319 min), or 16.2% of the total observation time. While the sample size is small and includes variation in the data, activity peaks occurred from 1400 to 1800 hr and 2400 to 0400 hr (Fig. 2), whereas a period of low activity extended from 0600 to 1000 hr with another possible low period from 2000 to 2200 hr. The average minimum convex polygon home range was 33.0 m², and ranged from 12.7 to 61.1 m². Female 335 and male 513 were the most active (1319 min or 19.6% and 1101 min or 22.4% of the time, respectively) and had the largest home ranges (61.1 and 45.9 m², respectively).

Tryon (1947) reported two intervals of peak activity for northern pocket gophers, one immediately after dawn and another in late afternoon, which he correlated with peak activities of non-fossorial rodents. Wilks (1963) reported the plains pocket gopher (*Geomys bursarius*) was most active in the morning in Texas. Gettinger (1984) noted that Botta's pocket gophers (*T. bottae*) in California exhibited peak times of activity between 1600 and 2200 hr. In our study, pocket gophers were active for an average of 16.2% of the time (range 5.6–22.4%), which is similar to *T. bottae* in New Mexico (Bandoli 1987) but less than reported in other studies: 28% and 34% of the time for plains pocket gophers in tall grass prairies (Benedix 1994) and Colorado (Vaughan and Hansen 1961), respectively; 36.3% for Botta's pocket gophers in California (Gettinger 1984), and 47.3% and 52% for northern pocket gophers in Alberta

(Proulx et al. 1995) and Utah (Anderson and MacMahon 1981), respectively. The lower activity periods we detected were likely due to the food-rich environment, which would reduce the search time for food and reduce the home range size. Turner et al. (1973) described home ranges averaging 185.8 m² on Black Mesa, a short grass prairie habitat. In studies of *T. bottae*, Gettinger (1984) described an average home range of 107 m² in the James San Jacinto Mountain Reserve, California and Bandoli (1987) reported average

home ranges of 286.4 m² for females and 474.7 m² for males in the Pajarito Land Grant, New Mexico. The largest home range (female 335; 61.1 m²) was located at the edge of the alfalfa field and contained a higher percentage of non-alfalfa plants. This lower density of alfalfa plants was likely responsible for the larger home range. Further, the lower activity periods we detected were the result of reduced search time and home range size.

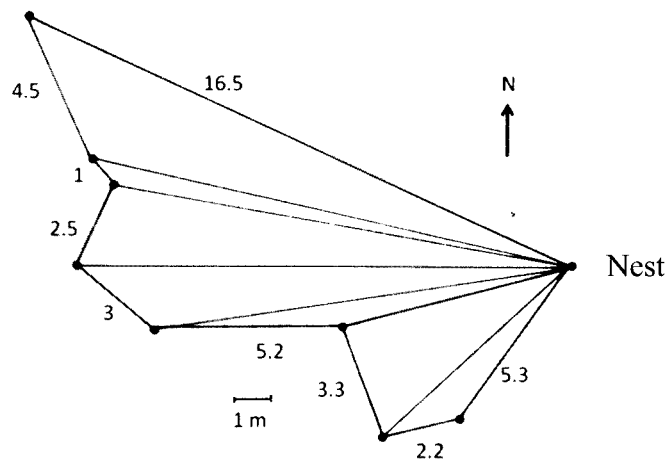


Figure 1. Minimum convex polygon home range of 61.1 m² for animal 335. The polygon is the sum of the areas of multiple triangles using the nest as the primary reference point and the outermost points of animal activity.

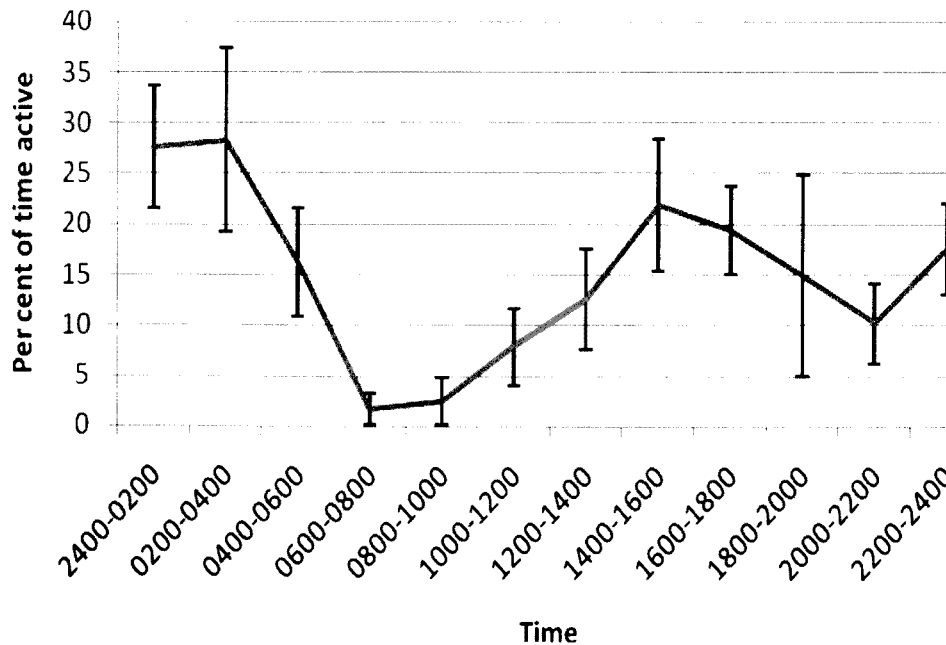


Figure 2. Mean activity pattern for five *Thomomys talpoides* in an alfalfa field in Elbert, Colorado, May–July 2005. Bars indicate standard error.

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CORRELATION OF MATURE WALLEYE RELATIVE ABUNDANCE TO EGG DENSITY

—Knowledge of spawning areas can benefit fisheries management (Marsden et al. 1991). Identification of spawning areas allows managers to protect, enhance, and/or restore critical habitat (Gunn et al. 1996, Thompson 2009), examine important biotic and abiotic conditions necessary for reproduction (Quist et al. 2003), and to efficiently collect broodstock for production (Satterfield and Flickinger 1996).

The most effective method to directly identify spawning areas of fish with demersal eggs is to sample the substrate for eggs (Marsden et al. 1991). This method has been used to locate spawning areas of several species (Michaletz 1984, Zorn et al. 1998, Martin 2008). However, direct estimation of egg deposition is time consuming and requires specialized equipment which often makes this method impractical. A more practical approach may be to indirectly identify spawning areas by sampling congregations of mature fish during the spawning season.

Mature male walleye (*Sander vitreus*) will congregate during the spawning season on the spawning grounds and remain there for the duration of the spawn (Scott and Crossman 1973). In contrast, mature female walleye will stage near the spawning grounds before moving onto the spawning ground to release their eggs, and will then return to the staging area within a single night (Scott and Crossman 1973, Thompson 2009). This sex-specific behavior suggests that locating male walleye as opposed to females may be more reliable for locating where egg deposition is occurring.

Sampling sex-specific congregations would allow either male or female walleye to be targeted. For example, electrofishing over spawning grounds is biased for collecting male walleye while using 5.1 cm mesh (bar measure) gill nets is biased for collecting females (Koupal et al. 1997). If a relationship exists between egg deposition and mature walleye relative abundance, implementing these gears would provide managers a more practical approach to identifying spawning areas. Our study objective was to determine if relative abundances of mature male walleye and mature female walleye were correlated to egg density.

We conducted this study at Sherman Reservoir, Nebraska during the walleye spawn (late-March to mid-April) 2007–2009. Sherman Reservoir is an off-stream irrigation reservoir located near Loup City, Nebraska. Water for the reservoir is diverted from the Middle Loup River and travels to the reservoir through a canal system where it is stored until needed by irrigators. At conservation pool, the reservoir covers 1,151 ha and stores 8,520 ha-m of water.

We estimated the relative abundance of mature male and female walleye and walleye egg density weekly at three sampling areas (randomly selected sites at each area) located throughout the reservoir. The sampling areas were hypothesized to have a wide range of mature walleye usage and egg deposition based on previous walleye broodstock collection efforts on Sherman Reservoir.

We collected mature male walleye using an electrofishing boat generating pulsed-DC current. We conducted 1 to 3 electrofishing runs with 2 dippers at each sampling site each week as conditions and catch rates would allow. We began electrofishing runs approximately 30 minutes after sunset. We considered male walleye mature if milt was expelled from the vent when pressure was applied to the abdomen (Satterfield and Flickinger 1996). We indexed relative abundance of mature male walleye as mean catch per unit effort (CPUE) for each sampling site each week. We standardized electrofishing CPUE as the number of mature male walleye captured per hour of electrofishing.

We sampled mature female walleye with gill nets that were 61.0 m long, 1.8 m deep and had 5.1 cm mesh (bar measure). We considered female walleye mature if they were gravid (Satterfield and Flickinger 1996). We set gill nets approximately 30 minutes after sunset and allowed them to fish for 90–150 minutes. We made multiple net sets at each sampling site until each site had a minimum of 2 net sets each week. We indexed relative abundance of mature female walleye as mean CPUE for each sampling site each sampling week. We standardized gill net CPUE as the number of mature female walleye captured per hour of gill netting.

We used egg sampling disks to sample walleye eggs (Katt et al. 2011). We deployed egg sampling disks in arrays of 10 disks with 3 arrays deployed at each sampling site. We checked disks weekly for the presence of eggs by placing each disk in a tub of water and scrubbing the entire surface of the disk twice. We poured the water from the tub through a 500 micron sieve and enumerated collected eggs. We derived a weekly egg density (number of walleye eggs/m²/night) for each sampling site.

We used Pearson correlations to test the relationship between mature male electrofishing CPUE and mature female gill net CPUE to egg density ($\alpha=0.05$). To meet assumptions of normality, we $\log_{10}+1$ transformed our data. We paired data points by week and represent the mean mature male electrofishing CPUE, mean mature female gill net CPUE and mean egg density from 2007–2009. We only used sampling weeks when all 3 variables were collected ($n = 19$).

Mature male walleye electrofishing CPUE was significantly correlated ($r_p = 0.89, P < 0.001$) to egg density while mature female walleye gill net CPUE was not significantly correlated ($r_p = 0.42, P = 0.07$) to egg density (Fig. 1).

Our results suggested that mature male walleye electrofishing CPUE was a better indicator of where eggs were deposited than mature female walleye gill net CPUE. Similar results were found in Sandusky Bay, Lake Erie, Ohio where male walleye had a higher probability of occurring over identified spawning substrates than female walleye (Thompson 2009). The location of male walleye during spawning is likely a better indicator of egg deposition because of walleye sex-specific spawning

behavior. By locating important walleye spawning areas, managers can protect critical habitats of walleye as well as locate habitats which can be restored or enhanced (Thompson 2009).

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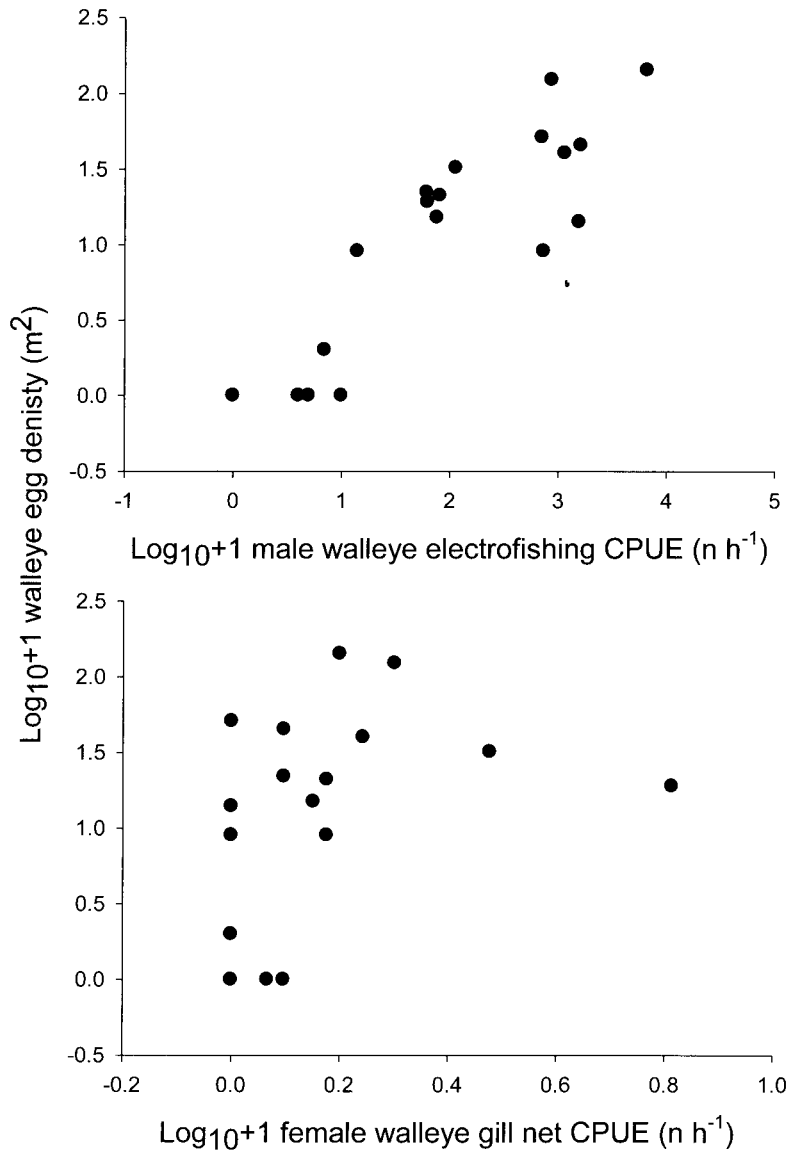


Figure 1. Relationship between mature male walleye electrofishing CPUE and walleye egg density (above) and between mature female walleye gill net CPUE and walleye egg density (below) in Sherman Reservoir, Nebraska 2007–2009. All data were $\log_{10}+1$ transformed.

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Book Review

Grouse of the Plains and Mountains – The South Dakota Story. Lester D. Flake, John W. Connelly, Thomas R. Kirschenmann, and Andrew J. Lindbloom. 2010. South Dakota Department of Game, Fish, and Parks, Pierre, South Dakota. 246 pages. \$15.00 (paper). ISBN: 978-0615350158.

Grouse are a fascinating group of birds that offer elaborate breeding displays for birders in the spring, provide sporting opportunities for hunters in the fall, and serve as indicators of grassland health. Though the authors claim that the book targets those who enjoy the outdoors, bird watching, and upland game bird hunting, there is ample reason for ecologists, ornithologists, and grouse researchers to reference this book as well. The book contains general information of interest to a broad audience, but often moves beyond the introductory information to greater detail. Many details are supported by peer-reviewed literature. This book strikes a pleasant balance between dry scientific literature and a coffee table book of intriguing photos. It remains informative while trading painfully formal language for the more conversational tone of popular literature.

The book discusses the four native grouse species that occur in South Dakota: ruffed grouse, greater sage-grouse, greater prairie-chicken, and sharp-tailed grouse. The text is well organized into 13 chapters, followed by appendices and the literature cited. Chapters cover South Dakota's grouse habitats, physical characteristics of the four species (including gender and age determination), behavior, population ecology, habitat use, monitoring, hunting, and habitat conservation.

The book is expertly illustrated with high-quality photographs, tables, graphs, and maps. Each illustration has carefully worded captions or headings such that the entire collection of figures could form a book of their own and remain useful. There are photos on nearly every page. The photos feature subjects that seldom appear in other literature, including those of young grouse chicks, crop contents, close-up views of characteristics that aid in determination of age and gender, and landscape shots that adeptly illustrate grouse habitat. Photos that illustrate research techniques (e.g., vegetation sampling, capturing grouse) and field observations (e.g., shells from a clutch of hatched eggs) will prove interesting to a wide audience.

Few states have made their grouse population survey data so readily available. Lay persons may find the tables of population statistics unappealing but their inclusion as appendices is appropriate. These appendices contain lek

survey data, brood survey data, and fall juvenile:adult ratios from hunter-killed birds. These data will be of interest to upland game or grassland bird biologists in other regions and also to researchers interested in comparative data for trend analyses.

The greatest positive attribute of this book, the photos, could actually lead to a minor criticism. Those who best absorb or, most enjoy, written material may actually find the numerous illustrations distracting. I admit it was difficult to maintain focus on the text when there were three or more stunning images on opposing pages. As I first leafed through the text, a particular habitat photo caught my eye. I had hoped to relocate it based on key text that I recalled from the caption but discovered the book has no index—it's greatest downfall.

The authors acknowledge the benefits of maintaining ranching operations versus converting grasslands to other land uses. Considerable space is then devoted to criticizing grazing practices. In many cases, grazing is inarguably too intensive to provide adequate nesting cover for prairie grouse or sage-grouse. However, few examples of "good" grazing management practices are provided and only brief descriptions of rotational grazing systems are mentioned. Suggestions for stocking rates and a few illustrations of rotations and grazing seasons would have given the reader a better understanding of how livestock and grouse can co-exist.

In summary, this is an excellent and easily read reference for the four grouse species that the book covers. The breadth of information is well balanced with the level of detail, and the general information is not so general as to be hopelessly frustrating to the more educated reader. It is an attractive and enjoyable book that can be read casually or with a careful eye for detail. It will bolster appreciation for grouse and has increased my interest in South Dakota's grouse habitats. This book should be required reading for any upland gamebird hunter who pursues grouse. I encourage budding (pun intended) grouse researchers to read it thoroughly as part of their introduction to grouse ecology. Much of the information presented is specific to South Dakota, but species biology and concepts regarding habitat and conservation make this book applicable to much of the West and the Great Plains. This book is very well done, bargain priced, and available from the SDGFP web site. It will be enjoyed by upland game hunters, biologists, and grassland ecologists who may count themselves as grouse enthusiasts after reading this book.—*Brent E. Jamison, U. S. Fish and Wildlife Service, Medicine Lake National Wildlife Refuge, Medicine Lake, MT 59247.*

Book Review

Weeds of the Midwestern United States & Central Canada.

Edited by Charles T. Bryson and Michael S. DeFelice. 2010. University of Georgia Press, Athens, Georgia. 427 pages + x. \$44.95 (paper). ISBN 978-0-8203-3506-3.

This volume is the culmination of work by more than 40 weed scientists and botanists. Its stated purpose is to help identify the great diversity of weedy and invasive plants that interface with agriculture, industry, and natural ecosystems in central North America. The geographic range covered by this book extends from southeastern Saskatchewan to eastern Kansas, northern Kentucky, northwestern Pennsylvania, and southwestern Quebec. This is a welcome edition because a current book on unwanted plants has not been available for the eastern two-thirds of this region. The book is arranged taxonomically by family and alphabetically by species within each family. Scientific nomenclature follows the accepted names specified by the Weed Science Society of America rather than the most current taxonomic treatments. This treatment focuses on weed identification rather than management recommendations.

The book covers the identification of about 350 species. A brief introduction is followed by a nine-page illustrated terminology depicting parts of a dicot stem, parts of a monocot collar, leaf shape and arrangement, flower parts, inflorescence types, root types, and stem types. A key to the families follows. The key is relatively simple, but a person using it will need some botanical knowledge. In my opinion, the key is not an important feature of the book.

Each species is presented on a single 7.5 by 10-inch page with a distribution map of the continental United States, Alaska, and Canada, rather than the region covered, and two to five photographs in color. Principal photography was done by Arlyn W. Evans and Michael S. DeFelice. Photographs usually are of the inflorescences/flowers, leaves, seedlings, and seeds. Photographs of the seedlings and seeds set this apart from most weed identification books. An illustration of the collar region is provided to assist with the identification of the grasses. The most widely used English common name is followed by a section which includes alternate common names, French common names, and synonymous botanical names. Many common botanical synonyms have been excluded while some obscure synonyms and others not used for decades are included. This section is followed by details of plant growth habit and life cycle, important vegetative and reproductive characteristics, special identifying features, and toxic properties. The book concludes with a glossary, bibliography, and index.

The process for selecting plants to include in this guide is not described, but I wonder how native prairie species such as porcupinegrass (*Hesperostipa spartea*) and purple

coneflower (*Echinacea purpurea*) made the list. The distribution maps are very good, although detail varies from one map to the next. A few of the distribution maps are not indicative of actual distribution. An example is purple coneflower which is shown restricted to the Midwest but occurs also to the west across the Great Plains. Closer attention could have been paid to origin. An example is common yarrow (*Achillea millefolium*) which is listed as a native to Europe. This is correct, but it is native also to much of North America.

The index is another concern. I was interested in reading about garlic mustard. I was unable to find it in the index under "garlic" and had to go to "mustard, garlic" to find the page number. This reverse style is followed throughout the index.

Most users will leaf through the book looking at the photographs to identify the weeds growing on their properties. They will be aided by the excellent quality of nearly all of the 1,423 photographs. The photographs, as well as the brief descriptions of the plant characteristics, are the greatest strengths of this book. Photographs of seedlings and seeds will be of interest to some; however, they may not be an important aid to identification. Photographs of grass seedlings are not definitive, but the illustrations of grass collars are excellent and will be helpful in identification. Most of the photographs of grass florets are mislabeled as caryopses. I went back to *Weeds of the South*, an earlier regional book edited by Bryson and DeFelice (2009, University of Georgia Press, Athens, Georgia. 469 pages. ISBN 978-0-8203-3046-4) and found that the photographs of florets were mislabeled as seeds.

Overall, *Weeds of the Midwestern United States & Central Canada* is an excellent publication. It will be a valuable guide for plant identification to producers, homeowners, and weed professionals.—James Stubbendieck, Department of Agronomy and Horticulture, University of Nebraska, Lincoln, NE 68583-0915.

The Prairie Naturalist – Call for Paper Submissions

The Great Plains Natural Science Society, founded in 1967, seeks to promote interest in and understanding of natural history in the Great Plains, to encourage the conservation of natural resources, and to provide communication among individuals, institutions, and organizations of like interests. The GPNSS publishes *The Prairie Naturalist*, a widely read, peer-reviewed journal which deals with the natural history and environment of the Great Plains region.

First published in 1969, *The Prairie Naturalist* has been published by South Dakota State University since 2010 and fills an important role as an avenue of communication for Great Plains research. Research topics include articles investigating Great Plains community and landscape ecologies, species-specific population dynamics, mammalogy, ornithology, invertebrate zoology, herpetology, ichthyology, botany, animal behavior, infectious diseases, and biostatistics. Additionally, original research dealing with infectious, parasitic, nutritional, and developmental diseases, environmental contamination, and various factors impacting health and survival of Great Plains fauna also are considered for possible publication. This journal offers timely technical information for researchers, educators, students, and the interested public. Currently published biannually, *The Prairie Naturalist* reaches subscribers throughout the United States and Canada, as well as libraries in Europe and Asia. About 10% of each volume is devoted to shorter and less comprehensive communications (notes) and book reviews.

The Prairie Naturalist Editorial staff seeks to restore a quarterly publication schedule of the Journal, which will require increasing current manuscript submission rates. Importantly, increasing manuscript submission rates will aid in accomplishing our long-term objective of recognition and indexing of *The Prairie Naturalist* on the Intercollegiate Studies Institute (ISI) Web of Knowledge. Thus, the Editorial staff encourages researchers throughout the Great Plains to submit their work for possible publication in the Journal. Thank you for considering *The Prairie Naturalist* as a publication venue for your research and we look forward to considering your future work for possible publication in the Journal.

With kind regards,

Chris Jacques
Editor-in-Chief

The Great Plains Natural Science Society

The Great Plains Natural Science Society, founded in 1967, seeks to promote interest in and understanding of natural history in the Great Plains, to encourage the conservation of natural resources, and to provide communication among individuals, institutions, and organizations of like interests. The GPNSS actively promotes the study of natural history of the Great Plains region, including geology, plants, birds, mammals, fish, insects, and other forms of life. Together with local, state, and national conservation organizations, the GPNSS fosters natural resource conservation and preservation of outstanding natural areas. The GPNSS publishes *The Prairie Naturalist*, a widely read, peer-reviewed journal which deals with the natural history and environment of the Great Plains region.

The GPNSS is currently composed of a diverse membership, many of whom are professional scientist. Society members have strong interests in sustainable management of Great Plains natural resources and their habitats. Natural history and ecology of the Great Plains is the primary focus and interest of the GPNSS, thus, the primary interests and goals of the Society seeks to promote increased scientific knowledge of the interactions of all Great Plains organisms with their natural environments, enhance professional stewardship of Great Plains natural resources and their habitats, and encourage use of applied research for informing Great Plains natural resource policy decisions.

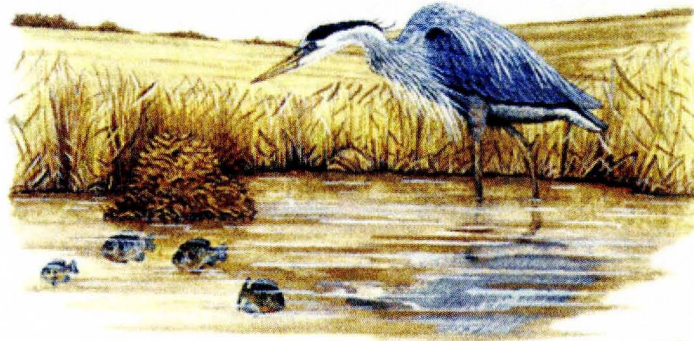
The GPNSS hosts annual meetings and serves host to symposiums covering a broad spectrum of topics. Located within the Department of Wildlife and Fisheries Sciences at South Dakota State University, the GPNSS takes great pride in working with students, staff, and faculty to foster a greater understanding of the natural history and ecology of Northern Great Plains organisms and their biota.

First published in 1969, *The Prairie Naturalist* has been published by South Dakota State University since 2010 and fills an important role as the avenue of communication of research on the North American grasslands and their biota. Research topics include articles investigating Great Plains community and landscape ecologies, species-specific population dynamics, mammalogy, ornithology, invertebrate zoology, herpetology, ichthyology, botany, animal behavior, infectious diseases, and biostatistics. This journal offers timely technical information for researchers, educators, students, and the interested public. Published quarterly, *The Prairie Naturalist* reaches subscribers throughout the United States and Canada, as well as libraries in Europe and Asia. About 10% of each volume is devoted to shorter and less comprehensive communications (notes) and book reviews. Manuscripts containing original material not submitted elsewhere are considered for publication; all are reviewed by specialists in relevant fields.

Cover Photograph by Doug Backlund

Doug Backlund is a retired wildlife biologist living in Pierre, SD. He worked at the SD Department of Game, Fish and Parks in the Wildlife Diversity Program for nineteen years. A graduate of Black Hills State University, he is an avid birder and avian photographer. He now travels from Alaska to Mexico photographing birds and other wildlife. His photography can be seen at www.wildphotosphotography.com.

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