Use of recent and historical records to estimate status and trends of a rare and imperiled stream fish, *Percina jenkinsi* (Percidae)

Megan M. Hagler, Mary C. Freeman, Seth J. Wenger, Byron J. Freeman, Patrick L. Rakes, and J.R. Shute

Abstract: Rarely encountered animals may be present but undetected, potentially leading to incorrect assumptions about the persistence of a local population or the conservation priority of a particular area. The federally endangered and narrowly endemic Conasauga logperch (*Percina jenkinsi*) is a good example of a rarely encountered fish species of conservation concern, for which basic population statistics are lacking. We evaluated the occurrence frequency for this species using surveys conducted with a repeat-observation sampling approach during the summer of 2008. We also analyzed museum records since the late 1980s to evaluate the trends in detected status through time. The results of these analyses provided support for a declining trend in this species over a portion of its historical range, despite low estimated detection probability. We used the results to identify the expected information return for a given level of monitoring where the sampling approach incorporates incomplete detection. The method applied here may be of value where historic occurrence records are available, provided that the assumption of constant capture efficiency is reasonable.

Résumé : Les animaux qui sont rarement rencontrés peuvent être présents mais non détectés, ce qui mène à des conclusions erronées sur la persistance des populations locales ou sur les priorités de conservation d'une région particulière. Le dard-perche de Conasauga (*Percina jenkinsi*), une espèce figurant sur la liste fédérale des espèces menacées et possédant une répartition endémique étroite, est un bon exemple d'une espèce de poisson rarement observée, dont la conservation suscite des inquiétudes et pour laquelle il n'existe pas de statistiques de base. Nous évaluons la fréquence d'occurrence de cette espèce d'après des inventaires par la méthode d'échantillonnage par observations répétées réalisés en 2008. Nous analysons aussi des données de musée depuis la fin des années 1980 afin de déterminer les tendances dans le statut de détection en fonction du temps. Les résultats de ces analyses semblent confirmer une tendance vers le déclin chez cette espèce sur une partie de son aire historique de répartition, malgré la faible probabilité de détection estimée. Nous utilisons les résultats pour déterminer le retour d'information à espérer en fonction d'un niveau de surveillance donnée lorsque la méthodologie d'échantillonnage tient compte d'une détection incomplète. La méthode que nous utilisons peut être intéressante dans les cas où des données historiques d'occurrence sont disponibles, à la condition qu'on puisse assumer raisonnablement que l'efficacité de capture est constante.

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Introduction

Many imperiled species are rare. This imposes a fundamental challenge for management: the population status and trends of such species are of great interest, but assessing these vital parameters can be difficult. In particular, it can be challenging to determine whether a rare species has been locally extirpated or is present at low abundances but undetected (Etnier 1994; Kery 2002). If detection probability is low, a time series of observations may overestimate population variability (Link and Nichols 1994) or even give the impression of successive extirpations and recolonizations at a site that has in fact been continuously occupied (Starnes et al. 1977; Etnier 1994). Additionally, an incorrect determina-

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M.M. Hagler.* Odum School of Ecology, University of Georgia, Athens, GA 30602, USA.
M.C. Freeman. US Geological Survey Patuxent Wildlife Research Center, Odum School of Ecology, University of Georgia, Athens, GA 30602, USA.
S.J. Wenger. Trout Unlimited – US Forest Service Rocky Mountain Research Station, 322 East Front Street, Suite 401, Boise, ID 83702, USA.
B.J. Freeman. Georgia Museum of Natural History and Odum School of Ecology, University of Georgia, Athens, GA 30602, USA.
P.L. Rakes and J.R. Shute. Conservation Fisheries, Inc., 3424 Division Street, Knoxville, TN 37919, USA.

Corresponding author: Megan Hagler (e-mail: megan@hemip.nhm.uga.edu).

*Present address: 110 Riverbend Road, Riverbend North, Room 101, University of Georgia, Athens, GA 30602, USA.

tion of extirpation could lead to failure to protect or properly manage a site that is important to the survival of a species (Kery 2002).

The problem of imperfect species detection has long been recognized (Otis et al. 1978), but in the past decade the issue has received increased attention and benefited from the development of new sampling and analytical methods (MacKenzie et al. 2002; Tyre et al. 2003; Royle 2004). These methods have been used to model occupancy of stream fishes (e.g., Albanese et al. 2007; Wenger et al. 2008), but to our knowledge have not been applied to the particular issue of detecting status trends of rare freshwater fish species. The growing number of freshwater fish species considered imperiled, especially in regions such as the Southeastern US (Warren et al. 2000), suggests a need for such an approach.

In this study we account for low and variable detection probability in examining the status and trends of an apparently rare and highly imperiled stream fish, the Conasauga logperch (*Percina jenkinsi*; family Percidae). Our objective is to test the hypothesis that the Conasauga logperch has declined in at least a portion of its range. We employ two approaches. First, we analyze replicated snorkel and seine samples collected in 2008 at known locations of historical Conasauga logperch occurrence to simultaneously estimate both species detection probability and species occurrence (i.e., proportion of sites currently occupied). Second, we analyze museum records collected over a 21-year period for evidence of a trend in observed presences over all or a portion of the species' range.

Throughout this paper, we use detection probability to refer to probability of observing at least one individual of a species in a sample from an occupied site. The probability of detecting a species with a given effort is a function of how many individuals are present (i.e., abundance) and the probability that any given individual is captured or observed by that effort (i.e., capture efficiency) (Bayley and Peterson 2001). We did not measure capture efficiency, and we discuss assumptions regarding capture efficiency needed for analyzing historic records of species detections.

Materials and methods

Study species

The Conasauga logperch is one of the most narrowly distributed stream fishes in North America. The species is known only from a 55 km reach of the mainstem of the Conasauga River (Coosa River system, Mobile River basin) in Georgia and Tennessee, USA. The species was listed as endangered under the Endangered Species Act in 1985, in large part because of its extremely restricted range. The Conasauga logperch is infrequently encountered, typically in low numbers (i.e., one or two individuals). Recently, biologists have expressed concern that it is becoming increasingly rare, indicating a decline in species abundance (Kuhajda et al. 2009). These anecdotal observations are of particular interest given that over the last decade, researchers have observed declines in other Conasauga River fish species (e.g., undescribed Coosa madtom (*Noturus* sp. cf. *N. munitus*), undescribed Coosa chub (*Macrhybopsis* sp. cf. *M. aestivalis*), and tricolor shiner (*Cyprinella trichroistia*)), as well was a decline in the submerged aquatic macrophyte riverweed (*Podostemum ceratophyllum*) and an apparent increase in algal production in the Conasauga River, including extensive benthic algal blooms during two summers (Freeman et al. 2007; Argentina et al. 2010; B.J. Freeman, personal observations).

The Conasauga logperch co-occurs with a more widespread and common congener, the Mobile logperch (*P. kathae*). These two species are similar in size, occur in the same habitats, and share a feeding behavior common to logperches, which use the tip of their snout to flip large gravel to expose macroinvertebrate prey. We have no reason to suspect a similar declining trend in the Mobile logperch, nor strong evidence that the probability of detecting these two species greatly differs, except as a result of differing abundances. Thus, we have included the Mobile logperch in the analysis to compare estimates for probability of detection and evidence of decline between a presumably more abundant and stable congener and the apparently rare and imperiled Conasauga logperch.

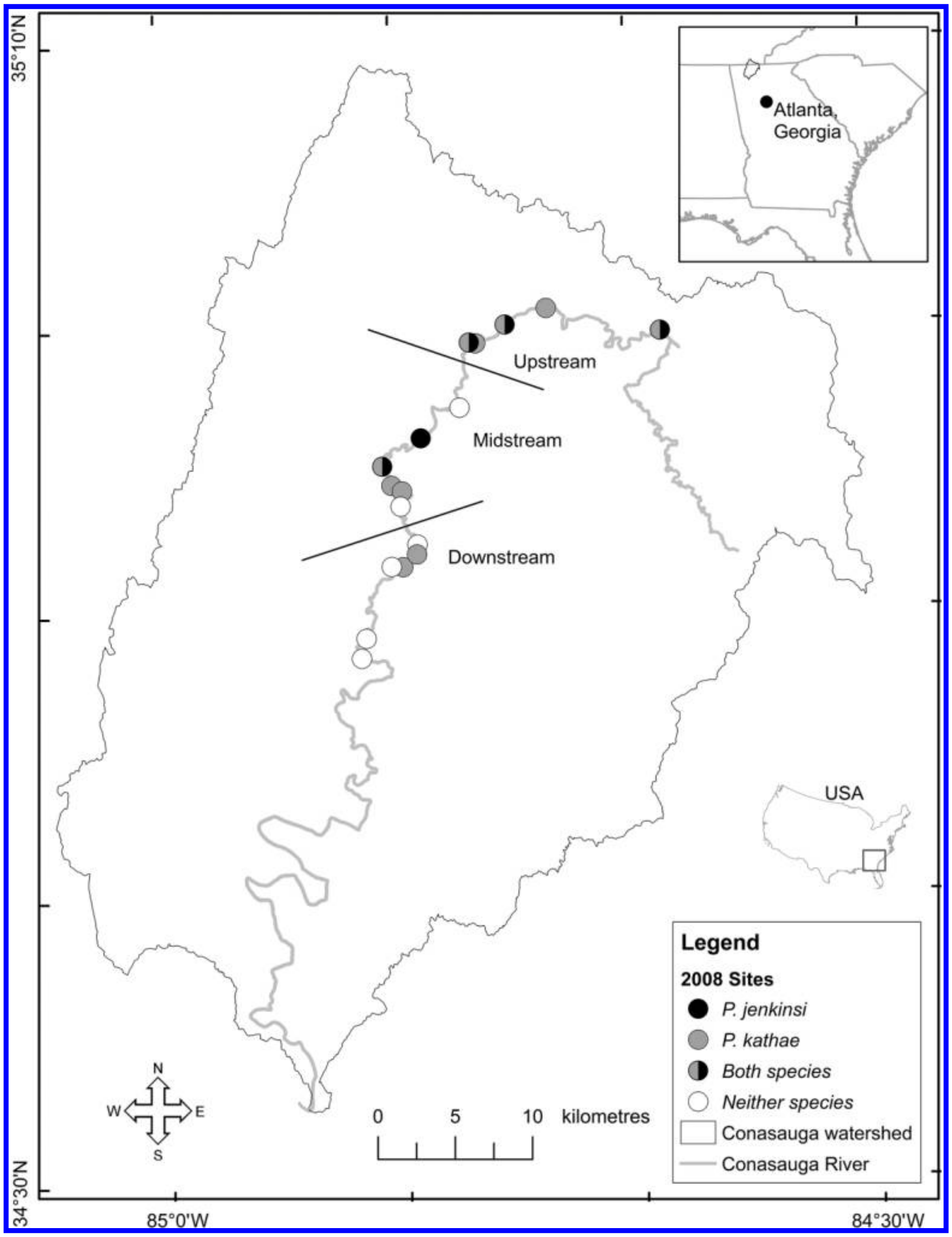
Surveys and analysis 2008

Using the Georgia Museum of Natural History database of fish records, we identified 20 unique localities at which the Conasauga logperch had been collected. All of these sites, which constituted the universe of known occurrences of the species, were located at shoals. We sampled 17 of these sites in 2008. We were forced to omit two sites in the upper portion of the reach owing to inaccessibility. A third site located in the downstream portion of the reach was omitted because the small shoal that had occurred there had completely washed away in recent years.

At each site we surveyed the shoal by snorkel observations (4 sites), using a seine (12 sites), or using both seine and snorkel methods (1 site). Snorkel observations were made at upstream sites where turbidity was less than 4.5 nephelometric turbidity units (NTU). Each of three snorkelers searched the shoal for an hour and made independent observations (i.e., Conasauga logperch and Mobile logperch were recorded as either observed or not observed by each person). Observers were well trained and used underwater cameras to document species, thus misidentifications were assumed to be zero. Two sites were snorkeled on two occasions, giving a maximum of six snorkel observations (6 × 1 person-hour) at a site. Seine surveys were conducted by a crew of five or six people, where two people held the ends of a seine net (1.8 m × 2.4 m, 3 mm mesh) while others moved downstream toward the net disturbing ("kicking") the stream bed to displace fishes. Each kick-set (seine-sampled area of approximately 3 m^2) was considered an independent observation where the target species were either observed or not observed. We also used seine haul methods in slower velocity or deeper areas, where the seine was pulled through the water column to collect fishes. The number of kick-sets and seine-hauls (sets) at a shoal depended on shoal size. One site was seined on two occasions (110 sets on 10 September 2008 and 61 sets on 13 October 2008), giving a maximum of 171 sets at a site. Across all sites sampled by seining, the minimum effort was 32 and the mean was 67 sets.

For the analysis, data were coded as target species observed "1" or not observed "0". We included a covariate on probability of detection to distinguish seine from snorkel survey methods. To evaluate evidence for the hypothesis that

Fig. 1. Sites along the Conasauga River surveyed in 2008 and the observed status of Conasauga logperch (*Percina jenkinsi*, black circles) and Mobile logperch (*P. kathae*, gray circle). Gray/black circles indicate that both species were observed; white circles indicate neither was observed.



species were less likely to occupy shoals in the lower portion of the study reach (where declines in riverweed and other fish species appear most likely; Argentina et al. 2010), we included a covariate on the probability of occupancy that indicated whether the site was located in the downstream-most portion of the study reach (Fig. 1). Data for Conasauga logperch and Mobile logperch were modeled separately.

The 2008 survey data were analyzed using an occupancy model, where the probability of detection is <1 (MacKenzie et al. 2002). The occupancy model uses data on species observed or not observed in replicates across sites to estimate simultaneously: (1) probability of species detection when a site is occupied, and (2) probability of occupancy at sites lacking detections. The model assumes the following: that occupancy does not change during surveys; that probabilities of occupancy and detection are constant across sites (except as specified by covariates); and that detections are independent among surveys at a site, and across sites (MacKenzie et al. 2006). Occupancy models were fit in WinBUGs (Spiegelhalter et al. 2003), which used Markov chain Monte Carlo simulation to derive posterior distributions for covariate parameters on detection (i.e., survey method) and occupancy (i.e., location in the downstream reach), and for the number of sites estimated to be occupied. A Bayesian analysis was

Table 1. Total number of surveys included in the analysis of historic data (1988–2008) summarized by year range and longitudinal river-reach.

Year range	Upstream	Middle	Downstream	Total
1988–1994	34	26	10	70
1995–2001	28	56	85	169
2002–2008	47	26	28	101
Total	109	108	123	340

appropriate because the sampled locations did not represent a random selection from a large population of sites. Instead, we estimated occupancy across nearly all of a small population of sites (i.e., 17 of 20 sites with historical Conasauga logperch occurrences). In this case, a maximum-likelihood modeling approach would have resulted in biased variance estimates for occupancy (MacKenzie et al. 2006). By using a Bayesian occupancy model (MacKenzie et al. 2006), we obtained unbiased estimates of credible intervals for probability of detection and for the number of the 17 sites that were occupied, for both species. Models were fit with diffuse priors (i.e., drawn for a normal distribution with a mean = 0 and variance = 1000), and posterior distributions were approximated using three simulation chains of 150 000 samples each, with the first 10 000 discarded as the burn-in period. Following the approach taken by Conroy et al. (2005), we evaluated model support using a modified AIC (Akaike's information criterion; Burnham and Anderson 2002) calculated as follows: (–2 log likelihood) + 2p, where p represents the number of parameters. We used mean posterior deviance (–2 log likelihood) averaged across all three chains to compare models with and without a downstream effect on occupancy. The total number of fixed-effect parameters was three or four, depending on the inclusion of downstream effect on occupancy. Lowest AIC score indicated the best-supported model.

Probability of detection was modeled at the scale of the individual set for seine surveys, but at the site scale for snorkel surveys. For comparability, and because many seine efforts are required to adequately survey a site, we scaled the estimates of detection for one seine set to the site scale. To do this, we calculated the probability of detecting at least one individual during a seine survey (conditional on species presence) as $1-(1-p)^n$, where p represents the probability of detection in one seine effort and n represents the number of seine efforts (Bayley and Peterson 2001, Albanese et al. 2007). This approach assumes that the probability of detecting a species in one seine effort is independent of the probability of detecting a species in other seine efforts (i.e., spatial replicates) within the site.

Using estimated detection probabilities for Conasauga logperch from the 2008 surveys, we calculated the effort that would be needed to more precisely estimate current occupancy rate than was possible given the 2008 data. We used the equation for asymptotic variance of occupancy rate provided by MacKenzie and Royle (2005) to estimate (*i*) the number of sites that would be needed to achieve a specified level of precision for occupancy, and (*ii*) the expected level of precision that an effort to thoroughly sample 30 sites would yield. We assumed that occupancy was 0.2, 0.4, 0.6, or 0.8, and that desired precision was 25% of the occupancy rate. Calculations considered both seine and snorkel methods.

Analysis of records collected from 1988 to 2008

To evaluate temporal and spatial trends in the occurrence of Conasauga logperch, we considered individual collection records from the Ichthyology database of the Georgia Museum of Natural History (GMNH, Athens, Georgia), beginning with 1988. We chose 1988 as the beginning year because earlier surveys occurred more sporadically and information available from those surveys often lacked essential detail (e.g., sampling method). Most of the existing occurrence records were incidental to sampling programs targeting the suite of imperiled fishes occurring in the Conasauga watershed, rather than part of a monitoring plan specifically designed for Conasauga logperch. We included all records from seine and snorkel surveys at any site where Conasauga logperch had ever been collected. As with the analysis of the 2008 data, we included data for the Mobile logperch for comparison. Mobile logperch was known from many more sites within the Conasauga River system than just those at which Conasauga logperch had been collected, but for our purpose, this information was ignored. Thus, we examined only trends of the two species at known Conasauga logperch sites.

We also conducted a new search for previously undigitized sampling records not included in the database. These additions raised the total number of known Conasauga logperch sites from 20 to 29. Records for which the survey method was unavailable (n = 3), or a boat or backpack electrofisher was used (n = 5), or the survey was stated to be incomplete owing to high water (n = 1) were excluded (the Conasauga logperch was not observed in any of the nine excluded records, but the Mobile logperch was observed in four). The remaining 340 individual surveys were included in the analysis (Table 1). Records selected from the GMNH database primarily included collections made by the authors, along with several records from the Georgia Department of Natural Resources (Atlanta, Georgia), University of Alabama Ichthyology Collection (Tuscaloosa, Alabama), and Florida Museum of Natural History (Gainesville, Florida).

The probability of detecting a species at a site is a function of the total number of individuals at a site (abundance) and the probability of an individual's capture (capture efficiency) given the sampling effort. Analyzing the historic Conasauga data set for evidence of logperch decline has required an assumption that capture efficiency was constant across surveys, in which case declining rates of detection would imply declining abundance. Generally this would be an unsupportable assumption when applied to data collected over an extended period, because changes in habitats sampled, environmental conditions, and methods would likely cause variability in capture efficiency (Tingley and Beissinger 2009). We believe the logperch data set represents an unusual case in which an assumption of constant capture efficiency is supportable, because the observations were made by a small number of experienced observers using consistent methods at a relatively small number of fixed sites. Further, 93% of the surveys occurred during warm months (May–October) with 46% of the surveys occurring in October. Assuming constant capture efficiency, temporal trends in the probability that a species is observed (i.e., present and detected) at a site allow us to infer changes in abundances.

We used logistic regression implemented in SAS (SAS Institute Inc. 2002) to model the probability that Conasauga logperch or Mobile logperch were observed (i.e., present and detected) in a given survey. We included four primary independent variables in the models. These were the continuous variables "rivermile" and "year" and the categorical variables "river reach" and "7-year block", which pooled data within upstream, midstream, and downstream sections of the Conasauga River (Fig. 1), and within early (1988–1994), middle (1995–2001), and late years (2002–2008), respectively. The categorical variables were used to test our a priori hypothesis that declines may be more prominent in the downstream portion of the study area and in recent years. The four variables were used in models individually, in uncorrelated pairs, and in pairs with an interaction between them (e.g., "rivermile × year" or "river reach × year") to test for a trend along the river and through time. Support for competing candidate models was evaluated using Akaike's information criterion adjusted for small sample size (AIC_c), where lowest AIC_c indicated greatest support, and where delta AIC_c was used to calculate model weights to compare the relative support among models (Burnham and Anderson 2002).

In a post hoc analysis, we evaluated whether two covariates potentially related to the detection component of "present and detected" substantially improved the best-supported model of the historic data for each species. These covariates were a binary variable, "snorkel", indicating survey method (i.e., snorkel versus seine survey), and a continuous variable, "flow", indicating average stream discharge on the day of the survey at the US Geological Survey Conasauga River Eton gage (gage number 02384500; located in the "midstream" section of the study area). Relaxing our assumption of constant capture efficiency, we hypothesized that species detectability may have differed depending on survey method and may have been lower in surveys conducted when river discharge was higher. The daily mean discharge was natural log transformed for the analysis.

In addition, because model results suggested strong evidence of a space-time interaction, we conducted separate analyses of data from the upstream or downstream reach, depending on interaction results. The models based on a reduced data set included only "year" or "7-year block", and in the case of the Mobile logperch, stream discharge on the day of the survey (see results below). Results of these reduced models helped to illustrate trends within particular reaches that were distinct from other reaches within the project area.

Results

Surveys and analysis 2008

The Conasauga logperch was observed at 5 of 17 historically occupied sites in 2008 and only in the upstream and midstream portions of its range (Table 2; Fig. 1). Occurrence records were sparse for Conasauga logperch (one observation by a single snorkeler at three different sites and one observation in a single seine sample at two sites, with eight individuals observed in total), but less so for Mobile logperch. Mobile logperch was observed at 10 sites throughout the project area: 2–6 observations at six sites and a single observation at four sites.

Support was equivocal for including a covariate on occupancy to distinguish the downstream reach for both species. Models with a downstream effect on occupancy were slightly less well supported ($\Delta AIC = 1.70$ for Mobile logperch and $\Delta AIC = 0.94$ for Conasauga logperch) compared with models holding occupancy constant across reaches. Based on evidence of declining trends in the downstream reach (e.g., declining fish species, declining riverweed, and an increase in algal production) we chose to use estimates from the

Table 2. Detections of target species during 2008 surveys by site and sample method.

Species	Sites	Snorkel efforts	Seine efforts
Conasauga logperch	5 of 17	3 of 21	2 of 942
Mobile logperch	10 of 17	17 of 21	10 of 942

Table 3. Median estimates for probability of detection using snorkel and seine methods as estimated in WinBUGS, with the 95% credible interval shown in parentheses.

	Conasauga logperch	Mobile logperch
Snorkel (1-person hour)	0.132 (0.032–0.318)	0.818 (0.618–0.942)
Seine (1 effort)	0.003 (0.000–0.010)	0.011 (0.006–0.021)
Seine (scaled to 67 efforts)	0.156 (0.023–0.485)	0.537 (0.315–0.753)

Note: Probability of detection for seine sampling is scaled to mean effort at a site during 2008 surveys.

Fig. 2. Estimated detection probability (unbroken line) with the 95% credible interval (broken lines) for Mobile logperch (gray) and Conasauga logperch (black) based on 2008 surveys, plotted over a range of seine sample effort.

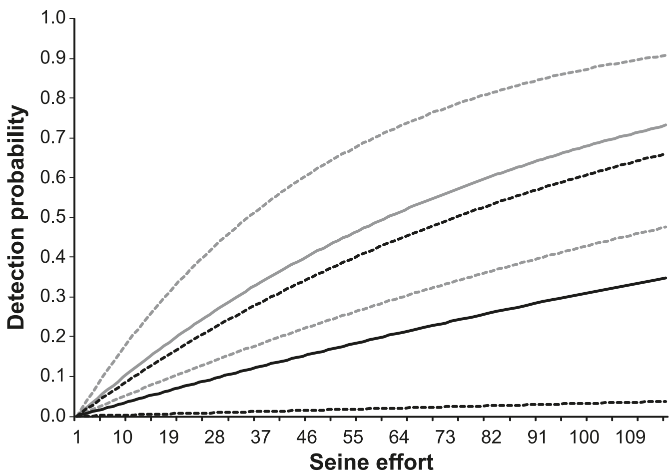
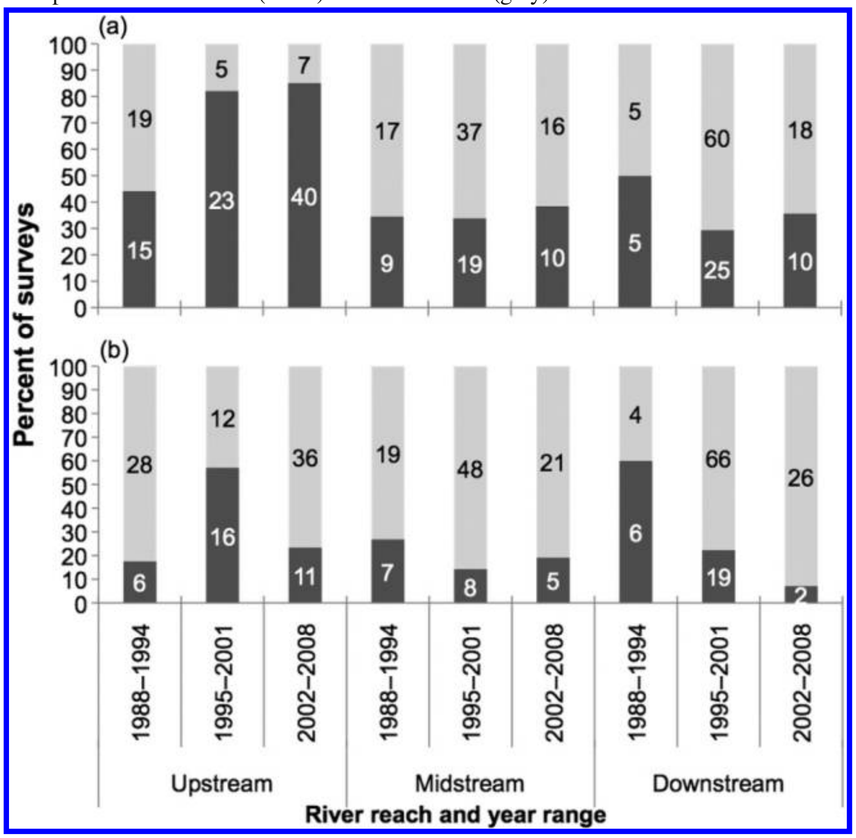


Table 4. Estimated required effort to achieve a desired precision on occupancy, and expected precision of occupancy estimates for a practicable effort, for Conasauga logperch surveys made by snorkeling or seining in suitable habitat, for four values of species occupancy.

		Snorkel surveys (p = 0.132/observer, 6 observers)		Seine surveys (p = 0.156/visit, 3 visits)	
Occupancy (ψ)	Desired SE (ψ)	No. sites needed to achieve desired SE(ψ)	Expected SE(ψ) if sites = 30	No. sites needed to achieve desired SE(ψ)	Expected SE(ψ) if sites = 30
0.2	0.05	252	0.14	799	0.26
0.4	0.10	118	0.20	392	0.36
0.6	0.15	73	0.23	256	0.44
0.8	0.20	51	0.26	188	0.50

Note: Desired standard error (SE) is set at 25% of estimated occupancy (ψ) for illustration. A practicable effort is defined as 30 sites surveyed in a given season, with six (snorkel) or three (seine) replicated surveys at each site, and detection probability (p) equal to levels estimated in 2008.

Fig. 3. Percent of surveys with (*a*) Mobile logperch and (*b*) Conasauga logperch detected, organized by year range and river reach. The number of surveys where each species was observed (black) or not observed (grey) is noted within each column.



model that included the downstream effect on occupancy. Parameter coefficients were similar between models.

The estimates for probability of detection in a snorkel survey were more than 6× higher for Mobile logperch than Conasauga logperch (Table 3). Probability of detection in one seine effort also was higher for Mobile logperch (0.011) than Conasauga logperch (0.003), and the credible interval for the Conasauga logperch estimate was relatively large (Table 3). Scaling the probability estimate for a single seine effort up to the mean effort for a site in 2008 (67 seine efforts), gave a probability of 0.537 of detecting at least one Mobile logperch and 0.156 of detecting at least one Conasauga logperch in an occupied shoal (Fig. 2). Thus, the estimated probability for observing the Conasauga logperch, when present, was somewhat lower for one person snorkeling for an hour (0.132), than for a small crew sampling with a seine (about 0.156 given average effort, Table 3). The estimated 95% credible interval for number of occupied sites was 10 to 17 (mean 14.0) sites for Conasauga logperch and 13 to 17 (mean 16.8) sites for Mobile logperch (of 17 total sites).

The estimated survey effort required to improve occupancy estimates for the Conasauga logperch (MacKenzie and Royle 2005) varied greatly by survey method and assumed occupancy rate. If actual occupancy equaled our naïve estimate for the upstream reach (3 observations/5 sites surveyed = 0.6), given six observers and given our estimated detection probability for a single snorkeler (0.132), one would need to survey an estimated 73 randomly-selected sites to achieve a standard error equal to 25% of the estimated occupancy rate (Table 4). To obtain similar precision in the downstream reach by seining, assuming an occupancy rate of 0.2 and three visits to a site in a season (with site-level detection = 0.156), would require surveys at 799 sites – or more total effort than was represented in the 21-year historical dataset

Table 5. Relative support for top models and the null or empty model predicting the probability of observing Conasauga logperch and Mobile logperch.

Top models	ΔAIC_c	Model weight
Conasauga logperch		
River reach, 7-year block, river reach × 7-year block	0.00	68.87%
Rivermile, 7-year block, rivermile × 7-year block	1.80	27.97%
River reach, year	8.55	0.96%
River reach, year, river reach × year	8.69	0.90%
Null	11.52	0.22%
Conasauga logperch, downstream reach only		
Year	0.00	63.98%
7-Year block	1.29	33.50%
Null	6.47	2.52%
Mobile logperch		
Rivermile, year, flow	0.00	28.01%
Rivermile, 7-year block, rivermile × 7-year block, flow	0.16	25.89%
Rivermile, year, rivermile × year, flow	0.75	19.24%
Rivermile, 7-year block, flow	2.57	7.79%
Rivermile, 7-year block, rivermile × 7-year block	3.47	4.94%
Null	52.35	0.00%
Mobile logperch, upstream reach only		
7-Year block, flow	0.00	64.99%
7-Year block	1.45	31.56%
Year	7.27	1.72%
Year, flow	7.39	1.61%
Null	12.92	0.10%
Flow	16.47	0.02%

Note: River reach and 7-year block are categorical variables dividing data spatially, into upstream, midstream, and downstream reaches (Fig. 1), and temporally, into early (1988–1994), middle (1995–2001), and late (2002–2008) years, respectively. Rivermile and year are continuous variables. Flow is a continuous variable for the mean discharge at the Conasauga River at Eton (US Geological Survey gage 02384500) on the day of the survey.

used in the present study. More practicable levels of effort, e.g., sampling 30 sites per season, would result in lower precision (Table 4).

Analysis of records collected from 1988 to 2008

Conasauga logperch was observed in 80 of 340 surveys (24%) since 1988 (Fig. 3). In 65 of 80 surveys where Conasauga logperch was detected, the total number of individuals was 1 or 2 (including 14 surveys where the total observed was not recorded and thus assumed to be low). In the remaining 15 surveys, an average of 5 individuals (mode = 4; range = 3–12) was observed. Of the 29 total sites, Conasauga logperch was detected only once at 16 sites and only two or three times at seven sites. At the other six sites (three upstream, one midstream, and two downstream) the species was detected on 4–10 occasions.

The best supported model predicting present and detected status for Conasauga logperch included the categorical variables distinguishing upstream, midstream, and downstream river reaches, and early, middle, and late years, and an interaction between them (Table 5). The top model predicting Conasauga logperch carried 68.87% of the total model weight, and parameter estimates for the interaction suggested a clear distinction between upstream and downstream reaches, but weaker support for differences between upstream and midstream reaches (when data from the upstream and midstream reaches were separately analyzed, the best model included 7-year block, indicating temporal differences but not trends (analytical results not shown) Fig. 3). Estimates for additional covariates distinguishing snorkel from seine surveys or indicating stream flow on the day of the survey were small and poorly estimated with no improvement in relative model support ($\Delta AIC = 0.2$ and $\Delta AIC = 2.2$, respectively). We reanalyzed data for the downstream reach only, to aid in interpreting the interaction effect and to test for a trend across years. We compared models with "year" and "7-year blocks" to the null model (Table 5). The greatest support indicated a trend across years, where the estimate for the effect of year was –0.169 (SE = 0.056; Table 6). There was little support for the null model (model weight = 2.52%; Table 5), in which the probability that the Conasauga logperch was present and detected was assumed to be constant across years. Thus, according to the best supported model, the odds that a Conasauga logperch was present and detected at a site in the downstream section decreased with each additional year in the record by about 15.6% (i.e., odds ratio for effect of year = 0.844, Table 6).

The Mobile logperch was observed in 156 of the 340 surveys (46%, Fig. 3). Analysis of the complete data set resulted in many closely weighted models (select results in Table 5). Parameter estimates in top models suggested that data from the upstream reach were driving the result. When data from the upstream reach were omitted from the analysis, none of the covariates used were predictive of the data observed in the midstream and downstream reaches (i.e., the null model was the best-supported model; results not shown). When data from the upstream reach were separately analyzed, the best supported model with 65% of model weight included 7-year-block and stream flow, indicating lower odds that the species was present and detected in the earliest time block (Table 6). The effect of stream flow was positive, contrary to our a priori expectation, but imprecisely estimated (Table 6); i.e., the 95% confidence limits on the odds ratio included 1, or no effect.

Discussion

We have described an approach to assessing evidence for a perceived decline in a rarely encountered species using both contemporary surveys and historical records, the latter collected for other purposes. Replicated field surveys in 2008 for the federally endangered Conasauga logperch resulted in few detections and low estimated probability of detecting the species when it was present. As a result, the single-season survey resulted in the unsatisfactory conclusion that this rare species "plausibly was present in all sites". An analysis of archived sampling records supported the hypothesis that the probability of encountering a Conasauga logperch in the downstream portion of the study reach (i.e., the downstream third of its known range) has declined over the past two decades. Models describing a temporal decline collectively had weights 40× higher than a nontemporal model, suggesting

Table 6. Parameter estimates, standard error (SE), odds ratio (OR), and 95% confidence interval (CI) on the odds ratio from the top model predicting Conasauga logperch in the downstream reach and Mobile logperch in the upstream reach.

Covariate	Estimate	SE	OR	95% CI
Conasauga logperch, downstream reach				
Year	–0.169	0.056	0.844	0.76–0.94
Mobile logperch, upstream reach				
7-Year block, middle relative to early	2.166	0.661	8.723	2.39–31.84
7-Year block, late relative to early	2.236	0.577	9.351	3.02–28.97
Flow	0.689	0.374	1.993	0.96–4.15

strong evidence of a trend. The trend observed for the Conasauga logperch was unlike that for the co-occurring and more common Mobile logperch, for which best-supported models suggested a positive trend (in the upstream section) or no temporal trend (midstream and downstream sections) in the probability of encountering the species.

The single-season data alone allow some inference regarding the abundance of the rare Conasauga logperch relative to the Mobile logperch. We have no basis for supposing that detection by experienced observers should greatly differ between the Mobile logperch and Conasauga logperch and, therefore, differences in probability of detection likely reflect differences in underlying abundance between the species. There may be behavioral differences between the two species that influence capture probability (e.g., perhaps greater reticence towards snorkelers by Conasauga logperch), but this would only explain a portion of the substantial difference in detection probabilities estimated here. Thus, the observation that the Mobile logperch was more than 3× as likely to be detected in an average seine survey as the Conasauga logperch provides evidence that the latter species is, in fact, relatively rare. Nonetheless, the single-season data have not allowed precise estimation of the number of historic sites currently occupied by the Conasauga logperch, because the estimated probability of detection is too low for confidently interpreting nondetections as species absence.

The use of museum and archived records allowed us to test support for a hypothesized decline in the Conasauga logperch, but with several assumptions. Historically, sampling has rarely been replicated within seasons or by sampling near-by sites as spatial replicates, nor have observations within sites been recorded in a way that would allow a partitioning of effort, as in our 2008 samples (and as in Albanese et al. 2007). For this reason, the analysis of historical data has necessarily addressed temporal and spatial trends in the combined response variable, "species present and detected". Interpreting these results as evidence of species decline requires the assumption that capture efficiency (i.e., the probability that any given individual is captured or observed) has not changed through time, and thus a decline in detections is a result of declining abundances (possibly to zero at some sites). This assumption may not be true if sampling technologies or efforts changed through time (e.g., the collectors grew old and less capable of catching or observing the target species), or if there were systematic changes in the habitats being sampled that also affected sampling efficiency. In the case of the Conasauga logperch, sites sampled, sampling methods, and even the observers (older, but arguably still capable) have remained relatively constant over the period used for analysis. Thus, it seems unreasonable that capture efficiency remained unchanged in the middle and upper reaches, but declined in the downstream reach, resulting in the temporal decline observed for Conasauga logperch. The lack of strong temporal trends for the co-occurring Mobile logperch in the same dataset supports the conclusion that systematically decreasing sampling efficiency is not responsible for apparent decline in the Conasauga logperch.

Even in cases where sampling involves repeated surveys at sites or groups of sites, low detection probabilities for rare species will limit the application of occupancy modeling for estimating either probability of species occurrence at a single time (MacKenzie et al. 2002) or occupancy dynamics across a span of time (MacKenzie et al. 2009). The problem, as noted earlier, lies in the inability, when detection probability is low, to discriminate confidently between species absence and failure to detect. The best way to address the challenges related to low detection is to maximize capture efficiency. This can be accomplished by an increase in effort, increase in skill, or by use of alternative sampling methods (McDonald 2004). Employing new sampling methods, such as a hand-pulled trawl net designed for sampling smaller-bodied benthic species from deeper habitats (Herzog et al. 2009) might be informative for Conasauga logperch, if incidental mortality can be minimized. For endangered species, however, sampling methods must be limited to nondestructive, minimally invasive techniques for both ethical and legal reasons. For example, many stream fishes are more efficiently sampled using electrofishing gear (Thurow et al. 2006) or ichthyocides (Bayley and Peterson 2001) rather than snorkeling, but neither of these methods may be acceptable for a highly imperiled species such as the Conasauga logperch.

Studies of rare populations commonly involve difficulties associated with deciding not only how, but where to sample for species that are not well known (McDonald 2004). Our single-year attempt to assess the status of Conasauga logperch involved sampling locales where the target species has occurred previously, several of which have been repeatedly sampled because they are located near a road crossing. McDonald (2004) notes that many successes in obtaining information on rare species have come from spreading the sample effort over the study area, and cites numerous examples of rare species occurring in unexpected habitats. The Conasauga River system, regarded as a headwater refuge for fish and mussel species extirpated from downstream portions of the exceptionally species-rich Mobile River basin (Burkhead et al. 1997; Freeman et al. 2005), has in fact been frequently sampled by biologists from mulitple institutions for many years. For example, Wenger et al. (2009) used >900 records of species occurrences from a 13-year period to priortize subwatersheds of the Conasauga for conservation and protection.

The small range of the Conasauga logperch, and the professional judgment that the species is in critical need of conservation action (Kuhajda et al. 2009), are not products of limited sampling in the Conasauga River. However, there is relatively little survey information from presumably suitable but less-accessible habitat, e.g., in upstream reaches where access requires an 8 h canoe trip. An expanded monitoring program using a probabilistic sampling design to allocate resources for investigating potentially occupied patches and habitats could expand the number of known Conasauga logperch locales.

Our 2008 effort to estimate the status of the Conasauga logperch might be considered a failure in that we were unable to precisely estimate the number of historical locales currently occupied. However, our single-season effort using replicated sampling has provided estimates of detection probability for two sampling methods (seining and snorkeling) that are currently acceptable for this imperiled species. An objective of future monitoring work may be to estimate occupancy for Conasauga logperch in the upstream portion of its range; a thorough effort at 30 randomly selected sites within the upstream reach will likely provide imprecise occupancy estimates. Repeated over multiple years, however, even imprecise estimates that account for incomplete detection would allow tests for trends in occupancy (or in detection) without requiring the assumption that capture efficiency remains constant.

This study has illustrated the potential utility of examining archived survey records to evaluate evidence that rarely encountered species are in decline, and of estimating detectability when assessing status of rare stream fishes. Nondestructive sampling methods that increase detectability and an investment in sampling a large number of randomly chosen sites, especially in under-sampled areas, offer the most promising options for improving our knowledge of the Conasauga logperch and of rare stream fishes more generally.

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