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2014–T002
Version 1.1, July 2014


# Spatially Explicit Habitat Models for 28 Fishes from the Upper Mississippi River System (AHAG 2.0)

Submitted to the U.S. Army Corps of Engineers, Rock Island District
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Cover photograph by Shawn Giblin, Wisconsin Department of Natural Resources, La Crosse, Wisconsin

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# Preface

The U.S. Army Corps of Engineers' (USACE) Upper Mississippi River Restoration-Environmental Management Program (UMRR-EMP), including its Long Term Resource Monitoring Program element (LTRMP), was authorized under the Water Resources Development Act of 1986 (Public Law 99–662). The UMRR-EMP is a multi-federal and state agency partnership among the USACE, the U.S. Geological Survey's (USGS) Upper Midwest Environmental Sciences Center (UMESC), the U.S. Fish and Wildlife Service (USFWS), and the five Upper Mississippi River System (UMRS) States of Illinois, Iowa, Minnesota, Missouri, and Wisconsin. The USACE provides guidance and has overall Program responsibility. UMESC provides science coordination and leadership for the LTRMP element.

The UMRS encompasses the commercially navigable reaches of the Upper Mississippi River, as well as the Illinois River and navigable portions of the Kaskaskia, Black, St. Croix, and Minnesota Rivers. Congress has declared the UMRS to be both a nationally significant ecosystem and a nationally significant commercial navigation system. The mission of the LTRMP element is to support decision makers with the information and understanding needed to manage the UMRS as a sustainable, large river ecosystem, given its multiple use character. The long-term goals of the LTRMP are to better understand the UMRS ecosystem and its resource problems, monitor and determine resource status and trends, develop management alternatives, and proper management and delivery of information.

This report supports Outcome 3: Enhanced use of scientific knowledge for implementation of ecosystem restoration programs and projects in the Strategic and Operational Plan for the Long Term Resource Monitoring Program on the Upper Mississippi River System, Fiscal Years 2010–2014 (2009) and fulfills milestone #2013B27 from the FY13 LTRMP scope of work. This report was developed with funding provided by the USACE through the UMRR-EMP.

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SI to Inch/Pound

| Multiply | By | To obtain |
|---|---|---|
| | Length | |
| centimeter (cm) | 0.3937 | inch (in.) |
| meter (m) | 3.281 | foot (ft) |
| kilometer (km) | 0.6214 | mile (mi) |
| kilometer (km) | 0.5400 | mile, nautical (nmi) |
| meter (m) | 1.094 | yard (yd) |
| | Flow rate | |
| meter per second (m/s) | 3.281 | foot per second (ft/s) |

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

°F=(1.8×°C)+32

Specific conductance is given in microsiemens per centimeter (µS/cm).

Concentrations of chemical constituents in water are given in milligrams per liter (mg/L)

### Abbreviations

| | |
|---|---|
| AHAG | Aquatic Habitat Appraisal Guide |
| HEP | Habitat Evaluation Procedures |
| HREP | Habitat Rehabilitation and Enhancement Project |
| HIS | habitat suitability index |
| IDW | inverse distance weighting |
| LTRMP | Long Term Resource Monitoring Program |
| MLR | Multiple Logistic Regression |
| SWB | splines with barriers |
| UMRR-EMP | Upper Mississippi River Restoration-Environmental Management Program |
| UMRS | Upper Mississippi River System |
| USACE | U.S. Army Corps of Engineers |
| USFWS | U.S. Fish and Wildlife Service |
| % | percent |

# Spatially Explicit Habitat Models for 28 Fishes from the Upper Mississippi River System (AHAG 2.0)

By Brian S. Ickes,[1] J.S. Sauer, N. Richards, M. Bowler, and B. Schlifer

## Abstract

Environmental management actions in the Upper Mississippi River System (UMRS) typically require pre-project assessments of predicted benefits under a range of project scenarios. The U.S. Army Corps of Engineers (USACE) now requires certified and peer-reviewed models to conduct these assessments. Previously, habitat benefits were estimated for fish communities in the UMRS using the Aquatic Habitat Appraisal Guide (AHAG v.1.0; AHAG from hereon). This spreadsheet-based model used a habitat suitability index (HSI) approach that drew heavily upon Habitat Evaluation Procedures (HEP; U.S. Fish and Wildlife Service, 1980) by the U.S. Fish and Wildlife Service (USFWS). The HSI approach requires developing species response curves for different environmental variables that seek to broadly represent habitat. The AHAG model uses species-specific response curves assembled from literature values, data from other ecosystems, or best professional judgment.

A recent scientific review of the AHAG indicated that the model's effectiveness is reduced by its dated approach to large river ecosystems, uncertainty regarding its data inputs and rationale for habitat-species response relationships, and lack of field validation (Abt Associates Inc., 2011). The reviewers made two major recommendations: (1) incorporate empirical data from the UMRS into defining the empirical response curves, and (2) conduct post-project biological evaluations to test pre-project benefits estimated by AHAG.

Our objective was to address the first recommendation and generate updated response curves for AHAG using data from the Upper Mississippi River Restoration-Environmental Management Program (UMRR-EMP) Long Term Resource Monitoring Program (LTRMP) element. Fish community data have been collected by LTRMP (Gutreuter and others, 1995; Ratcliff and others, 2014) for 20 years from 6 study reaches representing 1,930 kilometers of river and >140 species of fish. We modeled a subset of these data (28 different species; occurrences at sampling sites as observed in day electrofishing samples) using multiple logistic regression with presence/absence responses. Each species' probability of occurrence, at each sample site, was modeled as a function of 17 environmental variables observed at each sample site by LTRMP standardized protocols. The modeling methods used (1) a forward-selection process to identify the most important predictors and their relative contributions to predictions; (2) partial methods on the predictor set to control variance inflation; and (3) diagnostics for LTRMP design elements that may influence model fits.

Models were fit for 28 species, representing 3 habitat guilds (Lentic, Lotic, and Generalist). We intended to develop "systemic models" using data from all six LTRMP study reaches simultaneously; however, this proved impossible. Thus, we "regionalized" the models, creating two models for each species: "Upper Reach" models, using data from Pools 4, 8, and 13; and "Lower Reach" models, using data from Pool 26, the Open River Reach of the Mississippi River, and the La Grange reach of the Illinois River. A total of 56 models were attempted. For any given site-scale prediction, each model used data from the three LTRMP study reaches comprising the regional model to make predictions. For example, a site-scale prediction in Pool 8 was made using data from Pools 4, 8, and 13. This is the fundamental nature and trade-off of regionalizing these models for broad management application.

Model fits were deemed "certifiably good" using the Hosmer and Lemeshow Goodness-of-Fit statistic (Hosmer and Lemeshow, 2000). This test post-partitions model predictions into 10 groups and conducts inferential tests on correspondences between observed and expected probability of occurrence across all partitions, under Chi-square distributional assumptions. This permits an inferential test of how well the models fit and a tool for reporting when they did not (and perhaps why). Our goal was to develop regionalized models, and to assess and describe circumstances when a good fit was not possible.

[1]Principal investigator, UMRR-EMP LTRMP Fisheries Component, La Crosse, Wisconsin, and corresponding author.

Seven fish species composed the Lentic guild. Good fits were achieved for six Upper Reach models. In the Lower Reach, no model produced good fits for the Lentic guild. This was due to (1) lentic species being much less prominent in the Lower Reach study areas, and (2) those that do express greater prominence principally do so only in the La Grange reach of the Illinois River. Thus, developing Lower Reach models for Lentic species will require parsing La Grange from the other two Lower Reach study areas and fitting separate models. We did not do that as part of this study, but it could be done at a later time.

Nine species comprised the Lotic guild. Good fits were achieved for five Upper Reach models and six Lower Reach models. Four species had good fits for both regions (flathead catfish, blue sucker, sauger, and shorthead redhorse). Three species showed zoogeographic zonation, with a good model fit in one of the regions, but not in the region in which they were absent or rarely occurred (blue catfish, rock bass, and skipjack herring).

Twelve species comprised the Generalist guild. Good fits were achieved for seven Upper Reach models and eight Lower Reach models. Six species had good fits for both regions (brook silverside, emerald shiner, freshwater drum, logperch, longnose gar, and white bass). Two species showed zoogeographic zonation, with a good model fit in one of the regions, but not in the region in which they were absent or rarely occurred (red shiner and blackstripe topminnow).

Poorly fit models were almost always due to the diagnostic variable "field station," a surrogate for river mile. In these circumstances, the residuals for "field station" were non-randomly distributed and often strongly ordered. This indicates either fitting "pool scale" models for these species and regions, or explicitly model covariances between "field station" and the other predictors within the existing modeling framework. Further efforts on these models should seek to resolve these issues using one of these two approaches.

In total, nine species, representing two of the three guilds (Lotic and Generalist), produced well-fit models for both regions. These nine species should comprise the basis for AHAG 2.0. Additional work, likely requiring downscaling of the regional models to pool-scale models, will be needed to incorporate additional species. Alternately, a regionalized AHAG could be comprised of those species, per region, that achieved well-fit models. The number of species and the composition of the regional species pools will differ among regions as a consequence. Each of these alternatives has both pros and cons, and managers are encouraged to consider them fully before further advancing this approach to modeling multi-species habitat suitability.

# Introduction

Environmental management actions in the Upper Mississippi River System (UMRS; fig. 1) typically require pre-project assessments of predicted benefits for a range of project scenarios. The U.S. Army Corps of Engineers (USACE) now requires certified and peer-reviewed models to conduct these assessments. Previously, habitat benefits were estimated for fish communities in the UMRS using the Aquatic Habitat Appraisal Guide (AHAG v.1.0; AHAG from hereon). This spreadsheet-based model used a habitat suitability index (HSI) approach that drew heavily upon methods developed by the U.S. Fish and Wildlife Service (USFWS) in the 1980's, commonly referred to as Habitat Evaluation Procedures (HEP; U.S. Fish and Wildlife Service, 1980). The HSI approach requires developing species-response curves (typically using abundance as the biological response) for different environmental variables that seek to broadly represent habitat. The AHAG model uses species-specific response curves assembled from literature values, data from other ecosystems, or best professional judgment.

A recent scientific review of the AHAG was performed to assess the degree to which the AHAG model can be certified for regional use as a planning tool within the UMRS (Abt Associates Inc., 2011). The reviewers' findings indicated that the model's effectiveness is reduced by its dated approach to large river ecosystems, uncertainty regarding its data inputs and rationale for habitat-species response relationships, and lack of field validation. The reviewers made two major recommendations: (1) incorporate empirical data from the UMRS into defining the empirical response curves, and (2) conduct post-project biological evaluations to test pre-project benefits estimated by AHAG.

Prior to stating study objectives, it is necessary to reflect upon the theoretical underpinnings of habitat suitability modeling as exercised in AHAG, the fundamental nature of the problem domain, and some issues that arise as a consequence. These are provided both to help judge the inherent limitations and potential utility of these approaches for estimating habitat quality and to improve its application to the UMRS.

# Theoretical Underpinnings of AHAG

The underpinnings of AHAG have their foundation in G. Evelyn Hutchinson's concept of the ecological niche (Hutchinson, 1957). Earlier, Charles Elton had originated the concept of a niche, but in a functional way (Elton, 1927). The Eltonian niche describes a species "profession" or functional role within an ecosystem (zooplanktivore, herbivore, piscivore, etc.). In contrast, the Hutchinsonian concept attempts to redefine the niche as the "place or habitat" a species occupies, or otherwise, its address. The Hutchinsonian view has carried the day for nearly 70 years. As a "place based" or habitat centric construct, the AHAG approach has its roots in the Hutchinsonian concept and subsequent theoretical advances that have followed since 1957.

The core concept of the Hutchinsonian model is the hyper-volume, in which a set of multiple environmental factors determine the place, or habitat, that a species occupies. As such, it regards habitat as a species, space, and perhaps time-specific thing.

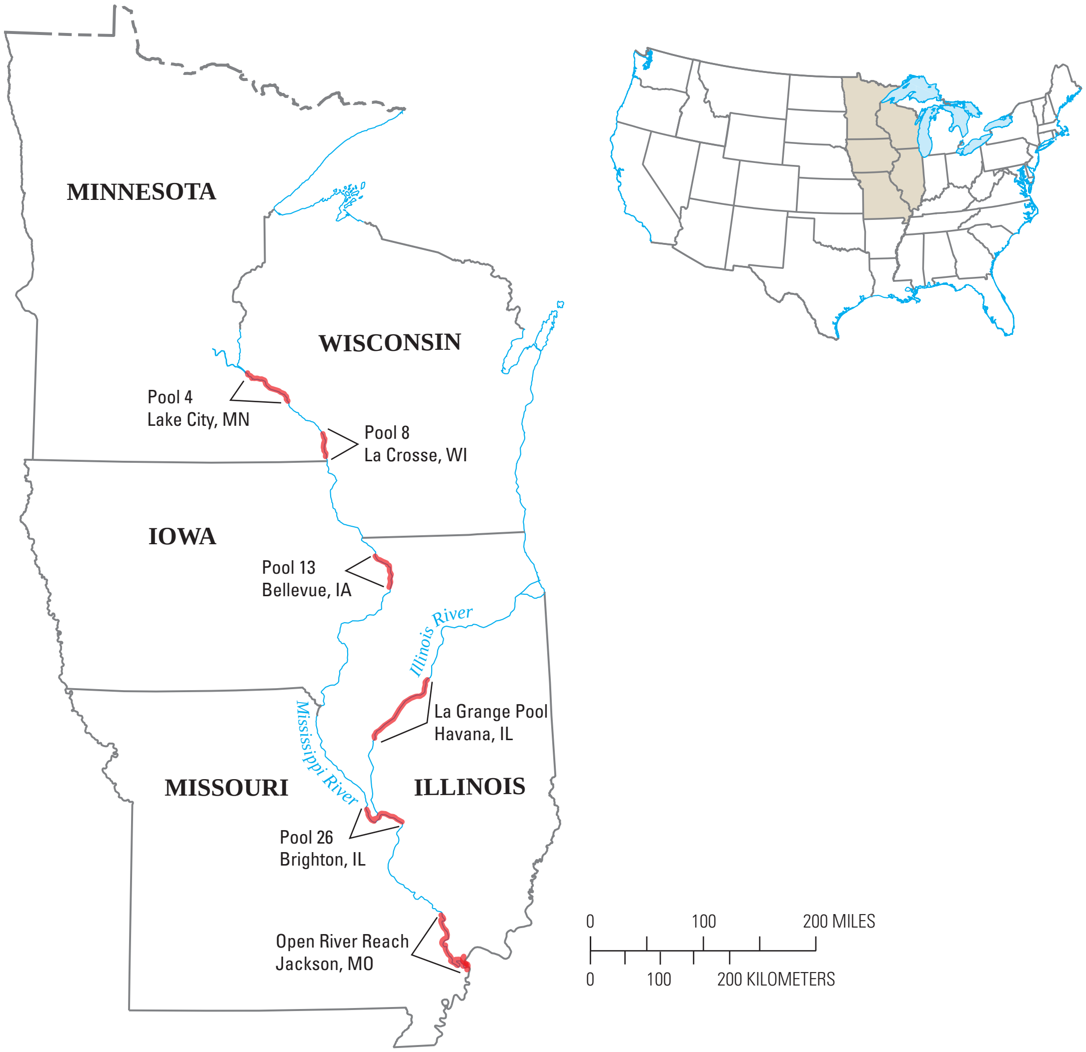


**Figure 1.** The Upper Mississippi River System and the locations of six study reaches in the Upper Mississippi River Restoration–Environmental Management Program Long Term Resource Monitoring Program element from which models were developed as part of this study.

AHAG evolved from a series of theoretical and applied advancements that have followed directly from this concept of defining habitat from a species point of view. The lineage is long, and often winding, but includes various approaches conceived to relate a species to its environment with the benefit of environmental observations. Some of these past efforts centered on water flow as the singular or predominant controlling variable (Physical HABitat SIMimulation [PHABSIM] and Instream Flow Incremental Methodology [IFIM]), while others simply tried to capture and express species responses to a wider set of seemingly important habitat occupancy determinants (Habitat Evaluation Procedures [HEP] and Habitat Suitability Indexes [HSI]). AHAG shares a lineage with this latter class, which is a more applied management lineage wherein the environment is sampled for important variables suspected or known to contribute towards habitat occupancy, resulting in a family of species-specific response curves that can be used in management assessments (HEP; U.S. Fish and Wildlife Service, 1980). Under the HEP approach, each species is represented by a singular "model" composed of some number of species-response curves.

As used within the UMRS, AHAG is essentially a multi-species HEP, executed in a spreadsheet. It uses primarily best professional judgment to define each species:environmental association, as opposed to actual field data. Our primary goal was to update the existing AHAG model using LTRMP data to empirically define the species:environmental relationships. In addition, we also explicitly modeled these relationships as a way to determine the principal environmental determinants of habitat occupancy and to gain spatially explicit predictions. As such, this represents a sizeable leap in the way AHAG will work and how it could be used.

## Ecological Niche Models

Many alternatives are available for ecological niche modeling (see Elith and Leathwick, 2009 for a review), and choosing among them will depend mainly upon the intended application of the models.

Ecological niche models can be categorized into three primary groups based on differences in methodology, assumptions, and intended application. Their applied goal is usually prediction, so that the suitability of the habitat in space (and perhaps time) can be evaluated and judged relative to management objectives (sustainable harvest, extinction or ascribing conservation status, habitat rehabilitation, predicted responses to changing environments, etc.).

Heuristic models are the crudest form of ecological niche models and are generally verbal, written, or graphical (flow charts and Venn diagrams) representations of a species known or suspected association with the environmental determinants of its habitat. Heuristic models are innately qualitative. As such, they are very useful in conceptualizing a problem, but of limited utility in predicting how a species may be distributed or respond to changes in its habitat over space or time. We suggest that this class of models has dominated habitat-management activities on the UMRS for the past 25 years.

Correlative models are quantitative mathematical models mainly used to predict an outcome (the probability of site occupancy, the cumulative area of species occupancy, etc.). Correlative models predict an outcome based upon (1) quantifiable associations (statistically or mathematically) derived from observational data; and (2) consider environmental variables thought to compose the species' habitat or niche. However, these models do not explain why, mechanistically, a species has such associations (Buckley et al. 2010). These models are typically implemented using statistical software packages (SAS, R, and S-Plus). Examples include logistic regression, generalized linear models, generalized additive models, Gaussian models, and Huisman-Olff-Fresco (Huisman and others, 1993) models.

Mechanistic models also are quantitative and used for prediction, but their methods of prediction differ notably from correlative models. Mechanistic models begin with biological knowledge of the species and incorporate only those variables and relations known to directly impact the physiology, survivability, reproduction, and (or) behavior of the species. These relations are typically developed from lab results or empirical data and are implemented in specialized software for simulation (MATLAB, EcoSim, and WinBUGS). These software packages (and others) are replete with examples of mechanistic species niche models.

## Habitat from the Species Point of View

The previously described approaches require modeling habitat from the species' point of view. Within the Upper Mississippi River Restoration-Environmental Management Program (UMRR-EMP), as a habitat restoration program, this requires us to define habitat concretely, and perhaps differently than practitioners have previously considered. To clarify this statement, consider there are at least three different ways to define habitat as applied in the UMRR-EMP.

The first is habitat as defined a priori by the investigator or manager, typically in a spatially explicit way using best professional judgment. Within the UMRR-EMP, this definition is perhaps best represented by the Habitat Needs Assessment (U.S. Army Corps of Engineers, 2000). Here, habitats are defined by human judgment and represented as polygons on maps. Human judgments are further made as to the suitability of a given polygon for any given species using scoring criteria and best professional judgment.

The second way, used herein, is to use either the correlative or mechanistic approach (described previously) to predict the probability of a species occurrence, occupancy, or abundance. It models habitat from the species' point of view—using statistical or simulation methods, from observed sample data with no a priori constraints—in terms of pre-defined habitat types.

The third way, which contributed to the method used herein, is to define habitat from a sampling design point of view, such as may occur in a long-term monitoring effort. Here, one summarizes species occupancy, occurrence, or abundance, regarding each sampling design element as a habitat (see *http://www.umesc.usgs.gov/data_library/fisheries/graphical/fish_front.html*, accessed 17 July 2013). The Long Term Resource Monitoring Program (LTRMP) uses a spatial stratification scheme (see Gutreuter and others, 1995 and Ratcliff and others, 2014), but the individual strata are not intended to represent habitat for any one species, let alone entire assemblages and communities (Soballe and Fischer, 2004). Habitats vary by species and can be ephemeral and dynamic over space and time, yet the LTRMP sampling strata are fixed in space and time. The LTRMP stratification is based upon enduring geomorphic features (Wilcox, 1993), no single strata is meant to strictly represent habitat for any given species, and each stratum indeed contains potentially many habitats for many species (Soballe and Fischer, 2004). The stratification scheme in LTRMP ensures randomized sampling-site selection across its sampling frame, and the stratification scheme exists to spread such annual effort across a study reach in an unbiased fashion, and across important environmental gradients (flow, vegetation, dissolved oxygen, water transparency, substrate type, etc.). Thus, the LTRMP site-scale data represent a random sample of the environment within each study reach, and these data can be used to infer habitat as defined from a species point of view. This is how we use the LTRMP data in this effort. Thus, this third definition contributes the requisite data toward our methods, but we do not use the sampling design as a definition of habitat or to pre-constrain habitat definitions.

While these three definitions may appear nuanced, each represents a profoundly different way to look at the habitat problem; each requires different methodological approaches to the problem; and each affords different insights into the problem. As such, readers are encouraged to understand these differences in habitat definition and the corresponding basis for addressing the problem under each.

## Inductive Nature of the Problem and Issues that Arise as a Consequence

Ecological niche modeling is inherently an inductive problem. Typically, no experimental controls are available to isolate the effects of any given environmental variable on species' responses, which would represent a deductive scientific approach to modeling habitat controls on occupancy or abundance. Rather, associations between a species response and any number of "uncontrolled" environmental variables are typically determined. The notion of a hyper-dimensional niche, which underlies the AHAG approach, presumes we know all of the environmental determinants contributing towards a species response, which is impossible.

Thus, AHAG, HSI's, HEP's, and other habitat based assessment "tools" are all inherently inductive in design and methodology. Since we cannot know all the environmental determinants of species response, they are all necessarily "incomplete" in any way someone could judge them. The problem with these methods essentially boils down to "what multivariate environmental characteristics are essential to determine an area's propensity to support a given species or assemblage?" Importantly, we cannot ever know all of them and can only consider those for which data are available.

An inductive problem requires stating some priorities and initial judgments to set bounds around the problem set. Otherwise, the inductive problem is infinite in its possible characterizations and permutations. In an applied setting (like UMRR-EMP), this needs to involve river managers because what, where, and how they can manage will help to bound the initial problem. In such an applied setting, the first nasty normative we encounter is at "what spatial and temporal scales shall we integrate environmental data to achieve desired predictions?" This depends entirely upon the purpose of the assessment and predictions and requires managers to clearly and unambiguously state their management objectives in quantifiable terms as models like these are developed and applied. In an inductive pursuit, not setting boundaries on the problem is more problematic than placing too conservative boundaries, because an unconstrained inductive pursuit is likely unnecessarily large, uninformative, and of little utility.

Habitat, as defined and used based upon these methods, does not exist in the abstract. Habitat only exists within the context of the species, location, and time defined by managers. These contexts, combined with the question "what can we actually manipulate in reality," can be used to great effect to bound the problem set. Habitat in this context is determined by quantifiable associations between a species' response and its environment, not human judgment or a priori constraints. Given that the intention of AHAG is to inform how to modify the environment to gain a specified species response, such intentions must be clear and quantifiable if these models are to be useful in the UMRS.

## Study Goals and Objectives

Our goal is to address the first of two reviewer comments (Abt and Associates Inc., 2011) that led to decertification of AHAG 1.0; namely apply empirical data from the UMRS to quantify the relation of species distribution to environmental variables. We do this by using daytime electrofishing data for select UMRS fishes, representing nearly 7,000 site-scale observations over a 20-year period of time and 1,930 kilometers of river.

Our objective was to use a correlative approach to model the probability of occurrence of 28 UMRS fish species, representing 3 guild classes, as a function of the 17 environmental variables observed during fisheries sampling by the LTRMP. This effort provides predictions of the probability of occurrence of each species at each sample site. A separate process, to be developed and reported by river managers, will be used to score and combine these predictions to determine habitat suitability in ways that relate to quantifiable management goals.

## Methods and Assumptions

### Modeled Response, Rationalization, and Data Assembly

Through a series of deliberations among participating agencies and collaborators, we decided to model the probability of occurrence of each species from LTRMP day electrofishing data using logistic regression for binary responses. Occurrence (presence) for 28 different species (table 1) was modeled as a function of 17 variables (table 2), each measured with fish observations at LTRMP stratified random sampling sites, 1993–2012 (see Gutreuter and others, 1995; and Ratcliff and others, 2014; for a description of the sampling design and methods employed by LTRMP). Thus, we modeled site-scale data, regarding them as a random sample of the environment over a 20-year period and a 1,930 km gradient of habitat availability and suitability.

**Table 1.** Fish species selected for inclusion in the Aquatic Habitat Appraisal Guide for the Upper Mississippi River System.

| Species | Scientific name | Guild |
|---|---|---|
| Black crappie | *Pomoxis nigromaculatus* | Lentic |
| White crappie | *Pomoxis annularis* | Lentic |
| Bluegill | *Lepomis macrochirus* | Lentic |
| Largemouth bass | *Micropterus salmoides* | Lentic |
| Warmouth | *Lepomis gulosus* | Lentic |
| Northern pike | *Esox lucius* | Lentic |
| Yellow perch | *Perca flavescens* | Lentic |
| Blue catfish | *Ictalurus furcatus* | Lotic |
| Flathead catfish | *Pylodictis olivaris* | Lotic |
| Rock bass | *Ambloplites rupestris* | Lotic |
| Skipjack herring | *Alosa chrysochloris* | Lotic |
| Blue sucker | *Cycleptus elongates* | Lotic |
| Shovelnose sturgeon | *Scaphirhynchus platorynchus* | Lotic |
| Sauger | *Sander canadense* | Lotic |
| Golden redhorse | *Moxostoma erythrurum* | Lotic |
| Shorthead redhorse | *Moxostoma macrolepidotum* | Lotic |
| Channel catfish | *Ictalurus punctatus* | Generalist |
| Red Shiner | *Cyprinella lutrensis* | Gereralist |
| Logperch | *Percina caprodes* | Gereralist |
| Brook silverside | *Labidesthes sicculus* | Gereralist |
| Freshwater drum | *Aplodinotus grunniens* | Gereralist |
| Emerald shiner | *Notropis atherinoides* | Gereralist |
| Blackstripe topminnow | *Fundulus notatus* | Gereralist |
| Smallmouth bass | *Micropterus dolomieu* | Gereralist |
| Longnose gar | *Lepisosteus osseus* | Gereralist |
| White bass | *Morone chrysops* | Gereralist |
| Smallmouth buffalo | *Ictiobus bubalus* | Gereralist |
| Walleye | *Sander vitreum* | Gereralist |

Occurrence (presence) seemed the most reasonable response to model for the following reasons:

- Initial summaries demonstrated that abundance was highly variable among species and study areas (unpublished results, available upon request to the corresponding author). Consequently, achieving reasonable model fits would have been unlikely.
- Abundance may be influenced by factors we were not considering (intra- and inter-specific competition, predator/prey dynamics, and harvest), which would increase variability and reduce model fits.
- Presence models should be more interpretable than abundance models because presence tends to be much more closely related to environmental factors than abundance (Legendre and Legendre, 2012).
- Occurrence scales all data between 0 and 1 across all models and species.
- Using abundance as the response would have required customized models per species and region, something that could not be achieved under the scope of this effort, and something that is unlikely to serve Habitat Rehabilitation and Enhancement Project (HREP) multi-species application of these models very well in project planning and evaluation.
- Project assessments would be based upon probability of occurrence, which is a more relevant criterion than abundance, because managers are typically trying to make more “space” (or habitat) for more species.
- Managers can use a scoring process based upon probability of occurrence for both habitat suitability and project evaluation, which is similar to what they already have in place. Importantly, we do not describe this process in this work, and the only contribution this work makes to the habitat suitability assessment is the predicted occurrences, not the processes by which they are scored, ranked, and weighted. Such is a management process requiring management judgments.

Day electrofishing observations (1993–2012) were obtained from the LTRMP online raw data browser (*http://www.umesc.usgs.gov/data_library/fisheries/fish1_query.shtml*; accessed 27 June 2013) for each species in table 1, and catch data were standardized to catch per 15 minutes. Nonzero catch was coded as “1” meaning present, and zero catch was coded as “0” meaning absent/not detected. Corresponding observations on environmental attributes (table 2) were merged with the presence/absence dataset to create an analytic dataset.

Standard pre-analysis diagnostics (ranges, means, standard errors, missing values, etc.) were performed on both the biological response data and the environmental data to identify errant or aberrant observations. Only two errors were found in the dataset of 191,800 observations, and these errors were removed from the analytic set. Thus, for each species, 6,848 samples were available for model fitting. These samples were divided into two groups for each species representing an “Upper River Reach” regionalized modeling domain (Pools 4, 8, and 13; N = 3,264 samples per species) and a “Lower River Reach” regionalized modeling domain (Pool 26, Open River, and La Grange; N = 3,584 samples per species). These constituted the analytic databases for model development.

**Table 2.** Environmental variables observed synpotically with Upper Mississippi River Restoration-Environmental Management Program Long Term Resource Monitoring Program element's fish component sampling in the Upper Mississippi River System. Methods associated with recording environmental observations, in highly standardized ways, are detailed in Gutreuter and others (1995) and Ratcliff and others (2014).

[cm, centimeter; µS/cm, miscosiemens per centimeter; m/s, meter per second; °C, degrees Celsius; m, meter; mg/L, milligrams per liter; %, percent]

| Variable name | Abbreviation | Variable type | Unit(s) |
|---|---|---|---|
| Environmental variables | | | |
| Secchi | Secchi | Continuous | cm (nearest 1) |
| Conductivity | SpecCond | Continuous | µS/cm (nearest 1) |
| Water velocity | Watervel | Continuous | m/s (nearest 0.1) |
| Water temperature | Temp | Continuous | °C (nearest 0.1) |
| Water depth | Depth | Continuous | m (nearest 0.1) |
| Dissolved oxygen | DO | Continuous | mg/L (nearest 0.1) |
| % emergent submersed vegetation | AqVeg | Categorical (4 categories) | % |
| Vegetation density | VegDens | Categorical (2 categories) | scaleless |
| Predominant substrate | Substrate | Categorical (4 categories) | descriptive |
| Other structures | | | |
| Woody debris | Woody | Binomial | Presence absence |
| Tributary mouth | Trib | Binomial | Presence absence |
| Inlet/outlet channel | InOut | Binomial | Presence absence |
| Flooded terrestrial | FloodTer | Binomial | Presence absence |
| Wing dam/dike | WingDam | Binomial | Presence absence |
| Revetment | Revetment | Binomial | Presence absence |
| Low-head dam, closing dam, weir | LowHead | Binomial | Presence absence |
| Diagnostic variables | | | |
| Field station | Fstation | Diagnostic | Numeric ordinal label |
| Period | Period | Diagnostic | Numeric ordinal label |

Missing values were occasionally encountered in the environmental data series for a variety of reasons (see appendix 1). To generate a complete environmental data series, as required for modeling, we estimated missing values using linear combination models among all available environmental predictors, doing so 1,000 times using maximum likelihood principles, and deriving the mean for each missing observation from the 1,000 simulated estimates (SAS 9.3; Proc MI). These mean values were substituted for missing observations in the final database.

## Inherent Assumptions and Limitations

All data and models have inherent assumptions and limitations. Here we express those that we feel are most relevant to the development and application of these models.

## Assumptions and Limitations in the Data

With the intention of predicting occurrence probabilities at HREP relevant scales (sub-pool scales), we are admittedly pushing the spatial limits of the LTRMP fisheries data sources, resulting in some data limitations.

First, to represent biological responses, we needed to select a single LTRMP fish-sampling method that was consistent across space and time and that also could be applied for project-scale assessments in the future. Day electrofishing was selected because it is the least species- and size-selective method used in the LTRMP assessments (Ickes and Burkhardt, 2002), and there is an ever-expanding fleet of electrofishing boats designed to LTRMP specifications being deployed throughout the basin, making their availability and use in HREP assessments a practical reality in future applied phases of these models.

Second, by selecting a single sampling method, sample size is substantially smaller than using all gears. However, electrofishing still provides nearly 7,000 samples per species that could be used to fit models.

Third, for any given sampling method used in the LTRMP, there are procedural constraints on where and how each gear is fished (Gutreuter and others, 1995; Ratcliff and others, 2014). For example, day electrofishing is used only along shorelines and at sites less than 3 meters deep, thus introducing an additional data constraint on the spatial scope and scale of the modeling efforts.

Lastly, we assumed that YEAR (or inter-annual dynamics) is unimportant in the intended model response. This assumption is reasonable for HREPs because projects are planned to produce effects over a 50-year period (Jeff Janvrin, Wisconsin Department of Natural Resources, oral commun., 15 July 2013). Thus, the general point in this modeling exercise is to model and predict "spatially coherent patterns in habitat suitability," not "determine the inter-annual dynamics of habitat associations."

## Assumptions and Limitations in the Modeling Framework

Given the intention to model the probability of occurrence for 28 species across the entire UMRS (fig. 1), we chose Multiple Logistic Regression (MLR) with binary responses (SAS version 9.3; Proc Logistic) as our modeling framework. For each species, the probability of occurrence is modeled as a function of 17 environmental variables measured synoptically with fish observations (table 2).

Initially, we intended to use data from all six LTRMP stations and develop "systemic models" for each species, resulting in 28 species-specific models. However, it proved largely impossible to get good fits for the systemic models. Thus, we divided the system into regions and developed an "Upper UMRS" regional model using these LTRMP study reaches—Pools 4, 8, and 13), and a "Lower UMRS" model using these LTRMP study reaches—Pool 26, Open River, and La Grange. This resulted in 56 attempted models. To fit this many models and gain predictions, we had to simplify the approach and apply it uniformly across all intended models, given constrained resources.

Although we used species presence/absence data, we modeled only presences (positive observations) and not absences, which may derive from a species either actually being absent or simply not detected. The LTRMP fish component does not collect information to adjust for non-detects in the determination of absences, and other available methods for dealing with this issue required adopting additional assumptions we could not test. Importantly, the goal here is to develop models to predict relative differences in habitat suitability based upon observed presences and their association with observed synoptic environmental data sources, not necessarily an adjusted and more accurate estimate of site occupancy. As such, estimates and predictions arising from these models should be viewed as conservative under-estimates because occurrence probabilities would be higher if we could adjust for non-detection. The important results are the relative comparisons and differences among model predictions in space, useful for identifying suitable or unsuitable conditions and considering habitat-rehabilitation project siting.

Within this modeling framework, we used the following basic model-fitting criteria:

- Only additive models were considered, interactions among predictors were not pursued.
- We developed models using partial methods on the predictor set to control variance inflation and gain parameters that reflected the unique contributions of each predictor relative to the response. This approach could be applied algorithmically across all models.
- We used a forward selection schema, and rather liberal controls for permitting predictors to enter the model ($\alpha$ <0.10), to identify the most important predictors and their relative contributions to predictions. Normally, one would use information theoretic approaches to produce parsimonious model fits (best predictions with the fewest variables), but at this somewhat exploratory stage, we adopted this more liberal stance. This liberal stance allows river managers to consider their ability to affect individual predictors that were found to be important.
- Generally, one would also use model averaging, realizing no single model is "right." We did not have the capacity or time to do such, and did not feel it would be very helpful as river managers consider how to incorporate these models into their habitat project planning activities. We thought it was best to provide a single, liberal model to inform these efforts.

# Results

Results are presented in appendix 2 for each species and region and comprise the bulk of this report. Even though we separated the system into two regions to improve model fit, we could not achieve good fits for all species and regions. Of the 56 potential regional models (28 species, 2 regions), 33 resulted in reasonable goodness of fit. However, in 11 of 33, "field station" was a strong predictor indicating improvements could be gained by developing pool-scale models. The 23 remaining models did not produce acceptable model fits. Reasons for poor fit and possible methods to improve fit include the following:

1. Some species were rare or absent in one of the regions (exhibited zoogeographic zonation), so a model could not be fit for that species-region pair.

2. Some regional models did not fit well even given sufficient occurrences. The reasons vary, and we developed diagnostics to gain insights into the reasons for the variations. Most often, it was due to the diagnostic variable "Field station" (table 2). When field station is important, or the most important variable, this indicates that occurrences, environmental attributes, or both vary notably among the three study reaches and indicates that pool-specific models need to be developed. For example, this occurred for the lower reach models for all lentic guild species, due to lentic species being present more often in La Grange than in Pool 26 and Open River. Gaining any reasonable lower reach lentic fits will likely require separating La Grange from the other two lower LTRMP study areas.

3. Only nine species yielded good regional fits for both regions. They are a mixture of "lotic" (N=3) and "generalist" (N=6) guilds. Until we resolve how best to deal with regional models that would not fit, these species will likely need to comprise the common basis for AHAG.

# Application of the Models

There are at least two ways to apply the model results. Each depends upon how a habitat project is considered, conceived, and executed.

The first approach presumes a manager has not yet decided where to site a project and desires spatially explicit information on the relative habitat quality within a pool or study reach. In this circumstance, the models we provide can only be applied to the areas that have the environmental data needed as input to the models, which is presently the LTRMP study reaches. Predictions may be mapped for each LTRMP study reach, explicitly showing areas with higher occurrence probabilities (presumptively "good habitats") and those with lower occurrence probabilities (presumptively "poorer habitats"). The predictions may be mapped as point estimates, or various data interpolations can be applied to create more continuous maps (importantly, with additional assumptions). Figures 2, 3, and 4 (ranging from liberal to conservative approaches for mapping predictions) portray various examples of how such maps could be readily generated from available results. Generating such maps was beyond the scope of our efforts here, but could be gained for all regions and species with well-fit models as part of a separate effort that gave thoughtful consideration to these three examples and their additional assumptions. Mapped in these ways, habitat quality/impairment can be evaluated and assessed in a spatially explicit yet presumptive way at a "pool-scale." This approach is useful if managers do not have a specific project in mind and wish an objective approach to considering where one may be sited. The model itself does not tell the manager where to place a project, but it does provide the spatial context for such considerations. This approach is presently limited to the six LTRMP study reaches. However, with pool-scale environmental data from other pools or reaches, occurrence probabilities for each species could be estimated using the models presented in this report, and similar maps could be generated (with the important caveat that the pool or reach is within the spatial domain of one of the regional models).

The second approach presumes the manager already knows where a project will be sited. In this circumstance, the manager will need an environmental data series from the project site (using new or existing data), and put those data into the model equations and predict pre-project occurrence probabilities for all desired species at each sample location. Moreover, a manager could state quantitative, post-project targets for the environmental attributes and calculate post-project presumptive changes in fish responses. This approach assumes (1) the environmental data series is gained with comparable methods to those used to generate the models; (2) that the environmental data series derive from a similar time period as those used to generate the models (summer-fall sampling; see Gutreuter and others, 1995 and Ratcliff and others, 2014); and (3) that the management site is within the spatial domain of the model being used to make the estimates ("upper" or "lower" region).

Each of these two circumstances can result in new data and information that can be used to validate model predictions, and likely improve the models further. In the former circumstance, pool-scale, pre-project fish sampling can gain data from both "good habitats" and "poorer habitats," as identified in the mapped predictions, and comparisons of sampling data to model predictions can be made to validate both the models and the maps. In the later circumstance, both pre-project and post-project fish sampling data can be gained at the project scale and used to validate (1) the pre-project predictions; and (2) responses to management intervention(s), post-project.

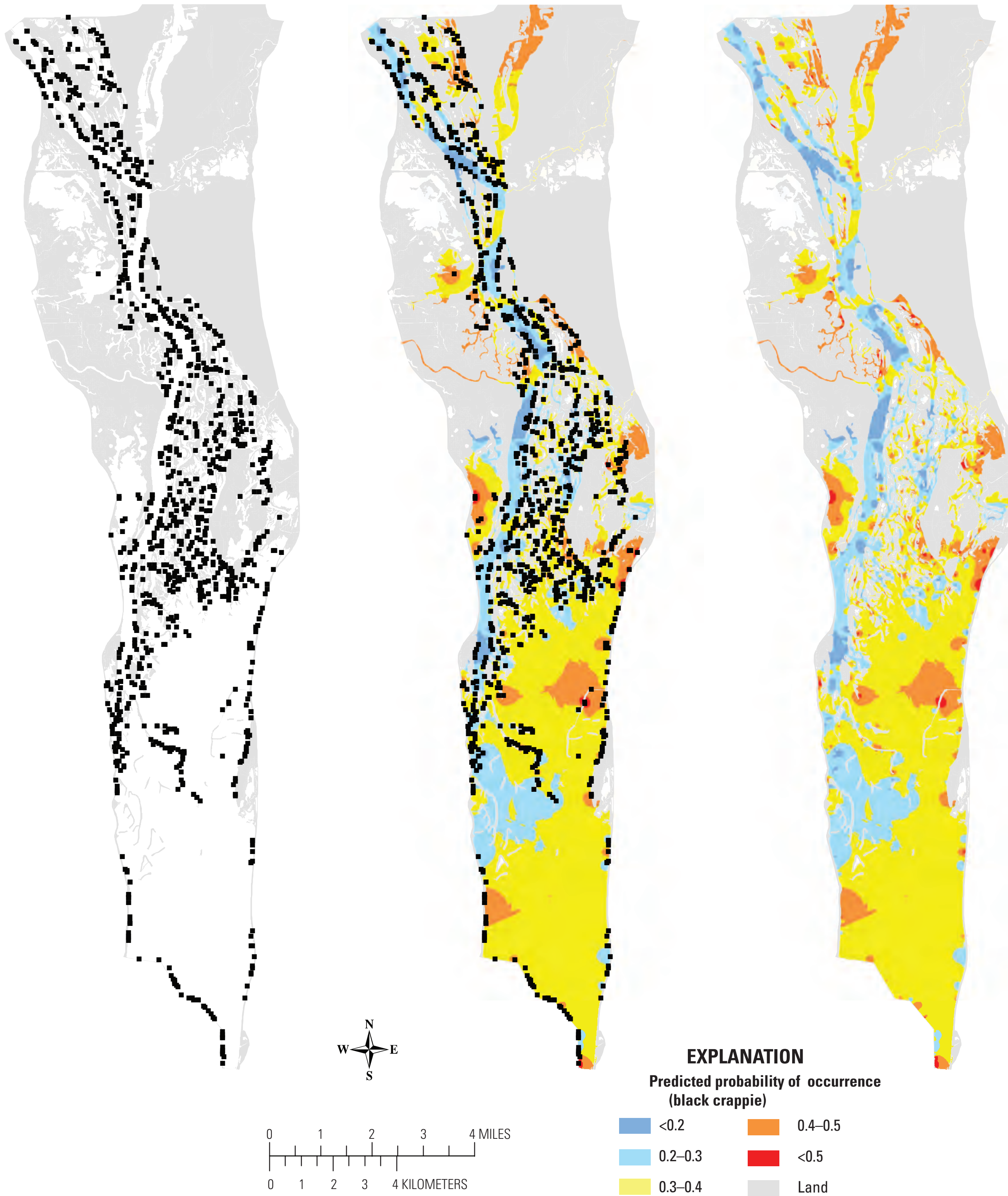


**Figure 2.** Mapped probability of occurrence predictions for black crappie (*Pomoxis nigromaculatus*) in Navigation Pool 8 of the Upper Mississippi River System (example 1). In this example, predictions were mapped back to a pool map using geospatial coordinates from the actual sample sites. An inverse distance weighting (IDW) interpolation algorithm was exercised to achieve predictions in areas not sampled. Predictions at each sampling locality are governed by the logistic regression assumptions involved to achieve the site scale predictions (see report). Predictions between points are governed by assumptions associated with the IDW interpolation algorithm. This is the most liberal mapped treatment of the predictions. Black dots indicate fish-sampling sites.

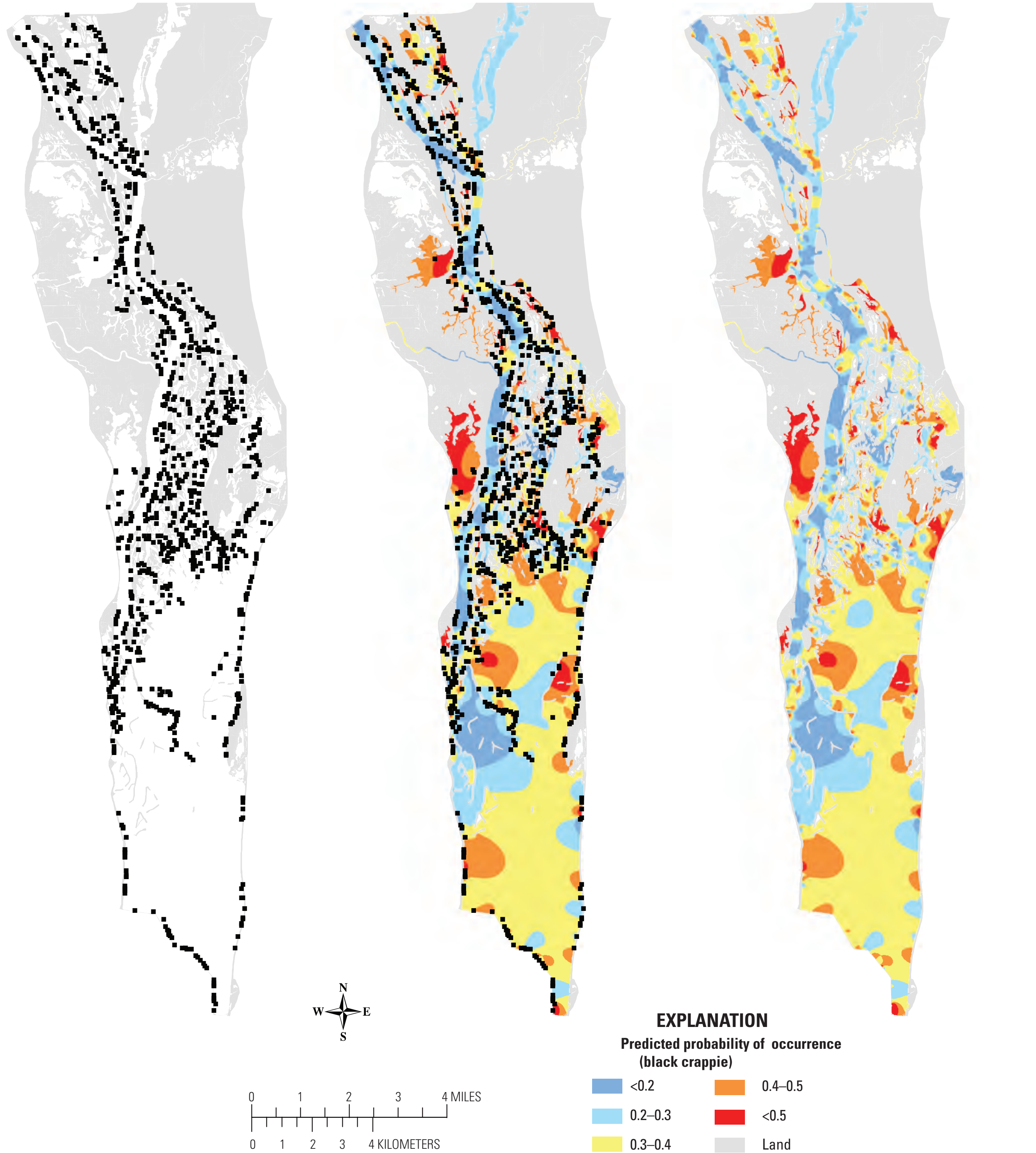


**Figure 3.** Mapped probability of occurrence predictions for black crappie (*Pomoxis nigromaculatus*) in Navigation Pool 8 of the Upper Mississippi River System (example 2). In this example, predictions were mapped back to a pool map using geospatial coordinates from the actual sample sites. An interpolation algorithm (splines with barriers (SWB)) was exercised to achieve predictions in areas not sampled. Additionally, aquatic areas containing no samples were clipped before the SWB interpolation was employed; limiting interpolated predictions to only those aquatic areas are in the Long Term Resource Monitoring Program sampling frame. Predictions at each sampling locality are governed by the logistic regression assumptions involved to achieve the site scale predictions (see report). Predictions between points are governed by assumptions associated with the SWB interpolation algorithm. This is a more conservative mapped treatment of the predictions. Black dots indicate fish-sampling sites.

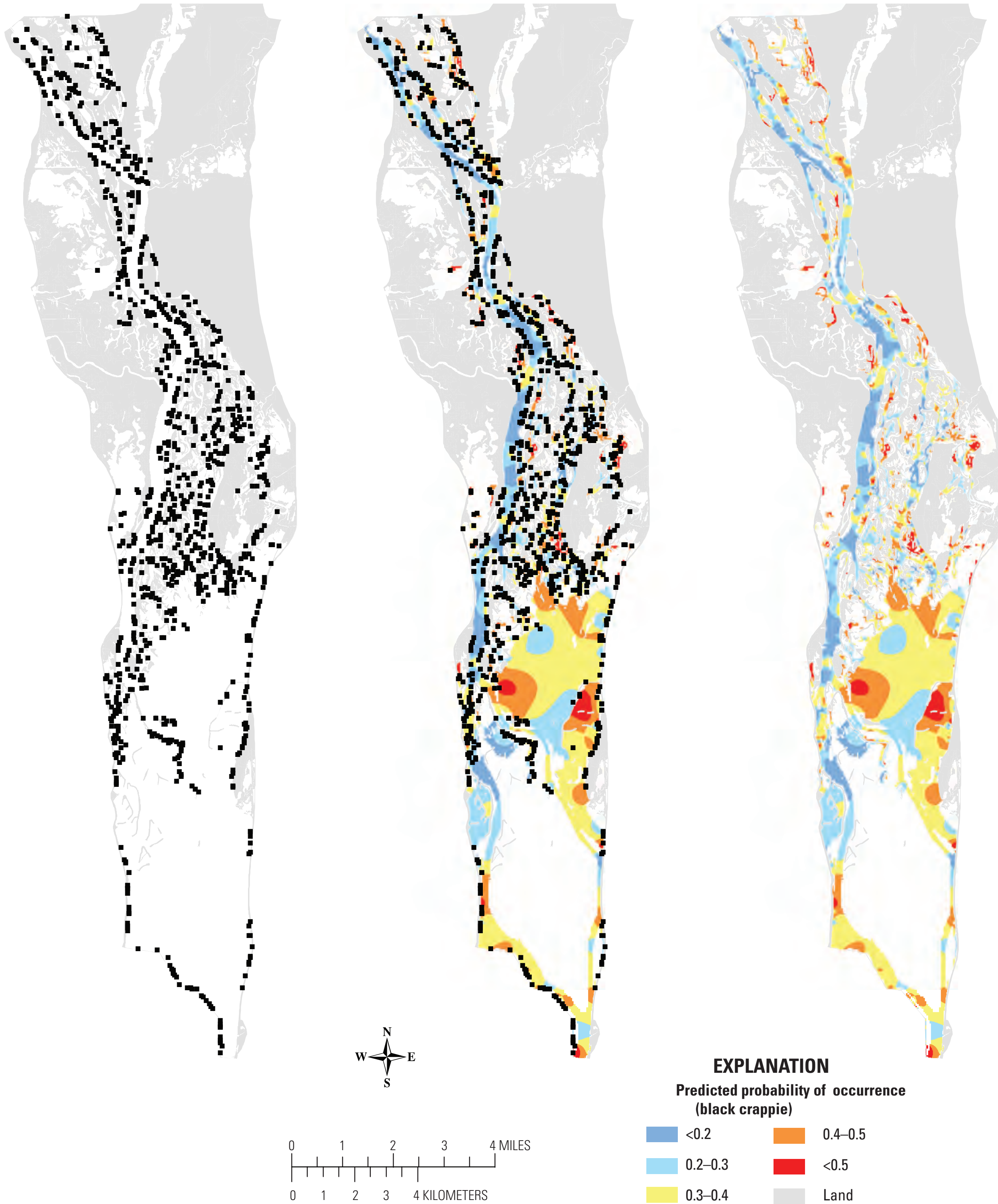


**Figure 4.** Mapped probability of occurrence predictions for black crappie (*Pomoxis nigromaculatus*) in Navigation Pool 8 of the Upper Mississippi River System (example 3). In this example, predictions were mapped back to pool map using geospatial coordinates from the actual sample sites. An interpolation algorithm (splines with barriers (SWB)) was exercised to achieve predictions in areas not sampled. Additionally, aquatic areas and the Long Term Resource Monitoring Program fish component impounded offshore stratum, containing no samples, were clipped before the SWB interpolation was employed, limiting interpolated predictions to only those aquatic areas that were sampled. Predictions at each sampling locality are governed by the logistic regression assumptions involved to achieve the site scale predictions (see report). Predictions between points are governed by assumptions associated with the SWB interpolation algorithm. This is the most conservative mapped treatment of the predictions. Black dots indicate fish-sampling sites.

## Conclusions and Recommendations

We attempted 56 regionalized occurrence models for 28 Upper Mississippi River System (UMRS) fish species representing three guild classes. In total, 33 regional models resulted in reasonable fits and, pending validation, may be used in regional habitat planning. Of the remaining 23 regional models, 16 did not result in well-fit models, primarily due to the need to discretize them further into pool-scale models. Seven of the potential regional models cannot be developed because the target species are absent or too rare.

Application of these models can proceed in either of two ways. The first presumes a manager does not already have a habitat project in mind and desires spatially explicit information to help objectively decide where to site a project. This mode is presently limited to the Long Term Resource Monitoring Program (LTRMP) study reaches, because it requires mapping the predictions and judging their distribution relative to management goals and objectives. Presently (2014), this can only be achieved in LTRMP study reaches for species with well-fit models. In time, with more environmental observations and validation of model performance from other pools or reaches, managers may be able to extend this modeling capability.

The second way the models may be applied is if a project is already planned and responses to management interventions need to be assessed. In this mode, the manager would gather environmental data from the project locality in a manner similar to those used to develop the models in the LTRMP fish-sampling protocols (Gutreuter and others, 1995; Ratcliff and others, 2014). Those data can then be plugged into the equations presented in the “Results” section for each species and region. Predicted values would serve as the basis for a pre-project assessment. If desired, they could also serve as a post-project reference against which to measure fisheries responses to the management action.

At this point, the models are simply developed, understated assumptions, which are not yet validated. Future work should (1) consider discretizing these initial models further, (2) consider alternative responses and predictors that align most closely with management actions, and (3) generate data for model validation.

Model validation can be achieved in up to four ways: (1) most simplistically, reporting model goodness-of-fit statistical criteria (achieved herein); (2) cross-validation methods in which a random sample of the data are held back during model development and used to test predictions; (3) gain a pool-scale environmental (and perhaps biological response) data series for a non-LTRMP pool or reach, making out-pool species occupancy predictions with one or more of the models, and testing them with the corresponding out-pool biological response observations; and (4) evaluate the performance of these models using habitat pre- and post-project data.

There are many additional developments and advancements that could be considered. For example, the Aquatic Habitat Appraisal Guide (AHAG) developed herein still functions on a species-by-species basis with a single predictive equation for each species. Consideration could be given to schemes to model all species concurrently, rather than individually. Additionally, future development could blend the Hutchinsonian (habitat) and Eltonian (functional) approaches by modeling the habitat (Hutchinsonian niche) for functional species groups. This presumes there is a functional basis (and objective) for habitat-management activities in the UMRS Basin, something of which we are presently unsure. We partially addressed that issue herein by choosing species representing three generalized guilds; however, we modeled the species, not the collective guilds. It also is possible to apply utility optimization methods that consider effects on multiple species. Changing any one variable with a management action will benefit some species to the detriment of others, so the idea would be to modify environmental attributes in ways that do not benefit just a select few species, but optimize benefits for the most species.

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# Appendix 1. Summary of Means, Standard Deviations, and Standard Errors for the Environmental Data Series used in Modeling each Species Presented in this Report

**Appendix 1–1.** Continuous variables.

[*n*, sample size; SD, standard deviations; SE, standard errors; --, not estimable]

| Common name | *n* | Secchi | | | Conductivity | | | Water velocity | | | Water temperature | | | Water depth | | | *n* | Dissolved oxygen | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | SD | SE | Mean | SD | SE | Mean | SD | SE | Mean | SD | SE | Mean | SD | SE | | Mean | SD | SE |
| Guild class - Generalists | | | | | | | | | | | | | | | | | | | | |
| Blackstripe topminnow | **50** | 20.94 | 7.54 | 1.07 | 631.64 | 109.86 | 15.54 | 0.05 | 0.10 | 0.01 | 23.57 | 5.56 | 0.79 | 1.26 | 0.89 | 0.13 | **44** | 7.09 | 2.91 | 0.44 |
| Brook silverside | **749** | 50.73 | 28.77 | 1.05 | 449.21 | 135.64 | 4.96 | 0.12 | 0.16 | 0.01 | 21.07 | 6.88 | 0.25 | 1.23 | 0.76 | 0.03 | **579** | 8.07 | 2.76 | 0.11 |
| Channel catfish | **2,766** | 30.99 | 19.55 | 0.37 | 517.69 | 150.56 | 2.86 | 0.17 | 0.20 | 0.00 | 23.07 | 5.28 | 0.10 | 1.23 | 0.93 | 0.02 | **2,173** | 7.54 | 2.35 | 0.05 |
| Emerald shiner | **4,362** | 40.46 | 24.81 | 0.38 | 482.56 | 149.64 | 2.27 | 0.17 | 0.20 | 0.00 | 22.13 | 5.87 | 0.09 | 1.27 | 0.88 | 0.01 | **3,146** | 7.71 | 2.41 | 0.04 |
| Freshwater drum | **3,829** | 34.51 | 22.35 | 0.36 | 498.04 | 149.93 | 2.42 | 0.16 | 0.20 | 0.00 | 23.00 | 5.24 | 0.08 | 1.21 | 0.89 | 0.01 | **2,846** | 7.59 | 2.40 | 0.05 |
| Logperch | **985** | 59.39 | 28.01 | 0.89 | 416.88 | 101.16 | 3.22 | 0.15 | 0.18 | 0.01 | 22.63 | 4.66 | 0.15 | 1.27 | 0.63 | 0.02 | **592** | 7.87 | 2.30 | 0.09 |
| Longnose gar | **568** | 41.76 | 28.25 | 1.19 | 493.44 | 141.05 | 5.92 | 0.23 | 0.22 | 0.01 | 24.20 | 4.93 | 0.21 | 1.59 | 0.97 | 0.04 | **436** | 7.08 | 2.19 | 0.10 |
| Red shiner | **465** | 24.64 | 11.28 | 0.52 | 594.02 | 141.01 | 6.54 | 0.21 | 0.24 | 0.01 | 23.55 | 5.59 | 0.26 | 1.71 | 1.21 | 0.06 | **413** | 7.07 | 2.10 | 0.10 |
| Smallmouth buffalo | **2,516** | 29.70 | 17.04 | 0.34 | 534.35 | 151.31 | 3.02 | 0.14 | 0.20 | 0.00 | 23.54 | 5.24 | 0.10 | 1.24 | 0.94 | 0.02 | **1,933** | 7.44 | 2.48 | 0.06 |
| Smallmouth bass | **1,511** | 67.31 | 26.17 | 0.67 | 401.07 | 88.33 | 2.27 | 0.21 | 0.20 | 0.01 | 20.78 | 5.56 | 0.14 | 1.45 | 0.65 | 0.02 | **979** | 8.26 | 2.29 | 0.07 |
| Walleye | **832** | 55.62 | 25.69 | 0.89 | 403.39 | 94.58 | 3.28 | 0.16 | 0.18 | 0.01 | 20.45 | 5.49 | 0.19 | 1.20 | 0.61 | 0.02 | **412** | 8.34 | 2.31 | 0.11 |
| White bass | **3,558** | 32.99 | 19.38 | 0.32 | 511.27 | 153.63 | 2.58 | 0.16 | 0.20 | 0.00 | 22.99 | 5.47 | 0.09 | 1.24 | 0.97 | 0.02 | **2,564** | 7.45 | 2.38 | 0.05 |
| Guild class - Lentic | | | | | | | | | | | | | | | | | | | | |
| Black crappie | **1,724** | 44.51 | 28.23 | 0.68 | 460.85 | 141.04 | 3.40 | 0.10 | 0.15 | 0.00 | 21.32 | 5.92 | 0.14 | 1.09 | 0.66 | 0.02 | **1194** | 7.78 | 2.62 | 0.08 |
| Bluegill | **4,144** | 44.86 | 28.23 | 0.44 | 467.15 | 142.06 | 2.21 | 0.12 | 0.16 | 0.00 | 22.20 | 5.85 | 0.09 | 1.18 | 0.75 | 0.01 | **3,047** | 7.86 | 2.60 | 0.05 |
| Largemouth bass | **3,599** | 48.18 | 28.70 | 0.48 | 458.11 | 136.28 | 2.27 | 0.11 | 0.16 | 0.00 | 22.04 | 5.73 | 0.10 | 1.16 | 0.69 | 0.01 | **2,583** | 7.90 | 2.61 | 0.05 |
| Northern pike | **690** | 68.81 | 28.10 | 1.07 | 398.89 | 88.01 | 3.35 | 0.15 | 0.19 | 0.01 | 20.14 | 5.76 | 0.22 | 1.26 | 0.52 | 0.02 | **492** | 8.05 | 2.35 | 0.11 |
| Warmouth | **313** | 29.10 | 14.80 | 0.84 | 486.49 | 123.57 | 6.98 | 0.04 | 0.09 | 0.01 | 21.60 | 6.10 | 0.35 | 0.93 | 0.61 | 0.03 | **242** | 7.74 | 2.63 | 0.17 |
| White crappie | **771** | 27.40 | 15.99 | 0.58 | 519.19 | 151.08 | 5.44 | 0.05 | 0.11 | 0.00 | 21.83 | 5.97 | 0.22 | 0.94 | 0.64 | 0.02 | **557** | 7.49 | 2.73 | 0.12 |
| Yellow perch | **1,058** | 67.74 | 27.96 | 0.86 | 388.66 | 87.05 | 2.68 | 0.13 | 0.18 | 0.01 | 20.51 | 5.74 | 0.18 | 1.20 | 0.54 | 0.02 | **761** | 8.12 | 2.54 | 0.09 |

**Appendix 1–1.** Continuous variables.—Continued

[*n*, sample size; SD, standard deviations; SE, standard errors; --, not estimable]

| Common name | *n* | Secchi | | | Conductivity | | | Water velocity | | | Water temperature | | | Water depth | | | *n* | Dissolved oxygen | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | SD | SE | Mean | SD | SE | Mean | SD | SE | Mean | SD | SE | Mean | SD | SE | | Mean | SD | SE |
| Guild class - Lotic | | | | | | | | | | | | | | | | | | | | |
| Blue catfish | **153** | 21.58 | 10.65 | 0.86 | 531.58 | 94.72 | 7.66 | 0.38 | 0.23 | 0.02 | 22.12 | 5.65 | 0.46 | 2.76 | 1.43 | 0.12 | **146** | 7.33 | 1.72 | 0.14 |
| Blue sucker | **94** | 43.62 | 27.85 | 2.87 | 499.07 | 112.52 | 11.61 | 0.39 | 0.21 | 0.02 | 22.48 | 4.25 | 0.44 | 2.05 | 1.20 | 0.12 | **71** | 7.42 | 1.95 | 0.23 |
| Flathead catfish | **1,306** | 33.04 | 21.06 | 0.58 | 504.53 | 140.85 | 3.90 | 0.22 | 0.23 | 0.01 | 24.78 | 4.06 | 0.11 | 1.47 | 1.09 | 0.03 | **983** | 7.17 | 2.19 | 0.07 |
| Golden redhorse | **967** | 70.23 | 27.07 | 0.87 | 408.08 | 103.43 | 3.33 | 0.18 | 0.17 | 0.01 | 20.95 | 5.52 | 0.18 | 1.40 | 0.54 | 0.02 | **598** | 8.11 | 2.26 | 0.09 |
| Rock bass | **1,032** | 66.84 | 24.12 | 0.75 | 394.02 | 85.05 | 2.65 | 0.19 | 0.19 | 0.01 | 21.11 | 5.29 | 0.16 | 1.29 | 0.55 | 0.02 | **698** | 8.25 | 2.30 | 0.09 |
| Sauger | **1,747** | 39.31 | 22.16 | 0.53 | 475.85 | 144.03 | 3.45 | 0.14 | 0.17 | 0.00 | 21.89 | 5.47 | 0.13 | 1.08 | 0.64 | 0.02 | **1,015** | 7.71 | 2.29 | 0.07 |
| Shorthead redhorse | **2,378** | 58.17 | 28.99 | 0.59 | 428.12 | 115.92 | 2.38 | 0.20 | 0.20 | 0.00 | 21.38 | 5.59 | 0.11 | 1.33 | 0.63 | 0.01 | **1,564** | 8.08 | 2.36 | 0.06 |
| Skipjack herring | **911** | 26.08 | 12.17 | 0.40 | 583.83 | 149.09 | 4.94 | 0.15 | 0.18 | 0.01 | 24.55 | 4.74 | 0.16 | 1.36 | 1.19 | 0.04 | **811** | 6.93 | 2.05 | 0.07 |
| Shovelnose sturgeon | **13** | 46.23 | 32.19 | 8.93 | 388.62 | 60.35 | 16.74 | 0.40 | 0.23 | 0.06 | 23.12 | 4.63 | 1.28 | 1.53 | 1.22 | 0.34 | **9** | 7.40 | 1.39 | 0.46 |

**Appendix 1–2.** Categorical variables.

[*n*, sample size; SD, standard deviations; SE, standard errors; --, not estimable]

| | | Percent emergent/ submersed aquatic vegetation | | | Vegetation density | | | Substrate | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Common name** | ***n*** | **Mean** | **SD** | **SE** | **Mean** | **SD** | **SE** | **Mean** | **SD** | **SE** |
| Guild class - Generalists | | | | | | | | | | |
| Blackstripe topminnow | **50** | -- | -- | -- | -- | -- | -- | 2.50 | 2.12 | 1.50 |
| Brook silverside | **748** | 0.73 | 0.97 | 0.04 | 0.64 | 0.80 | 0.03 | 2.38 | 0.96 | 0.03 |
| Channel catfish | **2,751** | 0.20 | 0.59 | 0.01 | 0.17 | 0.49 | 0.01 | 2.46 | 1.09 | 0.02 |
| Emerald shiner | **4,348** | 0.38 | 0.76 | 0.01 | 0.33 | 0.63 | 0.01 | 2.48 | 1.01 | 0.02 |
| Freshwater drum | **3,812** | 0.38 | 0.80 | 0.01 | 0.31 | 0.63 | 0.01 | 2.40 | 1.07 | 0.02 |
| Logperch | **982** | 0.78 | 0.95 | 0.03 | 0.68 | 0.77 | 0.02 | 2.71 | 0.83 | 0.03 |
| Longnose gar | **568** | 0.45 | 0.83 | 0.03 | 0.40 | 0.71 | 0.03 | 2.54 | 1.00 | 0.04 |
| Red shiner | **464** | 0.01 | 0.11 | 0.01 | 0.02 | 0.16 | 0.01 | 2.61 | 1.09 | 0.05 |
| Smallmouth buffalo | **2,507** | 0.17 | 0.55 | 0.01 | 0.15 | 0.45 | 0.01 | 2.42 | 1.13 | 0.02 |
| Smallmouth bass | **1,507** | 0.69 | 0.91 | 0.02 | 0.59 | 0.74 | 0.02 | 2.89 | 0.66 | 0.02 |
| Walleye | **829** | 0.77 | 0.96 | 0.03 | 0.66 | 0.77 | 0.03 | 2.53 | 0.89 | 0.03 |
| White bass | **3,544** | 0.23 | 0.61 | 0.01 | 0.20 | 0.51 | 0.01 | 2.49 | 1.05 | 0.02 |
| Guild class - Lentic | | | | | | | | | | |
| Black crappie | **1,720** | 0.68 | 0.99 | 0.02 | 0.57 | 0.78 | 0.02 | 2.27 | 1.03 | 0.02 |
| Bluegill | **4,131** | 0.60 | 0.94 | 0.01 | 0.50 | 0.75 | 0.01 | 2.37 | 1.03 | 0.02 |
| Largemouth bass | **3,592** | 0.69 | 0.99 | 0.02 | 0.58 | 0.78 | 0.01 | 2.38 | 1.01 | 0.02 |
| Northern pike | **689** | 1.32 | 1.08 | 0.04 | 1.08 | 0.81 | 0.03 | 2.47 | 0.83 | 0.03 |
| Warmouth | **311** | 0.32 | 0.73 | 0.04 | 0.26 | 0.56 | 0.03 | 1.92 | 1.08 | 0.06 |
| White crappie | **769** | 0.24 | 0.66 | 0.02 | 0.19 | 0.50 | 0.02 | 2.05 | 1.15 | 0.04 |
| Yellow perch | **1,055** | 1.52 | 1.03 | 0.03 | 1.23 | 0.76 | 0.02 | 2.37 | 0.85 | 0.03 |
| Guild class - Lotic | | | | | | | | | | |
| Blue catfish | **149** | 0.01 | 0.08 | 0.01 | 0.01 | 0.08 | 0.01 | 2.97 | 1.06 | 0.09 |
| Blue sucker | **91** | 0.10 | 0.30 | 0.03 | 0.11 | 0.35 | 0.04 | 3.10 | 0.92 | 0.09 |
| Flathead catfish | **1,296** | 0.18 | 0.54 | 0.02 | 0.16 | 0.48 | 0.01 | 2.66 | 1.07 | 0.03 |
| Golden redhorse | **965** | 0.88 | 0.97 | 0.03 | 0.79 | 0.82 | 0.03 | 2.84 | 0.69 | 0.02 |
| Rock bass | **1,030** | 1.17 | 1.01 | 0.03 | 1.01 | 0.80 | 0.02 | 2.69 | 0.76 | 0.02 |
| Sauger | **1,745** | 0.50 | 0.85 | 0.02 | 0.43 | 0.71 | 0.02 | 2.45 | 0.99 | 0.02 |
| Shorthead redhorse | **2,374** | 0.68 | 0.93 | 0.02 | 0.59 | 0.76 | 0.02 | 2.73 | 0.87 | 0.02 |
| Skipjack herring | **906** | 0.02 | 0.18 | 0.01 | 0.03 | 0.20 | 0.01 | 2.49 | 1.15 | 0.04 |
| Shovelnose sturgeon | **13** | 0.08 | 0.28 | 0.08 | 0.08 | 0.28 | 0.08 | 3.23 | 1.01 | 0.28 |

**Appendix 1–3.** Binary variables.

[*n*, sample size; SD, standard deviations; SE, standard errors; --, not estimable]

| Common name | *n* | Woody | | | Wing dam/dike | | | Tributary mouth | | | Revetment | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | SD | SE | Mean | SD | SE | Mean | SD | SE | Mean | SD | SE |
| Guild class - Generalists | | | | | | | | | | | | | |
| Blackstripe topminnow | **50** | 0.82 | 0.39 | 0.05 | 0.02 | 0.14 | 0.02 | -- | -- | -- | 0.04 | 0.20 | 0.03 |
| Brook silverside | **749** | 0.64 | 0.48 | 0.02 | 0.06 | 0.25 | 0.01 | 0.01 | 0.07 | 0.00 | 0.16 | 0.37 | 0.01 |
| Channel catfish | **2,762** | 0.61 | 0.49 | 0.01 | 0.10 | 0.30 | 0.01 | 0.01 | 0.08 | 0.00 | 0.19 | 0.39 | 0.01 |
| Emerald shiner | **4,347** | 0.62 | 0.49 | 0.01 | 0.11 | 0.32 | 0.00 | 0.01 | 0.10 | 0.00 | 0.17 | 0.38 | 0.01 |
| Freshwater drum | **3,815** | 0.61 | 0.49 | 0.01 | 0.09 | 0.29 | 0.00 | 0.01 | 0.09 | 0.00 | 0.18 | 0.39 | 0.01 |
| Logperch | **983** | 0.63 | 0.48 | 0.02 | 0.18 | 0.38 | 0.01 | 0.01 | 0.11 | 0.00 | 0.26 | 0.44 | 0.01 |
| Longnose gar | **568** | 0.67 | 0.47 | 0.02 | 0.11 | 0.32 | 0.01 | 0.01 | 0.10 | 0.00 | 0.18 | 0.38 | 0.02 |
| Red shiner | **465** | 0.62 | 0.49 | 0.02 | 0.09 | 0.29 | 0.01 | 0.01 | 0.08 | 0.00 | 0.15 | 0.36 | 0.02 |
| Smallmouth buffalo | **2,512** | 0.61 | 0.49 | 0.01 | 0.07 | 0.26 | 0.01 | 0.01 | 0.08 | 0.00 | 0.19 | 0.39 | 0.01 |
| Smallmouth bass | **1,505** | 0.62 | 0.48 | 0.01 | 0.25 | 0.43 | 0.01 | 0.02 | 0.15 | 0.00 | 0.29 | 0.45 | 0.01 |
| Walleye | **824** | 0.60 | 0.49 | 0.02 | 0.21 | 0.41 | 0.01 | 0.02 | 0.13 | 0.00 | 0.16 | 0.36 | 0.01 |
| White bass | **3,547** | 0.61 | 0.49 | 0.01 | 0.09 | 0.29 | 0.00 | 0.01 | 0.10 | 0.00 | 0.18 | 0.38 | 0.01 |
| Guild class - Lentic | | | | | | | | | | | | | |
| Black crappie | **1,719** | 0.70 | 0.46 | 0.01 | 0.05 | 0.22 | 0.01 | 0.01 | 0.10 | 0.00 | 0.16 | 0.37 | 0.01 |
| Bluegill | **4,134** | 0.65 | 0.48 | 0.01 | 0.09 | 0.28 | 0.00 | 0.01 | 0.08 | 0.00 | 0.19 | 0.40 | 0.01 |
| Largemouth bass | **3,589** | 0.65 | 0.48 | 0.01 | 0.08 | 0.28 | 0.00 | 0.01 | 0.08 | 0.00 | 0.19 | 0.39 | 0.01 |
| Northern pike | **688** | 0.70 | 0.46 | 0.02 | 0.07 | 0.26 | 0.01 | 0.02 | 0.14 | 0.01 | 0.20 | 0.40 | 0.02 |
| Warmouth | **313** | 0.69 | 0.46 | 0.03 | 0.04 | 0.18 | 0.01 | -- | -- | -- | 0.31 | 0.46 | 0.03 |
| White crappie | **769** | 0.72 | 0.45 | 0.02 | 0.01 | 0.11 | 0.00 | 0.00 | 0.05 | 0.00 | 0.12 | 0.33 | 0.01 |
| Yellow perch | **1,051** | 0.66 | 0.47 | 0.01 | 0.06 | 0.23 | 0.01 | 0.01 | 0.11 | 0.00 | 0.17 | 0.37 | 0.01 |
| Guild class - Lotic | | | | | | | | | | | | | |
| Blue catfish | **153** | 0.40 | 0.49 | 0.04 | 0.33 | 0.47 | 0.04 | 0.01 | 0.08 | 0.01 | 0.42 | 0.49 | 0.04 |
| Blue sucker | **94** | 0.46 | 0.50 | 0.05 | 0.43 | 0.50 | 0.05 | 0.04 | 0.20 | 0.02 | 0.26 | 0.44 | 0.05 |
| Flathead catfish | **1,305** | 0.60 | 0.49 | 0.01 | 0.15 | 0.35 | 0.01 | 0.01 | 0.10 | 0.00 | 0.27 | 0.44 | 0.01 |
| Golden redhorse | **964** | 0.58 | 0.49 | 0.02 | 0.22 | 0.41 | 0.01 | 0.01 | 0.11 | 0.00 | 0.23 | 0.42 | 0.01 |
| Rock bass | **1,028** | 0.71 | 0.46 | 0.01 | 0.09 | 0.29 | 0.01 | 0.01 | 0.09 | 0.00 | 0.22 | 0.42 | 0.01 |
| Sauger | **1,737** | 0.66 | 0.47 | 0.01 | 0.09 | 0.28 | 0.01 | 0.01 | 0.10 | 0.00 | 0.15 | 0.36 | 0.01 |
| Shorthead redhorse | **2,370** | 0.59 | 0.49 | 0.01 | 0.23 | 0.42 | 0.01 | 0.01 | 0.12 | 0.00 | 0.18 | 0.38 | 0.01 |
| Skipjack herring | **908** | 0.54 | 0.50 | 0.02 | 0.07 | 0.25 | 0.01 | 0.00 | 0.07 | 0.00 | 0.23 | 0.42 | 0.01 |
| Shovelnose sturgeon | **13** | 0.38 | 0.51 | 0.14 | 0.62 | 0.51 | 0.14 | -- | -- | -- | 0.08 | 0.28 | 0.08 |

**Appendix 1–3.** Binary variables.—Continued

[*n*, sample size; SD, standard deviations; SE, standard errors; --, not estimable]

| Common name | *n* | Inlet/outlet channel | | | Low head dam, closing dam, weir | | | Flooded terrestrial | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | SD | SE | Mean | SD | SE | Mean | SD | SE |
| Guild class - Generalists | | | | | | | | | | |
| Blackstripe topminnow | **50** | -- | -- | -- | -- | -- | -- | 0.14 | 0.35 | 0.05 |
| Brook silverside | **749** | 0.03 | 0.16 | 0.01 | 0.01 | 0.09 | 0.00 | 0.11 | 0.32 | 0.01 |
| Channel catfish | **2,762** | 0.02 | 0.13 | 0.00 | 0.01 | 0.09 | 0.00 | 0.11 | 0.32 | 0.01 |
| Emerald shiner | **4,347** | 0.03 | 0.16 | 0.00 | 0.01 | 0.10 | 0.00 | 0.15 | 0.36 | 0.01 |
| Freshwater drum | **3,815** | 0.03 | 0.16 | 0.00 | 0.01 | 0.09 | 0.00 | 0.13 | 0.34 | 0.01 |
| Logperch | **983** | 0.05 | 0.21 | 0.01 | 0.01 | 0.11 | 0.00 | 0.07 | 0.25 | 0.01 |
| Longnose gar | **568** | 0.03 | 0.17 | 0.01 | 0.01 | 0.11 | 0.00 | 0.23 | 0.42 | 0.02 |
| Red shiner | **465** | 0.02 | 0.12 | 0.01 | 0.00 | 0.07 | 0.00 | 0.24 | 0.43 | 0.02 |
| Smallmouth buffalo | **2,512** | 0.02 | 0.13 | 0.00 | 0.01 | 0.08 | 0.00 | 0.18 | 0.39 | 0.01 |
| Smallmouth bass | **1,505** | 0.06 | 0.24 | 0.01 | 0.03 | 0.16 | 0.00 | 0.09 | 0.29 | 0.01 |
| Walleye | **824** | 0.05 | 0.22 | 0.01 | 0.02 | 0.13 | 0.00 | 0.13 | 0.34 | 0.01 |
| White bass | **3,547** | 0.02 | 0.14 | 0.00 | 0.01 | 0.10 | 0.00 | 0.15 | 0.36 | 0.01 |
| Guild class - Lentic | | | | | | | | | | |
| Black crappie | **1,719** | 0.03 | 0.18 | 0.00 | 0.01 | 0.10 | 0.00 | 0.10 | 0.31 | 0.01 |
| Bluegill | **4,134** | 0.03 | 0.17 | 0.00 | 0.01 | 0.10 | 0.00 | 0.12 | 0.32 | 0.01 |
| Largemouth bass | **3,589** | 0.03 | 0.18 | 0.00 | 0.01 | 0.10 | 0.00 | 0.13 | 0.34 | 0.01 |
| Northern pike | **688** | 0.08 | 0.28 | 0.01 | 0.02 | 0.15 | 0.01 | 0.13 | 0.34 | 0.01 |
| Warmouth | **313** | 0.01 | 0.08 | 0.00 | -- | -- | -- | 0.05 | 0.23 | 0.01 |
| White crappie | **769** | 0.01 | 0.10 | 0.00 | 0.00 | 0.05 | 0.00 | 0.12 | 0.32 | 0.01 |
| Yellow perch | **1,051** | 0.06 | 0.25 | 0.01 | 0.02 | 0.14 | 0.00 | 0.11 | 0.31 | 0.01 |
| Guild class - Lotic | | | | | | | | | | |
| Blue catfish | **153** | 0.01 | 0.11 | 0.01 | 0.01 | 0.08 | 0.01 | 0.25 | 0.44 | 0.04 |
| Blue sucker | **94** | 0.04 | 0.20 | 0.02 | 0.02 | 0.15 | 0.01 | 0.13 | 0.34 | 0.03 |
| Flathead catfish | **1,305** | 0.02 | 0.13 | 0.00 | 0.01 | 0.10 | 0.00 | 0.11 | 0.31 | 0.01 |
| Golden redhorse | **964** | 0.08 | 0.26 | 0.01 | 0.01 | 0.12 | 0.00 | 0.08 | 0.27 | 0.01 |
| Rock bass | **1,028** | 0.07 | 0.25 | 0.01 | 0.02 | 0.12 | 0.00 | 0.09 | 0.29 | 0.01 |
| Sauger | **1,737** | 0.04 | 0.20 | 0.00 | 0.01 | 0.12 | 0.00 | 0.13 | 0.34 | 0.01 |
| Shorthead redhorse | **2,370** | 0.05 | 0.22 | 0.00 | 0.02 | 0.13 | 0.00 | 0.11 | 0.31 | 0.01 |
| Skipjack herring | **908** | 0.00 | 0.06 | 0.00 | 0.01 | 0.08 | 0.00 | 0.20 | 0.40 | 0.01 |
| Shovelnose sturgeon | **13** | -- | -- | -- | -- | -- | -- | 0.15 | 0.38 | 0.10 |

# Appendix 2. Model Results Presented for each Species and Region

**Species:** Black crappie (*Pomoxis nigromaculatus*)

**Guild:** Lentic

**Region:** Upper Reach model (Pools 4, 8, and 13)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** Y

**Goodness-of-fit (Hosmer Lemeshow Test):** $\chi^2$ = 9.0393, 8 df, p = 0.3390

**Parameter estimates:**

| Parameter* | DF | Estimate | Standard error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | −1.1056 | 0.4449 | 6.1758 | 0.0130 |
| SpecCond | 1 | −0.00085 | 0.000491 | 2.9791 | 0.0843 |
| Watervel | 1 | −1.3720 | 0.2838 | 23.3749 | <.0001 |
| Substrate | 1 | −0.2750 | 0.0512 | 28.8105 | <.0001 |
| Temp | 1 | 0.0285 | 0.0105 | 7.3878 | 0.0066 |
| VegDens | 1 | 0.2388 | 0.0534 | 20.0145 | <.0001 |
| Woody | 1 | 0.3530 | 0.0922 | 14.6552 | 0.0001 |
| WingDam | 1 | −0.9132 | 0.1560 | 34.2549 | <.0001 |
| Period | 1 | 0.5515 | 0.0791 | 48.5816 | <.0001 |
| Fstation | 1 | −0.2669 | 0.0536 | 24.8379 | <.0001 |

*See table 2 for a list of predictors and their abbreviations.

**Predictive equation:**

**log(p/1-p)** = −1.1056 - 0.00085*speccond - 1.3720*watervel - 0.2750*substrate + 0.0285*temp + 0.2388*vegdens + 0.3530*woody - 0.9132*wingdam + 0.5515*period - 0.2669*fstation

**Parameter contributions:**

**Summary of stepwise selection**

| Step | Effect* | DF | Number In | Score Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| 1 | WingDam | 1 | 1 | 148.4887 | <.0001 |
| 2 | Watervel | 1 | 2 | 69.4748 | <.0001 |
| 3 | Period | 1 | 3 | 47.0652 | <.0001 |
| 4 | VegDens | 1 | 4 | 25.7844 | <.0001 |
| 5 | Substrate | 1 | 5 | 21.6929 | <.0001 |
| 6 | Fstation | 1 | 6 | 18.7092 | <.0001 |
| 7 | Woody | 1 | 7 | 15.2560 | <.0001 |
| 8 | Temp | 1 | 8 | 7.4497 | 0.0063 |
| 9 | SpecCond | 1 | 9 | 2.9840 | 0.0841 |

*See table 2 for a list of predictors and their abbreviations.

**Issues encountered during fitting:**

None – well fit model

**Recommendations for resolving extant issues:**

**Species:** Black crappie (*Pomoxis nigromaculatus*)

**Guild:** Lentic

**Region:** Lower Reach model (Pool 26, Open River Reach, and La Grange Pool)

Data source: UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

Certifiable model fit?: N

**Goodness-of-fit (Hosmer Lemeshow Test):** $\chi^2 = 37.2363$, 8 df, p = <.0001

**Parameter estimates:**

| Parameter* | DF | Estimate | Standard error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | −1.8979 | 0.6485 | 8.5664 | 0.0034 |
| Secchi | 1 | −0.0179 | 0.00464 | 14.7896 | 0.0001 |
| SpecCond | 1 | −0.00314 | 0.000407 | 59.3353 | <.0001 |
| Watervel | 1 | −3.7287 | 0.3767 | 97.9680 | <.0001 |
| Temp | 1 | −0.0201 | 0.0121 | 2.7628 | 0.0965 |
| DO | 1 | −0.0515 | 0.0222 | 5.3657 | 0.0205 |
| Woody | 1 | 0.4820 | 0.0970 | 24.7053 | <.0001 |
| Revetment | 1 | 0.2580 | 0.1365 | 3.5732 | 0.0587 |
| FloodTer | 1 | −1.1744 | 0.1520 | 59.7153 | <.0001 |
| Period | 1 | 0.1630 | 0.0870 | 3.5054 | 0.0612 |
| Fstation | 1 | 0.6678 | 0.0764 | 76.3494 | <.0001 |

*See table 2 for a list of predictors and their abbreviations.

**Predictive equation:**

**log(p/1-p)** = -1.8979 - 0.0179*secchi - 0.00314*speccond - 3.7287*watervel - 0.0201*temp - 0.0515*DO + 0.4820*woody + 0.2580*revetment - 1.1744*floodter + 0.1630*period + 0.6678*fstation

**Parameter contributions:**

Summary of stepwise selection

| Step | Effect* | DF | Number In | Score Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| 1 | Watervel | 1 | 1 | 148.8325 | <.0001 |
| 2 | Secchi | 1 | 2 | 55.9363 | <.0001 |
| 3 | FloodTer | 1 | 3 | 42.8748 | <.0001 |
| 4 | Fstation | 1 | 4 | 30.0533 | <.0001 |
| 5 | SpecCond | 1 | 5 | 71.7386 | <.0001 |
| 6 | Woody | 1 | 6 | 22.8783 | <.0001 |
| 7 | Period | 1 | 7 | 15.0698 | 0.0001 |
| 8 | DO | 1 | 8 | 3.8134 | 0.0508 |
| 9 | Revetment | 1 | 9 | 3.5124 | 0.0609 |
| 10 | Temp | 1 | 10 | 2.7672 | 0.0962 |

*See table 2 for a list of predictors and their abbreviations.

**Issues encountered during fitting:**

Residuals strongly structured between La Grange Reach and the other two reaches (OR and Pool 26).

**Recommendations for resolving extant issues:**

It appears La Grange has the preponderance of black crappie occurrences, resulting in a poor regional fit. This model will need to be discretized further into a La Grange model and a combined Pool 26 and Open River model.

**Species:** Brook silverside (*Labidesthes sicculus*)

**Guild:** Generalist

**Region:** Upper Reach model (Pools 4, 8, and 13)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** Y

**Goodness-of-fit (Hosmer Lemeshow Test):** $\chi^2$ = 8.8619, 8 df, p = 0.3541

**Parameter estimates:**

| Parameter* | DF | Estimate | Standard error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | −4.2451 | 0.3963 | 114.7383 | <.0001 |
| Secchi | 1 | 0.00866 | 0.00205 | 17.8521 | <.0001 |
| SpecCond | 1 | −0.00155 | 0.000665 | 5.4636 | 0.0194 |
| VegDens | 1 | 0.3241 | 0.0663 | 23.9086 | <.0001 |
| WingDam | 1 | −0.9816 | 0.1804 | 29.6184 | <.0001 |
| Period | 1 | 0.6786 | 0.0703 | 93.1080 | <.0001 |
| Fstation | 1 | 0.4827 | 0.0762 | 40.0773 | <.0001 |

*See table 2 for a list of predictors and their abbreviations.

**Predictive equation:**

**log(p/1-p)** = -4.2451 + 0.00866*secchi - 0.00155*speccond + 0.3241*vegdens - 0.9816*wingdam + 0.6786*period + 0.4827*fstation

**Parameter contributions:**

Summary of stepwise selection

| Step | Effect* | DF | Number In | Score Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| 1 | Period | 1 | 1 | 96.4543 | <.0001 |
| 2 | VegDens | 1 | 2 | 53.8626 | <.0001 |
| 3 | Fstation | 1 | 3 | 23.5401 | <.0001 |
| 4 | WingDam | 1 | 4 | 24.0802 | <.0001 |
| 5 | Secchi | 1 | 5 | 18.5346 | <.0001 |
| 6 | SpecCond | 1 | 6 | 5.4799 | 0.0192 |

*See table 2 for a list of predictors and their abbreviations.

**Issues encountered during fitting:**

None – well fit

**Recommendations for resolving extant issues:**

**Species:** Brook silverside (*Labidesthes sicculus*)

Guild: Generalist

Region: Lower Reach Model (Pool 26, Open River Reach, and La Grange Pool)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** Y

**Goodness-of-fit (Hosmer Lemeshow Test):** $\chi^2 = 9.11$, 8 df, p = 0.3329

**Parameter estimates:**

| Parameter* | DF | Estimate | Standard error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | −5.2273 | 0.7775 | 45.2055 | <.0001 |
| Watervel | 1 | −2.0456 | 0.4837 | 17.8812 | <.0001 |
| Substrate | 1 | −0.1074 | 0.0603 | 3.1758 | 0.0747 |
| Temp | 1 | 0.0690 | 0.0180 | 14.7339 | 0.0001 |
| Trib | 1 | 1.2309 | 0.6480 | 3.6079 | 0.0575 |
| Period | 1 | 0.2284 | 0.1177 | 3.7629 | 0.0524 |
| Fstation | 1 | 0.1909 | 0.0732 | 6.8017 | 0.0091 |

*See table 2 for a list of predictors and their abbreviations.

**Predictive equation:**

**log(p/1-p)** = -5.2273 - 2.0456*watervel - 0.1074*substrate + 0.0690*temp + 1.2309*trib + 0.2284*period + 0.1909*fstation

**Parameter contributions:**

**Summary of stepwise selection**

| Step | Effect* | DF | Number In | Score Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| 1 | Watervel | 1 | 1 | 27.7689 | <.0001 |
| 2 | Temp | 1 | 2 | 12.1330 | 0.0005 |
| 3 | Fstation | 1 | 3 | 5.4727 | 0.0193 |
| 4 | Period | 1 | 4 | 4.1621 | 0.0413 |
| 5 | Trib | 1 | 5 | 3.5517 | 0.0595 |
| 6 | Substrate | 1 | 6 | 3.1855 | 0.0743 |

*See table 2 for a list of predictors and their abbreviations.

**Issues encountered during fitting:**

None – well fit

**Recommendations for resolving extant issues:**

**Species:** Blue catfish (*Ictalurus furcatus*)

**Guild:** Lotic

**Region:** Upper Reach model (Pools 4, 8, and 13)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** NO MODEL FIT

**Goodness-of-fit (Hosmer Lemeshow Test):**

**Parameter estimates:**

**Predictive equation:**

**Parameter contributions:**

**Issues encountered during fitting:**

Does not occur in the upper reach – zoogeographically constrained

**Recommendations for resolving extant issues:**

No upper reach model possible

**Species:** Blue catfish (*Ictalurus furcatus*)

**Guild:** Lotic

**Region:** Lower Reach model (Pool 26, Open River Reach, La Grange Pool)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** Y

**Goodness-of-fit (Hosmer Lemeshow Test):** $\chi^2 = 9.7084$, 8 df , p = 0.2861

**Parameter estimates:**

| Parameter* | DF | Estimate | Standard error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | −5.1913 | 0.4665 | 123.8555 | <.0001 |
| Secchi | 1 | −0.0390 | 0.00893 | 19.1133 | <.0001 |
| Watervel | 1 | 2.5019 | 0.3299 | 57.5127 | <.0001 |
| Substrate | 1 | 0.1628 | 0.0882 | 3.4065 | 0.0649 |
| Woody | 1 | −0.4047 | 0.1998 | 4.1017 | 0.0428 |
| WingDam | 1 | 1.9354 | 0.2222 | 75.8833 | <.0001 |
| Revetment | 1 | 0.6573 | 0.1990 | 10.9127 | 0.0010 |
| FloodTer | 1 | 0.7557 | 0.2335 | 10.4779 | 0.0012 |
| Period | 1 | 0.6798 | 0.1196 | 32.3183 | <.0001 |

*See table 2 for a list of predictors and their abbreviations.

**Predictive equation:**

**log(p/1-p)** = -5.1913 - 0.0390*secchi + 2.5019*waterlev + 0.1628*substrate - 0.4047*woody + 1.9354*wingdam + 0.6573*revetment + 0.7557*floodter + 0.6798*period

**Parameter contributions:**

**Summary of stepwise selection**

| Step | Effect* | DF | Number In | Score Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| 1 | WingDam | 1 | 1 | 180.6094 | <.0001 |
| 2 | Watervel | 1 | 2 | 121.7096 | <.0001 |
| 3 | Period | 1 | 3 | 26.6487 | <.0001 |
| 4 | Secchi | 1 | 4 | 17.3788 | <.0001 |
| 5 | Revetment | 1 | 5 | 13.8458 | 0.0002 |
| 6 | FloodTer | 1 | 6 | 7.4483 | 0.0063 |
| 7 | Woody | 1 | 7 | 5.5282 | 0.0187 |
| 8 | Substrate | 1 | 8 | 3.4251 | 0.0642 |

*See table 2 for a list of predictors and their abbreviations.

**Issues encountered during fitting:**

None – well fit

**Recommendations for resolving extant issues:**

**Species:** Bluegill (*Lepomis macrochirus*)

**Guild:** Lentic

**Region:** Upper Reach model (Pools 4, 8, and 13)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** Y

**Goodness-of-fit (Hosmer Lemeshow Test):** $\chi^2$ = 8.1424, 8 df, p = 0.4197

**Parameter estimates:**

| Parameter* | DF | Estimate | Standard error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | −3.5161 | 0.6292 | 31.2243 | <.0001 |
| Secchi | 1 | 0.0122 | 0.00194 | 39.4878 | <.0001 |
| SpecCond | 1 | −0.00182 | 0.000517 | 12.3917 | 0.0004 |
| Watervel | 1 | −0.8146 | 0.2522 | 10.4363 | 0.0012 |
| Substrate | 1 | −0.2649 | 0.0591 | 20.0937 | <.0001 |
| Temp | 1 | 0.0953 | 0.0126 | 57.5340 | <.0001 |
| DO | 1 | 0.0632 | 0.0299 | 4.4578 | 0.0347 |
| VegDens | 1 | 0.5508 | 0.0664 | 68.7604 | <.0001 |
| Woody | 1 | 0.3410 | 0.0972 | 12.3104 | 0.0005 |
| WingDam | 1 | −0.9631 | 0.1245 | 59.8494 | <.0001 |
| Revetment | 1 | 0.3728 | 0.1233 | 9.1441 | 0.0025 |
| FloodTer | 1 | −0.4879 | 0.1336 | 13.3402 | 0.0003 |
| Period | 1 | 0.7485 | 0.0844 | 78.6236 | <.0001 |

*See table 2 for a list of predictors and their abbreviations.

**Predictive equation:**

**log(p/1-p)** = -3.5161 + 0.0122*secchi - 0.00182*speccond - 0.8146*waterlev - 0.2649*substrate + 0.0953*temp + 0.0632*DO + 0.5508*vegdens + 0.3410*woody - 0.9631*wingdam + 0.3728*revetment - 0.4879*floodter + 0.7485*period

### Parameter contributions:

**Summary of stepwise selection**

| Step | Effect* | DF | Number In | Score Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| 1 | WingDam | 1 | 1 | 242.0782 | <.0001 |
| 2 | VegDens | 1 | 2 | 104.6570 | <.0001 |
| 3 | Watervel | 1 | 3 | 69.2654 | <.0001 |
| 4 | Fstation | 1 | 4 | 48.3886 | <.0001 |
| 5 | Period | 1 | 5 | 52.7070 | <.0001 |
| 6 | Temp | 1 | 6 | 51.7346 | <.0001 |
| 7 | Secchi | 1 | 7 | 39.7891 | <.0001 |
| 8 | Substrate | 1 | 8 | 14.8554 | 0.0001 |
| 9 | SpecCond | 1 | 9 | 10.7849 | 0.0010 |
| 10 | FloodTer | 1 | 10 | 13.0446 | 0.0003 |
| 11 | Woody | 1 | 11 | 11.2763 | 0.0008 |
| 12 | Revetment | 1 | 12 | 8.9218 | 0.0028 |
| 13 | DO | 1 | 13 | 4.4663 | 0.0346 |

*See table 2 for a list of predictors and their abbreviations.

### Issues encountered during fitting:

None – well fit

### Recommendations for resolving extant issues:

**Species:** Bluegill (*Lepomis macrochirus*)

**Guild:** Lentic

**Region:** Lower Reach model (Pool 26, Open River Reach, and La Grange Pool)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** N

**Goodness-of-fit (Hosmer Lemeshow Test):** $\chi^2$ = 74.6469, 8 df, p = <.0001

**Parameter estimates:**

| Parameter* | DF | Estimate | Standard error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | 0.1105 | 0.4178 | 0.0699 | 0.7914 |
| Secchi | 1 | −0.0189 | 0.00329 | 33.0347 | <.0001 |
| SpecCond | 1 | −0.00135 | 0.000349 | 14.8894 | 0.0001 |
| Watervel | 1 | −4.2066 | 0.2423 | 301.3845 | <.0001 |
| Substrate | 1 | −0.0610 | 0.0344 | 3.1419 | 0.0763 |
| Temp | 1 | 0.0174 | 0.00732 | 5.6347 | 0.0176 |
| DO | 1 | 0.0635 | 0.0189 | 11.2297 | 0.0008 |
| Woody | 1 | 0.3270 | 0.0776 | 17.7654 | <.0001 |
| Revetment | 1 | 0.8774 | 0.1090 | 64.7755 | <.0001 |
| FloodTer | 1 | −0.7196 | 0.0990 | 52.7911 | <.0001 |

*See table 2 for a list of predictors and their abbreviations.

**Predictive equation:**

**log(p/1-p)** = 0.1105 - 0.0189*secchi - 0.00135*speccond - 4.2066*waterlev - 0.0610*substrate + 0.0174*temp + 0.0635*DO + 0.3270*woody + 0.8774*revetment - 0.7196*floodter

**Parameter contributions:**

**Summary of stepwise selection**

| Step | Effect* | DF | Number In | Score Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| 1 | Watervel | 1 | 1 | 412.2985 | <.0001 |
| 2 | Revetment | 1 | 2 | 61.2374 | <.0001 |
| 3 | FloodTer | 1 | 3 | 42.8810 | <.0001 |
| 4 | Secchi | 1 | 4 | 35.9824 | <.0001 |
| 5 | Woody | 1 | 5 | 21.9275 | <.0001 |
| 6 | SpecCond | 1 | 6 | 10.7599 | 0.0010 |
| 7 | DO | 1 | 7 | 5.1868 | 0.0228 |
| 8 | Fstation | 1 | 8 | 4.8183 | 0.0282 |
| 9 | Temp | 1 | 9 | 5.7038 | 0.0169 |
| 10 | Substrate | 1 | 10 | 3.1440 | 0.0762 |

*See table 2 for a list of predictors and their abbreviations.

**Issues encountered during fitting:**

Residuals strongly structured between La Grange Reach and the other two reaches (OR and Pool 26).

**Recommendations for resolving extant issues:**

It appears La Grange has the preponderance of bluegill occurrences, resulting in a poor regional fit. This model will need to be discretized further into a La Grange model and a combined Pool 26 and Open River model.

**Species:** Blackstripe topminnow (*Fundulus notatus*)

**Guild:** Generalist

**Region:** Upper Reach model (Pools 4, 8, and 13) THIS SPECIES WAS NOT FOUND IN THE UPPER REACHES

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:**

**Goodness-of-fit (Hosmer Lemeshow Test):**

**Parameter estimates:**

**Predictive equation:**

**Parameter contributions:**

**Issues encountered during fitting:**

No occurrences in the Upper River Reach

**Recommendations for resolving extant issues:**

No model possible

**Species:** Blackstripe topminnow (*Fundulus notatus*)

**Guild:** Generalist

**Region:** Lower Reach model (Pool 26, Open River Reach, and La Grange Pool)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** Y

**Goodness-of-fit (Hosmer Lemeshow Test):** $\chi^2 = 3.3231$, 8 df, p = 0.9125

**Parameter estimates:**

| Parameter* | DF | Estimate | Standard error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | −15.5535 | 3.2162 | 23.3872 | <.0001 |
| Watervel | 1 | −11.9447 | 3.4655 | 11.8803 | 0.0006 |
| Woody | 1 | 1.5246 | 0.4461 | 11.6799 | 0.0006 |
| FloodTer | 1 | −2.0620 | 0.7296 | 7.9879 | 0.0047 |
| Fstation | 1 | 1.9349 | 0.5364 | 13.0127 | 0.0003 |

*See table 2 for a list of predictors and their abbreviations.

**Predictive equation:**

**log(p/1-p)** = -15.5535 - 11.9447*waterlev + 1.5246*woody - 2.0620*floodter + 1.9349*fstation

**Parameter contributions:**

**Summary of stepwise selection**

| Step | Effect* | DF | Number In | Score Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| 1 | Fstation | 1 | 1 | 37.0392 | <.0001 |
| 2 | Watervel | 1 | 2 | 12.5933 | 0.0004 |
| 3 | Woody | 1 | 3 | 11.4092 | 0.0007 |
| 4 | FloodTer | 1 | 4 | 11.0689 | 0.0009 |

*See table 2 for a list of predictors and their abbreviations.

**Issues encountered during fitting:**

This is a tragically poor model. We ran it once, aliased 8 high leverage cases, and ran it again, resulting in over a dozen more high leverage cases. FStation is the first variable in, which is a diagnostic variable standing as a surrogate for regionalized gradients. This species likely needs pool-scale models (if possible). Interpret these results with this warning at this stage.

**Recommendations for resolving extant issues:**

Try discretizing into pool-scale models.

**Species:** Blue sucker (*Cycleptus elongates*)

**Guild:** Lotic

**Region:** Upper Reach model (Pools 4, 8, and 13)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** Close (Only 33 presences recorded)

**Goodness-of-fit (Hosmer Lemeshow Test):** $\chi^2 = 14.4094$, 8 df, p = 0.0444

**Parameter estimates:**

| Parameter* | DF | Estimate | Standard error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | −5.6969 | 0.3188 | 319.2642 | <.0001 |
| Watervel | 1 | 2.0974 | 0.6875 | 9.3062 | 0.0023 |
| WingDam | 1 | 1.6736 | 0.3752 | 19.9014 | <.0001 |

*See table 2 for a list of predictors and their abbreviations.

**Predictive equation:**

**log(p/1-p)** = -5.6969 + 2.0974*waterlev + 1.6736*wingdam

**Parameter contributions:**

**Summary of stepwise selection**

| Step | Effect* | DF | Number In | Score Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| 1 | WingDam | 1 | 1 | 40.7456 | <.0001 |
| 2 | Watervel | 1 | 2 | 9.8157 | 0.0017 |

*See table 2 for a list of predictors and their abbreviations.

**Issues encountered during fitting:**

Only 33 presences observed, so a marginal fit accordingly.

**Recommendations for resolving extant issues:**

Consider dropping from consideration – too few occurrences in this reach, and a marginal model as a consequence.

**Species:** Blue sucker (*Cycleptus elongates*)

**Guild:** Lotic

**Region:** Lower Reach model (Pool 26, Open River Reach, and La Grange Pool)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** Y

**Goodness-of-fit (Hosmer Lemeshow Test):** $\chi^2 = 8.0291$, 8 df , p = 0.4306

**Parameter estimates:**

| Parameter* | DF | Estimate | Standard error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | −9.0968 | 0.9784 | 86.4472 | <.0001 |
| Secchi | 1 | 0.0214 | 0.0113 | 3.5981 | 0.0578 |
| SpecCond | 1 | 0.00297 | 0.00111 | 7.1972 | 0.0073 |
| Watervel | 1 | 4.2074 | 0.4860 | 74.9505 | <.0001 |
| WingDam | 1 | 1.7054 | 0.3195 | 28.4832 | <.0001 |
| Period | 1 | 0.5824 | 0.1810 | 10.3528 | 0.0013 |

*See table 2 for a list of predictors and their abbreviations.

**Predictive equation:**

**log(p/1-p)** = -9.0968 + 0.0214*secchi + 0.00297*speccond + 4.2074*watervel + 1.7054*wingdam + 0.5824*period

**Parameter contributions:**

**Summary of stepwise selection**

| Step | Effect* | DF | Number In | Score Chi-Square | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|---|
| 1 | Watervel | 1 | 1 | 96.3346 | | <.0001 |
| 2 | WingDam | 1 | 2 | 36.6010 | | <.0001 |
| 3 | Period | 1 | 3 | 11.9729 | | 0.0005 |
| 4 | SpecCond | 1 | 4 | 5.8086 | | 0.0159 |
| 5 | Secchi | 1 | 5 | 3.6356 | | 0.0566 |

*See table 2 for a list of predictors and their abbreviations.

**Issues encountered during fitting:**

None – well fit.

**Recommendations for resolving extant issues:**

**Species:** Channel catfish (*Ictalurus punctatus*)

**Guild:** Generalist

**Region:** Upper Reach model (Pools 4, 8, and 13)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** N

**Goodness-of-fit (Hosmer Lemeshow Test):** $\chi^2 = 20.5404$, 8 df, p = 0.0085

**Parameter estimates:**

| Parameter* | DF | Estimate | Standard error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | −4.9943 | 0.6719 | 55.2525 | <.0001 |
| Secchi | 1 | −0.00687 | 0.00215 | 10.1764 | 0.0014 |
| SpecCond | 1 | 0.00216 | 0.000651 | 11.0503 | 0.0009 |
| Watervel | 1 | 0.4909 | 0.2634 | 3.4742 | 0.0623 |
| Temp | 1 | 0.0485 | 0.0129 | 14.1676 | 0.0002 |
| DO | 1 | 0.0652 | 0.0285 | 5.2183 | 0.0223 |
| VegDens | 1 | −0.1378 | 0.0628 | 4.8148 | 0.0282 |
| Woody | 1 | 0.1996 | 0.1002 | 3.9734 | 0.0462 |
| InOut | 1 | 0.5132 | 0.2131 | 5.8010 | 0.0160 |
| FloodTer | 1 | −0.4912 | 0.1687 | 8.4755 | 0.0036 |
| Period | 1 | 0.2201 | 0.0892 | 6.0845 | 0.0136 |
| Fstation | 1 | 0.4845 | 0.0677 | 51.2342 | <.0001 |

*See table 2 for a list of predictors and their abbreviations.

**Predictive equation:**

**log(p/1-p)** =-4.9943 - 0.00687*secchi + 0.00216*speccond + 0.4909*watervel + 0.0485*temp + 0.0652*DO - 0.1378*vegdens + 0.1996*woody + 0.5132*inout - 0.4912*floodter + 0.2201*period + 0.4845*fstation

**Parameter contributions:**

**Summary of stepwise selection**

| Step | Effect* | DF | Number In | Score Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| 1 | Fstation | 1 | 1 | 115.1512 | <.0001 |
| 2 | Secchi | 1 | 2 | 15.2776 | <.0001 |
| 3 | SpecCond | 1 | 3 | 12.0003 | 0.0005 |
| 4 | FloodTer | 1 | 4 | 9.1917 | 0.0024 |
| 5 | InOut | 1 | 5 | 5.5922 | 0.0180 |
| 6 | VegDens | 1 | 6 | 6.0342 | 0.0140 |
| 7 | Temp | 1 | 7 | 3.4997 | 0.0614 |
| 8 | Period | 1 | 8 | 6.4330 | 0.0112 |
| 9 | DO | 1 | 9 | 3.6430 | 0.0563 |
| 10 | Woody | 1 | 10 | 3.0207 | 0.0822 |
| 11 | Watervel | 1 | 11 | 3.4871 | 0.0618 |

*See table 2 for a list of predictors and their abbreviations.

**Issues encountered during fitting:**

Fstation (field station dominates), suggesting pool-scale models will be needed. Also to note, channel catfish as scaleless organisms are not sampled well with day Electrofishing at power goals set by LTRMP protocols (Gutreuter and others, 1995). This likely grossly underestimates their occurrence in standardized electrofishing samples.

**Recommendations for resolving extant issues:**

Future efforts should attempt pool-scale models, with the caveat and acknowledgment of sampling methodology limitations. An alternative would be to develop models using a gear type designed to target these organisms (baited hoop nets). The trade-off, of course, is that sampling methods contributing data to models will differ among species comprising AHAG, and that application of a hoop net model would require hoop net effort at HREP project scale assessments, increasing logistic and cost demands in project applications.

**Species:** Channel catfish (*Ictalurus punctatus*)

**Guild:** Generalist

**Region:** Lower Reach model (Pool 26, Open River Reach, and La Grange Pool)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** N

**Goodness-of-fit (Hosmer Lemeshow Test):** $\chi^2$ = 21.6320, 8 df, p = 0.0056

**Parameter estimates:**

| Parameter* | DF | Estimate | Standard error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | 1.3489 | 0.4786 | 7.9446 | 0.0048 |
| Secchi | 1 | −0.0251 | 0.00328 | 58.7666 | <.0001 |
| Substrate | 1 | 0.0926 | 0.0328 | 7.9624 | 0.0048 |
| Temp | 1 | 0.0253 | 0.00968 | 6.8474 | 0.0089 |
| DO | 1 | −0.0374 | 0.0181 | 4.2553 | 0.0391 |
| VegDens | 1 | −0.2454 | 0.1486 | 2.7261 | 0.0987 |
| Woody | 1 | 0.2800 | 0.0751 | 13.8822 | 0.0002 |
| InOut | 1 | −0.7564 | 0.4455 | 2.8831 | 0.0895 |
| FloodTer | 1 | −1.0653 | 0.0962 | 122.5409 | <.0001 |
| Period | 1 | 0.4125 | 0.0662 | 38.8084 | <.0001 |
| Fstation | 1 | −0.3257 | 0.0425 | 58.7076 | <.0001 |

*See table 2 for a list of predictors and their abbreviations.

**Predictive equation:**

**log(p/1-p)** = 1.3489 - 0.0251*secchi + 0.0926*substrate + 0.0253*temp - 0.0374*DO - 0.2454*vegdens + 0.2800*woody - 0.7564*inout - 1.0653*floodter + 0.4125*period - 0.3257*fstation

**Parameter contributions:**

**Summary of stepwise selection**

| Step | Effect* | DF | Number In | Score Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| 1 | FloodTer | 1 | 1 | 222.8657 | <.0001 |
| 2 | Secchi | 1 | 2 | 39.2814 | <.0001 |
| 3 | Fstation | 1 | 3 | 45.6857 | <.0001 |
| 4 | Period | 1 | 4 | 29.6537 | <.0001 |
| 5 | Woody | 1 | 5 | 10.6673 | 0.0011 |
| 6 | Temp | 1 | 6 | 9.2362 | 0.0024 |
| 7 | Substrate | 1 | 7 | 8.3528 | 0.0039 |
| 8 | DO | 1 | 8 | 4.5196 | 0.0335 |
| 9 | InOut | 1 | 9 | 3.1334 | 0.0767 |
| 10 | VegDens | 1 | 10 | 2.7534 | 0.0971 |

*See table 2 for a list of predictors and their abbreviations.

**Issues encountered during fitting:**

Fstation (field station dominates), suggesting pool-scale models will be needed. Also to note, channel catfish as scaleless organisms are not sampled well with day Electrofishing at power goals set by LTRMP protocols (Gutreuter and others, 1995). This likely grossly underestimates their occurrence in standardized electrofishing samples.

**Recommendations for resolving extant issues:**

Future efforts should attempt pool-scale models, with the caveat and acknowledgment of sampling methodology limitations. An alternative would be to develop models using a gear type designed to target these organisms (baited hoop nets). The trade-off, of course, is that sampling methods contributing data to models will differ among species comprising AHAG, and that application of a hoop net model would require hoop net effort at project assessment scales, increasing logistic and cost demands in project applications.

**Species:** Emerald shiner (*Notropis atherinoides*)

**Guild:** Generalist

**Region:** Upper Reach model (Pools 4, 8, and 13)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** Y

**Goodness-of-fit (Hosmer Lemeshow Test):** $\chi^2 = 6.7762$, 8 df, p = 0.5610

**Parameter estimates:**

| Parameter* | DF | Estimate | Standard error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | 0.4585 | 0.1890 | 5.8875 | 0.0152 |
| Secchi | 1 | −0.0127 | 0.00155 | 66.5796 | <.0001 |
| Watervel | 1 | 0.8232 | 0.2517 | 10.6952 | 0.0011 |
| Substrate | 1 | 0.2127 | 0.0528 | 16.2153 | <.0001 |
| AqVeg | 1 | −0.3104 | 0.0420 | 54.6010 | <.0001 |
| Woody | 1 | 0.2804 | 0.0849 | 10.8991 | 0.0010 |
| WingDam | 1 | −0.6631 | 0.1167 | 32.2578 | <.0001 |
| Revetment | 1 | −0.2106 | 0.1051 | 4.0177 | 0.0450 |
| FloodTer | 1 | 0.3897 | 0.1358 | 8.2312 | 0.0041 |
| Period | 1 | 0.2304 | 0.0507 | 20.6752 | <.0001 |

*See table 2 for a list of predictors and their abbreviations.

**Predictive equation:**

**log(p/1-p)** = 0.4585 - 0.0127*secchi + 0.8232*waterlev + 0.2127*substrate - 0.3104*agveg + 0.2804*woody - 0.6631*wingdam - 0.2106*revetment + 0.3897*floodter + 0.2304*period

**Parameter contributions:**

**Summary of stepwise selection**

| Step | Effect* | DF | Number In | Score Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| 1 | AqVeg | 1 | 1 | 112.6595 | <.0001 |
| 2 | Secchi | 1 | 2 | 71.7674 | <.0001 |
| 3 | WingDam | 1 | 3 | 34.6826 | <.0001 |
| 4 | Substrate | 1 | 4 | 20.1689 | <.0001 |
| 5 | Woody | 1 | 5 | 13.1746 | 0.0003 |
| 6 | Period | 1 | 6 | 12.6682 | 0.0004 |
| 7 | Watervel | 1 | 7 | 15.0592 | 0.0001 |
| 8 | FloodTer | 1 | 8 | 8.4230 | 0.0037 |
| 9 | Revetment | 1 | 9 | 4.0255 | 0.0448 |

*See table 2 for a list of predictors and their abbreviations.

**Issues encountered during fitting:**

None – well fit

**Recommendations for resolving extant issues:**

**Species:** Emerald shiner (*Notropis atherinoides*)

**Guild:** Generalist

**Region:** Lower Reach model (Pool 26, Open River Reach, and La Grange Pool)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** Y

**Goodness-of-fit (Hosmer Lemeshow Test):** $\chi^2 = 3.7765$, 8 df, p = 0.8767

**Parameter estimates:**

| Parameter* | DF | Estimate | Standard error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | −0.1281 | 0.3937 | 0.1058 | 0.7450 |
| SpecCond | 1 | 0.00117 | 0.000337 | 12.0696 | 0.0005 |
| Temp | 1 | 0.0268 | 0.00931 | 8.2883 | 0.0040 |
| Revetment | 1 | −0.2970 | 0.0951 | 9.7475 | 0.0018 |
| FloodTer | 1 | −0.2382 | 0.0939 | 6.4386 | 0.0112 |
| Period | 1 | 0.4142 | 0.0646 | 41.1015 | <.0001 |
| Fstation | 1 | −0.2637 | 0.0564 | 21.8662 | <.0001 |

*See table 2 for a list of predictors and their abbreviations.

**Predictive equation:**

**log(p/1-p)** = -0.1281 + 0.00117*speccond + 0.0268*temp - 0.2970*revetment - 0.2382*floodter + 0.4142*period - 0.2637*fstation

**Parameter contributions:**

Summary of stepwise selection

| Step | Effect* | DF | Number In | Score Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| 1 | Period | 1 | 1 | 59.6439 | <.0001 |
| 2 | FloodTer | 1 | 2 | 18.5744 | <.0001 |
| 3 | Temp | 1 | 3 | 11.1219 | 0.0009 |
| 4 | Fstation | 1 | 4 | 5.1165 | 0.0237 |
| 5 | SpecCond | 1 | 5 | 11.8591 | 0.0006 |
| 6 | Revetment | 1 | 6 | 9.7840 | 0.0018 |

*See table 2 for a list of predictors and their abbreviations.

**Issues encountered during fitting:**

None – well fit.

**Recommendations for resolving extant issues:**

**Species:** Flathead catfish (*Pylodictis olivaris*)

**Guild:** Lotic

**Region:** Upper Reach model (Pools 4, 8, and 13)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** Y

**Goodness-of-fit (Hosmer Lemeshow Test):** $\chi^2$ =4.6783, 8 df, p = 0.7913

**Parameter estimates:**

| Parameter* | DF | Estimate | Standard error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | −6.1498 | 0.5879 | 109.4343 | <.0001 |
| Secchi | 1 | −0.00747 | 0.00285 | 6.8638 | 0.0088 |
| SpecCond | 1 | 0.00139 | 0.000802 | 3.0129 | 0.0826 |
| Watervel | 1 | 0.6423 | 0.3282 | 3.8298 | 0.0503 |
| Substrate | 1 | 0.1776 | 0.0757 | 5.5052 | 0.0190 |
| Temp | 1 | 0.1406 | 0.0136 | 106.9692 | <.0001 |
| AqVeg | 1 | −0.4057 | 0.0715 | 32.1693 | <.0001 |
| Woody | 1 | 0.4151 | 0.1406 | 8.7205 | 0.0031 |
| WingDam | 1 | −0.3188 | 0.1791 | 3.1674 | 0.0751 |
| FloodTer | 1 | −0.6102 | 0.2075 | 8.6493 | 0.0033 |
| Fstation | 1 | 0.1896 | 0.0826 | 5.2764 | 0.0216 |

*See table 2 for a list of predictors and their abbreviations.

**Predictive equation:**

**log(p/1-p)** = -6.1498 - 0.00747*secchi + 0.00139*speccond + 0.6423*waterlev + 0.1776*substrate + 0.1406*temp - 0.4057*aqveg + 0.4151*woody - 0.3188*wingdam - 0.6102*floodter + 0.1896*fstation

**Parameter contributions:**

**Summary of stepwise selection**

| Step | Effect* | DF | Number In | Score Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| 1 | Temp | 1 | 1 | 119.4262 | <.0001 |
| 2 | AqVeg | 1 | 2 | 60.9563 | <.0001 |
| 3 | Secchi | 1 | 3 | 11.2451 | 0.0008 |
| 4 | FloodTer | 1 | 4 | 8.0825 | 0.0045 |
| 5 | Woody | 1 | 5 | 9.7135 | 0.0018 |
| 6 | Watervel | 1 | 6 | 6.9470 | 0.0084 |
| 7 | Substrate | 1 | 7 | 3.3714 | 0.0663 |
| 8 | Fstation | 1 | 8 | 3.5194 | 0.0607 |
| 9 | WingDam | 1 | 9 | 3.2050 | 0.0734 |
| 10 | SpecCond | 1 | 10 | 3.0152 | 0.0825 |

*See table 2 for a list of predictors and their abbreviations.

**Issues encountered during fitting:**

None – well fit.

**Recommendations for resolving extant issues:**

**Species:** Flathead catfish (*Pylodictis olivaris*)

**Guild:** Lotic

**Region:** Lower Reach model (Pool 26, Open River Reach, and La Grange Pool)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** Y

**Goodness-of-fit (Hosmer Lemeshow Test):** $\chi^2 = 11.7232$, 8 df, p = 0.1640

**Parameter estimates:**

| Parameter* | DF | Estimate | Standard error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | −3.3723 | 0.5962 | 31.9944 | <.0001 |
| Watervel | 1 | 1.2560 | 0.1991 | 39.8167 | <.0001 |
| Substrate | 1 | 0.1948 | 0.0394 | 24.4744 | <.0001 |
| Temp | 1 | 0.0960 | 0.0120 | 64.3159 | <.0001 |
| DO | 1 | −0.0602 | 0.0222 | 7.3340 | 0.0068 |
| AqVeg | 1 | −1.6478 | 0.5066 | 10.5799 | 0.0011 |
| Woody | 1 | 0.3164 | 0.0889 | 12.6744 | 0.0004 |
| WingDam | 1 | 0.7893 | 0.1529 | 26.6585 | <.0001 |
| Revetment | 1 | 0.5753 | 0.1057 | 29.6344 | <.0001 |
| FloodTer | 1 | −0.9043 | 0.1276 | 50.1919 | <.0001 |
| Period | 1 | 0.2212 | 0.0769 | 8.2829 | 0.0040 |
| Fstation | 1 | −0.1829 | 0.0528 | 12.0016 | 0.0005 |

*See table 2 for a list of predictors and their abbreviations.

**Predictive equation:**

**log(p/1-p)** = -3.3723 + 1.2560*waterlev + 0.1948*substrate + 0.0960*temp - 0.0602*DO - 1.6478*aqveg + 0.3164*woody + 0.7893*wingdam + 0.5753*revetment - 0.9043*floodter + 0.2212*period - 0.1829*fstation

**Parameter contributions:**

**Summary of stepwise selection**

| Step | Effect* | DF | Number In | Score Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| 1 | Revetment | 1 | 1 | 114.9384 | <.0001 |
| 2 | Temp | 1 | 2 | 80.7699 | <.0001 |
| 3 | Watervel | 1 | 3 | 74.5206 | <.0001 |
| 4 | FloodTer | 1 | 4 | 84.6100 | <.0001 |
| 5 | WingDam | 1 | 5 | 30.9527 | <.0001 |
| 6 | Substrate | 1 | 6 | 15.6677 | <.0001 |
| 7 | Woody | 1 | 7 | 15.0852 | 0.0001 |
| 8 | AqVeg | 1 | 8 | 13.8220 | 0.0002 |
| 9 | Period | 1 | 9 | 7.5250 | 0.0061 |
| 10 | Fstation | 1 | 10 | 7.3998 | 0.0065 |
| 11 | DO | 1 | 11 | 7.3588 | 0.0067 |

*See table 2 for a list of predictors and their abbreviations.

**Issues encountered during fitting:**

None – well fit.

**Recommendations for resolving extant issues:**

**Species:** Freshwater drum (*Aplodinotus grunniens*)

**Guild:** Generalist

**Region:** Upper Reach model (Pools 4, 8, and 13)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** Y

**Goodness-of-fit (Hosmer Lemeshow Test):** $\chi^2 = 14.1301$, 8 df, p = 0.0784

**Parameter estimates:**

| Parameter* | DF | Estimate | Standard error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | −0.5860 | 0.3780 | 2.4028 | 0.1211 |
| Secchi | 1 | −0.0205 | 0.00175 | 136.3962 | <.0001 |
| Substrate | 1 | −0.2190 | 0.0431 | 25.7981 | <.0001 |
| Temp | 1 | 0.0994 | 0.0102 | 94.6989 | <.0001 |
| FloodTer | 1 | −0.3477 | 0.1211 | 8.2459 | 0.0041 |
| Period | 1 | 0.3492 | 0.0716 | 23.8126 | <.0001 |
| Fstation | 1 | −0.3327 | 0.0530 | 39.4291 | <.0001 |

*See table 2 for a list of predictors and their abbreviations.

**Predictive equation:**

**log(p/1-p)** = -0.5860 - 0.0205*secchi - 0.2190*substrate + 0.0994*temp - 0.3477*floodter + 0.3492*period - 0.3327*fstation

**Parameter contributions:**

Summary of stepwise selection

| Step | Effect* | DF | Number In | Score Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| 1 | Secchi | 1 | 1 | 181.1983 | <.0001 |
| 2 | Temp | 1 | 2 | 79.3086 | <.0001 |
| 3 | Fstation | 1 | 3 | 25.7077 | <.0001 |
| 4 | Period | 1 | 4 | 29.4855 | <.0001 |
| 5 | Substrate | 1 | 5 | 23.2080 | <.0001 |
| 6 | FloodTer | 1 | 6 | 8.2873 | 0.0040 |

*See table 2 for a list of predictors and their abbreviations.

**Issues encountered during fitting:**

None – well fit.

**Recommendations for resolving extant issues:**

**Species:** Freshwater drum (*Aplodinotus grunniens*)

**Guild:** Generalist

**Region:** Lower Reach model (Pool 26, Open River Reach, and La Grange Pool)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** Y

**Goodness-of-fit (Hosmer Lemeshow Test):** $\chi^2 = 11.6693$, 8 df, $p = 0.1666$

**Parameter estimates:**

| Parameter* | DF | Estimate | Standard error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | 1.6763 | 0.5095 | 10.8251 | 0.0010 |
| Secchi | 1 | −0.0467 | 0.00346 | 182.0946 | <.0001 |
| Temp | 1 | 0.0210 | 0.0104 | 4.1110 | 0.0426 |
| DO | 1 | 0.0684 | 0.0196 | 12.2026 | 0.0005 |
| Woody | 1 | 0.1323 | 0.0794 | 2.7729 | 0.0959 |
| WingDam | 1 | −0.2674 | 0.1522 | 3.0864 | 0.0789 |
| LowHead | 1 | −1.9101 | 0.5039 | 14.3676 | 0.0002 |
| FloodTer | 1 | −0.9853 | 0.0977 | 101.6483 | <.0001 |
| Period | 1 | 0.3191 | 0.0696 | 20.9973 | <.0001 |
| Fstation | 1 | −0.2423 | 0.0453 | 28.6525 | <.0001 |

*See table 2 for a list of predictors and their abbreviations.

**Predictive equation:**

**log(p/1-p)** = 1.6763 - 0.0467*secchi + 0.0210*temp + 0.0684*DO + 0.1323*woody - 0.2674*wingdam - 1.9101*lowhead - 0.9853*floodter + 0.3191*period - 0.2423*fieldsta

**Parameter contributions:**

**Summary of stepwise selection**

| Step | Effect* | DF | Number In | Score Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| 1 | FloodTer | 1 | 1 | 184.6242 | <.0001 |
| 2 | Secchi | 1 | 2 | 166.1412 | <.0001 |
| 3 | Fstation | 1 | 3 | 31.7092 | <.0001 |
| 4 | Period | 1 | 4 | 27.6962 | <.0001 |
| 5 | LowHead | 1 | 5 | 18.1447 | <.0001 |
| 6 | DO | 1 | 6 | 9.7704 | 0.0018 |
| 7 | WingDam | 1 | 7 | 4.7470 | 0.0293 |
| 8 | Temp | 1 | 8 | 3.8434 | 0.0499 |
| 9 | Woody | 1 | 9 | 2.7746 | 0.0958 |

*See table 2 for a list of predictors and their abbreviations.

**Issues encountered during fitting:**

None – well fit.

**Recommendations for resolving extant issues:**

**Species:** Golden redhorse (*Moxostoma erythrurum*)

**Guild:** Lotic

**Region:** Upper Reach model (Pools 4, 8, and 13)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** N

**Goodness-of-fit (Hosmer Lemeshow Test):** $\chi^2$ = 76.2694, 8 df, p = <.0001

**Parameter estimates:**

| Parameter* | DF | Estimate | Standard error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | −2.8539 | 0.2541 | 126.1032 | <.0001 |
| Secchi | 1 | 0.0157 | 0.00174 | 81.4286 | <.0001 |
| Substrate | 1 | 0.4484 | 0.0593 | 57.2342 | <.0001 |
| AqVeg | 1 | −0.3317 | 0.0900 | 13.5799 | 0.0002 |
| VegDens | 1 | 0.5738 | 0.1098 | 27.3350 | <.0001 |
| WingDam | 1 | 0.2388 | 0.1206 | 3.9227 | 0.0476 |
| Trib | 1 | −1.3403 | 0.3946 | 11.5341 | 0.0007 |
| Revetment | 1 | 0.5081 | 0.1113 | 20.8293 | <.0001 |
| InOut | 1 | 0.7194 | 0.1855 | 15.0343 | 0.0001 |
| FloodTer | 1 | −0.4404 | 0.1582 | 7.7461 | 0.0054 |
| Fstation | 1 | −0.2932 | 0.0653 | 20.1296 | <.0001 |

*See table 2 for a list of predictors and their abbreviations.

**Predictive equation:**

**log(p/1-p)** = -2.8539 + 0.0157*secchi + 0.4484*substrate - 0.3317*aqveg + 0.5738*vegdens + 0.2388*wingdam - 1.3403*trib + 0.5081*revetment + 0.7194*inout - 0.4404*floodter - 0.2932*fstation

**Parameter contributions:**

**Summary of stepwise selection**

| Step | Effect* | DF | Number In | Score Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| 1 | Secchi | 1 | 1 | 282.9112 | <.0001 |
| 2 | Substrate | 1 | 2 | 88.2317 | <.0001 |
| 3 | Fstation | 1 | 3 | 21.4245 | <.0001 |
| 4 | Revetment | 1 | 4 | 14.6289 | 0.0001 |
| 5 | VegDens | 1 | 5 | 15.4066 | <.0001 |
| 6 | AqVeg | 1 | 6 | 12.2420 | 0.0005 |
| 7 | FloodTer | 1 | 7 | 8.5100 | 0.0035 |
| 8 | InOut | 1 | 8 | 9.8958 | 0.0017 |
| 9 | Trib | 1 | 9 | 10.5964 | 0.0011 |
| 10 | WingDam | 1 | 10 | 3.9288 | 0.0475 |

*See table 2 for a list of predictors and their abbreviations.

**Issues encountered during fitting:**

Poor fit. Residuals and influence on field station seem to the issue here. We speculate this relates to including Upper Pool 4 in the Upper Reach model given goodness of fit diagnostics.

**Recommendations for resolving extant issues:**

We may need to fit minus Pool 4, and develop separate Pool 4 models.

**Species:** Golden redhorse (*Moxostoma erythrurum*)

**Guild:** Lotic

**Region:** Lower Reach model (Pool 26, Open River Reach, and La Grange Pool)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** Y

**Goodness-of-fit (Hosmer Lemeshow Test):** $\chi^2 = 4.9995$, 8 df, p = 0.7576

**Parameter estimates:**

| Parameter* | DF | Estimate | Standard error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | −5.8895 | 0.7209 | 66.7402 | <.0001 |
| Secchi | 1 | 0.0256 | 0.00934 | 7.4826 | 0.0062 |
| SpecCond | 1 | 0.00189 | 0.000853 | 4.8926 | 0.0270 |
| Watervel | 1 | −5.4130 | 1.3479 | 16.1269 | <.0001 |
| Substrate | 1 | 0.2897 | 0.1138 | 6.4746 | 0.0109 |
| Woody | 1 | −0.4473 | 0.2577 | 3.0138 | 0.0826 |
| Revetment | 1 | 0.6247 | 0.2971 | 4.4223 | 0.0355 |

*See table 2 for a list of predictors and their abbreviations.

**Predictive equation:**

**log(p/1-p)** = -5.8895 + 0.0256*secchi + 0.00189*speccond - 5.4130*waterlev + 0.2897*substrate -0.4473*woody + 0.6247*revetment

**Parameter contributions:**

**Summary of stepwise selection**

| Step | Effect* | DF | Number In | Score Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| 1 | Watervel | 1 | 1 | 14.8843 | 0.0001 |
| 2 | Substrate | 1 | 2 | 13.5108 | 0.0002 |
| 3 | Secchi | 1 | 3 | 7.0121 | 0.0081 |
| 4 | Woody | 1 | 4 | 4.8721 | 0.0273 |
| 5 | SpecCond | 1 | 5 | 3.0075 | 0.0829 |
| 6 | Revetment | 1 | 6 | 4.5224 | 0.0335 |

*See table 2 for a list of predictors and their abbreviations.

**Issues encountered during fitting:**

None – well fit.

**Recommendations for resolving extant issues:**

**Species:** Logperch (*Percina caprodes*)

**Guild:** Generalist

**Region:** Upper Reach model (Pools 4, 8, and 13)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** Y

**Goodness-of-fit (Hosmer Lemeshow Test):** $\chi^2 = 12.8174$, 8 df, $p = 0.1183$

**Parameter estimates:**

| Parameter* | DF | Estimate | Standard error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | −5.9574 | 0.4666 | 163.0368 | <.0001 |
| Secchi | 1 | 0.00342 | 0.00176 | 3.7753 | 0.0520 |
| Watervel | 1 | −0.6971 | 0.2682 | 6.7562 | 0.0093 |
| Substrate | 1 | 0.3081 | 0.0568 | 29.4770 | <.0001 |
| Temp | 1 | 0.1406 | 0.0120 | 136.9354 | <.0001 |
| AqVeg | 1 | −0.2269 | 0.0900 | 6.3601 | 0.0117 |
| VegDens | 1 | 0.1906 | 0.1101 | 2.9934 | 0.0836 |
| Woody | 1 | 0.3322 | 0.0913 | 13.2340 | 0.0003 |
| Trib | 1 | −0.7083 | 0.3807 | 3.4623 | 0.0628 |
| Revetment | 1 | 0.7387 | 0.1068 | 47.8678 | <.0001 |
| FloodTer | 1 | −0.6853 | 0.1674 | 16.7511 | <.0001 |
| Period | 1 | 0.6670 | 0.0843 | 62.5528 | <.0001 |
| Fstation | 1 | −0.2733 | 0.0609 | 20.1572 | <.0001 |

*See table 2 for a list of predictors and their abbreviations.

**Predictive equation:**

**log(p/1-p)** = -5.9574 + 0.00342*secchi - 0.6971*watervel + 0.3081*substrate + 0.1406*temp - 0.2269*aqveg + 0.1906*vegdens + 0.3322*woody - 0.7083*trib + 0.7387*revetment - 0.6853*floodter + 0.6670*period - 0.2733*fstation

**Parameter contributions:**

**Summary of stepwise selection**

| Step | Effect* | DF | Number In | Score Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| 1 | Revetment | 1 | 1 | 72.4379 | <.0001 |
| 2 | Temp | 1 | 2 | 54.2489 | <.0001 |
| 3 | Period | 1 | 3 | 77.1604 | <.0001 |
| 4 | Substrate | 1 | 4 | 46.7607 | <.0001 |
| 5 | Fstation | 1 | 5 | 19.7951 | <.0001 |
| 6 | FloodTer | 1 | 6 | 21.7385 | <.0001 |
| 7 | Woody | 1 | 7 | 11.9535 | 0.0005 |
| 8 | Watervel | 1 | 8 | 5.4570 | 0.0195 |
| 9 | Trib | 1 | 9 | 3.3595 | 0.0668 |
| 10 | Secchi | 1 | 10 | 2.7515 | 0.0972 |
| 11 | AqVeg | 1 | 11 | 4.1685 | 0.0412 |
| 12 | VegDens | 1 | 12 | 2.9991 | 0.0833 |

*See table 2 for a list of predictors and their abbreviations.

**Issues encountered during fitting:**

None – well fit.

**Recommendations for resolving extant issues:**

**Species:** Logperch (*Percina caprodes*)

**Guild:** Generalist

**Region:** Lower Reach model (Pool 26, Open River Reach, and La Grange)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** Y

**Goodness-of-fit (Hosmer Lemeshow Test):** $\chi^2 = 3.5328$, 8 df, p = 0.8966

**Parameter estimates:**

| Parameter* | DF | Estimate | Standard error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | −12.2844 | 1.4528 | 71.4977 | <.0001 |
| Secchi | 1 | 0.0246 | 0.00811 | 9.1965 | 0.0024 |
| SpecCond | 1 | −0.00421 | 0.000865 | 23.6837 | <.0001 |
| Watervel | 1 | −1.9646 | 0.6559 | 8.9710 | 0.0027 |
| Substrate | 1 | 0.3666 | 0.0920 | 15.8822 | <.0001 |
| Temp | 1 | 0.2152 | 0.0318 | 45.6659 | <.0001 |
| Woody | 1 | −0.5876 | 0.1983 | 8.7832 | 0.0030 |
| Revetment | 1 | 0.4148 | 0.2434 | 2.9037 | 0.0884 |
| FloodTer | 1 | −0.9895 | 0.3307 | 8.9514 | 0.0028 |
| Period | 1 | 0.4751 | 0.1851 | 6.5845 | 0.0103 |
| Fstation | 1 | 0.7503 | 0.1623 | 21.3817 | <.0001 |

*See table 2 for a list of predictors and their abbreviations.

**Predictive equation:**

**log(p/1-p)** = -12.2844 + 0.0246*secchi - 0.00421*speccond - 1.9646*watervel + 0.3666*substrate + 0.2152*temp - 0.5876*woody + 0.4148*revetment - 0.9895*floodter + 0.4751*period +0.7503*fstation

**Parameter contributions:**

Summary of stepwise selection

| Step | Effect* | DF | Number In | Score Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| 1 | Temp | 1 | 1 | 33.6469 | <.0001 |
| 2 | Substrate | 1 | 2 | 19.4887 | <.0001 |
| 3 | Watervel | 1 | 3 | 14.6064 | 0.0001 |
| 4 | Woody | 1 | 4 | 12.8139 | 0.0003 |
| 5 | SpecCond | 1 | 5 | 7.2167 | 0.0072 |
| 6 | Period | 1 | 6 | 8.4187 | 0.0037 |
| 7 | Fstation | 1 | 7 | 8.9042 | 0.0028 |
| 8 | FloodTer | 1 | 8 | 7.5908 | 0.0059 |
| 9 | Secchi | 1 | 9 | 9.4468 | 0.0021 |
| 10 | Revetment | 1 | 10 | 2.9262 | 0.0872 |

*See table 2 for a list of predictors and their abbreviations.

**Issues encountered during fitting:**

None – well fit.

**Recommendations for resolving extant issues:**

**Species:** Largemouth bass (*Micropterus salmoides*)

**Guild:** Lentic

**Region:** Upper Reach model (Pools 4, 8, and 13)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** Y

**Goodness-of-fit (Hosmer Lemeshow Test):** $\chi^2 = 10.0400$, 8 df, p = 0.2622

**Parameter estimates:**

| Parameter* | DF | Estimate | Standard error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | −5.6596 | 0.5775 | 96.0528 | <.0001 |
| Secchi | 1 | 0.0146 | 0.00199 | 53.5708 | <.0001 |
| Watervel | 1 | −1.4428 | 0.2576 | 31.3763 | <.0001 |
| Substrate | 1 | −0.1507 | 0.0609 | 6.1238 | 0.0133 |
| Temp | 1 | 0.1108 | 0.0129 | 73.4213 | <.0001 |
| DO | 1 | 0.0623 | 0.0308 | 4.0949 | 0.0430 |
| AqVeg | 1 | 0.1905 | 0.1069 | 3.1779 | 0.0746 |
| VegDens | 1 | 0.4706 | 0.1329 | 12.5451 | 0.0004 |
| Woody | 1 | 0.4050 | 0.0993 | 16.6463 | <.0001 |
| WingDam | 1 | −1.0759 | 0.1268 | 71.9927 | <.0001 |
| Period | 1 | 0.8240 | 0.0868 | 90.0802 | <.0001 |
| Fstation | 1 | 0.7335 | 0.0628 | 136.5299 | <.0001 |

*See table 2 for a list of predictors and their abbreviations.

**Predictive equation:**

**log(p/1-p)** = -5.6596 + 0.0146*secchi - 1.4428*waterlev - 0.1507*substrate + 0.1108*temp + 0.0623*DO + 0.1905*aqveg + 0.4706*vegdens + 0.4050*woody - 1.0759*wingdam + 0.8240*period + 0.7335*fstation

**Parameter contributions:**

**Summary of stepwise selection**

| Step | Effect* | DF | Number In | Score Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| 1 | WingDam | 1 | 1 | 268.3525 | <.0001 |
| 2 | Watervel | 1 | 2 | 134.3964 | <.0001 |
| 3 | VegDens | 1 | 3 | 100.4572 | <.0001 |
| 4 | Fstation | 1 | 4 | 126.6058 | <.0001 |
| 5 | Secchi | 1 | 5 | 50.8878 | <.0001 |
| 6 | Period | 1 | 6 | 24.0249 | <.0001 |
| 7 | Temp | 1 | 7 | 71.3909 | <.0001 |
| 8 | Woody | 1 | 8 | 16.9001 | <.0001 |
| 9 | Substrate | 1 | 9 | 6.9623 | 0.0083 |
| 10 | DO | 1 | 10 | 3.8339 | 0.0502 |
| 11 | AqVeg | 1 | 11 | 3.1872 | 0.0742 |

*See table 2 for a list of predictors and their abbreviations.

**Issues encountered during fitting:**

None – well fit

**Recommendations for resolving extant issues:**

F station is moderately important, largely owing to lower occurrences in upper Pool 4. Could consider discretizing this model further.

**Species:** Largemouth bass (*Micropterus salmoides*)

**Guild:** Lentic

**Region:** Lower Reach model (Pool 26, Open River Reach, and La Grange Pool)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** N

**Goodness-of-fit (Hosmer Lemeshow Test):** $\chi^2$ = 32.1279, 8 df, p = <.0001

**Parameter estimates:**

| Parameter* | DF | Estimate | Standard error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | −2.8286 | 0.4033 | 49.1982 | <.0001 |
| SpecCond | 1 | −0.00165 | 0.000351 | 22.1201 | <.0001 |
| Watervel | 1 | −4.9203 | 0.3119 | 248.8662 | <.0001 |
| Temp | 1 | 0.0189 | 0.00744 | 6.4543 | 0.0111 |
| DO | 1 | 0.0459 | 0.0180 | 6.5107 | 0.0107 |
| AqVeg | 1 | −0.5418 | 0.1719 | 9.9357 | 0.0016 |
| WingDam | 1 | −0.5902 | 0.1901 | 9.6402 | 0.0019 |
| Revetment | 1 | 1.0240 | 0.1093 | 87.7397 | <.0001 |
| FloodTer | 1 | −0.2761 | 0.1031 | 7.1674 | 0.0074 |
| Fstation | 1 | 0.5674 | 0.0633 | 80.2653 | <.0001 |

*See table 2 for a list of predictors and their abbreviations.

**Predictive equation:**

**log(p/1-p)** = -2.8286 - 0.00165*speccond - 4.9203*waterlev + 0.0189*temp + 0.0459*DO - 0.5418*aqveg - 0.5902*wingdam + 1.0240*revetment - 0.2761*floodter + 0.5674*fstation

**Parameter contributions:**

**Summary of stepwise selection**

| Step | Effect* | DF | Number In | Score Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| 1 | Watervel | 1 | 1 | 348.9650 | <.0001 |
| 2 | Revetment | 1 | 2 | 48.5528 | <.0001 |
| 3 | Fstation | 1 | 3 | 65.4768 | <.0001 |
| 4 | SpecCond | 1 | 4 | 14.4626 | 0.0001 |
| 5 | AqVeg | 1 | 5 | 11.3763 | 0.0007 |
| 6 | WingDam | 1 | 6 | 9.0012 | 0.0027 |
| 7 | FloodTer | 1 | 7 | 5.9233 | 0.0149 |
| 8 | DO | 1 | 8 | 3.2594 | 0.0710 |
| 9 | Temp | 1 | 9 | 6.4678 | 0.0110 |

*See table 2 for a list of predictors and their abbreviations.

**Issues encountered during fitting:**

Poor fit. Likely need to separate La Grange from the other 2 reaches, perhaps pool-scale models…

**Recommendations for resolving extant issues:**

Discretize and refit. Separate model for La Grange

**Species:** Longnose gar (*Lepisosteus osseus*)

**Guild:** Generalist

**Region:** Upper Reach model (Pools 4, 8, and 13)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** Y

**Goodness-of-fit (Hosmer Lemeshow Test):** $\chi^2 = 2.4422$, 8 df, p = 0.9644

**Parameter estimates:**

| Parameter* | DF | Estimate | Standard error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | −6.3552 | 0.5064 | 157.5143 | <.0001 |
| Secchi | 1 | 0.00727 | 0.00264 | 7.5589 | 0.0060 |
| Watervel | 1 | 1.1182 | 0.3365 | 11.0416 | 0.0009 |
| Substrate | 1 | 0.2382 | 0.0842 | 8.0052 | 0.0047 |
| Temp | 1 | 0.0755 | 0.0130 | 33.5007 | <.0001 |
| Woody | 1 | 0.2796 | 0.1504 | 3.4560 | 0.0630 |
| WingDam | 1 | −0.4820 | 0.1997 | 5.8250 | 0.0158 |
| Fstation | 1 | 0.4660 | 0.0987 | 22.3028 | <.0001 |

*See table 2 for a list of predictors and their abbreviations.

**Predictive equation:**

**log(p/1-p)** = -6.3552 + 0.00727*secchi + 1.1182*waterlev + 0.2382*substrate + 0.0755*temp + 0.2796*woody - 0.4820*wing-dam * 0.4660*fstation

**Parameter contributions:**

Summary of stepwise selection

| Step | Effect* | DF | Number In | Score Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| 1 | Temp | 1 | 1 | 39.5789 | <.0001 |
| 2 | Watervel | 1 | 2 | 14.5094 | 0.0001 |
| 3 | Fstation | 1 | 3 | 12.0534 | 0.0005 |
| 4 | Secchi | 1 | 4 | 7.7602 | 0.0053 |
| 5 | WingDam | 1 | 5 | 6.2728 | 0.0123 |
| 6 | Substrate | 1 | 6 | 7.1933 | 0.0073 |
| 7 | Woody | 1 | 7 | 3.4686 | 0.0625 |

*See table 2 for a list of predictors and their abbreviations.

**Issues encountered during fitting:**

None – well fit.

**Recommendations for resolving extant issues:**

**Species:** Longnose gar (*Lepisosteus osseus*)

**Guild:** Generalist

**Region:** Lower Reach model (Pool 26, Open River Reach, and La Grange Pool)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** Y

**Goodness-of-fit (Hosmer Lemeshow Test):** $\chi^2 = 8.6491$, 8 df, p = 0.3728

**Parameter estimates:**

| Parameter* | DF | Estimate | Standard error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | −3.3224 | 0.6027 | 30.3850 | <.0001 |
| Watervel | 1 | 1.7226 | 0.2652 | 42.1954 | <.0001 |
| Substrate | 1 | −0.0981 | 0.0576 | 2.8974 | 0.0887 |
| DO | 1 | −0.0770 | 0.0344 | 5.0143 | 0.0251 |
| Woody | 1 | 0.2566 | 0.1350 | 3.6150 | 0.0573 |
| Revetment | 1 | 0.4389 | 0.1748 | 6.3026 | 0.0121 |
| Period | 1 | −0.4370 | 0.0839 | 27.1374 | <.0001 |
| Fstation | 1 | 0.3709 | 0.0851 | 18.9822 | <.0001 |

*See table 2 for a list of predictors and their abbreviations.

**Predictive equation:**

**log(p/1-p)** = -3.3224 + 1.7226*waterlev - 0.0981*substrate - 0.0770*DO + 0.2566*woody + 0.4389*revetment - 0.4370*period + 0.3709*fstation

**Parameter contributions:**

**Summary of stepwise selection**

| Step | Effect* | DF | Number In | Score Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| 1 | Watervel | 1 | 1 | 54.2540 | <.0001 |
| 2 | Period | 1 | 2 | 41.1686 | <.0001 |
| 3 | Fstation | 1 | 3 | 21.9888 | <.0001 |
| 4 | DO | 1 | 4 | 6.1061 | 0.0135 |
| 5 | Revetment | 1 | 5 | 3.3810 | 0.0660 |
| 6 | Woody | 1 | 6 | 4.5359 | 0.0332 |
| 7 | Substrate | 1 | 7 | 2.9041 | 0.0884 |

*See table 2 for a list of predictors and their abbreviations.

**Issues encountered during fitting:**

None – well fit.

**Recommendations for resolving extant issues:**

One could consider pool-scale models, given fstation rank high. Try applying and validating first.

**Species:** Northern pike (*Esox lucius*)

**Guild:** Lentic

**Region:** Upper Reach model (Pools 4, 8, and 13)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** Close

**Goodness-of-fit (Hosmer Lemeshow Test):** $\chi^2$ = 15.7276, 8 df, p = 0.0464

**Parameter estimates:**

| Parameter* | DF | Estimate | Standard error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | −0.4353 | 0.4269 | 1.0396 | 0.3079 |
| Secchi | 1 | 0.00771 | 0.00175 | 19.4277 | <.0001 |
| Temp | 1 | −0.0424 | 0.00965 | 19.3051 | <.0001 |
| DO | 1 | −0.0466 | 0.0274 | 2.8989 | 0.0886 |
| VegDens | 1 | 0.5584 | 0.0617 | 81.8545 | <.0001 |
| Woody | 1 | 0.3265 | 0.1031 | 10.0211 | 0.0015 |
| WingDam | 1 | −0.8408 | 0.1729 | 23.6567 | <.0001 |
| Revetment | 1 | 0.2081 | 0.1180 | 3.1111 | 0.0778 |
| Fstation | 1 | −0.3995 | 0.0644 | 38.4451 | <.0001 |

*See table 2 for a list of predictors and their abbreviations.

**Predictive equation:**

**log(p/1-p)** = -0.4353 + 0.00771*secchi - 0.0424*temp - 0.0466*DO + 0.5584*vegdens + 0.3265*woody - 0.8408*wingdam + 0.2081*revetment - 0.3995*fstation

**Parameter contributions:**

**Summary of stepwise selection**

| Step | Effect* | DF | Number In | Score Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| 1 | VegDens | 1 | 1 | 157.3849 | <.0001 |
| 2 | Fstation | 1 | 2 | 85.9616 | <.0001 |
| 3 | WingDam | 1 | 3 | 29.1811 | <.0001 |
| 4 | Secchi | 1 | 4 | 28.3099 | <.0001 |
| 5 | Temp | 1 | 5 | 16.5594 | <.0001 |
| 6 | Woody | 1 | 6 | 11.4702 | 0.0007 |
| 7 | Revetment | 1 | 7 | 3.0739 | 0.0796 |
| 8 | DO | 1 | 8 | 2.9037 | 0.0884 |

*See table 2 for a list of predictors and their abbreviations.

**Issues encountered during fitting:**

Marginal fit. Fstation is prominent.

**Recommendations for resolving extant issues:**

Fit pool-scale models.

**Species:** Northern pike (*Esox lucius*)

**Guild:** Lentic

**Region:** Lower Reach model (Pool 26, Open River Reach, and La Grange Pool)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** NO MODEL FIT

**Goodness-of-fit (Hosmer Lemeshow Test):**

**Parameter estimates:**

**Predictive equation:**

**Parameter contributions:**

**Issues encountered during fitting:**

No fit. Zoogeographic constraint.

**Recommendations for resolving extant issues:**

Model not possible – too few occurrences.

**Species:** Red shiner (*Cyprinella lutrensis*)

**Guild:** Generalist

**Region:** Upper Reach model (Pools 4, 8, and 13)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** NO MODEL FIT

**Goodness-of-fit (Hosmer Lemeshow Test):**

**Parameter estimates:**

**Predictive equation:**

**Parameter contributions:**

**Issues encountered during fitting:**

No fit. Zoogeographic constraint.

**Recommendations for resolving extant issues:**

No model possible – too few occurrences.

**Species:** Red shiner (*Cyprinella lutrensis*)

**Guild:** Generalist

**Region:** Lower Reach model (Pool 26, Open River Reach, and La Grange Pool)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** N

**Goodness-of-fit (Hosmer Lemeshow Test):** $\chi^2$ = 16.8313, 8 df, p = 0.0319

**Parameter estimates:**

| Parameter* | DF | Estimate | Standard error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | −4.2818 | 0.6698 | 40.8693 | <.0001 |
| Secchi | 1 | 0.00914 | 0.00449 | 4.1385 | 0.0419 |
| Watervel | 1 | 1.7247 | 0.2458 | 49.2239 | <.0001 |
| Temp | 1 | −0.0520 | 0.0135 | 14.8950 | 0.0001 |
| Woody | 1 | 0.2750 | 0.1098 | 6.2748 | 0.0122 |
| WingDam | 1 | 0.6762 | 0.1975 | 11.7238 | 0.0006 |
| InOut | 1 | 1.4192 | 0.4960 | 8.1873 | 0.0042 |
| FloodTer | 1 | −0.3577 | 0.1407 | 6.4627 | 0.0110 |
| Period | 1 | −0.4273 | 0.0958 | 19.8992 | <.0001 |
| Fstation | 1 | 0.7195 | 0.0725 | 98.3686 | <.0001 |

*See table 2 for a list of predictors and their abbreviations.

**Predictive equation:**

**log(p/1-p)** = -4.2818 + 0.00914*secchi + 1.7247*watervel - 0.0520*temp + 0.2750*woody + 0.6762*wingdam + 1.4192*inout - 0.3577*floodter - 0.4273*period + 0.7195*fstation

**Parameter contributions:**

**Summary of stepwise selection**

| Step | Effect* | DF | Number In | Score Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| 1 | Fstation | 1 | 1 | 68.2040 | <.0001 |
| 2 | Watervel | 1 | 2 | 63.2629 | <.0001 |
| 3 | WingDam | 1 | 3 | 12.6711 | 0.0004 |
| 4 | InOut | 1 | 4 | 8.8216 | 0.0030 |
| 5 | Woody | 1 | 5 | 6.4996 | 0.0108 |
| 6 | Period | 1 | 6 | 4.3029 | 0.0380 |
| 7 | Temp | 1 | 7 | 12.7002 | 0.0004 |
| 8 | FloodTer | 1 | 8 | 4.9878 | 0.0255 |
| 9 | Secchi | 1 | 9 | 4.1515 | 0.0416 |

*See table 2 for a list of predictors and their abbreviations.

**Issues encountered during fitting:**

Marginal (no) fit. Fstation dominates.

**Recommendations for resolving extant issues:**

Separate La grange – discretize the regional model.

**Species:** Rock bass (*Ambloplites rupestris*)

**Guild:** Lotic

**Region:** Upper Reach model (Pools 4, 8, and 13)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** Y

**Goodness-of-fit (Hosmer Lemeshow Test):** $\chi^2 = 6.3871$, 8 df, p = 0.6040

**Parameter estimates:**

| Parameter* | DF | Estimate | Standard error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | −5.0128 | 0.4360 | 132.1904 | <.0001 |
| Secchi | 1 | 0.00637 | 0.00174 | 13.4185 | 0.0002 |
| Watervel | 1 | 1.9494 | 0.2543 | 58.7716 | <.0001 |
| Substrate | 1 | 0.3925 | 0.0569 | 47.5959 | <.0001 |
| Temp | 1 | 0.0362 | 0.00882 | 16.8761 | <.0001 |
| DO | 1 | 0.1678 | 0.0258 | 42.1873 | <.0001 |
| VegDens | 1 | 0.6431 | 0.0590 | 118.8316 | <.0001 |
| Woody | 1 | 0.5639 | 0.0949 | 35.3074 | <.0001 |
| WingDam | 1 | −1.0345 | 0.1447 | 51.1204 | <.0001 |
| Trib | 1 | −1.1325 | 0.4232 | 7.1627 | 0.0074 |
| Revetment | 1 | 0.5540 | 0.1098 | 25.4730 | <.0001 |
| FloodTer | 1 | −0.4184 | 0.1464 | 8.1645 | 0.0043 |
| Fstation | 1 | −0.1991 | 0.0603 | 10.8869 | 0.0010 |

*See table 2 for a list of predictors and their abbreviations.

**Predictive equation:**

**log(p/1-p)** = -5.0128 + 0.00637*secchi + 1.9494*watervel + 0.3925*substrate + 0.0362*temp + 0.1678*DO + 0.6431*vegdens + 0.5639*woody - 1.0345*wingdam - 1.1325*trib + 0.5540*revetment - 0.4184*floodter - 0.1991*fstation

**Parameter contributions:**

**Summary of stepwise selection**

| Step | Effect* | DF | Number In | Score Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| 1 | VegDens | 1 | 1 | 157.4937 | <.0001 |
| 2 | Substrate | 1 | 2 | 106.0512 | <.0001 |
| 3 | WingDam | 1 | 3 | 93.0859 | <.0001 |
| 4 | Watervel | 1 | 4 | 37.9203 | <.0001 |
| 5 | DO | 1 | 5 | 28.8547 | <.0001 |
| 6 | Revetment | 1 | 6 | 29.0044 | <.0001 |
| 7 | Woody | 1 | 7 | 26.7994 | <.0001 |
| 8 | Secchi | 1 | 8 | 19.9556 | <.0001 |
| 9 | Temp | 1 | 9 | 15.2460 | <.0001 |
| 10 | Trib | 1 | 10 | 7.3517 | 0.0067 |
| 11 | Fstation | 1 | 11 | 8.4944 | 0.0036 |
| 12 | FloodTer | 1 | 12 | 8.2221 | 0.0041 |

*See table 2 for a list of predictors and their abbreviations.

**Issues encountered during fitting:**

None – well fit.

**Recommendations for resolving extant issues:**

**Species:** Rock bass (*Ambloplites rupestris*)

**Guild:** Lotic

**Region:** Lower Reach model (Pool 26, Open River Reach, and La Grange Pool)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** NO MODEL FIT

**Goodness-of-fit (Hosmer Lemeshow Test):**

**Parameter estimates:**

**Predictive equation:**

**Parameter contributions:**

**Issues encountered during fitting:**

No fit. Zoogeographic constraint.

**Recommendations for resolving extant issues:**

No model possible – too few occurrences.

**Species:** Sauger (*Sander canadense*)

**Guild:** Lotic

**Region:** Upper Reach model (Pools 4, 8, and 13)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** Y

**Goodness-of-fit (Hosmer Lemeshow Test):** $\chi^2 = 4.5483$, 8 df, p = 0.8046

**Parameter estimates:**

| Parameter* | DF | Estimate | Standard error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | 0.3782 | 0.2421 | 2.4395 | 0.1183 |
| Secchi | 1 | −0.0285 | 0.00203 | 196.7423 | <.0001 |
| Substrate | 1 | 0.1470 | 0.0486 | 9.1427 | 0.0025 |
| Woody | 1 | 0.3571 | 0.0919 | 15.0882 | 0.0001 |
| WingDam | 1 | −0.4436 | 0.1287 | 11.8805 | 0.0006 |
| Revetment | 1 | −0.2213 | 0.1133 | 3.8120 | 0.0509 |
| InOut | 1 | 0.3321 | 0.1809 | 3.3684 | 0.0665 |
| LowHead | 1 | 0.7183 | 0.3168 | 5.1427 | 0.0233 |
| FloodTer | 1 | −0.5660 | 0.1324 | 18.2832 | <.0001 |
| Period | 1 | 0.2424 | 0.0505 | 23.0202 | <.0001 |
| Fstation | 1 | −0.2355 | 0.0562 | 17.5602 | <.0001 |

*See table 2 for a list of predictors and their abbreviations.

**Predictive equation:**

**log(p/1-p)** = 0.3782 - 0.0285*secchi + 0.1470*substrate + 0.3571*woody - 0.4436*wingdam - 0.2213*revetment + 0.3321*inout + 0.7183*lowhead - 0.5660*floodter + 0.2424*period -0.2355*fstation

**Parameter contributions:**

**Summary of stepwise selection**

| Step | Effect* | DF | Number In | Score Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| 1 | Secchi | 1 | 1 | 197.5064 | <.0001 |
| 2 | Period | 1 | 2 | 24.7848 | <.0001 |
| 3 | Fstation | 1 | 3 | 24.6683 | <.0001 |
| 4 | Woody | 1 | 4 | 19.6220 | <.0001 |
| 5 | FloodTer | 1 | 5 | 16.5113 | <.0001 |
| 6 | WingDam | 1 | 6 | 5.0207 | 0.0250 |
| 7 | Substrate | 1 | 7 | 8.2083 | 0.0042 |
| 8 | LowHead | 1 | 8 | 5.6782 | 0.0172 |
| 9 | Revetment | 1 | 9 | 3.9215 | 0.0477 |
| 10 | InOut | 1 | 10 | 3.3860 | 0.0658 |

*See table 2 for a list of predictors and their abbreviations.

**Issues encountered during fitting:**

None – well fit.

**Recommendations for resolving extant issues:**

Fstation reasonably prominent – may benefit from further discretization.

**Species:** Sauger (*Sander canadense*)

**Guild:** Lotic

**Region:** Lower Reach model (Pool 26, Open River Reach, and La Grange Pool)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** Y

**Goodness-of-fit (Hosmer Lemeshow Test):** $\chi^2 = 5.3716$, 8 df, p = 0.7172

**Parameter estimates:**

| Parameter* | DF | Estimate | Standard error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | −1.5213 | 0.3163 | 23.1402 | <.0001 |
| Secchi | 1 | −0.0237 | 0.00425 | 31.1194 | <.0001 |
| Watervel | 1 | −1.3326 | 0.2527 | 27.8173 | <.0001 |
| Substrate | 1 | 0.1054 | 0.0388 | 7.3604 | 0.0067 |
| VegDens | 1 | −0.4281 | 0.2073 | 4.2647 | 0.0389 |
| WingDam | 1 | −0.6703 | 0.2438 | 7.5565 | 0.0060 |
| Fstation | 1 | 0.1291 | 0.0508 | 6.4623 | 0.0110 |

*See table 2 for a list of predictors and their abbreviations.

**Predictive equation:**

**log(p/1-p)** = -1.5213 - 0.0237*secchi - 1.3326*watervel + 0.1054*substrate - 0.4281*vegdens - 0.6703*wingdam + 0.1291*fstation

**Parameter contributions:**

Summary of stepwise selection

| Step | Effect* | DF | Number In | Score Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| 1 | Fstation | 1 | 1 | 40.7437 | <.0001 |
| 2 | Secchi | 1 | 2 | 21.8519 | <.0001 |
| 3 | Watervel | 1 | 3 | 25.7330 | <.0001 |
| 4 | WingDam | 1 | 4 | 6.1549 | 0.0131 |
| 5 | Substrate | 1 | 5 | 7.1966 | 0.0073 |
| 6 | VegDens | 1 | 6 | 4.4316 | 0.0353 |

*See table 2 for a list of predictors and their abbreviations.

**Issues encountered during fitting:**

Fstation dominates, though well fit.

**Recommendations for resolving extant issues:**

Fstation dominates – may benefit from further discretization. Pool 26 is different from La Grange and Open River, as expressed in the residual plots.

**Species:** Shorthead redhorse (*Moxostoma macrolepidotum*)

**Guild:** Lotic

**Region:** Upper Reach model (Pool 26, Open River Reach, and La Grange Pool)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** Y

**Goodness-of-fit (Hosmer Lemeshow Test):** $\chi^2 = 5.7006$, 8 df, p = 0.6807

**Parameter estimates:**

| Parameter* | DF | Estimate | Standard error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | −2.6023 | 0.3820 | 46.4110 | <.0001 |
| Secchi | 1 | 0.00916 | 0.00168 | 29.6904 | <.0001 |
| Watervel | 1 | 1.6976 | 0.2683 | 40.0300 | <.0001 |
| Substrate | 1 | 0.4331 | 0.0512 | 71.4715 | <.0001 |
| Temp | 1 | 0.0372 | 0.00819 | 20.5725 | <.0001 |
| DO | 1 | 0.1149 | 0.0243 | 22.2587 | <.0001 |
| WingDam | 1 | 0.9496 | 0.1312 | 52.3686 | <.0001 |
| LowHead | 1 | −0.5454 | 0.3073 | 3.1507 | 0.0759 |
| Fstation | 1 | −0.3603 | 0.0547 | 43.4259 | <.0001 |

*See table 2 for a list of predictors and their abbreviations.

**Predictive equation:**

**log(p/1-p)** = -2.6023 + 0.00916*secchi + 1.6976*watervel + 0.4331*substrate + 0.0372*temp + 0.1149*DO + 0.9496*wingdam - 0.5454*lowhead - 0.3603*fstation

**Parameter contributions:**

**Summary of stepwise selection**

| Step | Effect* | DF | Number In | Score Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| 1 | Substrate | 1 | 1 | 365.2862 | <.0001 |
| 2 | Secchi | 1 | 2 | 59.2477 | <.0001 |
| 3 | WingDam | 1 | 3 | 55.0011 | <.0001 |
| 4 | Fstation | 1 | 4 | 40.5707 | <.0001 |
| 5 | Watervel | 1 | 5 | 32.7535 | <.0001 |
| 6 | DO | 1 | 6 | 7.8350 | 0.0051 |
| 7 | Temp | 1 | 7 | 20.6819 | <.0001 |
| 8 | LowHead | 1 | 8 | 3.2034 | 0.0735 |

*See table 2 for a list of predictors and their abbreviations.

**Issues encountered during fitting:**

None – well fit.

**Recommendations for resolving extant issues:**

**Species:** Shorthead redhorse (*Moxostoma macrolepidotum*)

**Guild:** Lotic

**Region:** Lower Reach model (Pool 26, Open River Reach, and La Grange Pool)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** Y

**Goodness-of-fit (Hosmer Lemeshow Test):** $\chi^2 = 4.4850$, 8 df, p = 0.8109

**Parameter estimates:**

| Parameter* | DF | Estimate | Standard error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | −2.5012 | 0.2417 | 107.0627 | <.0001 |
| Secchi | 1 | 0.00778 | 0.00420 | 3.4361 | 0.0638 |
| Substrate | 1 | 0.1250 | 0.0456 | 7.5199 | 0.0061 |
| DO | 1 | 0.0527 | 0.0231 | 5.2007 | 0.0226 |
| FloodTer | 1 | −0.4975 | 0.1472 | 11.4199 | 0.0007 |
| Period | 1 | −0.1416 | 0.0685 | 4.2710 | 0.0388 |

*See table 2 for a list of predictors and their abbreviations.

**Predictive equation:**

**log(p/1-p)** = -2.5012 + 0.00778*secchi + 0.1250*substrate + 0.0527*DO - 0.4975*floodter - 0.1416*period

**Parameter contributions:**

**Summary of stepwise selection**

| Step | Effect* | DF | Number In | Score Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| 1 | FloodTer | 1 | 1 | 9.5189 | 0.0020 |
| 2 | Substrate | 1 | 2 | 9.1117 | 0.0025 |
| 3 | Secchi | 1 | 3 | 5.6866 | 0.0171 |
| 4 | DO | 1 | 4 | 3.3477 | 0.0673 |
| 5 | Period | 1 | 5 | 4.2792 | 0.0386 |

*See table 2 for a list of predictors and their abbreviations.

**Issues encountered during fitting:**

None – well fit.

**Recommendations for resolving extant issues:**

**Species:** Skipjack herring (*Alosa chrysochloris*)

**Guild:** Lotic

**Region:** Upper Reach model (Pools 4, 8, and 13)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** NO MODEL FIT

**Goodness-of-fit (Hosmer Lemeshow Test):**

**Parameter estimates:**

**Predictive equation:**

**Parameter contributions:**

**Issues encountered during fitting:**

No fit. Zoogeographic constraint.

**Recommendations for resolving extant issues:**

No model possible – too few occurrences.

**Species:** Skipjack herring (*Alosa chrysochloris*)

**Guild:** Lotic

**Region:** Lower Reach model (Pool 26, Open River Reach, and La Grange Pool)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** N

**Goodness-of-fit (Hosmer Lemeshow Test):** $\chi^2 = 34.4558$, 8 df, p = <.0001

**Parameter estimates:**

| Parameter* | DF | Estimate | Standard error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | −4.2720 | 0.4786 | 79.6899 | <.0001 |
| Secchi | 1 | 0.0116 | 0.00332 | 12.1864 | 0.0005 |
| SpecCond | 1 | 0.00155 | 0.000277 | 31.2638 | <.0001 |
| Temp | 1 | 0.0709 | 0.0111 | 40.6523 | <.0001 |
| DO | 1 | −0.1062 | 0.0209 | 25.7935 | <.0001 |
| VegDens | 1 | −0.3624 | 0.1974 | 3.3678 | 0.0665 |
| Revetment | 1 | 0.4359 | 0.1013 | 18.5145 | <.0001 |
| FloodTer | 1 | 0.2101 | 0.1066 | 3.8859 | 0.0487 |
| Period | 1 | 0.4683 | 0.0740 | 40.0258 | <.0001 |

*See table 2 for a list of predictors and their abbreviations.

**Predictive equation:**

**log(p/1-p)** = -4.2720 + 0.0116*secchi + 0.00155*speccond + 0.0709*temp - 0.1062*DO - 0.3624*vegdens + 0.4359*revetment + 0.2101*floodter + 0.4683*period

**Parameter contributions:**

Summary of stepwise selection

| Step | Effect* | DF | Number In | Score Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| 1 | DO | 1 | 1 | 42.3927 | <.0001 |
| 2 | SpecCond | 1 | 2 | 26.4928 | <.0001 |
| 3 | Revetment | 1 | 3 | 24.7252 | <.0001 |
| 4 | Secchi | 1 | 4 | 14.0338 | 0.0002 |
| 5 | Temp | 1 | 5 | 7.8027 | 0.0052 |
| 6 | Period | 1 | 6 | 37.2623 | <.0001 |
| 7 | FloodTer | 1 | 7 | 3.2909 | 0.0697 |
| 8 | VegDens | 1 | 8 | 3.4644 | 0.0627 |

*See table 2 for a list of predictors and their abbreviations.

**Issues encountered during fitting:**

Poor fit.

**Recommendations for resolving extant issues:**

Not clear at this time.

**Species:** Smallmouth buffalo (*Ictiobus bubalus*)

**Guild:** Generalist

**Region:** Upper Reach model (Pools 4, 8, and 13)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** Y

**Goodness-of-fit (Hosmer Lemeshow Test):** $\chi^2$ = 9.8656, 8 df, p = 0.2746

**Parameter estimates:**

| Parameter* | DF | Estimate | Standard error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | −0.9387 | 0.3013 | 9.7091 | 0.0018 |
| Secchi | 1 | −0.0114 | 0.00259 | 19.4532 | <.0001 |
| Substrate | 1 | −0.1328 | 0.0586 | 5.1396 | 0.0234 |
| VegDens | 1 | −0.1675 | 0.0702 | 5.7000 | 0.0170 |
| InOut | 1 | 0.6067 | 0.2214 | 7.5095 | 0.0061 |
| Period | 1 | −0.2384 | 0.0650 | 13.4447 | 0.0002 |
| Fstation | 1 | 0.3089 | 0.0729 | 17.9721 | <.0001 |

*See table 2 for a list of predictors and their abbreviations.

**Predictive equation:**

**log(p/1-p)** = -0.9387 - 0.0114*secchi - 0.1328*substrate - 0.1675*vegdens + 0.6067*inout - 0.2384*period + 0.3089*fstation

**Parameter contributions:**

**Summary of stepwise selection**

| Step | Effect* | DF | Number In | Score Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| 1 | Secchi | 1 | 1 | 71.3712 | <.0001 |
| 2 | Fstation | 1 | 2 | 14.9861 | 0.0001 |
| 3 | Period | 1 | 3 | 12.1779 | 0.0005 |
| 4 | InOut | 1 | 4 | 6.6952 | 0.0097 |
| 5 | Woody | 1 | 5 | 3.6852 | 0.0549 |
| 6 | VegDens | 1 | 6 | 3.5990 | 0.0578 |
| 7 | Substrate | 1 | 7 | 3.5529 | 0.0594 |

*See table 2 for a list of predictors and their abbreviations.

**Issues encountered during fitting:**

None – well fit, but Fstation ranks high (second).

**Recommendations for resolving extant issues:**

Consider discretizing to pool-scale models is validation proves difficult.

**Species:** Smallmouth buffalo (*Ictiobus bubalus*)

**Guild:** Generalist

**Region:** Lower Reach model (Pool 26, Open River Reach, and La Grange Pool)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** N

**Goodness-of-fit (Hosmer Lemeshow Test):** $\chi^2 = 20.3282$, 8 df, p = 0.0092

**Parameter estimates:**

| Parameter* | DF | Estimate | Standard error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | −0.0728 | 0.2430 | 0.0898 | 0.7645 |
| SpecCond | 1 | −0.00087 | 0.000331 | 6.9900 | 0.0082 |
| Watervel | 1 | −1.1901 | 0.1722 | 47.7613 | <.0001 |
| AqVeg | 1 | −0.9847 | 0.4126 | 5.6945 | 0.0170 |
| VegDens | 1 | 0.7333 | 0.3922 | 3.4958 | 0.0615 |
| WingDam | 1 | −0.4904 | 0.1440 | 11.5911 | 0.0007 |
| Revetment | 1 | 0.4985 | 0.0970 | 26.4167 | <.0001 |
| LowHead | 1 | −1.0576 | 0.4742 | 4.9730 | 0.0257 |
| FloodTer | 1 | −0.3735 | 0.0952 | 15.3785 | <.0001 |
| Period | 1 | −0.1879 | 0.0454 | 17.1021 | <.0001 |
| Fstation | 1 | 0.2896 | 0.0565 | 26.3122 | <.0001 |

*See table 2 for a list of predictors and their abbreviations.

**Predictive equation:**

**log(p/1-p)** = -0.0728 - 0.00087*speccond - 1.1901*watervel - 0.9847*aqveg + 0.7333*vegdens - 0.4904*wingdam + 0.4985*revetment - 1.0576*lowhead - 0.3735*floodter - 0.1879*period + 0.2896*fstation

**Parameter contributions:**

**Summary of stepwise selection**

| Step | Effect* | DF | Number In | Score Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| 1 | Watervel | 1 | 1 | 62.7512 | <.0001 |
| 2 | Revetment | 1 | 2 | 11.3648 | 0.0007 |
| 3 | Fstation | 1 | 3 | 21.9906 | <.0001 |
| 4 | Period | 1 | 4 | 9.9830 | 0.0016 |
| 5 | FloodTer | 1 | 5 | 10.6550 | 0.0011 |
| 6 | WingDam | 1 | 6 | 10.4014 | 0.0013 |
| 7 | SpecCond | 1 | 7 | 6.5500 | 0.0105 |
| 8 | LowHead | 1 | 8 | 5.3453 | 0.0208 |
| 9 | AqVeg | 1 | 9 | 3.4998 | 0.0614 |
| 10 | VegDens | 1 | 10 | 3.6979 | 0.0545 |

*See table 2 for a list of predictors and their abbreviations.

**Issues encountered during fitting:**

Poor fit – La Grange expresses different associations with important variables in the model.

**Recommendations for resolving extant issues:**

Fit a separate model for La Grange

**Species:** Smallmouth bass (*Micropterus dolomieu*)

**Guild:** Generalist

**Region:** Upper Reach model (Pools 4, 8, and 13)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** N

**Goodness-of-fit (Hosmer Lemeshow Test):** $\chi^2 = 24.5110$, 8 df, p = 0.0019

**Parameter estimates:**

| Parameter* | DF | Estimate | Standard error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | −5.1421 | 0.5444 | 89.2168 | <.0001 |
| Secchi | 1 | 0.0148 | 0.00183 | 65.0290 | <.0001 |
| Watervel | 1 | 1.7628 | 0.2679 | 43.3099 | <.0001 |
| Substrate | 1 | 0.5638 | 0.0584 | 93.3103 | <.0001 |
| Temp | 1 | 0.0810 | 0.0121 | 44.9908 | <.0001 |
| DO | 1 | 0.1169 | 0.0265 | 19.4908 | <.0001 |
| VegDens | 1 | −0.3898 | 0.0618 | 39.7330 | <.0001 |
| Woody | 1 | 0.4263 | 0.0965 | 19.5350 | <.0001 |
| WingDam | 1 | 0.3329 | 0.1281 | 6.7556 | 0.0093 |
| Revetment | 1 | 1.4872 | 0.1228 | 146.6246 | <.0001 |
| FloodTer | 1 | −0.3487 | 0.1513 | 5.3137 | 0.0212 |
| Period | 1 | 0.3819 | 0.0837 | 20.8132 | <.0001 |
| Fstation | 1 | −0.7383 | 0.0619 | 142.0636 | <.0001 |

*See table 2 for a list of predictors and their abbreviations.

**Predictive equation:**

**log(p/1-p)** = -5.1421 + 0.0148*secchi + 1.7628*watervel + 0.5638*substrate + 0.0810*temp + 0.1169*DO - 0.3898*vegdens + 0.4263*woody + 0.3329*wingdam + 1.4872*revetment - 0.3487*floodter + 0.3819*period - 0.7383*fstation

**Parameter contributions:**

**Summary of stepwise selection**

| Step | Effect* | DF | Number In | Score Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| 1 | Substrate | 1 | 1 | 419.5957 | <.0001 |
| 2 | Fstation | 1 | 2 | 211.4126 | <.0001 |
| 3 | Revetment | 1 | 3 | 153.7030 | <.0001 |
| 4 | VegDens | 1 | 4 | 46.5079 | <.0001 |
| 5 | Secchi | 1 | 5 | 69.6059 | <.0001 |
| 6 | Watervel | 1 | 6 | 27.9968 | <.0001 |
| 7 | FloodTer | 1 | 7 | 9.5414 | 0.0020 |
| 8 | Woody | 1 | 8 | 12.0116 | 0.0005 |
| 9 | Temp | 1 | 9 | 8.8132 | 0.0030 |
| 10 | Period | 1 | 10 | 23.0732 | <.0001 |
| 11 | DO | 1 | 11 | 19.4972 | <.0001 |
| 12 | WingDam | 1 | 12 | 6.7742 | 0.0092 |

*See table 2 for a list of predictors and their abbreviations.

**Issues encountered during fitting:**

Poor fit. Fstation is second most controlling variable.

**Recommendations for resolving extant issues:**

Discretize into pool-scale models

**Species:** Smallmouth bass (*Micropterus dolomieu*)

**Guild:** Generalist

**Region:** Lower Reach model (Pool 26, Open River Reach, and La Grange Pool)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** N

**Goodness-of-fit (Hosmer Lemeshow Test):** $\chi^2$ = 23.1272, 8 df, p = 0.0032

**Parameter estimates:**

| Parameter* | DF | Estimate | Standard error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | −2.3503 | 1.2605 | 3.4767 | 0.0622 |
| Secchi | 1 | 0.0229 | 0.00876 | 6.7989 | 0.0091 |
| SpecCond | 1 | 0.00330 | 0.00146 | 5.0980 | 0.0240 |
| Substrate | 1 | 0.6126 | 0.1246 | 24.1596 | <.0001 |
| DO | 1 | 0.1702 | 0.0508 | 11.2063 | 0.0008 |
| Woody | 1 | 0.8004 | 0.2618 | 9.3491 | 0.0022 |
| WingDam | 1 | 0.5768 | 0.3258 | 3.1336 | 0.0767 |
| Revetment | 1 | 0.8567 | 0.2557 | 11.2248 | 0.0008 |
| Fstation | 1 | −1.6949 | 0.2964 | 32.7047 | <.0001 |

*See table 2 for a list of predictors and their abbreviations.

**Predictive equation:**

**log(p/1-p)** = -2.3503 + 0.0229*secchi + 0.00330*speccond + 0.6126*substrate + 0.1702*DO + 0.8004*woody + 0.5768*wing-dam + 0.8567*revetment - 1.6949*fstation

**Parameter contributions:**

**Summary of stepwise selection**

| Step | Effect* | DF | Number In | Score Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| 1 | Fstation | 1 | 1 | 80.8442 | <.0001 |
| 2 | Substrate | 1 | 2 | 40.7441 | <.0001 |
| 3 | DO | 1 | 3 | 13.5841 | 0.0002 |
| 4 | Revetment | 1 | 4 | 10.0041 | 0.0016 |
| 5 | Woody | 1 | 5 | 7.0215 | 0.0081 |
| 6 | Secchi | 1 | 6 | 7.8355 | 0.0051 |
| 7 | SpecCond | 1 | 7 | 4.5360 | 0.0332 |
| 8 | WingDam | 1 | 8 | 3.1877 | 0.0742 |

*See table 2 for a list of predictors and their abbreviations.

**Issues encountered during fitting:**

Poor fit – most presences from fstation 4 (Pool 26). Fstation dominant predictor…

**Recommendations for resolving extant issues:**

Discretize into pool-scale models.

**Species:** Shovelnose sturgeon (*Scaphirhynchus platorynchus*)

**Guild:** Lotic

**Region:** Upper Reach model (Pools 4, 8, and 13)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** NO MODEL FIT

**Goodness-of-fit (Hosmer Lemeshow Test):**

**Parameter estimates:**

**Predictive equation:**

**Parameter contributions:**

**Issues encountered during fitting:**

No fit – too few occurrences

**Recommendations for resolving extant issues:**

No model posisble

**Species:** Shovelnose sturgeon (*Scaphirhynchus platorynchus*)

**Guild:** Lotic

**Region:** Lower Reach model (Pool 26, Open River Reach, and La Grange Pool)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** NO MODEL FIT

**Goodness-of-fit (Hosmer Lemeshow Test):**

**Parameter estimates:**

**Predictive equation:**

**Parameter contributions:**

**Issues encountered during fitting:**

No fit – too few occurrences

**Recommendations for resolving extant issues:**

No models possible.

**Species:** Walleye (*Sander vitreum*)

**Guild:** Generalist

**Region:** Upper Reach model (Pools 4, 8, and 13)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** N

**Goodness-of-fit (Hosmer Lemeshow Test):** $\chi^2 = 19.6081$, 8 df, p = 0.0119

**Parameter estimates:**

| Parameter* | DF | Estimate | Standard error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | −0.2236 | 0.2104 | 1.1293 | 0.2879 |
| Secchi | 1 | −0.0118 | 0.00180 | 43.0246 | <.0001 |
| Woody | 1 | −0.2366 | 0.0918 | 6.6437 | 0.0100 |
| WingDam | 1 | 0.3881 | 0.1122 | 11.9641 | 0.0005 |
| Period | 1 | 0.2300 | 0.0523 | 19.3378 | <.0001 |
| Fstation | 1 | −0.3128 | 0.0565 | 30.6046 | <.0001 |

*See table 2 for a list of predictors and their abbreviations.

**Predictive equation:**

**log(p/1-p)** = -0.2236 - 0.0118*secchi - 0.2366*woody + 0.3881*wingdam + 0.2300*period - 0.3128*fstation

**Parameter contributions:**

**Summary of stepwise selection**

| Step | Effect* | DF | Number In | Score Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| 1 | Secchi | 1 | 1 | 13.6448 | 0.0002 |
| 2 | Fstation | 1 | 2 | 23.6867 | <.0001 |
| 3 | WingDam | 1 | 3 | 20.9984 | <.0001 |
| 4 | Period | 1 | 4 | 18.9758 | <.0001 |
| 5 | Woody | 1 | 5 | 6.6577 | 0.0099 |

*See table 2 for a list of predictors and their abbreviations.

**Issues encountered during fitting:**

No fit – Fstation dominates

**Recommendations for resolving extant issues:**

Discretize into pool-scale models

**Species:** Walleye (*Sander vitreum*)

**Guild:** Generalist

**Region:** Lower Reach model (Pool 26, Open River Reach, and La Grange Pool)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** Y

**Goodness-of-fit (Hosmer Lemeshow Test):** $\chi^2 = 11.1802$, 8 df, p = 0.1917

**Parameter estimates:**

| Parameter* | DF | Estimate | Standard error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | −2.1543 | 1.0032 | 4.6116 | 0.0318 |
| Watervel | 1 | −4.5150 | 1.5476 | 8.5119 | 0.0035 |
| Revetment | 1 | 0.6975 | 0.3781 | 3.4030 | 0.0651 |
| Fstation | 1 | −0.4392 | 0.1990 | 4.8712 | 0.0273 |

*See table 2 for a list of predictors and their abbreviations.

**Predictive equation:**

**log(p/1-p)** = -2.1543 - 4.5150*watervel + 0.6975*revetment - 0.4392*fstation

**Parameter contributions:**

**Summary of stepwise selection**

| Step | Effect* | DF | Number In | Score Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| 1 | Watervel | 1 | 1 | 7.6477 | 0.0057 |
| 2 | Fstation | 1 | 2 | 9.8301 | 0.0017 |
| 3 | Revetment | 1 | 3 | 3.5159 | 0.0608 |

*See table 2 for a list of predictors and their abbreviations.

**Issues encountered during fitting:**

None

**Recommendations for resolving extant issues:**

May benefit from further discretization.

**Species:** Warmouth (*Lepomis gulosus*)

**Guild:** Lentic

**Region:** Upper Reach model (Pools 4, 8, and 13)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** Y

**Goodness-of-fit (Hosmer Lemeshow Test):** $\chi^2 = 12.3794$, 8 df, p = 0.1351

**Parameter estimates:**

| Parameter* | DF | Estimate | Standard error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | −6.4360 | 0.9600 | 44.9505 | <.0001 |
| Watervel | 1 | −13.7959 | 3.0168 | 20.9131 | <.0001 |
| Substrate | 1 | −0.8290 | 0.1810 | 20.9720 | <.0001 |
| Revetment | 1 | 1.3895 | 0.2829 | 24.1215 | <.0001 |
| Period | 1 | 0.5636 | 0.1632 | 11.9231 | 0.0006 |
| Fstation | 1 | 1.4797 | 0.2622 | 31.8518 | <.0001 |

*See table 2 for a list of predictors and their abbreviations.

**Predictive equation:**

**log(p/1-p)** = -6.4360 - 13.7959*watervel - 0.8290*substrate + 1.3895*revetment + 0.5636*period + 1.4797*fstation

**Parameter contributions:**

**Summary of stepwise selection**

| Step | Effect* | DF | Number In | Score Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| 1 | Substrate | 1 | 1 | 133.7511 | <.0001 |
| 2 | Fstation | 1 | 2 | 42.6015 | <.0001 |
| 3 | Revetment | 1 | 3 | 34.9809 | <.0001 |
| 4 | Watervel | 1 | 4 | 22.2302 | <.0001 |
| 5 | Period | 1 | 5 | 12.3490 | 0.0004 |

*See table 2 for a list of predictors and their abbreviations.

**Issues encountered during fitting:**

None – well fit.

**Recommendations for resolving extant issues:**

Fstation is second leading variable – may benefit from further discretization.

**Species:** Warmouth (*Lepomis gulosus*)

**Guild:** Lentic

**Region:** Lower Reach model (Pool 26, Open River Reach, and La Grange Pool)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** N

**Goodness-of-fit (Hosmer Lemeshow Test):** $\chi^2 = 22.5966$, 8 df, p = 0.0039

**Parameter estimates:**

| Parameter* | DF | Estimate | Standard error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | −1.3217 | 0.4341 | 9.2693 | 0.0023 |
| Secchi | 1 | −0.0392 | 0.00796 | 24.2440 | <.0001 |
| SpecCond | 1 | −0.00179 | 0.000508 | 12.4482 | 0.0004 |
| Watervel | 1 | −9.8247 | 1.2032 | 66.6733 | <.0001 |
| Woody | 1 | 0.2903 | 0.1568 | 3.4280 | 0.0641 |
| Revetment | 1 | 1.0851 | 0.1807 | 36.0517 | <.0001 |
| FloodTer | 1 | −1.6052 | 0.3720 | 18.6219 | <.0001 |
| Period | 1 | 0.4393 | 0.1037 | 17.9591 | <.0001 |

*See table 2 for a list of predictors and their abbreviations.

**Predictive equation:**

**log(p/1-p)** = -1.3217 - 0.0392*secchi - 0.00179*speccond - 9.8247*watervel + 0.2903*woody + 1.0851*revetment - 1.6052*floodter + 0.4393*period

**Parameter contributions:**

**Summary of stepwise selection**

| Step | Effect* | DF | Number In | Score Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| 1 | Watervel | 1 | 1 | 87.5301 | <.0001 |
| 2 | Revetment | 1 | 2 | 43.2463 | <.0001 |
| 3 | FloodTer | 1 | 3 | 32.8292 | <.0001 |
| 4 | Secchi | 1 | 4 | 15.8121 | <.0001 |
| 5 | Period | 1 | 5 | 17.5525 | <.0001 |
| 6 | SpecCond | 1 | 6 | 14.1506 | 0.0002 |
| 7 | Woody | 1 | 7 | 3.4422 | 0.0635 |

*See table 2 for a list of predictors and their abbreviations.

**Issues encountered during fitting:**

Poorly fit.

**Recommendations for resolving extant issues:**

Strong positive residuals for Watervel and FloodTer. Needs further investigation into why these strong positive residuals manifest. FloodTer may be due to our assumption that YEAR is unimportant (positive residuals suggest higher occurrences in flooded conditions, which occur intermittently and vary among YEAR).

**Species:** White bass (*Morone chrysops*)

**Guild:** Generalist

**Region:** Upper Reach model (Pools 4, 8, and 13)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** Y

**Goodness-of-fit (Hosmer Lemeshow Test):** $\chi^2 = 11.1866$, 8 df, p = 0.1913

**Parameter estimates:**

| Parameter* | DF | Estimate | Standard error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | 1.2761 | 0.2694 | 22.4317 | <.0001 |
| Secchi | 1 | −0.0296 | 0.00210 | 198.6996 | <.0001 |
| Substrate | 1 | 0.1510 | 0.0501 | 9.0813 | 0.0026 |
| Temp | 1 | 0.0387 | 0.00718 | 29.0706 | <.0001 |
| AqVeg | 1 | −0.2430 | 0.0903 | 7.2367 | 0.0071 |
| VegDens | 1 | −0.2690 | 0.1139 | 5.5724 | 0.0182 |
| Woody | 1 | 0.1547 | 0.0916 | 2.8518 | 0.0913 |
| WingDam | 1 | −0.3228 | 0.1250 | 6.6636 | 0.0098 |
| Fstation | 1 | −0.5117 | 0.0559 | 83.8255 | <.0001 |

*See table 2 for a list of predictors and their abbreviations.

**Predictive equation:**

**log(p/1-p)** = 1.2761 - 0.0296*secchi + 0.1510*substrate + 0.0387*temp - 0.2430*aqveg - 0.2690*vegdens + 0.1547* - 0.3228*wingdam - 0.5117*fstation

**Parameter contributions:**

**Summary of stepwise selection**

| Step | Effect* | DF | Number In | Score Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| 1 | Secchi | 1 | 1 | 244.9376 | <.0001 |
| 2 | Fstation | 1 | 2 | 75.5754 | <.0001 |
| 3 | AqVeg | 1 | 3 | 87.5864 | <.0001 |
| 4 | Temp | 1 | 4 | 28.4885 | <.0001 |
| 5 | Woody | 1 | 5 | 5.5570 | 0.0184 |
| 6 | Substrate | 1 | 6 | 5.7042 | 0.0169 |
| 7 | WingDam | 1 | 7 | 5.1697 | 0.0230 |
| 8 | VegDens | 1 | 8 | 5.5941 | 0.0180 |

*See table 2 for a list of predictors and their abbreviations.

**Issues encountered during fitting:**

None – well fit.

**Recommendations for resolving extant issues:**

Fstation important, yet well fit. May further benefit by discretizing into pool-scale models.

**Species:** White bass (*Morone chrysops*)

**Guild:** Generalist

**Region:** Lower Reach model (Pool 26, Open River Reach, and La Grange Pool)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** Y

**Goodness-of-fit (Hosmer Lemeshow Test):** $\chi^2 = 8.3297$, 8 df, p = 0.4019

**Parameter estimates:**

| Parameter* | DF | Estimate | Standard error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | −0.4096 | 0.4082 | 1.0066 | 0.3157 |
| Secchi | 1 | −0.0152 | 0.00306 | 24.5947 | <.0001 |
| Watervel | 1 | −0.6378 | 0.1757 | 13.1718 | 0.0003 |
| Substrate | 1 | 0.1367 | 0.0337 | 16.4601 | <.0001 |
| Temp | 1 | 0.0366 | 0.00988 | 13.6944 | 0.0002 |
| DO | 1 | −0.0408 | 0.0178 | 5.2375 | 0.0221 |
| FloodTer | 1 | −0.6567 | 0.0916 | 51.4352 | <.0001 |
| Period | 1 | 0.4235 | 0.0671 | 39.8300 | <.0001 |

*See table 2 for a list of predictors and their abbreviations.

**Predictive equation:**

**log(p/1-p)** = -0.4096 - 0.0152*secchi - 0.6378*watervel + 0.1367*substrate + 0.0366*temp - 0.0408*DO - 0.6567*floodter + 0.4235*period

**Parameter contributions:**

**Summary of stepwise selection**

| Step | Effect* | DF | Number In | Score Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| 1 | FloodTer | 1 | 1 | 109.2146 | <.0001 |
| 2 | Secchi | 1 | 2 | 21.7996 | <.0001 |
| 3 | Period | 1 | 3 | 23.6334 | <.0001 |
| 4 | Temp | 1 | 4 | 20.0336 | <.0001 |
| 5 | Substrate | 1 | 5 | 11.4284 | 0.0007 |
| 6 | Watervel | 1 | 6 | 11.4181 | 0.0007 |
| 7 | DO | 1 | 7 | 5.2541 | 0.0219 |

*See table 2 for a list of predictors and their abbreviations.

**Issues encountered during fitting:**

None – well fit.

**Recommendations for resolving extant issues:**

**Species:** White crappie (*Pomoxis annularis*)

**Guild:** Lentic

**Region:** Upper Reach model (Pools 4, 8, and 13)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** N

**Goodness-of-fit (Hosmer Lemeshow Test):** $\chi^2 = 102.4742$, 8 df, p = <.0001

**Parameter estimates:**

| Parameter* | DF | Estimate | Standard error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | 0.2757 | 0.3735 | 0.5450 | 0.4603 |
| Secchi | 1 | −0.0251 | 0.00456 | 30.2218 | <.0001 |
| Watervel | 1 | −11.8533 | 1.2677 | 87.4334 | <.0001 |
| Substrate | 1 | −0.4912 | 0.0905 | 29.4529 | <.0001 |
| VegDens | 1 | −0.8038 | 0.1052 | 58.3549 | <.0001 |
| Fstation | 1 | 0.4546 | 0.0962 | 22.3401 | <.0001 |

*See table 2 for a list of predictors and their abbreviations.

**Predictive equation:**

**log(p/1-p)** = 0.2757 - 0.0251*secchi - 11.8533*watervel - 0.4912*substrate - 0.8038*vegdens + 0.4546*fstation

**Parameter contributions:**

**Summary of stepwise selection**

| Step | Effect* | DF | Number In | Score Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| 1 | Substrate | 1 | 1 | 241.0904 | <.0001 |
| 2 | Secchi | 1 | 2 | 77.8556 | <.0001 |
| 3 | Watervel | 1 | 3 | 73.9897 | <.0001 |
| 4 | VegDens | 1 | 4 | 63.7478 | <.0001 |
| 5 | Fstation | 1 | 5 | 22.9929 | <.0001 |

*See table 2 for a list of predictors and their abbreviations.

**Issues encountered during fitting:**

Poorly fit. Residuals all strongly structured, negative residuals for Pool 4, near zero residuals for Pool 8, and positive residuals for Pool 13.

**Recommendations for resolving extant issues:**

This species needs pool-scale models developed for this reach.

**Species:** White crappie (*Pomoxis annularis*)

**Guild:** Lentic

**Region:** Lower Reach model (Pool 26, Open River Reach, and La Grange Pool)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** N

**Goodness-of-fit (Hosmer Lemeshow Test):** $\chi^2$ = 40.6460, 8 df, p = <.0001

**Parameter estimates:**

| Parameter* | DF | Estimate | Standard error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | −3.6828 | 0.4466 | 68.0140 | <.0001 |
| Secchi | 1 | −0.0399 | 0.00614 | 42.3157 | <.0001 |
| SpecCond | 1 | −0.00282 | 0.000433 | 42.5775 | <.0001 |
| Watervel | 1 | −4.6087 | 0.5160 | 79.7825 | <.0001 |
| Woody | 1 | 0.4065 | 0.1092 | 13.8489 | 0.0002 |
| FloodTer | 1 | −0.9960 | 0.1726 | 33.3030 | <.0001 |
| Period | 1 | 0.2749 | 0.0703 | 15.2695 | <.0001 |
| Fstation | 1 | 0.7988 | 0.0822 | 94.3232 | <.0001 |

*See table 2 for a list of predictors and their abbreviations.

**Predictive equation:**

**log(p/1-p)** = -3.6828 - 0.0399*secchi - 0.00282*speccond - 4.6087*watervel + 0.4065*woody - 0.9960*floodter + 0.2749*period + 0.7988*fstation

**Parameter contributions:**

**Summary of stepwise selection**

| Step | Effect* | DF | Number In | Score Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| 1 | Fstation | 1 | 1 | 139.1577 | <.0001 |
| 2 | Watervel | 1 | 2 | 105.1397 | <.0001 |
| 3 | Secchi | 1 | 3 | 69.5667 | <.0001 |
| 4 | FloodTer | 1 | 4 | 31.4187 | <.0001 |
| 5 | SpecCond | 1 | 5 | 46.9903 | <.0001 |
| 6 | Period | 1 | 6 | 15.8215 | <.0001 |
| 7 | Woody | 1 | 7 | 13.9486 | 0.0002 |

*See table 2 for a list of predictors and their abbreviations.

**Issues encountered during fitting:**

Poorly fit. Fstation dominates.

**Recommendations for resolving extant issues:**

Need pool-scale models.

**Species:** Yellow perch (*Perca flavescens*)

**Guild:** Lentic

**Region:** Upper Reach model (Pools 4, 8, and 13)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** Y

**Goodness-of-fit (Hosmer Lemeshow Test):** $\chi^2 = 12.7107$, 8 df, p = 0.1222

**Parameter estimates:**

| Parameter* | DF | Estimate | Standard error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | −1.2788 | 0.3413 | 14.0418 | 0.0002 |
| Secchi | 1 | 0.00926 | 0.00181 | 26.0814 | <.0001 |
| SpecCond | 1 | −0.00125 | 0.000512 | 6.0120 | 0.0142 |
| Substrate | 1 | −0.1403 | 0.0563 | 6.2067 | 0.0127 |
| AqVeg | 1 | 0.4258 | 0.0800 | 28.3577 | <.0001 |
| VegDens | 1 | 0.5613 | 0.1017 | 30.4539 | <.0001 |
| WingDam | 1 | −1.0874 | 0.1637 | 44.1114 | <.0001 |
| LowHead | 1 | 0.5825 | 0.3236 | 3.2399 | 0.0719 |
| Period | 1 | 0.3592 | 0.0570 | 39.6842 | <.0001 |
| Fstation | 1 | −0.3807 | 0.0613 | 38.5749 | <.0001 |

*See table 2 for a list of predictors and their abbreviations.

**Predictive equation:**

**log(p/1-p)** = -1.2788 + 0.00926*secchi - 0.00125*speccond - 0.1403*substrate + 0.4258*aqveg + 0.5613*vegdens - 1.0874*wingdam + 0.5825*lowhead + 0.3592*period - 0.3807*fstation

**Parameter contributions:**

**Summary of stepwise selection**

| Step | Effect* | DF | Number In | Score Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| 1 | AqVeg | 1 | 1 | 578.0712 | <.0001 |
| 2 | Fstation | 1 | 2 | 74.0737 | <.0001 |
| 3 | Period | 1 | 3 | 58.4646 | <.0001 |
| 4 | WingDam | 1 | 4 | 45.6402 | <.0001 |
| 5 | VegDens | 1 | 5 | 37.6675 | <.0001 |
| 6 | Secchi | 1 | 6 | 22.3280 | <.0001 |
| 7 | Substrate | 1 | 7 | 5.9614 | 0.0146 |
| 8 | SpecCond | 1 | 8 | 5.8056 | 0.0160 |
| 9 | LowHead | 1 | 9 | 3.2851 | 0.0699 |

*See table 2 for a list of predictors and their abbreviations.

**Issues encountered during fitting:**

None – well fit.

**Recommendations for resolving extant issues:**

**Species:** Yellow perch (*Perca flavescens*)

**Guild:** Lentic

**Region:** Lower Reach model (Pool 26, Open River Reach, and La Grange Pool)

**Data source:** UMRR-EMP LTRMP fisheries component day electrofishing samples 1993–2012

**Certifiable model fit?:** NO MODEL FIT

**Goodness-of-fit (Hosmer Lemeshow Test):**

**Parameter estimates:**

**Predictive equation:**

**Parameter contributions:**

**Issues encountered during fitting:**

No fit.

**Recommendations for resolving extant issues:**

Too few occurrences to fit a model for this reach.

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**Long Term Resource Monitoring Program—Spatially Explicit Habitat Models for 28 Fishes from the Upper Mississippi River System (AHAG 2.0), ver. 1.1**

The Upper Mississippi River Restoration-Environmental Management Program (UMRR-EMP), including its Long Term Resource Monitoring Program (LTRMP) element, was authorized by the Water Resources Development Act (WRDA) of 1986. The mission of the LTRMP element is to provide river managers with information for maintaining the Upper Mississippi River System as a sustainable large river ecosystem given its multiple use character. The LTRMP element is implemented by the U.S. Geological Survey, Upper Midwest Environmental Sciences Center, in cooperation with the five Upper Mississippi River System states of Illinois, Iowa, Minnesota, Missouri, and Wisconsin; overall management responsibility of the UMRR-EMP is vested with the U.S. Army Corps of Engineers